S. HRG. 112–963

OVERSIGHT: REVIEW OF THE ENVIRONMENTAL PROTECTION AGENCY'S MERCURY AND AIR TOXICS STANDARDS (MATS) FOR POWER PLANTS

HEARING

BEFORE THE

SUBCOMMITTEE ON CLEAN AIR
AND NUCLEAR SAFETY

OF THE

COMMITTEE ON
ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE

ONE HUNDRED TWELFTH CONGRESS

SECOND SESSION

MARCH 20, 2012

Printed for the use of the Committee on Environment and Public Works

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ONE HUNDRED TWELFTH CONGRESS
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C O N T E N T S

OVERSIGHT: REVIEW OF THE ENVIRONMENTAL PROTECTION AGENCY'S MERCURY AND AIR TOXICS STANDARDS (MATS) FOR POWER PLANTS

TUESDAY, MARCH 20, 2012

U.S. SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
SUBCOMMITTEE ON CLEAN AIR AND NUCLEAR SAFETY,
Washington, DC.

The Subcommittee met, pursuant to notice, at 10 a.m. in room 406, Dirksen Senate Office Building, Hon. Thomas R. Carper (Chairman of the Subcommittee), presiding.

Present: Senators Carper, Lautenberg, Merkley, Barrasso, and Alexander.

OPENING STATEMENT OF HON. THOMAS R. CARPER, U.S. SENATOR FROM THE STATE OF DELAWARE

Senator CARPER. This hearing will come to order.

Good morning, everybody. I appreciate the effort of all of our witnesses to be with us today.

Today's hearing is focused on the Mercury and Air Toxics Standard, which the EPA finalized in December this past year. Senators will have 5 minutes to make their opening statements.

I will then recognize the Assistant Administrator for the Office of Air and Radiation at EPA to offer her statement to the Committee. Following her statement, we will have one round of questions, then our second panel of witnesses will come forward. And their testimony will be followed by one round of questions.

I am going to give my statement now and yield to whoever shows up. If no one else shows up, it is Senator Lautenberg's ball game.

In 1990 Congress overwhelmingly passed and President George H.W. Bush signed the Clean Air Act Amendments of 1990. This law established the framework for modern day clean air protections like the one we are talking about here today. In the Clean Air Act Amendments of 1990 Congress identified 188 air toxics—toxics like mercury, lead, and arsenic—that were known to be harmful to public health and needed to be controlled. Many of these air toxics are silent killers, getting into food we eat as well as the air we breathe and building up in our bodies without our knowledge.

In the Clean Air Act amendments of 1990 Congress also established a common sense approach to reducing air toxics. Congress required sources of these toxics to implement proven technologies which were already being used by 12 percent of all actors in their

respective industries. After decades of study EPA has concluded that coal- and oil-fired power plants emit over 60 of these identified air toxics, roughly one-third.

The EPA has also found that these types of utilities are the largest source of mercury emissions in this country.

Over the years, we have seen through State-led examples that clean mercury from dirty coal power plants can significantly reduce the mercury in nearby lakes, fish, and fowl. Yet 22 years after Congress approved addressing coal- and oil-fired power plants, air toxics under the Clean Air Act Amendments of 1990, the Federal Government is just now starting to curb these harmful pollutants.

This February the EPA issued the Mercury and Air Toxics Standards for power plants, known as the MATS rule, directing dirty coal- and oil-fired power plants to use current technology to clean up their toxic emissions. As someone who has tried for years to work across the aisle to find a way to clean up our Nation's power plants, I was encouraged to see the EPA finally act to address these harmful emissions.

Furthermore, as someone who also believes the role of Government is to provide a nurturing environment for job growth and job preservation while ensuring corporations act as good citizens, I was encouraged by how the EPA issued the Mercury and Air Toxics Rules.

This long overdue public health measure will help ensure our Nation's utilities are doing their very best to keep our air clean, allowing many people in this country to live better, healthier, and in some cases longer lives.

At the same time the EPA has provided a reasonable and achievable schedule for our dirtiest power plants to reduce harmful emissions. The agency has even allowed extra time if needed for industry and States to address any possible local reliability concerns.

As we will hear today, some utilities will decide to close down their dirtiest, most inefficient coal plants rather than comply. It is just not affordable to modernize some of these plants. And as these plants do close, some communities will be impacted more than others.

However, most communities will see great benefits from these rules. In fact, nationally, I am told we will see up to $90 billion in public health benefits. And as we will also hear today, modernizing our coal fleet is expected to be a net job creator, not a job killer.

Which leads me to my final thought. I believe it is possible to have a clean environment and a strong economy. I believe it is a false choice to say that we can only have one or the other. We can have both. And in this country today, we must have both. And that is also true for cleaning up our air pollution.

In fact, as the EPA has implemented the Clean Air Act Amendments of 1990, our Nation's air has gotten cleaner. Electricity rates, I am told, have stayed constant. Our economy has grown by some 60 percent. Moreover, for every dollar we spend cleaning our air, we have seen some $30 returned in reduced health care costs, better workplace productivity, and lives saved.

Now with our economy moving out of a deep recession, some people—many of whom are my colleagues—are asking us to choose again between the economy and public health. They say we must

choose between cleaning up our biggest mercury polluters and jobs. They say we must choose between keeping our children safe from deadly toxics and keeping the lights on. Let me say again, we do not have to choose. We can have both; we must have both.

And on that statement, I look forward to having here an open and thoughtful dialogue with our witnesses and with our colleagues today.

I am happy to recognize, on my left from Wyoming, not Camden-Wyoming, Delaware, but from the State of Wyoming, Senator John Barrasso.

Good morning.

[The prepared statement of Senator Carper follows:]

STATEMENT OF HON. THOMAS R. CARPER,
U.S. SENATOR FROM THE STATE OF DELAWARE

In 1990 Congress overwhelmingly passed—and President George H.W. Bush signed—the Clean Air Act Amendments of 1990. This law established the framework for our modern day clean air protections—like the one we are talking about today.

In the Clean Air Act Amendments of 1990 Congress identified 188 air toxics—toxics like mercury, lead, and arsenic—that were known to be harmful to public health and needed to be controlled. Many of these air toxics are silent killers—getting into the food we eat as well as the air we breathe and building up in our body without our knowledge.

In the Clean Air Act Amendments of 1990 Congress also established a common sense approach to reducing air toxics. Congress required sources of these toxics to implement proven technologies—which were already being used by the best 12 percent of all actors in their respective industries. After decades of study the Environmental Protection Agency (EPA) has concluded that coal- and oil-fired power plants emit over 60 of the identified air toxics. The EPA has also found that these types of utilities are the largest source of mercury emissions in this country.

Over the years we have seen through State-led examples that cleaning up mercury from dirty coal power plants can significantly reduce the mercury in nearby lakes, fish, and fowl. Yet 22 years after Congress approved addressing coal- and oil-fired power plant air toxics under the Clean Air Act Amendments of 1990, the Federal Government is just now starting to curb these harmful pollutants. This February the EPA issued the Mercury and Air Toxics Standards for Power Plants (MATS) rule, directing dirty coal- and oil-fired power plants to use current technology to clean up their toxic emissions.

As someone who has tried for years to work across the aisle to find a way to clean up our Nation's power plants, I was encouraged to see the EPA finally act to address these harmful emissions. Furthermore, as someone who also believes the role of Government is to provide a nurturing environment for job growth and job preservation while ensuring corporations act as good citizens, I was encouraged by how the EPA issued the Mercury and Air Toxics Rule.

This long overdue public health measure will help ensure our Nation's utilities are doing their very best to keep our air clean—allowing many people in this country to live better, healthier, and in some cases, longer lives. At the same time the EPA has provided a reasonable and achievable schedule for our dirtiest power plants to reduce harmful emissions. The agency has even allowed extra time if needed for industry and States to address any possible local reliability concerns.

As we will hear today, some utilities will decide to close down their dirtiest, most inefficient coal plants rather than comply. It is just not affordable to modernize these plants. And as these plants close, some communities will be impacted more than others. However, most communities will see great benefits from these rules—in fact nationally we will see up to $90 billion in public health benefits. And as we will also hear today, modernizing our coal fleet is expected to be a net job creator not a job killer.

Which leads me to my final thought: I believe it's possible to have a clean environment and a strong economy. I think it's a false choice to say that we have to have one or the other; we can have both. That is especially true for cleaning up our air pollution. In fact, as the EPA has implemented the Clean Air Act Amendments of 1990, our Nation's air has gotten cleaner while electricity rates have stayed constant and our economy has grown by 60 percent. For every dollar we spend cleaning the

air we've seen $30 returned in reduced health care costs, better workplace productivity, and lives saved.

Now with our economy moving out of a deep recession, some people—many of which are my colleagues—are asking us to choose again between the economy and public health. They say we must choose between cleaning up our biggest mercury polluters and jobs. Choose between keeping our children safe from deadly toxics and keeping the lights on. Let me say again—we do not have to choose. We can have both. And on that note, I look forward to having an open and thoughtful dialogue with our witnesses and my colleagues today.

OPENING STATEMENT OF HON. JOHN BARRASSO, U.S. SENATOR FROM THE STATE OF WYOMING

Senator BARRASSO. Thank you, Mr. Chairman. I prefer to be on your right, as I tend to be on the right on most issues. So thank you, Mr. Chairman, for the opportunity to testify and to talk about this, about the EPA's Utility MACT rule.

I will wait until the witness pays attention to my comments. Thank you.

Mr. Chairman, EPA's Utility MACT rule is designed to protect the public health. In reality, it is not a boon for public health. It should be, but it is not. And that is unfortunate.

The rule is meant to address mercury emissions from coal-fired power plants. Yet over 99 percent of the benefits the EPA claims are from reducing particulate matter, even though it is strictly regulated under other Clean Air Act programs. This is misleading the public about the true cost of this rule.

EPA estimates that the health benefits for reducing mercury—and Mr. Chairman, you made the comment about mercury—the EPA estimates that the health benefits of reducing mercury to between a half a million and $6 million a year. EPA also states that the cost of the rule would be $9.6 billion in 2016, meaning the costs far, far, far outweigh the benefits, contrary to the rhetoric coming out of this agency.

According to a recent NERA study, the rule, combined with EPA's Cross-State Air Pollution Rule, could cost 1.4 million jobs. It is not a good investment for the public. The costs dramatically outweigh the benefits. Especially if you quantify the negative health consequences of unemployment on families with children and on the elderly. When the income dries up after the husband or wife is laid off at the now-defunct power plant, the impacts are devastating to communities and families. Especially if you factor in the lost local tax revenue to towns where coal-fired power plants close.

As the witness from Avon Lake, Ohio, is going to testify, millions of dollars in property taxes will be lost to his town when their coal-fired power plant closes. A big chunk of those funds would have gone to the local school and to emergency services.

What programs for children will be cut? How many policemen and firefighters will be laid off because of decisions made by this Administration?

We don't have the answers to all of those questions, but since plant closures are occurring in towns like Avon Lake across the country, we need those answers. As I stated, the Utility MACT rule cost $9.6 billion. I am here to ask the question, how many lives could we save with that kind of money? The answer is many. Not like this, and I think we can and should do better.

So the question remains, why are we doing this? I believe this rule is part of the Administration's ongoing war on coal. The Administration can't flat-out ban coal, because they know Congress wouldn't stand for it in a bipartisan way. Instead, they have decided to regulate everything that a coal-fired power plant does until it can't function any more.

The EPA has denied that their rules are going to close that many coal-fired power plants. EPA predicted about 9.5 gigawatts of electric power retirements in total because of Utility MACT in the Cross-State Air Pollution Rule. Instead, according to the National Mining Association, over 25 gigawatts have already gone on the chopping block, and more are likely. According to the association, 25 gigawatts is enough power and energy to power 18.8 million homes affordably. Now those homes will have to get their power from somewhere else. Power is going to cost more, and it's going to cost jobs.

As the President said when he was running for office, under his plan electricity costs would necessarily skyrocket. Seniors on fixed incomes, struggling families, and small business owners can thank the EPA and this Administration for their higher electric bills.

This rule is a bad bet for the public. It is one of many made by this Administration. The Administration is picking winners and loser. Unfortunately, the losers are losing, and the winners are also losing. President Obama's plan in subsidizing Solyndra-style green energy venture capitalists while over-regulating affordable coal-fired power has failed the public. We need a change.

That is why I support the efforts by Ranking Member Inhofe using the Congressional Review Act, his amendment that would send EPA's Utility MACT rule back to the drawing board at EPA. It would save millions of jobs.

Thank you, Mr. Chairman. I look forward to the testimony.

Senator CARPER. Thank you, Senator.

All right, I think our next speaker is Senator Lautenberg. Welcome, good to see you. I would just ask everyone to try and limit their statements to 5 minutes, please.

OPENING STATEMENT OF HON. FRANK R. LAUTENBERG, U.S. SENATOR FROM THE STATE OF NEW JERSEY

Senator LAUTENBERG. Thanks very much, Mr. Chairman.

I open up with a question. Is there anything more important than the health of our children and families? And that is why I applaud the Environmental Protection Agency for setting new pollution standards for mercury and toxic air pollution. It is a major victor in the fight for public health and cleaner air; one of the biggest wins in a generation.

These standards have been in the making since 1990, when Democrats and Republicans came together to pass Clean Air Act Amendments and require EPA to set strict limits on pollution. Today we are finally discussing the new EPA standards that will cut toxic air emissions from power plants by as much as 90 percent. For the first time in history, we will limit mercury emissions, brain poison to children.

Mercury can also badly damage a child's kidney, liver, and nervous system. Pregnant women exposed to high levels of mercury can

give birth to children, to babies who suffer from brain damage, learning disabilities, and hearing loss, among other conditions. It is frightening, but mercury is only one of the many air toxics released by power plants. Power plants are also a major source dioxins, which can cause birth defects; lead, which can damage nervous systems and reduce children's intelligence levels; and arsenic, which causes cancer.

Clearly, these new rules are desperately needed. And the benefits to public health go even farther. According to the EPA these rules will prevent more than 100,000 asthma attacks, almost 5,000 heart attacks, and up to 11,000 premature deaths each year. That is a fantastic result, without even considering the reduction in costs to our country.

We have waited a long time to see this day, but now the big polluters and their friends in Congress are stalling, claiming it is going to cost businesses too much to comply. It is nonsense. EPA's standards simply ensure that all companies use modern pollution control. The cleanest plants in our country have already demonstrated that they can succeed by investing in clean technology.

And to our colleagues who claim that these measures will be too costly to business, we have to ask, what about the health costs of breathing dirty air, and how do you put a price on human life? We have a distinguished colleague here who is a physician. And he asks the question, and it is kind of a rhetorical question, how many lives can you save? The question is, well, if you can't save a given number, why bother. Well, I think we have to bother. I am a grandfather of an asthmatic child. My sister was 53 when she had an asthma attack, tried to get to the respirator that she carried in a car, fell in a parking lot, and 3 days later died.

So we know what the effects are with an asthma attack. They are devastating. When my daughter takes my grandson to play in a sports event, she listens to see when he wheezes and finds out where the nearest emergency facility is.

Industry lobbyists have already succeeded in delaying these measures for more than a decade, and children are paying the price. Further delay is simply reckless. The bottom line is, rules and regulations aren't making our children sick—pollution is.

But clean air isn't just good for health, it is also good for business. And for those who disagree, I say come to New Jersey and look at PSE&G, an outstanding power company. They cut emissions of mercury and acid gases by 90 percent or more, and they created more than 1,600 jobs. We have to look at what the positives can be here, and not just throw up our hands, oh, well, it is going to cost too much, and thousands of people will be out of work. Thousands of people, maybe millions, will be healthier.

PSE&G proves that improving the health of our air can improve also the health of our economy. Don't just take my word for it. The CEO of PSE&G wrote in the Wall Street Journal that the EPA rules will provide certainty to move forward with large, job creating investments to modernize America's electric power infrastructure. Action is long overdue, and I know that we can have clean air, healthy families, and a strong economy. I think that these new standards are the way to do it, and I look forward to hearing from our witnesses.

Senator CARPER. Thank you, Senator Lautenberg.
Senator Alexander.

OPENING STATEMENT OF HON. LAMAR ALEXANDER, U.S. SENATOR FROM THE STATE OF TENNESSEE

Senator ALEXANDER. Thanks, Mr. Chairman.

At a roundtable on the Clean Air Amendments that Senator Carper hosted recently, former EPA Administrator Bill Riley, who was with the first President Bush, said the following: "Congress doesn't matter to most of these environmental debates; it is all EPA and the courts." He was referring to the so-called stalemate here in the Congress.

And that stalemate exists. Senator Carper and I have been trying to pass a law that regulates mercury from coal-fired power plants in a reasonable way since 2003, ever since I came to the Senate. But depending on the political balance here, the environmentalists are waiting for a better rule from EPA, and the industry is trying to delay, and those are generalizations, but they are about right. So we have no results, so we leave it to the EPA and the courts. And then we complain about the rule.

If the rule is defective, if this rule is defective, the way to deal with that is not to kill the rule, we have to change the law. I think generally speaking we ought to provide a clear performance standard and then err on the side of giving utilities a reasonable amount of time to do it at a low cost, so it can be done. But that is not what we are doing here.

But if we look at the law, this rule is clearly within the law. Utilities have known since 1990 that they would have to get mercury out of coal plants. That is what the law says you have to do. It specifically mentions mercury. The law that was written in 1990—more than 20 years ago—also says that the EPA must come up with a rule to do it. The law also says that after EPA has a rule the utilities have 3 years to comply with it, with some allowance for 3 more years if States and the President agree. That is all in the law. That is not in the rule, that is in the law.

And it also says that utilities have to use the maximum achievable technology, in other words, the best technology available. That is also in the law. So if we don't like the rule, we will have to change the law.

We also know that mercury is a particularly nasty element. It is bad. When it gets into the water and is ingested by fish, it turns into very toxic stuff, and it can very dangerous to small children and to fetuses, and child-bearing women are advised not to each much fish as a result of that today. We also know that a lot of it comes out of our coal-fired power plants.

My own view is that we need to rely on coal for a long time in the United States. But there is no excuse for operating coal plants that don't have pollution control equipment on them for sulfur, nitrogen, and mercury. If we put that pollution control equipment on plants, and some plants would close, primarily because they are too old and because natural gas is so cheap today, but if we put that on plants then probably we would still be using coal for 30 to 40 percent of our electricity while we struggle to figure out what to do about carbon that comes out of the coal plants.

We know what to do about sulfur, nitrogen, and mercury. And as I have been saying since 2003, we ought to get on with it and do it. Many utilities have, particularly the unregulated utilities. They have seen this coming for 20 years; they saw that the Bush administration had a rule on mercury in 2005. The court invalidated that in 2008, and then the court told the EPA to write a rule on mercury.

So we have the Congress telling EPA to write a rule on mercury, the courts telling EPA to write a rule on mercury. They have now written a rule on mercury that is within the law, and if we want to change the rule, we have to change the law.

My preference would be that utilities would have a certain 6 years in order to implement the new pollution control equipment. The way the rule is written, based upon the law, is that they have to do it within 3 years. And then the State can give the utility 1 more year under the EPA guidance and the law. And then the President can give another 2 years.

If I were a utility executive I would want a certain 6 years in order which to make a decision about, am I going to close the plant down, or am I going to buy the equipment.

The last thing I would say, we have heard for several years that there is no question but that there is technology available to control mercury. It has been there. So for 20 years utilities have known they have to do this. It is within the law to do it. The only question about this, it seems to me, in terms of the rule, is that it would be better if we had 5, 6, 7 certain years. That was more like what we did in the Carper-Alexander legislation. But that would require change in the law. It couldn't be done by killing the rule.

So I look forward to the testimony, Mr. Chairman, and I think it is important to keep in mind exactly what the law requires, which is the Congress' responsibility and what the EPA has done in promulgating the rule at the direction of the Federal court.

Senator CARPER. I just want to make a minor correction to the statement of the Senator from Tennessee. The Clean Air Roundtable that he talked about was one actually we co-hosted. I did not host it. And we have worked together on these issues for a long time. It has been my pleasure to do so.

Senator Merkley.

OPENING STATEMENT OF HON. JEFF MERKLEY, U.S. SENATOR FROM THE STATE OF OREGON

Senator MERKLEY. Thank you, Mr. Chair.

I applaud the work of my colleagues on this and the fact that this has been in the works for over 20 years. These standards which EPA has been instructed both by Congress and by the courts to produce will provide enormous health benefits for millions of Americans and protect children and adults from dangerous air pollution.

It is estimated they will prevent 90 percent of the mercury in coal-burning power plants from being emitted into the air, reduce 88 percent of the acid gas emissions from power plants, reduce 41 percent of the sulfur dioxide, and reduce fine particulate matter by 19 percent. Those have a significant health impact.

There is no reason why almost all oil- and coal-fired plants can't comply with these new standards. The technology is available, and it is the right thing to do to protect public health. The EPA has estimated the health benefits associated with this new rule to be $37 billion to $90 billion in 2016. That is a dollar number, but the real-life impact that families will observe will be the impact on premature deaths, heart attacks, chronic bronchitis, asthma, respiratory symptoms, and so forth.

So I look forward to the testimony, and thank you for the work of my colleagues.

Senator CARPER. All right, thank you.

Let me welcome our first witness this morning, Gina McCarthy. Ms. McCarthy, as many of us know, is the EPA Assistant Administrator for the Office of Air and Radiation. Gina has also been doing a terrific job since she joined the EPA 400 years ago. Probably seems that long, doesn't it?

[Laughter.]

Senator CARPER. Ms. McCarthy, you will have 5 minutes to read your opening statement. If you go way over that, I will rein you in. Try to stay fairly close to that. The full content of your written statement will be included in the record. Please proceed.

STATEMENT OF HON. REGINA MCCARTHY, ASSISTANT ADMINISTRATOR, OFFICE OF AIR AND RADIATION, U.S. ENVIRONMENTAL PROTECTION AGENCY

Ms. MCCARTHY. Thank you, Chairman Carper, Ranking Member Barrasso, members of the Committee. I appreciate the opportunity to testify before you today.

Last December EPA finalized the Mercury and Air Toxics Standards. These standards, required by the Clean Air Act, are the first national standards to protect American families from power plant emissions of mercury and other toxic air pollutants such as arsenic, acid gases, nickel, selenium, and cyanide. These long overdue standards will help make our children and our communities healthier.

MATS will eliminate 20 tons of mercury emissions and hundreds of thousands of tons of acid gas and toxic pollutants each year. The control equipment that reduces these toxic emissions will also reduce fine particle pollution. As a result MATS will help protect children and adults from the effects of exposure to toxic air pollutants, save thousands of lives, and prevent more than 100,000 heart attacks and asthma attacks each year.

We project that the annual benefits associated with MATS in terms of public health are $37 billion to $90 billion annually. And they will far outweigh the annual projected costs of $9.6 billion. Technologically we know how to achieve these standards. MATS relies heavily on available pollution prevention control equipment that is already in use and installed in more than half of the Nation's coal-fired power plants. These standards are also affordable. EPA projects that electricity prices on average will rise 3 percent as a result of MATS. With MATS and the Cross-State Air Pollution Rule combined, the rates are projected to stay well within the range of normal historical fluctuations.

In addition, the updated standards will support thousands of good jobs for American workers, who will be hired to build, to install, and operate control equipment. We already see examples of that job growth happening as a result of this rule.

My staff recently was told by a plant owner in Tennessee that manufactures pollution control equipment that they now expect to hire an additional 100 people to manufacture control equipment that is going to be used for compliance with the Mercury and Air Toxics Standards. Furthermore, the country can achieve these reductions while maintaining a strong, reliable electric grid. Several EPA and Department of Energy analyses conclude that MATS will not adversely affect capacity reserve margins in any region of this country.

A January 2012 Congressional Review Service report reached similar conclusions.

There are liability concerns we heard were largely tied to concerns that 3 years was not enough time for compliance. Well, we have addressed that concern. Sources will generally have 4 years, until the spring of 2016, to comply with MATS. And reliability-critical units may have an additional year, until 2017.

Let me explain. All power plants will have at least 3 years. That is the latest compliance date available under the Clean Air Act. But in addition State and local permitting authorities can grant an additional year under certain circumstances. And EPA has recommended that this 4 years be broadly available to sources that require it for a wide range of activities, including completing technology installations, constructing replacement power, upgrading transmission lines, maintaining reliability, while other sources complete their compliance activities.

My staff and I have already begun and will continue to reach out to States to help develop a clear, straightforward process for requesting and granting this extension.

Additionally, EPA has provided a well defined pathway for reliability-critical units to get an additional year beyond the 4 years, using a pathway that was set forth in a policy memorandum from EPA's Office of Enforcement and Compliance Assurance. While we don't foresee any problems in the country maintaining a reliable electric grid as a result of our rules, the President has also issued a memo which was released at the same time as the MATS rule, reminding EPA, DOE, and FERC to work together to ensure that they address any potential localized reliability concerns that might arise.

My staff and I have been and will continue to work with the organizations that have responsibility for maintaining the Nation's electricity grid to ensure that we address any problems that arise. We are also working to help power plant owners understand their responsibilities.

Over the last weeks and months we have had extensive meetings with both our environmental regulators as well as the power plant industry. We will continue that outreach effort moving forward.

In summary, EPA's final MATS standard will reduce emissions of toxic air pollutants from power plants and will lead to healthier communities and a safer environment. For 40 years we have been able to implement the Clean Air Act, we have been able to grow

the American economy, and we have been able to keep the lights on. MATS will not change that.

Thank you for this opportunity to testify. I look forward to your questions.

[The prepared statement of Ms. McCarthy follows:]

Opening Statement of Regina McCarthy
Assistant Administrator
U.S. Environmental Protection Agency

Committee on Environment and Public Works

Subcommittee on Clean Air and Nuclear Safety

March 20, 2012

Hearing Titled "Oversight: Review of the Environmental Protection Agency's Mercury and Air Toxics Standards (MATS) for Power Plants"

Chairman Carper, Ranking Member Barrasso, and members of the Subcommittee, I appreciate the opportunity to testify before you today on EPA's Mercury and Air Toxics Standards.

On December 16, 2011, EPA finalized the Mercury and Air Toxics Standards (MATS), the first national standards to protect American families from power plant emissions of mercury and other toxic air pollution like arsenic, acid gas, nickel, selenium, and cyanide. The standards will slash emissions of these dangerous pollutants by relying on widely available, proven pollution controls that are already in use at more than half of the nation's coal-fired power plants.

MATS will save thousands of lives and prevent more than 100,000 heart and asthma attacks each year while providing important health protections to the most vulnerable, such as children and older Americans. We do not have to choose between the significant public health benefits from reducing air pollution from power plants and a strong, reliable electric grid. Nor do we have to choose between clean, healthy air and robust economic growth and job creation. We can reduce harmful pollution while growing the U.S. economy and ensuring the reliable delivery of electricity to our families and businesses. As President Obama recently stated, "And because we acted, we're going to prevent thousands of premature deaths, thousands of heart attacks and cases of childhood asthma...We're creating healthier communities. But that's not all. Safeguarding our environment is also about strengthening our economy. I do not buy the notion

that we have to make a choice between having clean air and clean water and growing this economy in a robust way. I think that is a false debate."[1]

EPA received hundreds of thousands of public comments strongly supporting our Mercury and Air Toxics Standards to protect children and families from mercury and other toxic pollution. Some of the comments that EPA received during the public comment process allowed us to make changes to the standards that make them clearer, more flexible, and less expensive, while maintaining human health protections that will provide tangible benefits to American families for generations to come

Cleaning up the power sector is overdue

In 1990, three source categories made up approximately two-thirds of total U.S. mercury emissions: power plants, municipal waste combustors (MWCs), and medical waste incinerators (MWIs). Since then, MWCs have reduced their emissions by 96% and MWIs have reduced their emissions by over 98%. Many other major sources categories, such as cement plants and steel manufacturers, are also reducing their mercury emissions.

The power plant rules EPA has developed are necessary to protect public health and the environment from the pollution these plants produce – a need that both Republican and Democratic administrations have recognized for decades. For over 20 years, since President George H.W. Bush proposed what became the Clean Air Act Amendments of 1990, power plant clean-up has been the continuous policy of the U.S. government under two Democratic and two Republican presidents.

Over the years, many power plants have invested in modern pollution controls to reduce their emissions and have contributed to the significant progress this country has made in providing healthy air to our citizens. Many other power plants, however, have delayed investments in pollution control equipment that have been widely available for years – including equipment to reduce emissions of mercury and other toxic air pollutants. As a result, power plants remain the country's largest source of mercury and sulfur dioxide (SO_2) emissions, and the largest stationary source of nitrogen oxide (NO_X) emissions.[2] Power plant pollution contaminates the fish we eat; damages our nation's sensitive lakes, rivers, and streams; and is

[1] http://www.whitehouse.gov/the-press-office/2012/01/10/remarks-president-epa-staff
[2] EPA National Emissions Inventory (2008) http://www.epa.gov/air/emissions/index.htm

linked to tens of thousands of premature deaths and hundreds of thousands of asthma attacks each year.

MATS is needed to protect public health

In 2011, EPA issued two long-overdue rules to reduce air pollution from power plants – MATS and the Cross State Air Pollution Rule.[3] Both of these affordable, technologically achievable rules will provide enormous public health benefits for Americans that are significantly greater than the costs.

The Mercury and Air Toxics Standards, the topic of today's hearing, are required by the 1990 Clean Air Act Amendments. They are designed to reduce emissions of mercury, other toxic metals such as cadmium, nickel and arsenic, acid gases, and other toxic air pollutants. Mercury, depending on the form and dose, may cause neurological damage in children who are exposed before birth and is also associated with impacts on children's cognitive thinking, memory, attention, language, and fine motor and visual spatial skills. Metals such as arsenic, chromium, and nickel cause cancer and other health risks. Acid gases cause lung damage and contribute to asthma, bronchitis and other chronic respiratory diseases, especially in children and the elderly. Until these standards were finalized in December 2011, there were no national requirements to reduce mercury and other air toxic emissions from power plants.[4] These overdue national standards will level the playing field and help modernize the fleet of aging power plants.

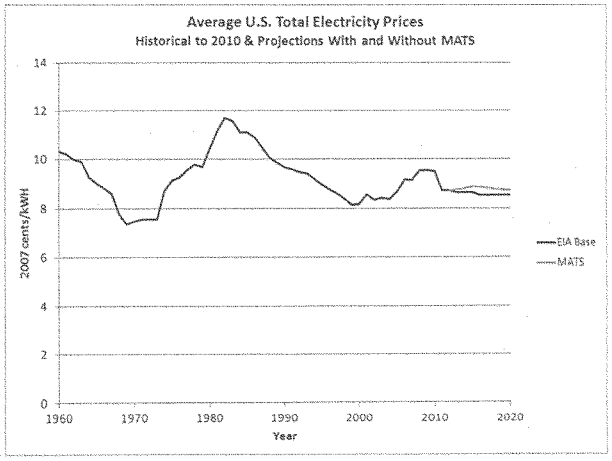
The final MATS will eliminate 20 tons of mercury emissions and hundreds of thousands of tons of acid gases and toxic pollutants each year. The control equipment that reduces emissions of these toxics also will reduce fine particle pollution. Based on the reductions in fine particle pollution, we project that in 2016 these standards will prevent approximately:

- 4,200 to 11,000 premature deaths
- 4,700 heart attacks
- 130,000 cases of childhood asthma symptoms
- 6,300 cases of acute bronchitis among children
- 5,700 emergency room visits and hospital admissions

[3] This was called the "Transport Rule" when it was proposed.
[4] The last Administration's rule attempting to limit national mercury emissions from power plants was overturned in court in 2008 for failing to meet the requirements of the Clean Air Act.

• 540,000 days of work missed due to respiratory illness.[5]

In total, the annual public health benefits from MATS are estimated to be $37 to $90 billion. These benefits will continue each year after the control equipment is in place. In addition, there are many health effects associated with toxic air pollution (like mercury, chromium, nickel and arsenic) that EPA is unable to quantify. We also cannot yet quantify the benefits of MATS for outdoor recreational enthusiasts, or in preventing adverse effects on fish, birds, mammals and ecosystems. If we were able to quantify all of these effects, the benefits would potentially exceed the costs by an even larger margin than we currently estimate.



MATS is affordable

EPA's modeling indicates the annual cost of implementing MATS will be approximately $9.6 billion, significantly less than the estimated annual benefits of $37-90 billion. EPA's modeling for the final standards indicates that any change in retail electricity prices will be very small (approximately 3% on a national basis) and will not cause prices to rise even to 1990 levels. In fact, as shown in Figure 1, EPA's modeling shows that after both MATS and the Cross State Rule (in the base case) are implemented, electricity rates are projected to stay well within the range of normal historical fluctuations and below levels seen as recently as 2009. In addition, the updated standards will support thousands of good jobs for American workers who will be

[5] These benefits are from emissions reductions achieved solely by the final Mercury and Air Toxics Standards, and not from the Cross State Rule or any other emissions reduction regulation. When EPA estimated the benefits for MATS, we included the Cross State Air Pollution Rule (known then as the Transport Rule) in the baseline for our analysis, so these estimates represent the incremental benefits of MATS alone.

hired to build, install, and operate the equipment to reduce health-threatening emissions of mercury, acid gases, and other toxic air pollutants. EPA estimates that investments made to comply with MATS will provide 8,000 long term jobs in the power sector and 46,000 short term construction jobs.

MATS is achievable and will not "turn out the lights"

There were three primary concerns among the stakeholders who raised implementation concerns about MATS during the public comment period: a) the magnitude and technical feasibility of pollution control retrofits needed to comply with the standards; b) the time available to complete necessary installations and retrofits; and c) the effect of the standards on electric reliability before and after the compliance deadlines. Of these three related issues, the last one has received the greatest amount of public and Congressional attention.

In response to stakeholder comments EPA received on operational concerns related to the magnitude and technical feasibility of retrofits required by the standard, we made a number of substantive changes to the compliance requirements. These changes include switching to a filterable particulate matter (PM) emissions limit and providing sources the option to use a more flexible facility-wide averaging approach as long as it provides equivalent reductions in mercury. We are also providing separate sub-categories of standards for limited use and non-continental oil-fired units, as well as more achievable new source standards. These changes maintain reductions in air toxics while making implementation easier and less costly.

EPA also paid close attention to comments raised by stakeholders regarding the time available to achieve compliance with MATS, as well its impacts on electric reliability. Before MATS was finalized, EPA and the Department of Energy (DOE) conducted several analyses of its effects on electric generation resources.[6] EPA's and DOE's analyses demonstrate that the vast majority, if not all, sources will be able to meet the MATS requirements within the time frames provided under the Clean Air Act – which I discuss at greater length below.

EPA's resource adequacy analysis continues to demonstrate that only a modest amount of generating capacity will become uneconomic to operate under the MATS standards, and removal

[6] Environmental Protection Agency (2011). "Resource Adequacy and Reliability in the IPM Projections for the MATS Rule" http://www.epa.gov/ttn/atw/utility/revised_resource_adequacy_tsd.pdf
Department of Energy (2011). "Resource Adequacy Implications of Forthcoming EPA Air Quality Regulations" http://energy.gov/sites/prod/files/2011%20Air%20Quality%20Regulations%20Report_A_120911.pdf

of this capacity will not adversely affect capacity reserve margins in any region of the country. In addition, new capacity will be added between now and 2015. The analysis projects that, as a result of MATS, plant operators will choose to retire less than one half of one percent (4.7 gigawatts (GW)) of the more than 1,000 GW that make up the nation's electric generating capacity. This retiring generation capacity is an average of more than fifty years old, relatively inefficient, and does not have modern pollution controls installed. It should be noted that over the last few years low natural gas prices and an aging coal generation fleet have been pushing the industry towards less reliance on coal and greater reliance on natural gas. David Sandalow, DOE Assistant Secretary for Policy and International Affairs, summarized the DOE analysis as "demonstrat[ing] that new EPA rules – which will provide extensive public health protections from an array of harmful pollutants – should not create resource adequacy issues[7]." In addition, a recent Congressional Research Service report (January 2012)[8] reviewed industry data on planning reserve margins and potential retirement of units that do not currently meet the standards and concluded, based on these data "that, although the rule may lead to the retirement or derating of some facilities, almost all of the capacity reductions will occur in areas that have substantial reserve margins."

EPA took steps in the final MATS standards to address stakeholder concerns that compliance with MATS could not be achieved within the maximum three-year compliance date authorized under the statute. In the final rule, EPA described in detail the wide range of situations where we believe an additional year for compliance could be granted by permitting authorities. This fourth year - in addition to the three years provided to all sources - is provided by the Clean Air Act as needed to complete installation of control technologies. EPA suggests that permitting authorities make this fourth year broadly available to sources that require it to complete their compliance activities, including installing pollution control equipment, constructing on- or off-site replacement power, and upgrading transmission. EPA is also encouraging the fourth year to be available as needed to units that continue to operate for reliability purposes while other units are installing pollution controls. As described in more detail below, EPA has reached out to states and permitting authorities to help ensure that the fourth year for compliance is broadly available. We believe that requests for the fourth year extension

[7] http://energy.gov/articles/energy-department-releases-study-electricity-system-ahead-proposed-epa-air-quality
[8] James E. McCarthy, January 9, 2012. "EPA's Utility MACT: Will the Lights Go Out?" http://www.eenews.net/assets/2012/01/19/document_gw_03.pdf

for air toxic standards are being handled well by states and encourage them to continue processing these requests as they have done in the past. EPA staff, including both our headquarters and regional offices, are available to quickly provide assistance and answer any questions as needed. As a result, EPA estimates that sources generally will have until spring of 2016 to comply – one year longer than our analysis indicates is necessary for most sources.

Although EPA's analysis indicates that most, if not all, sources can comply within three years, and that the fourth year should be available in the broad range of situations described above, EPA is also providing a clear pathway for units that are shown to be critical for electric reliability to obtain a schedule to achieve compliance within up to an additional year beyond the four years mentioned above. This pathway is set forth in a policy memorandum from EPA's Office of Enforcement and Compliance Assurance.[9] As stated above, EPA believes there will be few, if any, situations in which this pathway will be needed. In addition, in the unlikely event that there are situations where sources that do not fall into any of these categories cannot come into compliance on a timely basis, EPA will address them on a case-by-case basis, at the appropriate time, to determine the appropriate response and resolution. This is consistent with its longstanding historical practice under the Clean Air Act.

As part of the Administration's commitment to maximize flexibilities under the law, MATS was accompanied by a Presidential Memorandum that directs EPA to take a number of steps to ensure continued electric reliability. These steps include: 1) working with State and local permitting authorities to make the additional year for compliance with MATS provided under section 112(i)(3)(B) of the Clean Air Act broadly available to sources; 2) working with the Department of Energy, the Federal Energy Regulatory Commission, State utility regulators, Regional Transmission Organizations, the North American Electric Reliability Corporation and regional electric reliability organizations, other grid planning authorities, electric utilities, and other stakeholders, as appropriate to promote early, coordinated, and orderly planning; and 3) making available to the public, including relevant stakeholders, information that describes the process for identifying circumstances where electric reliability concerns might justify allowing additional time to comply. EPA is in the process of taking a number of steps to implement the directives in this memo.

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[9] EPA Memorandum December 16, 2011. "The Environmental Protection Agency's Enforcement Response Policy For Use of Clean Air Act Section 113(a) Administrative Orders in Relation To Electric Reliability and the Mercury and Air Toxics Standard" http://www.epa.gov/compliance/resources/policies/civil/erp/mats-erp.pdf

EPA is actively engaging power plants and other entities that will be involved in getting power plants retrofitted while maintaining the reliability of the electric grid. EPA has held, and will continue to hold, a series of discussions with the Department of Energy, the Federal Energy Regulatory Commission, State utility regulators, Regional Transmission Organizations, the North American Electric Reliability Corporation, regional electric reliability organizations, and other grid planning authorities to promote early compliance planning, to support orderly implementation of the MATS standards, and to ensure that any potential, localized reliability concerns are identified and addressed. EPA has started and will continue discussions with power plant owners and operators to help them understand their responsibilities under the standards and their role in early, coordinated, and orderly planning. EPA is conducting specific outreach to stakeholders with unique concerns such as rural electric cooperatives, public power facilities, and investor-owned utilities. In addition, EPA will also engage in outreach to states and permitting authorities to help ensure that the fourth year for compliance is broadly available and that the process for sources to request and states to grant the extensions is clear and straightforward.

The nation's power grid is strong and resilient because numerous agencies and organizations fulfill their obligations to maintain the nation's electric reliability. As discussed above, EPA has already been working and will keep working with these organizations so that they can take the necessary steps to continue to fulfill this obligation while ensuring smooth implementation for MATS. Key steps include early planning and early notification of compliance plans by affected sources, system operators, and state and federal regulators. One regional transmission organization, PJM Interconnection, which operates a competitive wholesale electricity market and manages the high-voltage electricity grid to ensure reliability for more than 58 million people in the eastern U.S., has already begun asking its members for MATS compliance planning information. Over the 40 year history of the Clean Air Act, these stakeholders – working together with State and Federal regulators – have had an outstanding track record of substantially reducing pollution while maintaining reliability. We remain confident that, together, we have the tools to address any challenges that may arise in connection with the implementation of the MATS standards.

The Clean Air Act

The Cross State and MATS rules will continue the decades-long Clean Air Act success story. For 40 years, the Clean Air Act has fostered steady progress in reducing the threats posed by pollution and allowing us all to breathe easier. In 2010 alone, programs implemented pursuant to the Clean Air Act Amendments of 1990 are estimated to have reduced premature mortality risks equivalent to saving over 160,000 lives; spared Americans more than 100,000 hospital visits; and prevented millions of cases of respiratory problems, including bronchitis and asthma attacks.[10] They also enhanced productivity by preventing 13 million lost workdays; and kept kids healthy and in school, avoiding 3.2 million lost school days due to respiratory illness and other diseases caused or exacerbated by air pollution.[11]

However, few of the emission control standards that gave us these huge gains in public health were uncontroversial at the time they were developed and promulgated. Most major rules have been adopted amidst claims that that they would be bad for the economy and bad for employment. In contrast to doomsday predictions, history has shown, again and again, that we can clean up pollution, create jobs, and grow our economy all at the same time. Over that same 40 years since the Act was passed, the Gross Domestic Product of the United States grew by more than 200 percent.[12] It is misleading to say that enforcement of the Clean Air Act is bad for the economy and employment. It isn't. Families should never have to choose between a job and healthy air. They are entitled to both.

Some may find it surprising that the Clean Air Act also has been a good economic investment for our country. A study led by Harvard economist Dale Jorgenson found that implementing the Clean Air Act actually increased the size of the US economy because the health benefits of the Clean Air Act lead to a lower demand for health care and a healthier, more productive workforce. According to that study, by 2030 the Clean Air Act will have prevented 3.3 million lost work days and avoided the cost of 20,000 hospitalizations every year.[13] Another

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[10] USEPA (2011). The Benefits and Costs of the Clean Air Act from 1990 to 2020. Final Report. Prepared by the USEPA Office of Air and Radiation. February 2011. Table 5-6. This study is the third in a series of studies originally mandated by Congress in the Clean Air Act Amendments of 1990. It received extensive peer review and input from the Advisory Council on Clean Air Compliance Analysis, an independent panel of distinguished economists, scientists and public health experts.

[11] Ibid.

[12] Bureau of Economic Analysis, National Economic Accounts, "Table 1.1.5. Gross Domestic Product," http://bea.gov/national/index.htm#gdp

[13] Dale W. Jorgenson Associates (2002a). *An Economic Analysis of the Benefits and Costs of the Clean Air Act 1970-1990. Revised Report of Results and Findings.* Prepared for EPA. http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0565-01.pdf/$file/EE-0565-01.pdf

study that examined four regulated industries (pulp and paper, refining, iron and steel, and plastic) concluded that, "We find that increased environmental spending generally does not cause a significant change in employment."[14]

The EPA's updated public health safeguards under the Clean Air Act will encourage investments in labor-intensive upgrades that can put current unemployed or under-employed Americans back to work. Environmental spending creates jobs in engineering, manufacturing, construction, materials, operation, and maintenance. For example, EPA vehicle emissions standards directly sparked the development and application of a huge range of automotive technologies that are now found throughout the global automobile market. The vehicle emissions control industry employs approximately 65,000 Americans with domestic annual sales of $26 billion.[15] Likewise, in 2008, the United States' environmental technologies and services industry of 1.7 million workers generated approximately $300 billion in revenues and led to exports of $44 billion of goods and services,[16] larger than exports of sectors such as plastics and rubber products.[17] The size of the world market for environmental goods and services is comparable to the aerospace and pharmaceutical industries and presents important opportunities for U.S. industry.[18]

Jobs also come from building and installing pollution control equipment. For example, the U.S. boilermaker workforce grew by approximately 35 percent, or 6,700 boilermakers, between 1999 and 2001 during the installation of controls to comply with EPA's regional nitrogen oxide reduction program.[19] Over the past seven years, the Institute for Clean Air

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[14] Morgenstern, R. D., W. A. Pizer, and J. S. Shih. 2002. "Jobs versus the Environment: An Industry-Level Perspective." *Journal of Environmental Economics and Management* 43(3):412-436.
[15] Manufacturers of Emissions Control Technology (http://www.meca.org/cs/root/organization_info/who_we_are)
[16] DOC International Trade Administration. "Environmental Technologies Industries: FY2010 Industry Assessment. http://web.ita.doc.gov/ete/eteinfo.nsf/068f3801d047f26e85256883006ffa54/4878b7e2fc08ac6d85256883006c452c/$FILE/Full%20Environmental%20Industries%20Assessment%202010.pdf (accessed February 8, 2011)
[17] U.S. Census Bureau, Censtats Database, International Trade Data--NAICS, http://censtats.census.gov/naic3_6/naics3_6.shtml (accessed September 6, 2011)
[18] Network of Heads of the European Environment Protection Agencies, 2005. "The Contribution of Good Environmental Regulation to Competitiveness." http://www.eea.europa.eu/about-us/documents/prague_statement/prague_statement-en.pdf (accessed February 8, 2011).
[19] International Brotherhood of Boilermakers, *Boilermaker Labor Analysis and Installation Timing,* March 2005, EPA Docket OAR-2003-0053 (docket of the Clean Air Interstate Rule).

Companies (ICAC) estimates that implementation of just one rule – the Clean Air Interstate Rule Phase 1 – resulted in 200,000 jobs in the air pollution control industry.[20]

Conclusion

As we did more than two decades ago during debate of the Clean Air Act Amendments of 1990, we are hearing claims that our rules will lead to potential adverse impacts on electric reliability. Our analysis and past experience indicate that warnings of dire consequences of moving forward with these important rules are exaggerated at best. For example, during development of the 1990 Clean Air Act Amendments, one utility warned of unrealistic compliance dates and issues with electrical reliability. Industry estimated at the time that the cost of the new requirements for sulfur dioxide would be $7.5 billion per year; in reality, the cost of achieving the reductions was around $1.5 - 2 billion per year – a fraction of the costs estimated by those seeking to prevent enactment of that landmark legislation.[21] The resulting emission reductions are providing substantial health and ecosystem benefits with a monetized value of between $170 billion and $430 billion per year (2008$).[22] The dire predictions were not true then, and industry's remarkably similar claims about the current Clean Air Act regulations are not true now.

EPA's final MATS standards are data-driven, will reduce emissions of toxic air pollutants from power plants, and will lead to healthier communities and a safer environment. Public review and comment ensured that all interested stakeholders had an opportunity to look at the details of the standards and weigh in – ultimately helping EPA to write a better, more effective regulation. The adjustments between the proposed and final standards maintain reductions in air toxics while making implementation easier and less costly. For 40 years, we have been able to implement the Clean Air Act, grow the American economy, and keep the lights on. MATS will not change that.

Thank you for the opportunity to testify today. I look forward to your questions.

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[20] November 3, 2010 letter from David C. Foerter, Executive Director of the Institute of Clean Air Companies, to Senator Thomas R. Carper (http://www.icac.com/files/public/ICAC_Carper_Response_110310.pdf (accessed February 8, 2011).

[21] National Acid Precipitation Assessment Program Report to Congress 2011: An Integrated Assessment http://www.whitehouse.gov/sites/default/files/microsites/ostp/2011_napap_508.pdf . All costs reported in $2000

[22] Ibid

Enclosure

Environment and Public Works Committee Hearing
March 20, 2012
Follow-Up Questions for Written Submission

Questions for Gina McCarthy

Questions from:

Senator Barbara Boxer

1. **Do coal- and oil-burning power plants emit pollution that contains mercury, arsenic, chromium, and other hazardous air pollutants that also stick to or is part of particulate matter ("toxic soot") emitted by the facilities?**

   Yes.

2. **Does the EPA's mercury and air toxics rule for coal- and oil-burning power plants require these facilities to use modern and available pollution controls technologies that makes it easier to remove larger amount of hazardous air pollutants, including by making dangerous heavy metals stick to toxic soot created by the facilities?**

   Yes.

3. **If coal- and oil-burning power plants use the modern and available pollution control technologies described in EPA's mercury and air toxics rule to reduce levels of toxic soot pollution, will these facilities also reduce their levels of mercury and other toxic air pollutants?**

   Yes.

4. **Are children and other people in communities at greater risk of suffering from harmful health effects that are easily recognizable -- such as aggravated asthma attacks, heart attacks, and premature death -- when they inhale toxic soot pollution emitted by coal- and oil-burning power plants?**

   Yes.

a. **Could you please describe the scientific basis for the Agency's answer, including whether the Agency relied on peer review science when using such information to estimate the benefits of reducing such pollution.**

   The EPA uses a three-step process to estimate health benefits related to air pollution regulations. This process uses peer-reviewed models and techniques that have been refined over several decades. This approach, updated to reflect advances in research over

time, has been used widely in EPA regulatory documents, as well as in the peer-reviewed literature.

First, we use atmospheric models to translate emission reductions into changes in ambient air concentrations that people breathe. Second, we use risk estimates from peer-reviewed epidemiology studies to derive a health impact function. This function estimates the number of avoided health effects associated with an improvement in overall air quality. Third, we use commonly used valuation techniques to put a dollar value on those avoided health effects.

The EPA's methods for estimating health benefits of air pollution regulations have been peer reviewed by the National Academies of Science and several panels of EPA's independent Science Advisory Board. In addition, every Regulatory Impact Analysis (RIA) is reviewed by scientists and economists within the EPA as well as other federal agencies. Every RIA is available for public review and comment along with the associated proposed regulation.

5. **Do certain hazardous air pollutants, such as mercury and lead, cause potentially subtle but still serious adverse health effects, including damage to the brain and nervous system of pregnant women, including pre-term fetuses, infants, and children?**

Exposure to mercury and/or lead, at levels much lower than that which would compromise adult health, can cause damage to the developing nervous systems of pre-term fetuses, infants and children. Pregnant women themselves are not generally at risk for damage to their own nervous systems due to mercury exposure unless they eat amounts of fish above the EPA and FDA guidelines for safe consumption by adults.

Power plants are currently the largest domestic source of mercury emissions to the air. Once mercury from the air reaches water, microorganisms can change it into methylmercury, a highly toxic form that builds up in fish. People are primarily exposed to mercury by eating contaminated fish. Methylmercury exposure is a particular concern for women of childbearing age, unborn babies, and young children, because studies have linked high levels of methylmercury to damage to the developing nervous system. This damage can impair children's ability to think and learn.

a. **If so, can you please describe the scientific basis for the Agency's benefits estimates for reducing hazardous air pollutants that can cause such harmful effects, including whether the Agency relied on peer review science in this work?**

The EPA used peer-reviewed methods to estimate the benefits of reducing hazardous air pollutants in the MATS RIA. The EPA estimated the monetary value of just one air toxics benefit – the change in IQ for people eating some kinds of fish from some U.S. waters. In order to accomplish this analysis we use models to translate emission reductions into changes in mercury concentrations in fish. Then we use risk estimates from peer-reviewed epidemiology studies to derive an IQ impact function. This function estimates the number of avoided IQ points loss associated with a reduction in mercury

emissions. Finally, we use commonly used valuation techniques to put a dollar value on those avoided health effects.

This monetized value is an underestimate of the mercury benefits for a number of reasons:

- it does not include consumption of commercially-caught fish
- it does not include mercury exposure from fish consumption for many water bodies in the U.S., including estuaries or the Great Lakes
- IQ loss is not the most sensitive endpoint to mercury exposure, and several other neurological and developmental endpoints are considered more sensitive according to the review of the mercury risk assessment by EPA's Science Advisory Board. These endpoints were not monetized, leading to an underestimation of benefits.

At the time of the rulemaking, the EPA also did not have data to quantify the environmental impacts of mercury emissions on ecosystems and wildlife especially fish, birds, and mammals.

Additionally, MATS will reduce emissions of hazardous air pollutants that at elevated levels can cause chronic irritation of the lung, skin, and mucous membranes; chronic and acute effects on the central nervous system; chronic and acute kidney damage; and cancer. While we know these effects can occur, the EPA was unable to quantify these benefits.

6. **Could you please describe the number of states that already require coal- and oil-burning power plants to use pollution control technologies that can meet the requirements in EPA's mercury and air toxics rule?**

A number of states have multi-pollutant power plant requirements that require some or all of their plants to install technologies that would reduce many (and in some cases all) of the pollutants required by this rule. States with multi-pollutant control requirements include: Illinois, North Carolina, Georgia, Minnesota, Colorado, Delaware, New Jersey, Massachusetts and Connecticut.

7. **Could you please describe some commonly used air pollution control technologies that can meet the standards in the EPA's mercury and air toxics rule?**

- Electrostatic precipitator (ESP) - charges fly ash particles in the flue gas and collects them on a surface. Subsequently, this surface is shaken to dislodge the collected particulate matter (PM).
- Fabric filter (FF) – flue gas passes through tightly woven fabric, resulting in collection of PM on the fabric. Subsequently fabric is shaken to dislodge the collected PM.
- Wet scrubber – flue gas comes in contact with limestone or lime slurry in the scrubber; sulfur dioxide (SO_2) reacts to form calcium sulfate/calcium sulfite salts, which are removed, and in some cases used for gypsum production (which has many

uses including in construction drywall and on soils to prevent fertilizer/pesticide run off).

- Activated Carbon Injection (ACI) - used to remove mercury.
- Dry Sorbent Injection (DSI) - used to remove acid gases, SO2 and SO3.
- Dry scrubber – used by some power plants now for SO2 reduction (and acid gas removal).

8. **Could you please describe the mercury and air toxics rule's benefits to public health and welfare and to the environment that EPA could not quantify?**

   MATS will reduce emissions of hazardous air pollutants, including mercury and acid gases, that can cause chronic irritation of the lung, skin, and mucous membranes; chronic and acute effects on the central nervous system; chronic and acute kidney damage; and cancer. In addition, mercury emissions can cause environmental impacts to ecosystems and wildlife especially fish, birds, and mammals. Most of these benefits cannot be quantified at this time. The EPA also considers the unquantified benefits of the criteria pollutants reduced by MATS. These include benefits to ecosystems as acidification, euthrophication and nutrient over-enrichment are reduced due to reductions in nitrogen and sulfur deposition to ecosystems.

   a. **Please explain whether EPA included non-quantifiable benefits in the Agency's final estimate of the rule's beneficial impacts?**

      The EPA considered the full range of benefits, even though many are unquantified. This methodology reflects best practices for economic analysis, and follows existing law, executive orders, and current guidance from OMB.

   b. **Does the failure to include such benefits likely underestimate the total benefits to public health and the environment from the rule?**

      Yes, without the monetized benefits from the benefits categories in question 5a the benefits are likely underestimated. See the MATS RIA for a discussion of the unquantified benefits.

9. **Could you please describe the mercury and air toxics rule's benefits to public health and welfare and to the environment for which the EPA could not establish monetary values?**

   None of the unquantified benefits listed in response to question 5a above could be monetized at this time.

   a. **Please explain whether EPA included non-monetized benefits in the Agency's final estimate of the rule's beneficial impacts?**

The EPA considered the full range of benefits, even though many are unmonetized. This methodology reflects best practices for economic analysis, and follows existing law, executive orders, and current guidance from OMB.

b. Does the failure to include such benefits likely underestimate the total benefits to public health and the environment from the rule?

Yes, without the monetized benefits from the benefits categories in question 5a the benefits are likely underestimated. See the MATS RIA for a discussion of the unquantified benefits.

10. Will EPA's mercury and air toxics rule level the playing field between power plants that already use modern pollution control technologies and power plants that do not use such technologies?

Yes. Installing and using pollution control equipments increases the total operating costs of a unit. However, it also decreases pollution, thereby reducing the economic and non-economic health and environmental degradation costs to the public at large.

Senator Tom Carper

1. **During the hearing I asked for you to explain how the EPA estimated benefits for the Mercury and Air Toxics Standards Rule. Can you provide a more detailed answer to how the agency estimated the benefits of the Mercury and Air Toxics Standards Rule? Can you explain why it is difficult to quantify the benefits of reducing air toxics?**

   In the MATS RIA, the EPA estimated the monetary value of just one air toxics benefit – the change in IQ for people eating some kinds of fish from some U.S. waters. In order to accomplish this analysis we use models to translate emission reductions into changes in mercury concentrations in fish. Then we use risk estimates from peer-reviewed epidemiology studies to derive an IQ impact function. This function estimates the number of avoided IQ points loss associated with a reduction in mercury emissions. Finally, we use commonly used valuation techniques to put a dollar value on those avoided health effects.

   This monetized value is an underestimate of the mercury benefits for a number of reasons:

   - it does not include consumption of commercially-caught fish
   - it does not include mercury exposure from fish consumption for many water bodies in the U.S., including estuaries or the Great Lakes
   - IQ loss is not the most sensitive endpoint to mercury exposure, and several other neurological and developmental endpoints are considered more sensitive according to the review of the mercury risk assessment by EPA's Science Advisory Board. These endpoints were not monetized, leading to an underestimation of benefits.

   The EPA also did not yet have data to quantify the environmental impacts of mercury emissions on ecosystems and wildlife especially fish, birds, and mammals.

   Additionally, MATS will reduce emissions of hazardous air pollutants that can cause chronic irritation of the lung, skin, and mucous membranes; chronic and acute effects on the central nervous system; chronic and acute kidney damage; and cancer. The EPA did not have data available to quantify or monetize these health impacts at this time. As discussed in Section 4.9 of the MATS RIA, EPA's Advisory Council on Clean Air Compliance Analysis concluded that "the challenges for assessing progress in health improvement as a result of reductions in emissions of hazardous air pollutants (HAPs) are daunting...due to a lack of exposure-response functions, uncertainties in emissions inventories and background levels, the difficulty of extrapolating risk estimates to low doses and the challenges of tracking health progress for diseases, such as cancer, that have long latency periods" (U.S. EPA-SAB, 2008). Due to these methodology and data limitations, the EPA provided a qualitative analysis of the health effects associated with the HAPs anticipated to be reduced by MATS.

Senator James Inhofe

1. **There has been a great deal of concern that the MACT standards for new electric generating facilities are so strict that no new coal-fired generating stations can be built.**

    a. **Is it EPA's contention that new coal-fired electric generating facilities can meet the standards for new generating facilities?**

    On July 20, 2012, the EPA notified petitioners of our intent to grant reconsideration of certain new source issues, including measurement issues related to mercury and the data set to which the variability calculation was applied when establishing the new source standards for particulate matter and hydrochloric acid, that may affect the new source standards. The EPA plans to issue a Federal Register notice shortly, initiating notice and comment rulemaking on the new source issues for which the Agency is granting reconsideration.

    We anticipate that the focus of the reconsideration rulemaking will be a review of issues that are largely technical in nature. Our expectation is that under the reconsideration rule new sources will be required to install the latest and most effective pollution controls and will be able to monitor compliance with the new standards with proven monitoring methods. As a result, the final reconsideration rule will maintain the significant progress in protecting public health and the environment that was achieved through the rule published in February, while ensuring that the standards for new sources are achievable and measurable.

    b. **Has EPA been able to identify any existing electric generation facility that meets all of the standards for new generating facilities? If so, which ones? Would you provide this committee with a list of facilities that meet all of the standards for new generating facilities?**

    The EPA does not have test data for each unit at each facility. Of the 252 electric utility steam generating units (EGUs) for which we have data provided by the companies for mercury, particulate matter, and hydrochloric acid, 68 EGUs exhibited the ability to achieve the level of all of the final emission limits for existing sources. This list of units is attached.

2. **EPA estimates that only 4.7 gigawatts (GW) of coal-fired electric generating capacity will retire as a result of its Mercury and Air Toxics Standards. Closures attributed to EPA rules have already exceeded this amount. Yet, EPA continues to deny that these closures are actually due to its actions. Do you think firms are misleading the public and their shareholders?**

    Announced retirement decisions are made based on the broad array of factors that affect the economics of individual power plants, including low natural gas prices, rising coal prices, and excess capacity in light of low electricity demand, as well as costs associated

with retrofitting outdated power plants in order to reduce emissions to levels that would protect public health and the environment. The context for these announcements is very different than EPA's regulatory impact analysis of MATS, which evaluated the power sector impact of MATS in isolation. Because of the significant differences in context, comparing announced retirements to the MATS RIA projections is an apples-to-oranges comparison.

Current trends in power sector economics, particularly changing fuel prices and demand, are increasingly leading utilities to make the economic decision to announce retirements of coal-fired plants. These plants are often older, inefficient, and underutilized. Recent studies have evaluated and highlighted the underpinnings of this trend. Respected power sector consultants such as Analysis Group have found, "recent retirement announcements are part of a longer-term trend that has been affecting both existing coal plants and many proposals to build new ones. The sharp decline in natural gas prices, the rising cost of coal, and reduced demand for electricity are all contributing factors in the decisions to retire some of the country's oldest coal-fired generating units. These trends started well before the EPA issued its new air pollution rules."[1]

3. **EPA has now issued its Cross-State Air Pollution Rule and its Mercury and Air Toxics Rule. It has also just issued a proposed rule for New Source Performance Standards for greenhouse gas emissions from electric generation facilities. At some point, it will be finalizing its coal ash proposal and its 316(b) water intake structures rule.**

    a. **EPA has refused to conduct an analysis of the effect all of these rules, together and cumulatively, will have on jobs, the economy, and the use of coal. Is EPA ever going to tell the American people what the effect of all of its rules together will be? Don't you think the American people deserve to be informed of how EPA's overall regulatory agenda will affect electric rates, jobs and the economy?**

    The EPA performs detailed analysis of the impacts of our regulations as part of the regulatory impact analysis. The modeling approaches we use can take into account other rules, but the EPA's approach is to examine each rule individually, accounting for each rule's incremental impacts. For example, when the EPA modeled our mercury and air toxics rule using our integrated planning model, those requirements were added on top of the existing finalized air rules which are already included into the model's baseline. In the case of the final MATS rule, this included the final Cross State Air Pollution rule.[2]

    The EPA has also conducted a peer-reviewed study of the cumulative impact of the Clean Air Act Amendments of 1990. That study showed that the benefits outweigh

[1] Analysis Group, Inc. Tierney, Susan F. Ph.D., Why Coal Plants Retire: Power Market Fundamentals as of 2012

[2] On August 21, 2012, the U.S. Court of Appeals for the D.C. Circuit issued an opinion that would vacate the Cross State Air Pollution Rule. The EPA is still reviewing the opinion at the time of this writing and will determine the appropriate course of action when that review is complete.

the costs by 30 to 1, saving 160,000 lives and avoiding millions of cases of respiratory problems like asthma last year. The EPA will continue to look at cumulative effects of regulations as we comply with OMB's recent guidance on "Cumulative Effects of Regulations." We will also continue to look for new tools to better characterize the impacts on industries, and be mindful of impacts on small businesses.

4. **UBS warns Utility MACT plant closures could increase northern Ohio electricity capacity prices by 60% due to "severe transmission constraints" of imported replacement power; whereas EPA said prices in that region would increase just 4.5%. FERC Commissioner Moeller has expressed concern that Utility MACT reliability modeling did not properly account for transmission issues. Could this be why EPA's electricity price forecasting is so far off?**

   This is not a valid comparison. Capacity auction prices represent the cost for a power plant to be available to provide power in the future. These prices provide little insight into retail electricity prices to consumers because a change in capacity price does not cause an equal change in electricity price. These costs are one component of the cost to actually generate, transmit, and deliver the electricity from power plants to consumers – much like the price a store pays in rent is only a small part of the price a consumer pays when he or she buys a product from that store. PJM[3] estimates that capacity costs only affect around 15% of total wholesale energy costs, which in turn account for only a portion of consumers' overall retail electricity bills (which also reflect transmission, distribution, and other costs). Therefore, any increase in capacity prices will have a much smaller effect on a consumer's electricity bill itself.

   Additionally, capacity prices across PJM are declining on average -- broadly indicating that robust capacity exists throughout the system. PJM Capacity market prices for 2015/2016 increased modestly (about 8%) over last year's auction, but they are actually middle-of-the-road prices when put into proper historical context. The regional price of $136.00 is well below the historic (2010/2011) peak of $174.29. Further, respected power sector consultants found that, "looking ahead and based on actual forward contract prices that could be purchased today for delivery of energy supply into PJM's western hub region, wholesale energy prices in 2015 would drop by over 10 percent on an inflation-adjusted basis compared to the average PJM."[4]

   Finally, the EPA's detailed regulatory impact analysis does account for capacity prices in its assessment of the power sector's response to MATS.

5. **You have repeatedly noted that Utility MACT's supposed benefits outweigh costs by 3-to-1. You have pointed to reducing mercury as a vital public health concern. Yet,**

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[3] PJM Interconnection is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of 13 states and DC, and includes the state of Ohio. For more information, see: http://www.pjm.com/

[4] Analysis Group, Inc. Tierney, Susan F. Ph.D., America's Bright Future: Cleaner Air and Affordable, Reliable Electricity

99% of Utility MACT's claimed benefits are actually so-called " $PM_{2.5}$ co-benefits" that have nothing to do with mercury. In fact, the Utility MACT, itself, says "[i]t is important to note that the $PM_{2.5}$ co-benefits reported here contain uncertainty." Why doesn't EPA also point out these facts when Agency officials make grand claims about Utility MACT's benefits?

While MATS is designed to reduce air toxics, the pollution control equipment we expect power plants to use would also lead to real and significant reductions in fine particle pollution. Accounting for ancillary benefits is standard practice in benefit-cost assessment since these benefits are a consequence of the rule, regardless of the rule's intended purpose. As such, the EPA estimates all of the anticipated costs and benefits associated with a regulatory action, to the extent feasible, for the purpose of determining the likely impacts, not to justify an action. This rule is expected to achieve substantial PM2.5 health benefits resulting from primary PM and SO2 emission reductions, and these co-benefits are thus an important category to quantify.

It is also directed by EPA's Guidelines for Preparation of Economic Analyses (p. 11-2, available at: http://yosemite.epa.gov/ee/epa/eed.nsf/pages/Guidelines.html):

"An economic analysis of regulatory or policy options should present all identifiable costs and benefits that are incremental to the regulation or policy under consideration. These should include directly intended effects and associated costs, as well as ancillary (or co-) benefits and costs."

Decades of scientific research has shown over and over again that $PM_{2.5}$ causes premature death and decreases the life expectancy of Americans. The MATS RIA contains several different types of analyses that examine the effects of the most important methodological choices on results. For example, we estimate mortality impacts using health effect estimates garnered from an EPA-sponsored expert elicitation (Roman et al. 2008). While we are unable to quantify the impact of all sources of uncertainty, we estimate the fraction of PM2.5-related benefits that would occur at or above the lowest measured level in the epidemiology studies. We also conduct sensitivity analyses examining different assumptions, including cessation lags, income growth, and risk estimates from alternate epidemiology studies. The uncertainties that are not quantifiable are listed in tables to acknowledge their possible influence on estimated benefits.

Part of the reason why co-benefits are such a large fraction of the total benefits is because the EPA was unable to quantify most of the benefits associated with reduced emissions of hazardous air pollutants. MATS will reduce emissions of hazardous air pollutants, including mercury and acid gases, which can cause chronic irritation of the lung, skin, and mucous membranes; chronic and acute effects on the central nervous system; chronic and acute kidney damage; and cancer. In addition, mercury emissions can cause environmental impacts to ecosystems and wildlife especially fish, birds, and mammals.

6. **The Utility MACT Regulatory Impact Assessment euphemistically describes the power-plants unable to meet the rule's stringent standards as being "uneconomic"**

to operate. Does this mean Utility MACT causes some coal generation to be uneconomic?

EPA's detailed modeling indicated that, all else being equal, the incremental cost of MATS compliance would cause a small amount of coal-fired capacity, about 4.7 GW (less than 2 percent of all coal-fired capacity in 2015), to become uneconomic to maintain by 2015. By holding all else equal, EPA's modeling specifically evaluated the power sector's response to MATS and generated results that are attributable to MATS.

7. **Natural gas prices are roughly at the same point now as what they've been since 2010. Yet, environmentalists and Agency officials claim power plants are closing now due to economic reasons rather than Utility MACT. If that were the case, why didn't those plant close year two years ago? What else has changed for these plants, besides EPA regulations that justifies public claims from EPA officials contradicting firms statements on the reason for plant closures?**

Recent natural gas prices have been well below 2010 levels. Natural gas prices in 2011 were the lowest annual average price for natural gas since 2002 – falling from $4.37/mmBtu in 2010 to $3.98/mmBtu in 2011.[5] The average wellhead price during the first four months of 2012 has been roughly $2.40/tcf according to EIA.[6] Natural gas prices, along with rising coal prices and low electricity demand are increasingly leading utilities to announce retirements of coal-fired plants that are often older, inefficient, and underutilized. Profits made by coal plants often depend on the difference in price between baseline coal-fired generation and price-setting natural gas generation. In competitive power markets, falling natural gas prices cause wholesale electricity prices to fall and lead to lower revenues for coal-fired power plants. Rising coal prices can further narrow the margins of coal plant operators. Many coal-fired generators are feeling the squeeze, especially the older and less efficient ones.[5]

8. **Has EPA analyzed the potential effect of the rule on particular fuel(s)? Does EPA anticipate favoring one fuel or fuel source over another? Will EPA share its analysis of the impact of the rule on fuels, fuel sources, the industry sectors that rely on those fuel(s), and the impact on the national economy?**

The EPA's detailed analysis of MATS included analysis of the impacts of MATS on fuels used to generate electricity as well as the broader economic impact of the rule. These assessments are available in chapters 3 and 6 of the MATS Regulatory Impact Analysis, respectively.

9. **Utility MACT proponents, including EPA, have repeatedly said that early operator plant closure announcements are vital to ensuring reliability while transitioning to Utility MACT. But it seems like every time a utility announces plant closures due to EPA regulations, it instantly comes under attack.**

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[5] Analysis Group, Inc. Tierney, Susan F. Ph.D., Why Coal Plants Retire: Power Market Fundamentals as of 2012
[6] http://www.eia.gov/dnav/ng/hist/n9190us3m.htm

a. **How can EPA tell utilities to announce closures early on, and then attack those same utilities for saying something that EPA doesn't want to hear?**

The EPA is not attacking utilities for announcing retirement plans. The EPA and other independent observers see power sector economics, outside of EPA's rules, playing the primary role in retirement decisions, and a transparent and constructive dialogue regarding announced retirements and the impacts of environmental regulation should not be misconstrued as an attack on utilities.

b. **What will be the cost to reliability of EPA's public relations campaign to deny the impact of Agency regulations?**

The EPA is not engaged in a public relations campaign to deny the impact of Agency regulations.

10. **In the run-up to finalizing Utility MACT, Regional Transmission Organizations and FERC staff repeatedly warned EPA that the proposed rule's reliability assessments were seriously flawed. In fact, PJM Interconnection said the rule could close 11 to 14 GW of generation in its operating region, and MISO identified another 13 GW in its region. Yet not only did EPA keep its low-ball retirement projection in the final rule, the Agency actually responded to these experts concerns by cutting its nationwide retirement projection in half from about 10 GW to 5 GW.**

a. **Does EPA believe it is more qualified than the RTO's to determine the impact of regulations on power-plants?**

EPA's projections with regard to expected retirements attributed specifically to the MATS rule decreased between the proposal and final stages primarily because the Cross State rule[7] was finalized in the interim and thus became part of the baseline for the final MATS rule analysis. As was made clear in the documentation for the final MATS rule, the total projected retirements attributed to the two rules together changed little between proposal and final. The EPA has a collaborative relationship with RTOs and FERC staff. We have listened to their concerns and have incorporated the specific technical inputs they provided into our regulatory impact analysis for the MATS rule. There are substantial differences between the assessments referenced in the question and EPA's MATS regulatory impact analysis. MISO's assessment, for example, evaluated the impact of power sector economics including low electricity demand and low natural gas prices alongside multiple EPA rules at once (most of which were not yet final). This is very different than EPA's regulatory impact analysis of MATS, which evaluates the power sector impact of MATS in isolation. Because of the significant differences between these assessments, comparing the results is an apples-to-oranges comparison.

[7] On August 21, 2012, the U.S. Court of Appeals for the D.C. Circuit issued an opinion that would vacate the Cross State Air Pollution Rule. The EPA is still reviewing the opinion at the time of this writing and will determine the appropriate course of action when that review is complete.

b. **How did EPA's reliability analysis find less impact from Agency regulations across the country than transmission experts found in just one region? Will you commit EPA to take steps to address the errors in your modeling?**

See response to question 10.a.

c. **According to Commissioner Wellinghoff, since at least last March, FERC staff have suggested to EPA that the Agency consult regional planning authorities in forecasting reliability. Did EPA not meet with PJM and MISO regarding retirements, or did the Agency simply choose to ignore transmission reliability experts on the issue?**

The EPA met with PJM and MISO and incorporated the specific technical inputs they provided into our regulatory impact analysis of MATS.

d. **In your testimony, you say EPA is holding "dialogues" with Regional Transmission Organizations. Does that "dialogue" include any listening? What specific impact on the final rule or your analysis of the impact of Utility MACT did**

The EPA had a productive exchange with RTOs in developing the MATS rule, both before and after finalization of the MATS rule. As mentioned above, the EPA incorporated the specific technical inputs they provided into our regulatory impact analysis. Additionally, the EPA took the RTOs' comments into account in developing a the December 16, 2011 memo from the Agency's Office of Enforcement and Compliance Assurance, which discusses a clear pathway for units that are shown to be critical for reliability to obtain a schedule with up to one additional year to achieve compliance with MATS. The EPA believes there will be few, if any situations, in which this pathway will be needed. In coordination with FERC and DOE, the EPA is engaged in regular communication with the RTOs with regard to issues related to the implementation of MATS.

11. **How do you define the term "generally" as it applies to the general ability to install the necessary pollution control equipment? Do you agree that the term implies a level of uncertainty? Does that uncertainty raise issues for how energy-intensive industries – the U.S. manufacturing sectors that rely on energy inputs as a power source and in some cases as a feedstock – will be affected?**

There is substantial evidence that companies can comply with this rule using existing technologies. Over 65 units have demonstrated the ability to meet all of the existing-source standards; over 175 have demonstrated the ability to meet the existing-source Hg standard; over 560 have demonstrated the ability to meet the existing-source PM standard; and over 175 have demonstrated the ability to meet the existing-source acid gas standard. Based on EPA's analysis, we do not believe that this rule will adversely impact energy-intensive industries.

12. EPA concurrently released a memorandum with the Utility MACT describing how utilities with reliability-critical power-plants unable to comply Utility MACT deadlines can apply for an additional year under an administrative order. According to the memo, "an [administrative order] cannot be issued under Section 113(a) prior to the MATS compliance date," but "EPA intends . . . to give the owner/operator as much advance written notice as practicable" about whether the Agency will issue an administrative order.

a. Doesn't it seem unfair to write a regulation that forces utilities into non-compliance before providing those utilities relief to keep the lights on? Can you explain how this is reasonable?

b. If you can't tell a plant owner now whether they'll get the extra time they need, and whatever you tell them now isn't binding anyway, and they can still be sued by someone else for being out of compliance, how do you seriously think that anyone is going to start lengthy retrofits now with that uncertainty?

c. Would Administrative Orders necessary for the additional year protect utilities from being sued by environmentalists under the Clean Air Act? If not, would EPA commit to defending such utilities sued in such a manner?

The EPA believes that all affected sources will be able to comply with the MATS within the maximum three year compliance period required by Section 112(i)(3) of the CAA – by April 16, 2015 - and, as applicable, the one year extension permitted under Section 112(i)(3)(B) – by April 16, 2016.

Nonetheless, in light of the EPA's commitment to achieving compliance with the MATS while ensuring electric reliability, the EPA's Office of Enforcement and Compliance Assurance issued a memorandum discussing the EPA's intended approach regarding the use of administrative orders ("AOs") under CAA Section 113(a) with respect to sources that must operate in noncompliance with the MATS rule for up to one additional year to address a specific and documented reliability concern (the "MATS Enforcement Policy"). The MATS Enforcement Policy can be accessed at: http://www.epa.gov/compliance/resources/policies/civil/erp/mats-erp.pdf. As reflected in the preamble to the final rule and in the MATS Enforcement Policy, the EPA believes there will be few, if any, situations in which an AO will be needed.

The EPA expects that owners/operators will begin compliance planning early to meet the statutorily required April 16, 2015 (or 2016, as applicable) MATS compliance date. Early notice and planning can discourage delays in coming into compliance, encourage timely action to avoid or mitigate reliability concerns, and minimize the need for issuance of AOs of the type described in the MATS Enforcement Policy. Although pursuant to Section 113(a) of the Clean Air Act, an AO can only be entered after noncompliance occurs, and although the EPA generally does not speak in

advance to the intended scope of its enforcement efforts, the EPA recognizes the need for advance planning with regard to the future availability of any reliability critical EGUs to operate as needed to maintain electric reliability. Thus, as reflected in the MATS Enforcement Policy, where the owner/operator has timely submitted a complete request for an AO and has provided appropriate cooperation, the EPA intends to give the owner/operator as much advance written notice as practicable of the Agency's plans with regard to such an AO.

While an AO does not provide a legal shield from third party lawsuits, as a practical matter, we think the incentive to bring such a suit is low. If a third party did bring a citizen suit, at most it could seek injunctive relief, civil penalties and attorneys' fees. It would be very difficult for a third party lawsuit to proceed to judgment in the one-year time frame of an AO, and thus it is unlikely that a plaintiff could obtain any meaningful injunctive relief. Any penalties awarded in such a suit go to the U.S. Treasury, not the plaintiff. In evaluating the merits of the suit and determining whether to impose conditions or penalties in addition to those in an AO, a court would consider a range of factors in making its own determination about the appropriate relief, if any, including: the length of the violation, the public interest (including the need to maintain the reliability of the electric system), the conditions imposed by the EPA under the AO (e.g., injunctive conditions, such as operational restraints and pollution mitigation measures), whether the EPA has assessed a penalty, etc. As stated in the MATS Enforcement Policy, the EPA does not intend to seek civil penalties for violations of the MATS that occur as a result of operation for up to one year in conformity with an AO, unless there are misrepresentations in the materials submitted. While a court does not have to agree with the path to compliance prescribed by the EPA, we think a court would be unlikely to materially disagree. For all these reasons, the EPA believes that an AO of the type contemplated by the Enforcement Policy will discourage third party suits.

13. Why is EPA pursuing a complex and uncertain system of Administrative Orders to extend compliance for reliability-critical units, when the President could have simply deemed reliability a national security interest and granted the extensions as necessary?

a. The President took the time to write a letter promising "liberal use" of extensions, wouldn't it have been easier to just have the President say reliability is a national security interest?

b. Does the President believe that electric reliability is not a national security interest?

c. Does EPA believe that electric reliability is not a national security interest?

We assume that your questions refer to the President's authority, under section 112(i)(4) of the Clean Air Act, to provide a temporary (renewable) exemption from a section 112 standard where the President "determines that the technology to

implement the standard is not available and that it is in the national security interests of the United States to do so." Because this authority is conferred upon the President, not EPA, the Agency is not in a position to respond with regard to the proper interpretation or potential applicability of this provision in this context.

14. EPA has stated on numerous occasions that the failure to take certain actions required by the deadlines established in the Boiler MACT suite of rules do not constitute violations of the Clean Air Act while the Agency reconsiders the rules.

a. I understand that initially, EPA verbally informed the regulated community that, if necessary, it would be issuing a 90-day Administrative Stay of the Boiler MACT rules. EPA stated in its proposed reconsideration of the Boiler Area Source Rule that it "could" administratively stay the effectiveness of the area source rule for 90 days. Comments from the regulated community strongly supported that course of action. EPA's statement related to the existing compliance deadline of March 21, 2012 for the completion of tune-up requirements at area sources. Has EPA formally issued that stay, and has it been made publicly available?

Response: The EPA has not issued a 90-day administrative stay of the area source boiler rule to date. The Agency did issue a no action assurance in a March 13, 2012 letter to the regulated community announcing the Agency would exercise its enforcement discretion not to pursue enforcement action against sources subject to the area source boiler rule requirement to have completed a tune-up by March 21, 2012. On July 18, 2012, the EPA issued a memorandum extending the March 13, 2012 no action assurance to the requirement to file a notification of initial compliance status for sources subject to the tune-up requirement. Copies of the letter and the memorandum are available on the agency's website.

The March 13, 2012 letter is available at:
http://www.epa.gov/ttn/atw/boiler/area_source_nna_2012-03-13.pdf

The July 18, 2102 memorandum is available at:
http://www.epa.gov/ttn/atw/boiler/20120718memo.pdf

The July 18, 2012 memorandum also provides that the March 13, 2012 no action assurance letter remains in effect until the earlier of the completion of the reconsideration or 11:59 P.M. EST on December 31, 2012.

b. Administrator Jackson communicated with Sen. Wyden on March 5, 2012, indicating that the Agency would address Boiler MACT –related issues. Do you consider Administrator Jackson's letter to be an indication that all related deadline issues would be addressed, or some specific subset of those deadline issues?

Response: The EPA is still in the process of analyzing the data submitted in response to the proposed reconsideration rule, and also of ensuring coordination of this rule with related rulemakings. Thus, EPA's administrative process is continuing at this time. The EPA does intend to address issues related to the compliance deadline for existing major source boilers in its final action.

Senator David Vitter

1. **EPA has stated on numerous occasions that the failure to take certain actions required by the deadlines established in the Boiler MACT suite of rule do not constitute violations of the Clean Air Act while the Agency reconsiders the rules.**

    a. **I understand that initially, EPA verbally informed the regulated community that, if necessary, it would be issuing a 90-day Administrative Stay of the Boiler MACT rules. EPA stated in its proposed reconsideration of the Boiler Area Source Rule that it "could" administratively stay the effectiveness of the area source rule for 90 days. Comments from the regulated community strongly supported that course of action. EPA's statement related to the existing compliance deadline of March 21, 2012 for the completion of tune-up requirements at area sources. Has EPA formally issued that stay, and has it been made publicly available?**

    Please see response to Senator Inhofe Question #14a.

2. **With respect to the Utility Mercury and Air Toxics (MATs) rule, EPA has stated that, "[It] has concluded that 4 years should generally be sufficient to install the necessary emission control equipment, and DOE has issued analysis consistent with that conclusion. President Obama has pointed out that the Clean Air Act "also provides the EPA with flexibility to bring sources into compliance over the course of an additional year, should unusual circumstances arise that warrant such flexibility."**

    a. **How do you define the term "generally" as it applies to the general ability to install the necessary pollution control equipment? Do you agree that the term implies a level of uncertainty? Does that uncertainty raise issues for how energy-intensive industries – the U.S. manufacturing sectors that rely on energy inputs as a power source and in some cases as a feedstock – will be affected?**

    Please see response to Senator Inhofe Question #11.

    b. **Has EPA analyzed the potential effect of the rule on particular fuel(s)? Does EPA anticipate favoring one fuel or fuel source over another? Will EPA share its analysis of the impact of the rule on fuels, fuel sources, the industry sectors that rely on those fuel(s), and the impact on the national economy?**

    Please see response to Senator Inhofe Question #8.

Senator CARPER. Thank you so much for that testimony and for the leadership that you continue to provide.

I am going to ask you a series of yes or no questions. I don't normally do this, but I am going to do it in this case, and if you would, just answer these yes or no.

The first is, did it take the EPA 10 years after the implementation of the Clean Air Act Amendments of 1990 to list coal- and oil-fired utilities as sources that should be regulated under Section 112 of the Clean Air Act for their air toxics emissions?

Ms. MCCARTHY. Yes.

Senator CARPER. Second question is, was this listing based on numerous health studies as directed by Congress?

Ms. MCCARTHY. Yes.

Senator CARPER. Did these studies determine that coal-fired power plants are the No. 1 source of mercury emissions in this country?

Ms. MCCARTHY. Yes, sir.

Senator CARPER. In 2005 did the EPA try to circumvent its legal duties to regulate coal- and oil-fired power plants under Section 112 Air Toxics program by establishing a cap and trade program for mercury?

Ms. MCCARTHY. Some would characterize it that way, yes.

Senator CARPER. In 2008 did the U.S. Court of Appeals, I think for the District of Columbia, determine the agency, EPA, could not create a separate cap and trade program for mercury and had to in fact regulate coal- and oil-fired utilities under the Section 112 Air Toxics program?

Ms. MCCARTHY. Yes, sir.

Senator CARPER. And finally, do you believe the Mercury and Air Toxics rule meets previous court decisions and meets EPA's legal responsibilities as Congress intended in 1990?

Ms. MCCARTHY. Yes, I do.

Senator CARPER. Thank you.

And now for some essay questions.

[Laughter.]

Senator CARPER. One of my colleagues believes the EPA has overestimated the health benefits from the Mercury and Air Toxics rule. Can you explain how the EPA estimated benefits and may have underestimated health benefits, rather than overestimated them?

Ms. MCCARTHY. EPA has used sound science as well as peer-reviewed methodologies and gone through an extensive transparent peer review process to evaluate the health impacts associated with this rule. Unfortunately, the data and methodology associated with really calculating the costs associated with many of the toxic emission reductions that will be achieved by these rule we can't calculate effectively. We have calculated what we could for mercury reductions related to IQ loss, but we know there are many developmental issues associated with exposure to mercury. And we certainly know that there is a vast number of benefits that we have yet to calculate, the result of reductions in acid gases, toxic metals, arsenic, cadmium.

But what we also know is that there are co-benefits associated with reductions of particulate matter that are associated with the

control technologies that are installed as a result of this rule. We have calculated all those benefits, and we know that the costs associated with this rule are for every dollar that you spend, you get $9 in return for health benefits. The benefits significantly outweigh the costs.

Senator CARPER. All right.

In your testimony, you mentioned that—like we did more than two decades ago during the debate of the Clean Air Act Amendments of 1990—we are hearing claims today that the EPA's rule will lead to potential adverse impacts on electrical reliability. Despite the numerous studies that conclude that the Mercury and Air Toxics Standards will not impair reliability, people continue to argue that the Mercury and Air Toxics Standard will cause blackouts.

Can you explain to us today what substantive changes the EPA made to the compliance requirements of the rule and also what the EPA has done to the compliance framework to ensure electric reliability and maximum flexibility?

Ms. MCCARTHY. EPA received extensive comment on this rule and made a number of changes between proposal and final on the basis of data received that allows more flexibility in this rule and that we believe enhances the ability of compliance to happen in a cost-effective way.

We have also directly addressed the issue of reliability. We have the 3-year window that is available to the Federal Government to provide for compliance. We have been very forward leaning in terms of advising States to issue that fourth year, not just for technology installations on that unit, but to maintain the reliability of the electricity supply. We also have issued an administrative order and a policy that—I am sorry, I should say a policy that outlines an administrative order that will allow an additional year to comply, bringing us to 2017 in order to comply with these rules.

We do not believe that that additional time is necessary, and the good news is many of the utilities are now agreeing with us. For example, Southern Company just announced that they are going to be able to achieve compliance much less expensively than anticipated.

Senator CARPER. Southern Company?

Ms. MCCARTHY. And by 2016.

Senator CARPER. Really? Well, that is good to hear. Thank you so much.

Senator Barrasso.

Senator BARRASSO. Thank you very much, Mr. Chairman.

Ms. McCarthy, you state in your testimony that EPA's analysis resulted from the utility MACT rule, the coal-fired power plant operators will "choose to retire less than one-half of 1 percent, or about 4.7 gigawatts." And then that the EPA predicts that the amount of coal-fired power plants that will close as a result of the cross-State air pollution is about 4.8 gigawatts.

Were those predictions made using models, or how do you come up with the numbers?

Ms. MCCARTHY. They were made using our integrated planning model, yes, and information provided by other Federal agencies.

Senator BARRASSO. Because in reality, many more coal-fired power plants have announced closures, and that totals about 25 gigawatts, which is more than EPA's model has predicted. So more closures are likely on the way. Were you aware of the additional closure announcements before you testified to these numbers? Why is the EPA so far off on the predictions?

Ms. MCCARTHY. We actually think we are not far off in the predictions associated with the impacts of this rule. There are many reasons why power plants are closing. Many of the announcements that you are reading today were actually announced many years ago. There is a change in the energy world as a result of natural gas prices, low demand. And many of the small coal units are inefficient, they are not being called on to supply electricity generation. And a decision is being made on a business case about not upgrading those facilities.

Senator BARRASSO. Has the EPA ever done a cumulative impact analysis on all of the proposed rule that are going to place burdens on coal-fired power plants, the cumulative of coal ash, cooling water intake structures, climate change, cross-State air pollution as well as mercury reduction?

Ms. MCCARTHY. We actually have done—our analysis, our economic analysis of the MATS rule consider the Cross-State Air Pollution Rule. The other rules that you have identified have yet to be finalized.

Senator BARRASSO. So there has not really been a cumulative analysis of the impact of all of these on our communities and coal-fired power plants and jobs around the country. You are going to take them one at a time in spite of the fact that you are working on all of them.

Ms. MCCARTHY. There have been studies released that claim to look at that cumulative impact. But it was done on the basis of the rule not being completed, and in many cases done in a way that we wouldn't agree was economical.

Senator BARRASSO. But not EPA studies? The EPA has not studied it cumulatively?

Ms. MCCARTHY. We have not, that is correct.

Senator BARRASSO. OK, thank you.

I just want to give you a chance to respond to some of the written testimony of our second panel. Mr. Robert James, of the city of Avon Lake, Ohio, has stated that because of the Avon Lake power plant closing, the city is going to lose millions in tax revenue; $4 million a year is expected to be cut from their public schools budget each year. He stated many of the health and welfare programs for the students may need to be eliminated. He also stated there will be cuts to emergency medical services, including the firing of a paramedic who is funded by those tax revenues. He states that this will have a direct impact on the health of Avon Lake residents.

Has the EPA considered the health implications to the public of lost tax revenue for emergency medical services and schools in any of these cost-benefit analyses that you do?

Ms. MCCARTHY. Senator, we have looked at the health benefits, we have looked at the economic consequences associated with our

rule, consistent with the guidance that is provided to us and the methodology that has been peer-reviewed.

Senator BARRASSO. But not these specific consequences, because it seems to me that the costs are real, and the benefits truly are unknown. I have read your assessment, and it just seems that the costs are very real to all of these communities around the country.

Ms. MCCARTHY. I believe we have calculated benefits that far exceed the costs. And those benefits are real.

Senator BARRASSO. Well, we will see how that plays out.

When a plant shuts down in a town, the power often must be replaced somehow. And for those plants not shut down but retrofitted, the retrofits cost money, too. The fact is, retrofitting or building a new power plant or transmitting power from somewhere else almost always means paying more for the power.

Folks across America are already suffering from high gas prices. So after the EPA's new rules are in effect, how much is it going to cost to turn on the lights and keep them on, relative to beforehand? I don't know if you have looked at specific communities and what this is going to cost in terms of the needs in communities around the country.

Ms. MCCARTHY. We have done a national analysis, and we have looked at the different energy regions. And our assessment is that the average increase at its height of cost would be 3 percent increase in retail price of electricity.

Senator BARRASSO. Three percent, OK.

You talk about the fact that families should never have to choose between a job and healthy air, that they are entitled to both. As of now, I count 57 plants closing across 20 States because of the Clean Air rules coming out. It is estimated 29,000 plant workers are going to lose their jobs. EPA has put those workers and the families on the unemployment line in the middle of a recession. In the EPA's analysis, what kind of future is in store for those newly unemployed folks, their children, their depends who are not given the option to keep their jobs and healthy air?

Ms. MCCARTHY. Senator, our analysis, in all due respect, doesn't come out with those same numbers. We believe that this actually produces 46,000 construction jobs, as well as 8,000 long-term utility jobs.

Senator BARRASSO. Thank you.

Thank you, Mr. Chairman.

Senator CARPER. Thank you.

Senator Lautenberg.

Senator LAUTENBERG. Thanks, Mr. Chairman.

Ms. McCarthy, thank you for your testimony. We looked at the situation, after 10 years of delay by polluters, this EPA has set an historic standard to cut mercury pollution. Unfortunately, there is an effort underway here in the Senate to overturn these life saving standards. And if we are forced to wait another 10 years for limits on toxic air pollution, how many Americans might suffer health consequences and even die prematurely as a result?

Ms. MCCARTHY. Well, we have estimated that the benefits associated with this rule are about 11,000 premature deaths avoided each year, up to hundreds of thousands of asthma attacks, heart attacks, over a half a million lost work days would be avoided with

this rule. We are talking about very significant health benefits associated with this rule at very significantly lower costs.

Senator LAUTENBERG. The discussion we are having here is something that has to be looked at squarely. What we are saying is, look, it is not worth saving all those lives because it is going to cost so much. But if you look into the eyes of your child or children, or those adults who suffer severely from asthma, just one of the diseases that can possibly arise as a result of exposure to mercury and the other toxics, it is discouraging to hear what is not being said, but is being heard. And that is, all those lives are not worth the inconvenience and the money that we would have to spend, even though we are going to recapture it in spades, as they say.

So this is a very difficult discussion, and I am alarmed. I come out of a strong business career, and I know what it is like to take a chance and make investments on the promises of tomorrow. And so it ought to be here. We ought to be able to look at families who come in with asthmatic children and say, worry not, we are going to do something to prevent your kid from losing his ability or her ability to participate normally with other children. It is money, don't you understand that? It is money. No, it is life. And we are kind of moving that aside.

We know that children are especially susceptible to the effects of air pollution. How do you take the unique vulnerability of children into account when developing pollution standards?

Ms. MCCARTHY. Well, we know that mercury is a potent neurotoxin that causes a wide range of developmental problems, beyond what we have been able to calculate, IQ loss.

Senator LAUTENBERG. Have you heard that being challenged at all, people saying, no, you are wrong?

Ms. MCCARTHY. No, I have not. I have heard it being basically inferred that if we can't put a cost number on it, then it doesn't count. There are learning and attention difficulties associated with exposure to this potent neurotoxin. And there are many other effects, particularly in children. And in fact the CDC estimates that tens of thousands of babies are born in the U.S. every year with high enough mercury levels to put them at risk for one or more of these developmental problems.

Senator LAUTENBERG. These are the invisible results that occur?

Ms. MCCARTHY. These are the results that we can't calculate, but we know are happening.

Senator LAUTENBERG. Almost 8 years ago New Jersey set pollution limits that are nearly identical to EPA's new national standards. Our utilities have cut mercury pollution by 90 percent, contrary to industry claims that we are hearing now, and hear, our lights are still on and electricity rates are stable. Did EPA look at the experience of New Jersey and other States when developing these standards?

Ms. MCCARTHY. We did. We understand that there have been approximately 18 States that have gone out to try to address these issues aggressively on the toxic side. We want to congratulate New Jersey. In fact, what we have identified is there is a 20-year-old power plant in New Jersey that has set the pace for new construction and standards for new facilities because they are already achieving the new source standards associated with toxics.

So we know this can be done. The technology is available, it is cost-effective, it is in use at over half of the coal facilities that are out there today. We can achieve these reductions cost effectively and provide these children a healthier future.

Senator LAUTENBERG. I can tell you this, that we in New Jersey don't like throwing our money away. We don't have enough, but we like it less when it affects children and a family, when we hear about a child that is disabled as a result of an asthmatic condition.

Thank you very much, Ms. McCarthy.

Ms. MCCARTHY. Thank you.

Senator CARPER. Senator Lautenberg, thanks very much.

Senator Alexander.

Senator ALEXANDER. Thanks, Mr. Chairman.

Ms. McCarthy, I keep thinking that if Congress in its wisdom had passed Senator Carper's and my bill in 2003 when we first introduced it, this would all have been done 4 or 5 years ago. We have this ping-pong match that really keeps Congress from doing its job.

My only concern about the rule is the amount of time that utilities have to comply with it. And I want to make sure I understand what you're saying about that, what the law and EPA rules are and what the options are.

It would seem to me—my general attitude toward environmental rules is we ought to come up with a good performance standard, and then we ought to give the people who are affected by it plenty of time to get there. I think of the rule that got rid of sulfur in diesel fuel. I think that took 10 years from the beginning of the Clinton administration all the way to the end, but it got the job done. If I am not mistaken, it was something like that.

And in the process new engines were invented, and the truckers supported it and bought the more expensive engines because it saved them money on fuel efficiency. So there was enough time for everybody to make the adjustment in a reasonable way, and the air is a lot cleaner in the Great Smoky Mountains because the big trucks aren't using that kind of fuel.

So in this case you are saying that the law is that every utility who tries to follow this rule about mercury and other use has at least 3 years by law, right?

Ms. MCCARTHY. Yes.

Senator ALEXANDER. Three years. The fourth year the State has to approve, is that correct?

Ms. MCCARTHY. That is correct.

Senator ALEXANDER. But if a State does approve a fourth year based upon reliability or some other issue, then they are 4 years. So if I am a utility executive, and I think the State will agree with that, that is 4 years.

Doesn't the President have the opportunity to add 2 years to that by executive order?

Ms. MCCARTHY. There is a provision in the law that has never been used that provides an opportunity for the President to do that.

Senator ALEXANDER. Well, wouldn't it be a good idea for him to use it? In this case, I mean, the last version of the Carper-Alexander bill in effect would give 5 years. You have mentioned the

Southern Company said they have now learned they may be able to do it a little more rapidly. But why wouldn't it make more sense across the country to say, we are going to get this done, we don't want to go to court about it, the President issues an executive order and says, the State can give you 1 year and I am going to give you 2 more, so Mr. and Ms. Utility Executive, put the pollution control equipment on your plants. You have 6 years to do it if you don't close the plant.

Why wouldn't that be a better, more certain way to deal with this issue and maybe other issues?

Ms. MCCARTHY. Senator, you are asking a question that is a little bit over my pay grade. But let me bring it down.

Senator ALEXANDER. But you are very experienced.

[Laughter.]

Senator ALEXANDER. Your advice would be useful.

Ms. MCCARTHY. I would just say that I think that the difference between the analogy with sulfur and this is that we already have these technologies available and in use today. These facilities have been on notice and have made their own businesses——

Senator ALEXANDER. Well, that is true of the unregulated facilities. Most of them have gone ahead and done it. But the regulated facilities have a harder time going to their State commissions and getting approval for an additional cost before there is a final rule. So now there is about to be a final rule, unless Congress acts to overturn it. And there may be a reliability issue, we don't know. Why would we even risk that? Why don't we just say to the utilities, OK, you have lots of decisions to make, you have several considerations, you have 6 years to get this done?

And the problem I am thinking about is that even if you put out policy guidance and memos, TVA or the Southern Company or any utility might get a citizen lawsuit. They might get hauled into court. If they had an executive order, they wouldn't.

Ms. MCCARTHY. Senator, we have not identified issues or circumstances that would warrant more than the 3-, 4-, or the 5-year certain pathway that we have provided. The President made it very clear in his memo that reliability is a significant concern. We are addressing those issues. I just don't see that there is a problem that need to be fixed. You are deferring health benefits by——

Senator ALEXANDER. Well, we have been deferring them for 10 years, because the environmentalists and the utilities keep ping-ponging it back and forth, one trying to delay and the other trying to take an extreme view. I would much rather see us give a certain amount of time to the utilities, and if you err on that side, at least you will get it done. Otherwise, your rule may get hauled into court, and then we have another 3 years of delay just like we did with the last rule EPA did. And you don't get certainty that way, either. But if utilities saw you had 6 years, and it was certain, and your risk of a lawsuit was a lot less, you might get a quicker and better environmental result. That is what I am suggesting.

Ms. MCCARTHY. I certainly appreciate what you are saying, but we just don't believe that there are circumstances that require time beyond what is already provided.

Senator ALEXANDER. But the President could, if he wished, add 2 years to the 4 years that utilities now can get.

Ms. MCCARTHY. There is a provision in the law that requires it that relates to national security, yes. We do not believe, and we have not recommended that there is any need to take any action beyond what we have already accommodated in the law and that Congress has provided to us, as well as the policy for the administrative order that grants an additional year.

Senator ALEXANDER. Thank you.

Thank you, Mr. Chairman.

Senator CARPER. Before you leave us, I am going to ask unanimous consent that a 1-page document that I just shared with Senator Alexander be made a part of the record. It is a document which indicates that Southern Company, which I think previously had thought they could not comply with this regulation by 2016, now believes that they can, and not for more money, but actually for less, I think for about a third less. That is what we call in my business better results for less money.

[The referenced document follows:]

Southern Company

Court remands Kemper County approval; On road with CEO

Company Update **BUY**

Equity | United States | Electric Utilities
15 March 2012

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Mississippi Court remands Kemper County approval

On 3/15, the Mississippi Supreme Court remanded the PSC's approval of SO's 582 MW Kemper County coal gasification plant (now called the Ratcliffe plant). The two page ruling stated that there was not sufficient detail in the order to support the approval decision. The $2.4b plant has already started construction and is expected on line in 2014. While it is unclear how the PSC will proceed, we expect them to act relatively quickly given that the project is now in some limbo. SO plans to continue construction in the meantime. Opposition to the plant mainly comes from the Sierra Club, which filed this appeal, as well as independent gas generators in the region. This issue may cause some overhang on SO stock, but we believe it will be resolved reasonably.

Meetings with CEO

We hosted investor meetings with SO management this week. The new nuclear construction at Vogtle 3 and 4 remain a key focus, and management believes it has saved nearly $2b from the initial cost estimate through financing savings, PTCs, locking in costs, and CWIP recovery. The net customer rate hike for the plant is now expected to be only 5-6% (net of fuel savings) of which 3.3% is already in place. SO still hopes to close on DOE loan guarantees but will only do it on reasonable terms since it is not required.

Environmental and financing updates

Of its 20,000MWs of coal plants, SO expects to close 4,000MWs and repower with nat gas another 3,200MWs in response to EPA's MATs rule. The remaining 12,000MWs+ require some retrofits, but the company now believes that these can be done for $0.5b to $1.0b less than its initial $2.7b estimate. Moreover, the company now believes it can meet EPA's 2016 time line. As a result of the lower potential capex, SO may not need all of the $1.5b of new equity in 2013/2014 disclosed in its year end forecast.

Maintain Buy; $47 PO

Our PO is based on 15.5x 2014E utility earnings and 8.5x 2014E EBITDA at Southern Power. Our 15.5x P/E is a premium to the group average of 13.5x to account for high quality earnings and ROEs.

Stock Data

Price	US$44.87
Price Objective	US$47.00
Date Established	23-Jan-2012
Investment Opinion	A-1-7
Volatility Risk	LOW
BofAML Ticker / Exchange	SO / NYS
Bloomberg / Reuters	SO US / SO.N

Price objective basis & risk

Southern Company (SO)

We value SO at a premium to reflect its high quality history. Our price objective is $47 based on 15.5x 2014E utility earnings (a premium to the group (13.5x) to account for high quality) and 8.5x 2013E EBITDA at Southern Power. Risks are: 1) better/worse-than expected economic recovery. 2) better/worse-than expected regulatory risk. 3) execution risk for Vogtle nuclear plant and Ratcliffe IGCC plant.

Link to Definitions

Energy

Click here for definitions of commonly used terms.

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I, Steve Fleishman, hereby certify that the views expressed in this research report accurately reflect my personal views about the subject securities and issuers. I also certify that no part of my compensation was, is, or will be, directly or indirectly, related to the specific recommendations or view expressed in this research report.

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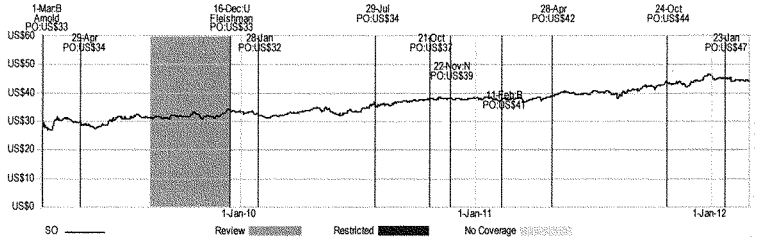
SO Price Chart



B : Buy, N : Neutral, U : Underperform, PO : Price objective, NA : No longer valid, NR: No Rating

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Coverage Universe	Count	Percent	Inv. Banking Relationships*	Count	Percent
Buy	79	42.47%	Buy	51	71.83%
Neutral	50	26.88%	Neutral	35	76.09%
Sell	57	30.65%	Sell	28	56.00%

Investment Rating Distribution: Global Group (as of 01 Jan 2012)

Coverage Universe	Count	Percent	Inv. Banking Relationships*	Count	Percent
Buy	2029	52.00%	Buy	1337	72.11%
Neutral	1009	25.86%	Neutral	657	71.34%
Sell	864	22.14%	Sell	487	60.20%

* Companies in respect of which BofA Merrill Lynch or one of its affiliates has received compensation for investment banking services within the past 12 months. For purposes of this distribution, a stock rated Underperform is included as a Sell.

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Investment rating	Total return expectation (within 12-month period of date of initial rating)	Ratings dispersion guidelines for coverage cluster*
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Neutral	≥ 0%	≤ 30%
Underperform	N/A	≥ 20%

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Senator CARPER. With that having been said, thank you for your testimony, for your good work and that of your team. We look forward to continuing to have this dialogue and working with you. For our colleagues who weren't able to join us this morning, they will have the opportunity to present questions to you for—how long? For 2 years.

[Laughter.]

Ms. MCCARTHY. That is added to the 400 I have already been here?

Senator CARPER. There you go, starting to stretch out.

Two weeks, and we would ask that you respond promptly. Thank you so much. Have a good day.

And with that, we will ask our second panel of witnesses to join us.

Good morning, everyone, welcome. Nice to see you all. On this panel we are pleased to have joining us Dr. Robert Summers, Secretary of the Environment for the State of Maryland, whose University of Maryland Terrapins women's basketball team is the only team this year to defeat the University of Delaware women's basketball team, which plays Kansas tonight in the second round of the NCAA women's basketball playoffs. So hopefully we will be able to keep it down to one loss tonight; we will see. Welcome, all that notwithstanding.

Dr. William Lambert, Director of Epidemiology and Biostatistics for the Department of Public Health and Preventive Medicine at Oregon Health and Science University. Where is that located?

Dr. LAMBERT. [Remarks made off microphone.]

Senator CARPER. OK, good, welcome.

Mr. Rob James, member of the Avon Lake City Council of Avon Lake, Ohio, suburb of Cleveland. He explained to me when I tried to give him my Ohio State cheer, he explained to me he is not a Buckeye. We are glad you are here, nonetheless. Welcome.

Mr. Harry Alford, President of the National Black Chamber of Commerce. It is nice to see you again, welcome, thank you for joining us.

And Vickie Patton, all the way from Colorado, I believe, General Counsel of the Environmental Defense Fund. Great to see you again, thank you joining us.

I am going to ask each of you to try to limit your statements to about 5 minutes. The full content of your written statements will be included in the record. We will let our neighbor from the neighboring State of Maryland, who shares the DelMarVa peninsula, lead off.

You are recognized. Please proceed.

STATEMENT OF ROBERT M. SUMMERS, PH.D., SECRETARY OF THE ENVIRONMENT, STATE OF MARYLAND

Mr. SUMMERS. Thank you, Chairman Carper, Ranking Member Barrasso, and honorable members of the Committee. I am Bob Summers, Secretary of the Maryland Department of the Environment.

Thank you for the opportunity to testify and share Maryland's positive experience with the early installation of air pollution control technologies required by the 2006 Maryland Healthy Air Act,

technologies that will now be required on many of the Nation's coal-fired power plants by the Federal Mercury and Air Toxics Standards.

Achieving compliance with Federal ambient air quality standards and reducing levels of mercury and other air pollutants has been particularly challenging for Maryland because so much of our air pollution is the result of transport from upwind, out of State sources. Our monitoring data shows that on the worst air quality days up to 70 percent of Maryland's ozone pollution is the result of transport. Without reductions from upwind sources, Maryland will not achieve compliance with Federal ambient air quality standards for ozone or with future, more stringent fine particle standards that are needed to protect public health.

In addition, the Chesapeake Bay program estimates that up to one-third of the nitrogen that pollutes Chesapeake Bay and its rivers comes from the air. The same is true for mercury deposition. Most of Maryland's lakes and reservoirs are subject to fish consumption advisories for mercury. Mercury emissions from upwind sources account for more than 70 percent of the mercury deposition in Maryland. This is why Federal regulatory initiatives to reduce regional emissions are vitally important to improving Maryland's air and water quality.

We are confident that the MATS rules can be implemented without risk to reliability of our electricity supply because Maryland successfully implemented the Healthy Air Act and required steep cuts in emissions from our coal-fired power plants through the installation of the same controls that will be required to achieve compliance with MATS.

The Maryland Healthy Air Act is now fully implemented and has achieved its goals. State generators invested approximately $2.6 billion in new control technologies and achieved dramatic reductions in power plant emissions. Mercury emissions were reduced by 90 percent, SO_2 by 80 percent, and NO_x by 75 percent, direct particulate matter by 60 percent, and hydrogen chloride by 83 percent.

These are not estimates or projections; they are based on actual monitored emissions at our plants. The controls work extremely well and in almost all cases have resulted in even lower emission rates than were originally projected in 2006. The construction and installation of the controls also boosted Maryland's economy. The effort resulted in the creation of approximately 90 new permanent jobs, and during the peak construction period more than 3,000 jobs, including high skilled architects, engineers, steamfitters, pipefitters, millwrights, master electricians, boilermakers, heavy equipment operators, and carpenters.

The regulations implementing the Act were not finalized until 2007, resulting in a relatively short lead time for the power plants. NO_x controls were operational in less than 2 years, and SO_2 and mercury controls were operational in less than 3 years. Because implementation of the Healthy Air Act was occurring at the same time that many power plants in the east were installing NO_x and SO_2 controls to achieve compliance with the Clean Air Interstate Rule, Maryland's generators expressed serious concerns that sufficient labor and materials would not be available to complete construction prior to the compliance deadlines.

Similar to the provisions in MATS, the Healthy Air Act allowed emergency extension of compliance deadlines to address any issues related to reliability or the availability of equipment or labor. Significantly, no compliance deadline extensions were needed or requested. All of the necessary controls were installed in time, and the emission reductions occurred as expected.

Maryland worked very closely with our power plants to facilitate a smooth implementation process and timely compliance with the emission limitations. This was a key reason for our success.

In closing, I would like to quote Paul Allen of Constellation Energy, one of our State's largest power companies: "These systems work effectively and result in dramatically lower emissions of mercury, sulfur dioxide, particulate matter, and acid gases." We know from experience that constructing this technology can be done in a reasonable timeframe, especially with good advance planning, and there is meaningful job creation associated with these projects. We commend EPA for moving forward with MATS. We look forward to further improvements in our air quality as implementation of the new standards reduces upwind transport of emissions into Maryland.

Thank you for giving me the opportunity to testify regarding these important air quality issues.

[The prepared statement of Mr. Summers follows:]

Testimony of Robert M. Summers, Ph.D.
Secretary of the Maryland Department of the Environment
Before the United States Senate
Committee on Environment and Public Works
Subcommittee on Clean Air and Nuclear Safety
Tuesday, March 20, 2012
"Review of the Environmental Protection Agency's Mercury and Air Toxics Standards (MATS) for Power Plants"

Chairman Carper, Ranking member Barrasso and honorable members of the Committee, thank you for the opportunity to share Maryland's positive experience with the early installation of air pollution control technologies under the 2006 Maryland Healthy Air Act—technologies that will now be required on many of the nation's coal-fired power plants by the recently finalized federal Mercury and Air Toxics Standards or "MATS." For the reasons explained below, Maryland strongly supports the new federal regulations adopted by the Environmental Protection Agency. This past Friday, Maryland, along with 12 other states, moved to intervene in support of EPA in the federal appeal brought by industry groups challenging the MATS rule. Based on Maryland's experience, we believe that implementation of the air toxic rule will generate positive economic benefits and can be achieved without risk to the country's electricity supply.

Background

Achieving compliance with federal ambient air quality standards and reducing levels of mercury and other air pollutants has been particularly

challenging for Maryland because so much of our air pollution is the result of transport from upwind out-of-state sources over which we have no control. Maryland has undisputed monitoring data showing that on the worst air quality days, up to 70% of Maryland's ozone pollution is the result of transport. The Chesapeake Bay Program estimates that up to one-third of the nitrogen that pollutes the Bay and its rivers comes from the air. While the past 10 years have brought significant improvements in Maryland's air quality because of the adoption of aggressive air pollution controls on our own sources, without similar reductions from upwind sources, Maryland will not achieve compliance with federal ambient air quality standards for ozone, or with future more stringent fine particle standards that are needed to protect public health.

The same is true for mercury deposition in our State. Most of Maryland's lakes and reservoirs are subject to fish consumption advisories for mercury. Mercury emissions from upwind sources account for more than 70 percent of mercury deposition in Maryland. This is why federal regulatory initiatives to reduce regional emissions—in particular, the MATS utility rule—are vitally important to improving Maryland's air and water quality.

We are confident that the MATS rule can be implemented without risk to the reliability of our electricity supply. The reason for our confidence—Maryland successfully implemented a state regulatory initiative—the Healthy Air Act—that required steep cuts in emissions of nitrogen oxides (NOx), sulfur dioxides (SO_2) and mercury from our coal-fired power plants through the installation of the same controls that will be required to achieve compliance with MATS.

Maryland's Experience With the Healthy Air Act

Maryland continues to be heavily reliant on coal-fired power plants for its electricity supply. Coal-fired plants produce approximately 60% of the electricity generated in Maryland. Uncontrolled, coal-fired plants remain the single largest source category of NOx, SO_2 and mercury emissions. Recognizing the need for steep cuts in power plant emissions, in 2006, Maryland's legislature enacted the Healthy Air Act, a multi-pollutant approach to reducing emissions from the power sector. The Healthy Air Act required significant reductions in three key pollutants from the State's largest coal-fired power plants: NOx, SO_2 and mercury. The pollution controls required to reduce these emissions also resulted in significant reductions in emissions of particulates, hydrogen chloride and other air toxics. The Act also required Maryland to join the Regional Greenhouse Gas Initiative (RGGI), a multi-state collaborative regulatory initiative to reduce greenhouse gas emissions from power plants.

The Healthy Air Act is the most significant emissions reduction program ever adopted in Maryland. Widely applauded by the environmental community when it was enacted in 2006, the Healthy Air Act is now fully implemented and has achieved its goals. The Maryland Department of the Environment worked in close partnership with the State's power plants to plan for and implement the law. Maryland generators invested approximately $2.6 billion in new control technologies. This substantial investment funded a wide range of new pollution controls including:

- 6 scrubbers to reduce SO_2 emissions
- 7 SCRs (Selective Catalytic Reduction) and 6 SNCRs (Selective Non-Catalytic Reduction) to reduce NOx emissions
- 2 baghouses to reduce particulate and mercury emissions

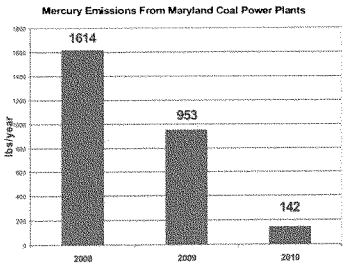
- 2 hydrated limestone injection systems to reduce SO_2 and mercury emissions
- 6 powdered activated carbon (PAC) injection systems to reduce mercury emissions

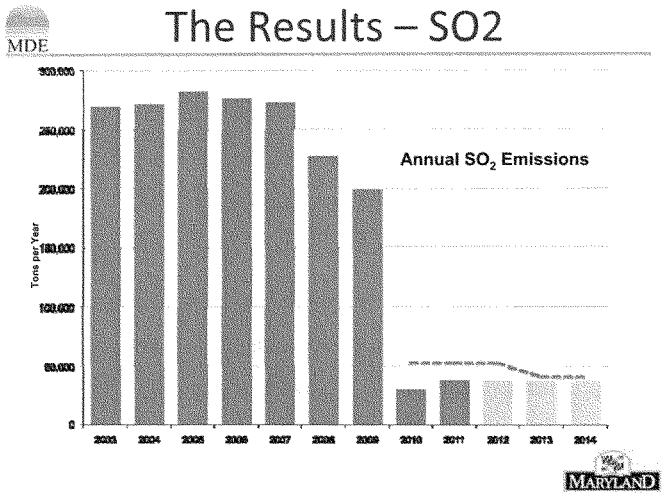
By 2010, the operation of these controls resulted in dramatic reductions in power plant emissions: Mercury emissions were reduced by more than 90%; SO_2 emissions by more than 80%; NOx emissions by more than 75%; direct particulate matter emissions by more than 60%; and hydrogen chloride emissions by approximately 83%.

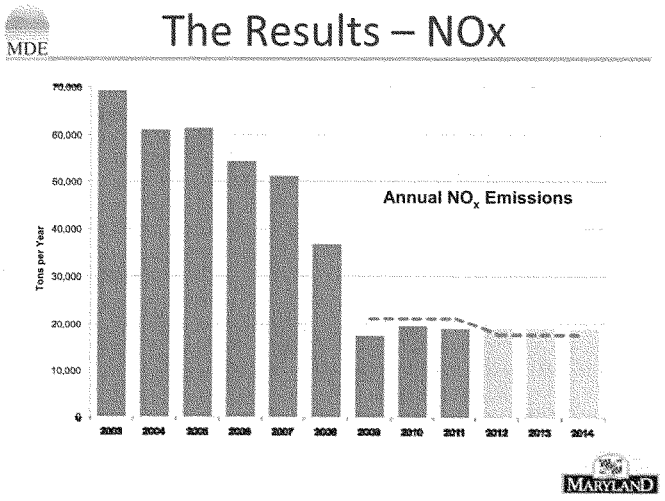
MDE

The Results – Mercury & Other Air Toxics

- Mercury
  - Exceeding 2012 90% reduction requirement in 2010
- Hydrogen Chloride (HCl) reduced 83%
- Direct particulate matter reduced 60%







These numbers are not estimates or projections. They are based on actual monitored emissions at the plants. It has been our experience, that the controls to reduce mercury, other air toxics, sulfur dioxide and nitrogen

oxides work extremely well. In almost all cases, the controls have resulted in even lower emission rates than were originally projected in 2006.

The construction and installation of the controls also boosted Maryland's economy. The effort resulted in the creation of approximately 90 new permanent jobs, and during the peak construction period, more than 3,000 jobs.

Maryland's Experience with Timing

The regulations implementing the Act were not finalized until 2007, resulting in a relatively short lead time for the power plants. The deadline for achieving a first phase of NOx reductions was December 31, 2009. This meant that all NOx controls needed to be operational by January of 2009, in less than two years. The compliance deadline for achieving a first phase of SO_2 and mercury reductions was December 31, 2010, so that as a practical matter, the controls for these pollutants needed to be operational by January of 2010—within two-and-a-half years. Because implementation of the Healthy Air Act was occurring at the same time that many power plants in the East were installing NOx and SO_2 controls to achieve compliance with EPA's Clean Air Interstate Rule (CAIR), Maryland's generators expressed serious concerns that sufficient labor and materials would not be available to complete construction prior to the compliance deadlines. Similar to provisions in the MATS rule, the Healthy Air Act allowed "emergency" extensions of the compliance deadlines to address any issues related to reliability or the availability of equipment or labor. Significantly, no compliance deadline extensions were needed or requested. All of the necessary controls were installed in time and the emission reductions occurred as expected, starting in 2009.

Working in Partnership with Affected Power Plants

Maryland worked very closely with our power plants to facilitate a smooth implementation process and timely compliance with the emission limitations. The Department of the Environment coordinated with our State Public Service Commission and Maryland's Department of Natural Resources to ensure an efficient planning and permitting process. This was a key reason for our success.

In closing, I would like to quote Paul Allen of Constellation Energy, one of our State's largest power companies.

> *"We recently completed the installation of a major air quality control system, including scrubbers, a baghouse, and other equipment at one of our major coal facilities in Maryland....These systems work effectively and result in dramatically lower emissions of mercury, sulfur dioxide, particulate matter, and acid gases. We know from experience that constructing this technology can be done in a reasonable time frame, especially with good advance planning; and there is meaningful job creation associated with the projects."(from March 16, 2011 press release)*

Thank you for taking the initiative to look into these important air quality issues and for providing this opportunity to Maryland to share our experience and perspective. Marylanders now benefit from improved air quality. We commend EPA for moving ahead with the MATS standards. We believe, based on our experience, that these standards can be timely achieved without disruption of our electricity supply system. We look forward to further improvements in Maryland's air quality as implementation of the new standards reduces upwind transport of emissions into our airshed.

Environment and Public Works Committee Hearing
March 20, 2012
Follow-Up Questions for Written Submission

Senator Barbara Boxer

1. Could you please describe the benefits to human health and welfare and to the environment from reducing mercury and other toxic air contaminants from coal- and oil-burning power plants?

Response: EPA's MATS rule covers mercury, arsenic, nickel, chromium, and other metals; acid gases; and pollutants such as benzene. These chemicals are known or suspected carcinogens or are associated with other serious health threats, such as increased respiratory disease and kidney damage. Also, mercury, consumed in contaminated fish, is a neurotoxin. Fish consumption advisories have been issued across the United States, including in Maryland, as a result of widespread mercury contamination in rivers, lakes, and streams. Hydrochloric acid (HCl) and other acid gases deposited from the atmosphere acidify lakes, killing aquatic organisms. Reducing coal- and oil-fired power plant emissions of mercury and other toxic air contaminants is expected to result in significant benefits to human health and the environment, particularly reductions in impacts such as the following: cancers, damage to children's developing nervous systems, heart attacks, respiratory disease, premature deaths, and destruction of fish species.

According to the EPA's benefits and costs analysis completed for the MATS rule, the requirements of the rule will save thousands of lives and prevent more than 100,000 heart and asthma attacks each year[1]. Additionally, the rule will result in significant reductions in uncontrolled releases of toxic air pollutants like mercury which can damage children's developing nervous systems, reducing their ability to think and learn. Releases of other toxic air pollutants, which this rule addresses, can cause a range of dangerous health problems in adults, from cancer to respiratory illnesses. The value of the air quality improvements for human health from the MATS rule totals $37 billion to $90 billion each year. Additionally, 540,000 missed work or "sick" days will be avoided each year, thus enhancing economic productivity and lowering health care costs.

2. Would you consider Maryland's law to limit mercury and other toxic air pollutants from power plants more stringent, less stringent, or about the same as the EPA's mercury and air toxics rule?

Response: Most facilities in Maryland will find the control requirements from the EPA MATS rule and Maryland's law about the same. The two exceptions are that Maryland's law also addresses nitrogen oxides (NOx) emissions (which requires Maryland facilities to install additional control technologies) and greenhouse gases (Maryland is part of the Regional Greenhouse Gas Initiative or RGGI).

3. Are the technologies to achieve the pollution reduction limits in EPA's mercury and air toxics rule available and being used today by power plants?

Response: Yes. Many Maryland power plants have installed and are currently operating mercury controls to comply with the limits of the Maryland Healthy Air Act. In most cases these plants are achieving mercury emission rates below those required by the EPA's rule. The most common technology implemented is activated carbon injection combined with a particulate control device such as a baghouse. Other power plants in Maryland have achieved the required mercury reductions through the co-benefits provided by the combination of a selective catalytic reduction (SCR) device for control of nitrogen oxides and a wet scrubber for sulfur control. These technologies also reduce some of the other air toxics that the EPA's MATS rule covers.

Senator Tom Carper

1. Based on your experiences in Maryland, do you think the EPA has given enough flexibilities to utilities to meet these new clean air standards? Would you have done something differently?

Response: While the EPA's rule provides flexibility, such as the option of showing compliance via emissions averaging for some existing electric generating units (EGUs), and the possibility of a 1-year extension to the three year compliance deadline for existing sources, the Maryland Healthy Air Act incorporates slightly different, but equally effective, flexibilities. Maryland's law uses a multi-pollutant control concept where the EPA rule is driven by the specific toxics requirements of the Clean Air Act. Given these different authorities, Maryland believes that EPA has provided meaningful and appropriate flexibilities in the MATs rule.

Senator James Inhofe

1. Testimony at the recent FERC Technical Conference pointed out how reliability can impact public safety in Maryland. Lower power reserve margins could cause blackouts in D.C., resulting in a sewage treatment plant dumping raw sewage into the Potomac River. Are you concerned about the public safety impacts in Maryland from reduced electric reliability?

Response: Maryland does not agree that reliability of electricity service will be adversely impacted as a result of the final MATS rule. PJM Interconnection, the Regional Transmission Organization which serves Maryland and the District of Columbia, as well as all or part of 12 other States, has procedures in place to track and analyze the impacts on system reliability of units that have announced retirements and those that are possibly at risk of retirement, so they can undertake transmission system enhancements where necessary. In August 2011, PJM issued a report that concluded that MATS and the Cross-State Air Pollution Rule (CSAPR) together do not threaten resource adequacy in the PJM region[2]. The PJM report, in looking at MATS and CSAPR, concludes that about 11 GW of electricity are at high risk of retiring and another 14 GW are at some risk. Even with these findings, PJM finds that system reliability will not be threatened by these rules. PJM still anticipates being able to carry a reserve margin at or above the target installed reserve margin. The PJM report notes the importance of new cleaner generation, including natural gas, and demand response in supplementing regional reliability and ensuring that resource adequacy will not be threatened.

In PJM's August 26, 2011 report they do note that there could be localized reliability concerns that may arise given the location of particular units and the unique locational services they provide. PJM registered these concerns in its comments to EPA, noting that a "reliability safety valve" should be included in the final EPA MATS rule to address these particular circumstances. EPA was receptive to PJM's concerns regarding localized reliability issues and as a result these concerns were addressed in the final MATS rule that EPA issued in December 2011. In response to the issuance of the final MATS rule, PJM announced that it was "pleased that the EPA Administrator has included the key elements of our proposed process to preserve reliability into documents accompanying the final rule."[3]

[1] Environmental Protection Agency, "EPA Fact Sheet: Mercury and Air Toxics Standards – Benefits and Costs of Cleaning Up Toxic Air Pollution from Power Plants"
http://www.epa.gov/mats/pdfs/20111221MATSImpactsfs.pdf

[2] PJM Interconnection, August 26, 2011, "Coal Capacity at Risk for Retirement in PJM: Potential Impacts of the Finalized EPA Cross State Air Pollution Rule and Proposed National Emissions Standards for Hazardous Air Pollutants"
http://pjm.com/~/media/documents/reports/20110826-coal-capacity-at-risk-for-retirement.ashx

[3] PJM Interconnection, December 21, 2011, "PJM's Response to the Issuance of the Final EPA MATS Rule"
http://www.pjm.com/~/media/about-pjm/newsroom/2011-releases/20111221-pjm-response-to-final-epa-mats-rule.ashx

Senator CARPER. Mr. Secretary, thanks a lot for what you said and for what you have done in Maryland.

For those of us literally in some cases have to breathe the pollution that was put up in the air in Maryland that blows our way, we especially are grateful for the work you have done and for expediting it.

We have a special guest here from Oregon, and I believe Senator Merkley would be pleased to introduce him.

Senator MERKLEY. Thank you, Mr. Chairman.

It is with great pleasure that I welcome Dr. William Lambert from Oregon to our panel today. Dr. Lambert is an associate professor at the Oregon Health & Science University in Portland, where he has conducted groundbreaking work quantifying the frequency and magnitude of exposure to toxic chemicals in communities and workplaces.

Dr. Lambert has a longstanding interest in exposure to airborne pollutants and related health effects. His research has contributed to how we understand exposure-response relationships and our susceptibility to carbon monoxide, environmental tobacco smoke, silica, and uranium dust and other toxic chemicals. He is also studying the effects of pesticides on children.

Before coming to Oregon Health Sciences University, Dr. Lambert held a number of positions at the University of New Mexico, including professor in the Department of Family and Community Medicine at the School of Medicine, as principal investigator for the epidemiology and cancer control program at the University of New Mexico Health Sciences Center, and professor in the Department of Internal Medicine at the School of Medicine.

I am delighted that Dr. Lambert is here today to testify, and I look forward to his remarks.

Senator CARPER. Dr. Lambert, before you testify, is any of that true?

[Laughter.]

Senator CARPER. It is pretty impressive. Please proceed.

STATEMENT OF WILLIAM E. LAMBERT, PH.D., DIRECTOR, EPIDEMIOLOGY AND BIOSTATISTICS TRACK, OREGON MPH PROGRAM; HEAD, DIVISION OF EPIDEMIOLOGY, DEPARTMENT OF PUBLIC HEALTH AND PREVENTIVE MEDICINE, OREGON HEALTH & SCIENCE UNIVERSITY

Mr. LAMBERT. Good morning and thank you, Senator Merkley, thank you Chairman Carper, Ranking Member Barrasso, and members of the Committee.

I really appreciate this invitation to present to you on public health matters related to the Mercury and Air Toxics Standards rule. I believe that my experience as a researcher and teacher contribute, but also importantly, it should be noted that for 8 years I have served on our State's Science Advisory Committee on Air Toxics.

I will start my testimony by stating that the central tenet of the Clean Air Act is the protection of public health, specifically the protection of the most susceptible sub-groups of the population with an adequate margin of safety. It is precisely this principle—the protection of our most vulnerable citizens—that the recently finalized

MATS is designed to meet, by scrubbing mercury, acids, and fine particulate matter from the emissions of power plants.

Who are the most vulnerable and how are they affected? Pregnant women, fetuses in children in the womb, even very small amounts of mercury damages the developing baby's brain and nervous system and impairs their ability to think and learn. These health effects are manifest as permanent deficits, leading to reduced success in school and eventually lower earnings. In childhood, exposure to acid gases in outdoor air pollution impairs lung growth and function and predisposes children to asthma.

Another vulnerable group are seniors and those with chronic medical conditions. They are affected by acid aerosols and fine particulate matter, which worsen emphysema and chronic bronchitis and are associated with heart attacks, hospitalizations, and premature deaths. Vulnerable groups may also be defined by high risk of exposure such as subsistence fish consumers and sport fishers who are exposed to methyl mercury accumulated in fish.

Further, minority and low income populations disproportionately live in areas with higher levels of outdoor air pollution. Compounding their health risks is access and utilization of health care, allowing health effects to progress to more advanced stages before treatment. Viewed in total, these are serious health effects that are spread across broad segments of the U.S. population and more commonly affect minority and low income groups.

The scientific evidence supporting benefits for health is strong. Relative to other compounds and pollutants, the scientific evidence for the toxic effects of mercury on the brain is strong, and similarly very strong evidence exists for the toxic effects of fine particulate matter and acid gases on the lungs and heart. We have good data from well conduced epidemiologic studies on human populations as opposed to relying solely on data from animal toxicology that then must be extrapolated to humans with uncertainty.

For mercury, the subtle changes in neurologic function are observed in multiple locations and populations. This consistency increases our confidence that the changes can be attributed to exposure to mercury in the womb. For acid gases, ozone, and fine particulate matter, damage to lung growth and lung function of children and in adults, emergency room visits, and premature deaths have been observed in multiple U.S. cities using various scientific approaches. The combined health effects of reduction of mercury, other metals, acid gases, and fine particulate are substantial.

In the EPA's quantitative risk assessment, a small shift in average IQ is forecast in 2016 for an estimated quarter-million children exposed to mercury in the womb. Moving the average IQ level of such a large number of exposed children is challenging and will take many years. But this prediction indicates a good start is possible, and there is likely a greater benefit for reductions in the upper part of the distribution of most highly exposed children.

The health benefits from the reduction of mercury emissions should not be considered in isolation but rather in combination with reductions in other toxic compounds which will be scrubbed along with mercury from stack emissions. EPA estimates very large co-benefits with thousands of avoided cases of chronic lung diseases and heart attacks, hospitalizations, lost school and work days. The

economic valuation of the total avoided health effects ranges in the billions.

In conclusion, the under-appreciated wisdom of the Clean Air Act is simply this: by providing protection for the most vulnerable, we broadly provide protection to all Americans. Mercury, fine particulate matter, and acid gases associated with the burning of coal present a clear hazard to the health of the public, particularly fetuses, children, and the elderly. By reducing exposures to these toxics, we provide protection to large cross-sections of the American population. The scientific evidence to support the exposures and the health damages to the population is extensive.

The Utility MATS final rule was developed over years with considerable thoughtfulness and input from technical experts. To public, industry, and lawmakers, this rule should be allowed to move to implementation for the protection of the public health.

Thank you very much for your time and consideration.

[The prepared statement of Mr. Lambert follows:]

Written Testimony
prepared by William Lambert, PhD
for the hearing entitled
"Oversight: Review of the Environmental Protection Agency's Mercury and Air Toxics Standards (MATS) for Power Plants"
Subcommittee on Clean Air and Nuclear Safety
Committee on Environment & Public Works
United States Senate
Tuesday, March 20, 2012
10:00 AM EDT
EPW Hearing Room – 406 Dirksen

The coal-fired boilers of utilities are the largest remaining source of airborne mercury emissions in the United States, and they are a major source of hazardous air pollutant emissions for other metals including arsenic, chromium, cadmium, and nickel. In addition these sources emit large amounts of acid gases and fine particulate matter. The primary objective of the Mercury and Air Toxics Standards published in the Federal Register on February 16, 2012 is the reduction of airborne mercury, a known neurotoxin with that impairs the brain development of children, resulting in permanent impairment of cognition and learning ability, with potential repercussions across the lifespan, adversely affecting future earnings and quality of life. The technologies available to remove mercury from smokestack emissions will at the same time remove the other toxic metals, acid gases, and fine particulate matter. These compounds are associated with cancer, asthma, chronic obstructive pulmonary disease, and heart disease. Combined, reduction of these emissions from coal-fired utilities will yield substantial benefits for the protection of public health.

Mercury (Hg) is an environmental pollutant of concern because it is persistent and accumulates in biological systems. Because of its persistent nature, mercury deposited in the environment today can be re-mobilized in the future, and therefore poses a long-lasting risk to public health. The form of mercury emitted

from coal-fired plants determines its behavior in the environment, and the potential hazard to humans. The three forms of mercury are: (1) gaseous elemental mercury, (2) oxidized mercury compounds, and (3) particle-bound mercury. Elemental mercury does not quickly react in the atmosphere, nor does it wash out, resulting in long-range transport and global scale deposition. Oxidized mercury and particle-bound mercury deposit quickly from the atmosphere impacting local and regional areas in proximity to sources. After mercury has fallen out of the air by dry and wet deposition processes, it is present in waterbodies and on the land. Microbes in aquatic sediments and soils convert these forms of mercury into an organic form called methylmercury (MeHg), which is taken up by aquatic organisms and accumulates up the food web. The tissues of predatory fish in the upper part of the aquatic food web may have methylmercury concentrations many times higher than that of the concentrations in the surrounding water and sediments. Methylmercury is much more toxic to humans than mercury in its elemental and oxidized forms, and it is through the ingestion of contaminated fish that human exposure occurs and health is harmed.

Over the past twenty years, multiple scientific panels and the U.S. EPA have reviewed extensive human data and have developed and revised the Reference Dose (RfD) for methylmercury. Epidemiologic data from observation of exposed populations, including the sensitive subpopulation of pregnant women and fetuses, is of sufficient size and quality to negate the need to rely on toxicological models and make extrapolations from animals to humans. These directly collected data from multiple studies of exposed populations in The Seychelles, Faroe Islands, and New Zealand, increase our confidence as to the neurological health effects associated with ingestion of contaminated fish. The available studies, particularly those of the Faroe Islands, suggest there is no evidence of a threshold for methylmercury-related neurotoxicity. The Faroe Island study is the primary basis for the RfD developed by the EPA. Exposures above the RfD can

be interpreted to represent an appreciable potential hazard to public health, although effects are demonstrable at lower levels of exposure. In these studies, children exposed *in utero* and during early life showed reduced performance on several neurobehavioral tests. Following the opinion of an expert panel of the National Academy of Sciences, the EPA used multiple neurobehavioral test measures from these studies as the basis for the RfD. These endpoints are related to the ability of children to learn and to be successful in school. Impairments measured at this age represent long-lasting and permanent impacts that continue into adulthood, affecting learning ability across the lifespan, and in all likelihood adversely affecting future earnings and quality of life.

Of all the hazardous air pollutants emitted by coal-fired plants, mercury presents the greatest hazard to the developing brains of children, and the evidence for adverse effects is well established in science. Children who are prenatally exposed to even low concentrations of methylmercury are at increased risk of reduced performance on neurobehavioral tests of attention, fine motor function, language, visual and spatial abilities, and verbal memory.

The health of populations that consume high amounts of self-caught fish are likely to be exposed to methylmercury levels exceeding the RfD. These subgroups include minority and low-income communities because of their higher levels of subsistence fishing. Among the communities of concern are American Indians and Alaska Natives, African Americans, Hispanics, and Asian Americans and recent immigrants from eastern Europe. In turn, children in these populations are at higher risk for the adverse neurological health effects described above. Children living in Environmental Justice communities are exposed to other stressors in addition to mercury that can result in lower educational performance, creating the potential for combined interaction of environmental toxins with other stressors.

Estimating the extent of neurologic damage in the population from these exposures is a complex process and the EPA followed established and accepted methods developed for another toxic metal, lead. This prior experience also allowed the economic valuation of these health effects using avoided IQ deficits. The use of global IQ to represent the health outcome is a trade-off, because ideally we would choose the more sensitive measures of language, attention, and memory that were directly assessed in these research studies. However, the use of IQ as a proxy allows monetization of benefits that are not possible with these neurobehavioral tests, which makes IQ very useful for the benefits analysis.

In the quantitative risk analysis presented in the Regulatory Impact Analysis of Mercury and Air Toxics Standards (2011), dispersion models identified geographic deposition of airborne mercury with and without controls on coal-fired utilities. Census tract data was used to estimate the number of women and childbearing age and annual pregnancies, and regional data on recreational and subsistence fishing were applied to estimate levels of consumption of locally caught fish. Applying dose-response curves, and accounting for variation, estimates of the shift in IQ points were calculated. Almost a quarter-million children are estimated to be exposed prenatally, with an average IQ loss due to mercury from all sources of 0.11 points in 2005, and 0.10 points in 2016. The average estimated ingestion rate of mercury in pregnant women is estimated to be 6.6% lower in 2016 under the Toxics Rule, relative to 2005. This translates into an estimated 0.00209 IQ points saved per prenatally exposed child compared to the 0.10 points 2016 base estimate.

While the avoided IQ loss may seem small, it must be realized that given the persistence of mercury in the environment, reductions in fish tissue levels will be slow, and moving the average IQ score of 240,000 children will also be accomplished across many years. Unseen in this average is the accompanying movement in the upper tail of the most highly exposed children. As previously

mentioned, using IQ as the outcome is relatively insensitive and probably underestimates the true benefits to reducing prenatal exposures. Impaired cognitive development, problems with language, and abnormal social development likely are related to later success in life and earnings. Other technical uncertainties also limit our confidence in the interpretation of this benefit analysis, and include the inability to focus on susceptible and vulnerable populations. It was not possible to quantify other potential health benefits of reducing mercury; immune and cardiovascular effects, and neurological effects in later life could not be considered because of inadequate scientific evidence. Even recognizing these limitations, this quantitative risk assessment provides valuable insights to gaps in knowledge and areas to improve scientific understanding so that we can better measure the impacts of air pollution control programs.

The health benefits from the reduction of mercury emissions from coal- and oil-fired facilities should not be considered in isolation, but rather in combination with reductions in other metals (arsenic, chromium, cadmium, nickel), organic compounds (benzene, formaldehyde), acid gases (sulfates), and fine particulate matter which also would be scrubbed along with mercury from boiler exhaust flows. The co-occurring pollutants are associated with cancer, asthma, chronic obstructive pulmonary disease, and heart disease. The burden of adverse health effects in the population is largely driven by fine particulate matter ($PM_{2.5}$) and acid gases, including sulfur dioxide (SO_2).

Using similar methods of quantitative risk assessment as those described above for mercury the EPA estimates substantial co-benefits for adults:

- 6,600 to 17,000 fewer premature deaths
- 4,300 fewer cases of chronic bronchitis
- 10,000 fewer non-fatal heart attacks

- 12,000 fewer hospitalizations (for respiratory and cardiovascular disease combined)
- 4.9 million fewer days of restricted activity due to respiratory illness, and
- 830,000 fewer lost work days.

For children, the avoided health damages include:

- 110,000 fewer childhood asthma attacks
- 6,700 fewer hospital admissions due to asthma
- 10,000 fewer cases of acute bronchitis, and
- 210,000 fewer cases of upper and lower respiratory illness.

The economic valuation of the total avoided health effects ranges from $37 billion to $90 billion per year.

EPA's analyses also consider the distribution of benefits of the Toxics Rule by race/ethnicity and income, and they demonstrate broad benefits to all groups in the United States. The Regulatory Impact Analysis estimates that people living in counties with the highest $PM_{2.5}$ mortality risk (top 5 percent) will receive the largest reduction in mortality risk after the Toxics Rule takes effect. Further, the people now living in the poorest 5 percent of the counties are estimated to receive a larger reduction in $PM_{2.5}$ mortality risk than all other counties. When viewed with other clean air policies (the Cross-State Air Pollution Rule), disparities in exposure to $PM_{2.5}$ and its associated health effects will be further reduced for the highest risk counties.

In conclusion, mercury is a potent neurotoxin that threatens the brains and nervous systems of fetuses and young children. Exposure from eating contaminated fish can lead to multiple and life-long neurological problems, including learning and attention disabilities. In 2012, the contamination of our country's lakes and rivers by mercury is widespread. Twenty-six states have issued advisories to limit consumption of mercury-laden fish, and all but Hawaii and the District of Columbia have advisories for specific bodies of water.

Reducing levels of mercury in fish in these waters will reduce exposures to those who eat large amounts of fish for subsistence and recreation. Engineering controls to reduce mercury emissions from coal-fired utilities will also reduce emissions of other toxic metals, acid gases, and fine particulate matter that pose health risks many Americans, and particularly minority and low-income communities. The Mercury and Air Toxics Rule, when implemented and in effect, will immediately reduce these co-occurring hazards, which are extensive and require costly treatment. Over time, I am confident the benefits of reducing mercury will also be manifest in the public's health.

Thank you for the invitation to submit this testimony and to speak at the hearing.

Respectfully submitted,

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Senator CARPER. Dr. Lambert, thanks so much. Thanks for coming all the way from Portland to be with us today.

And sitting right here next to a fellow from Avon Lake, Ohio, where Rob James is a member of the city council.

Do they call you Councilman James?

Mr. JAMES. Mr. James is fine, or Councilman James.

Senator CARPER. Councilman James, we are happy you are here. You are recognized for 5 minutes. Please proceed.

STATEMENT OF ROB JAMES, AVON LAKE CITY COUNCIL, WARD I, AVON LAKE, OHIO

Mr. JAMES. I would like to thank Chairman Carper, Ranking Member Barrasso, and the other members of the Subcommittee for inviting me to testify today. My name is Rob James, and I am a member of the Avon Lake City Council.

Avon Lake is a beautiful community of nearly 23,000 residents on the shores of Lake Erie, approximately 20 miles west of Cleveland. Although I am currently an attorney in private practice, I previously served as an assistant attorney general to the Ohio attorney general, where I represented the State of Ohio and its agencies, including the Ohio EPA.

My work as an assistant attorney general included enforcing environmental laws and regulations and ensuring that the natural resources of Ohio were protected. However, I am here today because I think it is important that Congress understands the impacts of environmental rules, such as the Mercury and Air Toxics Rule, on local communities like Avon Lake.

On February 29th of this year GenOn Energy, Inc. announced that it would close the coal- and fuel-oil fired electric generating plant in Avon Lake in 2015. The Avon Lake Generating Station is capable of generating 734 megawatts, providing baseload electric capacity and load following capability to the grid as well as essential peaking capacity and black start capability. This facility plays an important role in providing reliable and affordable supplies of electricity.

The reasons behind the closure are clear. GenOn stated that the closure was a result of the rising costs associated with EPA's regulations and the fact that overwhelming costs associated with complying with the rules could not be recovered by continuing to operate the facility. While some may celebrate the closure of these types of facilities based on broader policy objectives, the loss of power plans has a very real impact on the communities in which they are located. These are not just abstract costs.

The most immediate impact on people will be on the 80 people employed by the Avon Lake facility. The type of quality jobs at the Avon Lake plant are increasingly hard to find in our country, let alone in Ohio and the greater Cleveland area. But this is more about than just the jobs of the people employed at the plant. Instead, it is about the ripple effect that harms an entire community. In present dollars, closure of the Avon Lake generating facility will cost the city of Avon Lake over $77,000 in income taxes and at least $268,000 in property taxes per year.

This loss does not just represent the loss of general revenue used to fund the city and its programs. Significantly, a sizable portion

of taxes collected from the facility is used to fund Avon Lake paramedics, firefighters, and emergency medical services. This loss of nearly $50,000 from the EMS budget, which is the amount that will be lost from the closure, will reduce the EMS operating budget by half and may represent the loss of one paramedic. Undoubtedly, this will have a direct impact on the health of Avon Lake residents.

Even more concerning is the impact the closure will have on the Avon Lake school district. At present, Avon Lake schools collect $2.4 million in utility taxes alone and another $1.5 million in real property taxes from the facility. The potential loss of $4 million each year will have an unimaginable effect on Avon Lake schools. Not only will the loss of revenue directly impact the ability of the schools to provide a high quality of education for all students, many of the programs offered by the school for students with the greatest needs will be lost.

Indeed, many of the health and welfare programs for the students my need to be eliminated. For instance, the loss of the Avon Lake power plant would force the school district to end no-cost programs to help children and teens who are struggling with depression, anxiety, ADHD, and the effects of trauma or abuse, among other programs.

In addition, consumers in northeastern Ohio are likely to pay more for their electricity. This Committee in the past has heard from Catholic Charities of Cleveland, a group on the front line of addressing high energy costs. It testified that the loss of power plants would have a devastating effect on the people of Ohio and our country, particularly the poor and the elderly.

Unfortunately, other communities in addition to Avon Lake are suffering from the cost of the MATS rule. In Ohio alone, nine other power plants have announced that they will close, representing a loss of 5,870 megawatts. Additional losses will also be felt outside of Ohio. In each of these communities and all the other locations where plants are closing, it will be harder to pay for the schools, hospitals, and basic services that will keep communities vibrant and healthy.

As the debate over the MATS rule continues, I hope that Congress will keep in mind communities like Avon Lake. While the need for environmental regulation is important, EPA must understand the consequences of its regulations on our communities. Places like Avon Lake need affordable and reliable electricity, a strong educational system, and opportunities for our economies to rebuild and grow. The U.S. economy is struggling to recover, and northeastern Ohio is at the center of this struggle. We know that we can have clean air, good jobs, and reliable electricity, but only if polices are implemented based on sound analysis and with full consideration of the real costs of the choices made by regulators.

It is my hope and belief that there is still time to change the debate and apply environmental regulation in a responsible manner before more unnecessary damage is done. Thank you again for the opportunity to testify this morning.

[The prepared statement of Mr. James follows:]

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COUNCIL OFFICE

TESTIMONY OF ROBERT K. JAMES
MEMBER OF THE AVON LAKE CITY COUNCIL
BEFORE THE
U.S. SENATE COMMITTEE ON ENVIRONMENT & PUBLIC WORKS
SUBCOMMITTEE ON CLEAR AIR AND NUCLEAR SAFETY

"Oversight: Review of the Environmental Protection Agency's Mercury and Air Toxics Standards (MATS) for Power Plants"

March 20, 2012

I would like to thank Chairman Carper, Ranking Member Barraso, and the other members of the subcommittee for inviting me to testify today. My name is Rob James, and I am a member of the City Council of Avon Lake, Ohio, where I represent the residents of Ward 1. In addition, I am the chairman of the Environmental Committee and a member of the Economic Development Committee on City Council. Avon Lake, Ohio is a beautiful community of nearly 23,000 residents on the shores of Lake Erie, approximately twenty miles west of Cleveland.

Although I am currently an attorney in private practice, I have previously served as an assistant attorney general for the Office of the Ohio Attorney General, where I represented the State of Ohio and numerous state officials and agencies, including the Ohio Environmental Protection Agency. My work as an assistant attorney general

included enforcing environmental laws and regulations and ensuring that the natural resources of Ohio were protected. However, I am here today because I think it is important that Congress understands the impact of environmental rules, such as the Mercury and Air Toxics ("MATS") rule, on local communities such as Avon Lake.

Introduction

On February 29th of this year, GenOn Energy, Inc. announced that it would close the coal and fuel-oil fired electric generating plant in Avon Lake in 2015. The Avon Lake Generating Station is capable of generating 734 megawatts, providing baseload electric capacity and load-following capability to the grid, as well as essential peaking capacity and black start capability. This facility plays an important role in providing a reliable and affordable supply of electricity.

The reasons behind the closure are clear. GenOn stated that the closure was a result of the rising costs associated with EPA's regulations, and the fact that the overwhelming costs associated with complying with the rules could not be recovered by continuing to operate the facility.

While some may celebrate the closure of these types of facilities based on broader policy objectives, the loss of power plants have a very real impact on the communities in which they are located. These are not just abstract costs. The families of my community have to absorb theses significant losses.

Impact on the City of Avon Lake

The most immediate impact will be on the 80 people employed by the Avon Lake facility. The type of quality jobs at the Avon Lake plant are increasingly hard to find in

our country, let alone in Ohio and in the greater Cleveland area. But this is about more than just the jobs of the people employed at the plant; instead, it is about the ripple effect that harms an entire community. In present dollars, closure of the Avon Lake generating facility will cost the City of Avon Lake over $77,000 in income taxes, and at least $268,000 in property taxes per year.

This loss of taxes does not just represent the loss of general revenue used to fund the city and its programs. Significantly, a sizeable portion of the property taxes collected is used to fund Avon Lake paramedics and emergency medical services. The loss of nearly $50,000 annually from the EMS budget, which is the amount that would be lost from the closure, would reduce the EMS operating budget by half.

In particular, the loss would be realized by the inability to fund critical items ranging from paramedic supplies (i.e. cardiac medications, oxygen, oxygen masks, heart monitors), ambulance maintenance and repair, fuel, insurance, the purchase of ambulances, and the training and education of paramedics. With respect to personnel costs, it may eliminate one of the eight paramedics funded by property tax revenues, which represents a 12.5% reduction in the paramedic work force.

In addition to the taxes paid by the Avon Lake power plant, GenOn has donated various equipment and training to the Avon Lake Fire Department and EMS. For instance, the Fire Department has received a thermal imaging camera, with an approximate value of $7,200, which assists firefighters to see heat in limited visibility, locating victims and the exact location of the fire more rapidly. Additionally, the Fire Department has been given a piercing nozzle, which has a value of nearly $6,000, and is

used in firefighting to penetrate steel and other materials to combat hidden or inaccessible fires, and well as firefighting foam, worth several thousands of dollars, which helps extinguish flammable and combustible liquid fires.

Thus, the closure would directly affect ability of the City of Avon Lake to effectively deliver an emergency paramedic and firefighting service to its 23,000 residents. Undoubtedly, this will have a direct impact on the health of Avon Lake residents.

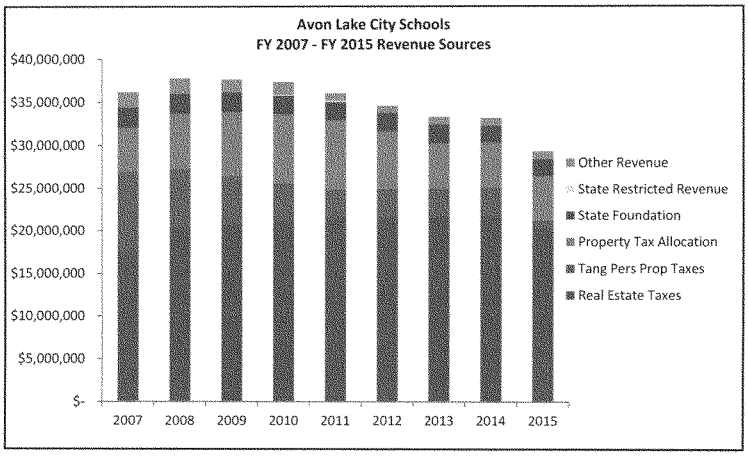
Impact on the Avon Lake City School District

Even more concerning is the impact the closure will have on the Avon Lake City School District. The Avon Lake City School District currently has an enrollment of approximately 3834 students. It has 249 teachers, of whom 100% percent are state certified, and 70% have master's degrees or higher. In addition, the district has another 257 non-teaching staff, which includes administrative assistants, custodians, bus drivers, and other employees.

In 2011, 93% of Avon Lake graduates enrolled in a two year college, four year college, or in the military, and 65% of the students received college credit before graduating. Moreover, the students earned approximately $9 million in scholarship awards for college.

Not surprisingly, Avon Lake City School District has been rated as "Excellent" by the State of Ohio for the past nine consecutive years. Of 937 school districts in the state, Avon Lake ranks 25th, or in the top 2.5% of all districts.

At present, Avon Lake City School District collects $2.4 million in utility taxes alone, and another $1.5 million in real property taxes. The potential loss of nearly $4 million dollars *each year* would have an unimaginable effect on Avon Lake's schools. Based on fiscal year 2011 revenue of $35,997,561, a loss of $3.9 million equates to an 11% reduction. Revenues for fiscal years 2012 and 2013 are forecast to be even lower, so the reduction will likely be even greater. This projected loss to the school district can be summarized in the following chart:



The steep decline in revenue from 2014 to 2015 can clearly be seen, which represents the loss of taxes from the Avon Lake power plant. Not only will the loss of revenue directly impact the ability of the schools to provide a high quality of education for all students, but many of the programs offered by the school for students with the greatest needs would be lost.

Indeed, many of the health and welfare programs for the students may need to be eliminated. The loss of the Avon Lake power plant would force the school district to end, for example, outreach services at the Cleveland Clinic Learner Center for Autism that help meet the needs of autistic students without having to send them to outside placement; no-cost programs at Applewood Center, which helps children and teens who are struggling with depression, anxiety, Attention Deficit Hyperactivity Disorder, the effects of trauma or abuse, or are having behavioral difficulties at home or in school; anonymous counseling and awareness programs from the Lorain County Alcohol and Drug Abuse Services, and a program through Genesis House and Teen Street Team to assist students in talking to their peers about abuse.

As Avon Lake School District Superintendent Dr. Robert Scott has noted, these losses are "devastating," especially in light of the fact that the school district is already having to reduce the number of teachers in schools because of state budgetary issues.

These same sentiments are shared by many parents of students in Avon Lake schools. Deborah Ludwig, a parent of a student at Troy Elementary School, stated:

> With the Avon Lake GenOn closing, it will highly impact the community's energy costs and quality of life. There are many unforeseen factors that will be generated by this plant's closing that will impact not only the residential establishments BUT also the Avon Lake School System. With the Federal Government continually raising the bar on EPA standards and in effect costing our energy plants upgrades that they cannot afford to make, the end result will be a wealth of empty and useless plants across the state, higher consumer costs and a downgrade on everyone's quality of life especially here in Avon Lake.

Kris Simecek, a parent of a student at Westview Elementary School, shares a similar perspective. She said:

> My husband and I moved to Avon Lake over 20 years ago because of one specific reason - the quality of Avon Lake City Schools. Since then, we have raised four boys who all went through the Avon Lake school system. If GenOn closes, the economic impact on our high quality school system will be highly detrimental. The future of the school system, and therefore the future of the children of Avon Lake, is dependent on consistent resources. As a mother, the health of my children is very important. If the closing of GenOn is the only way to improve the air quality and the health of our children and community, it should not be done to the detriment of those very same children and community members.

The loss of the Avon Lake power plant clearly represents an incredibly difficult challenge for the Avon Lake School District. While the intended objective of clean air is important, the unintended consequence of the loss of revenue to the school system must be considered in promulgating environmental regulations.

Impact on the Cost of Electricity

In addition, consumers in Northeast Ohio are likely to pay more for their electricity. This Committee has in the past heard from Catholic Charities of Cleveland, a group on the frontlines of addressing the impact of high energy costs. It testified that the loss of power plants "would have a devastating effect on the people of Ohio and our country, particularly the poor and the elderly."

The group attempted to quantify the impact of such closures as follows:

> The overall impact on the economy in Northeast Ohio would be overwhelming, and the needs that we address at Catholic Charities in Ohio with the elderly and poor would be well

> beyond our capacity and that of our current partners in government and the private sector. In a recent study on Public Opinion on Poverty, it was reported that one-quarter of Americans report having problems paying for several basic necessities. In this study, currently 23% have difficulty in paying their utilities - that is, one out of four Americans.

Unfortunately, other communities in addition to Avon Lake are suffering from the costs of the MATS rule. In Ohio alone, nine other power plants have announced that they will close, including Conesville, Muskingum River, Picway, Beckjord, Miami Fort, Ashtabula, Bay Shore, Eastlake, Lake Shore, and Niles. This represents a loss of 5,870 megawatts in just Ohio. Additional losses will be felt outside of Ohio, including Glen Lyn, Virginia; Muskegon, Michigan; and Upper Mount Bethel Township, Pennsylvania. In each of these communities, and all the other locations where plants are closing, it will be harder to pay for the schools, hospitals, and basic services that keep communities vibrant and healthy.

Conclusion

As the debate over the MATS rule continues, I hope that Congress will keep in mind communities like Avon Lake. While the need for environmental regulation is important, EPA must understand the consequences of its regulations on our communities. Places like Avon Lake need affordable and reliable electricity, a strong educational system, and opportunities for our economies to rebuild and grow. The U.S. economy is still struggling to recover, and Northeast Ohio is at the center of this struggle. We know that we can have clean air, good jobs, and reliable electricity – but only if policies are implemented based on sound analysis, and with full consideration of

the real costs of the choices made by regulators. It is my hope, and belief, that there is still time to change the debate and apply environmental regulation in a responsible manner before more unnecessary damage is done.

Thank you again for the opportunity to testify today.

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May 1, 2012

VIA U.S. MAIL AND EMAIL (Jonathan_Aronchick@epw.senate.gov)

United States Senate Committee on Environment and Public Works
Subcommittee on Clean Air and Nuclear Safety
Attn: Jonathan Aronchick
410 Dirksen Senate Office Building
Washington, DC 20510-6175

Re: Additional Questions from Senator James Inhofe

Dear Sir:

Please find below responses to the additional questions from Senator James Inhofe relating to my March 20, 2012 testimony before the Subcommittee on Clean Air and Nuclear Safety hearing entitled "Oversight: Review of the Environmental Protection Agency's Mercury and Air Toxics Standards for Power Plants."

1. The Avon Lake Powerplant's closure could cost schools in your county $2.4 million in utility taxes. How will this impact local education?

Significantly, the Avon Lake Public School District is estimated to lose not only $2.4 million in utility taxes, but an additional $1.5 million in property taxes each year. The total estimated loss of $3.9 million *each year* represents an 11% decrease in the school district's annual budget. Moreover, other local entities besides the school district collect property taxes from the GenOn facility, such as the Avon Lake Public Library and the Lorain County Joint Vocational School District, so the total loss to local education will likely be even greater.

The loss in revenue will require the school district to make difficult choices between providing a high quality of education for all students as well as providing programs for students with particular needs, including health and welfare programs.

2. EPA claims Utility MACT will cause a slight increase in people's IQ's by .00209%. Yet, Utility MACT powerplant closures cut millions in tax revenue for schools in communities like Avon Lake. EPA takes credit for making us smarter, shouldn't the Agency also account for Utility MACT's impact on schools across the country?

Although inherent intelligence is very important, without education, intelligence cannot be guided to greater accomplishment. U.S. EPA should consider the impact of its regulations on such worthy societal needs such as education and school funding. Indeed, with the projected loss of revenue to various educational entities within Avon Lake and Lorain County, schools will have a more difficult time providing educational opportunities for all of its students, including those with increased intelligence.

3. Deutsch Bank warns Utility MACT could cause electricity capacity prices in your community to go up by 1,700%. Are you concerned such electricity prices could regressively impact lower income residents in your community?

I am very concerned that the closure of the GenOn facility, as well as the closure of other electric generating facilities across Ohio, may impact the cost of electricity. The decrease in supply, coupled with other economic pressures, may make it difficult for the neediest in my community, including the poor and the elderly, to provide for their needs. Indeed, many of these individuals are on tight or fixed-incomes, so even marginal increases in utility costs have very significant impacts on their budgets.

4. Does the city have any strong possibilities of attracting replacement revenue, either through new taxpayers or new funds from the state?

There is little chance that the State of Ohio will directly provide replacement revenue to the City of Avon Lake or the Avon Lake School District. In fact, in 2011, the State of Ohio greatly reduced the amount of funding it provided to municipalities and school districts in order to close an $8 billion deficiency in the state budget.

The City of Avon Lake will undertake all efforts, however, to attract new taxpayers or other sources of revenue in an effort to replace the lost revenue for the city and the school district. However, particularly in the current economy, it is uncertain whether such efforts will ultimately be successful and completely replace the revenue that has historically been generated by the GenOn facility.

5. The Avon Lake Powerplant's closure could cost schools in your county $2.4 million in utility taxes. Worse, UBS is projecting Utility MACT could cause local electricity prices to skyrocket 60%. The Chicago Tribune reported similar increases are already costing the Chicago Public Schools an extra $2.7 million a year. EPA is blasting a hole in your revenue base while drastically increasing your energy costs - how is your community going to make up the difference?

The City of Avon Lake and the Avon Lake Public School District have yet to completely determine how the lost revenue will be replaced. Due to declining property values and a decrease in direct funding from the State of Ohio, the city and the school district are already looking at raising additional tax revenue through levies. For instance, the City of Avon Lake has placed a measure on the August 2012 ballot to increase property taxes to support its paramedics and EMS personnel. The Avon Lake School Board is also considering a levy for the November 2012 ballot. Significantly, these measures are to only address the current decline in revenue. When the closing of the GenOn facility occurs in 2015, the city and the school district will have to determine how to address that lost revenue. While the city is hopeful that increased economic development may offset some of the lost revenue, the city and the school district may need to consider decreases in services or additional tax revenue to ultimately replace the lost revenue.

6. EPA's modeling projected that its regulations would close the Avon Lake Powerplant as far back as 2010. To your knowledge, did EPA ever reach out to local officials to determine the effect this would have on your community?

To my knowledge, U.S. EPA did not reach out to local officials, including officials in Avon Lake, either following its modeling in 2010, or even after the announced closing of the GenOn facility in February 2012. In fact, U.S. EPA only became involved *after* the announcement by GenOn when Avon Lake officials contacted U.S. EPA in Washington, D.C. and at its regional office in Chicago, Illinois for assistance relating to the closure.

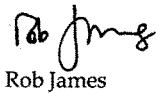
7. Do you anticipate the Avon Lake school district having to make a decision between, on the one hand, its ability to attract students and prepare them exceptionally well for college, on the other hand, and programs that help students with greatest needs — like programs for autistic students or those at the Applewood Center — as a result of the budget cuts the School system face with the closing of GenOn?

I am quite concerned that the Avon Lake School District will be required to make difficult choices that unavoidably will have a negative impact on district and its students. Many residents moved to Avon Lake due to the high quality of its school district. The school district is faced with a dilemma: either reduce its substantive educational programs and risk decreasing the overall quality of the district, thereby limiting the attractiveness of Avon Lake to new residents; or reducing other programs, including extracurricular activities or programs to assist students with important needs such as special education or mental health. Clearly, no one choice is correct, and the school district will have to balance all of the needs of the school district and its students. Nevertheless, the school district would not have to face these difficult choices but for the closing of the GenOn facility in Avon Lake.

Thank you for the opportunity to answer these additional questions regarding the impact of the closure of the GenOn facility on the Avon Lake community. Should you

have further questions or require additional information from me, please do not hesitate to let me know by contacting me at the above address or telephone number, or by email at rjames@avonlake.org.

Sincerely yours,



Rob James
Avon Lake City Council for Ward I

Senator CARPER. Councilman James, very nice to meet you, and welcome you to the Committee. Thank you for coming and for your statement.

I would ask unanimous consent that it be published in the record an article from earlier this month from the Sun News that begins, Avon Lake Mayor Greg Zilka Sees Opportunity, Not Just Gloom, in the news that GenOn Energy will shutter the Avon Lake Power Plant in April 2015. I would just ask unanimous consent that this be made a part of the record. No objection.

[The referenced article follows:]

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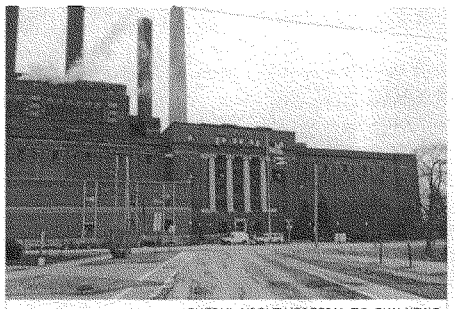
Avon Lake's GeOn Energy plant set to close in 2015

Published: Thursday, March 08, 2012, 10:01 AM Updated: Friday, March 09, 2012, 8:05 AM

By **Cheryl Higley, Sun News**



CHERYL HIGLEY/SPECIAL TO SUN NEWS

Plans call for the GenOn Energy's plant to be shut down in April 2015, but Mayor Greg Zilka says the city will immediately begin to explore alternative uses for the site.

AVON LAKE Mayor Greg Zilka sees opportunity, not just gloom, in the news that GenOn Energy will shutter the Avon Lake power plant in April 2015.

With advance notice of the closure, the city's economic development team can get a head start on pursuing options for the site, including whether it is feasible for the coal-powered plant to produce alternative energy instead. The city does not have the money to purchase the plant, which sits on prime lakefront real estate, but he said private development is a possibility.

"A developer could turn that site into something very positive for the lakefront and for the city. But, as with any industrial area, I would not be surprised if there were problems with the soil, given the site's history," Zilka said.

The city will pursue cleanup funds that might be available.

"We will explore all of our options. We owe it to our residents and to the school system," he added.

Based on 2011 figures, the city will lose about $78,000 in income tax and $134,000 in property tax when the plant closes. While the city will take a hit financially, the school district will bear the brunt of the impact from the closure. The district already lost $1.3 million in yearly revenue with the devaluation of the plant. The schools are facing a deficit of nearly $3 million by fiscal year 2014, according to forecasts from the treasurer's office.

Zilka said he had no advance notice of the closure. He met with GenOn officials in late October after a report

by National Public Radio cited the plant as the county's top polluter, and no mention was made then of the intent to close the plant. In November, the U.S. Environmental Protection Agency filed an enforcement action against the power plant for failing to install pollution control devices during an upgrade.

"We're lucky to have three years' notice. As we look long-term, we can make the adjustment with what we'll need to do with that loss. It was disheartening, but we will be creative and make adjustments," Zilka said.

According to a news release from the power company, the decision was made "because forecasted returns on investments necessary to comply with environmental regulations are insufficient." Mark Baird, director of external affairs for GenOn, said the expense to improve the site may prove cost-prohibitive.

"The decision to invest in Avon Lake 9 requires us to look not only at the cost of the scrubber to comply with the EPA but also the costs to comply with expected future regulations, including stricter EPA, ozone and water regulations. We will invest only if the expected return exceeds our cost of capital," he said.

While the initial investment analysis indicated those returns were insufficient, Baird said evaluations are continuing and the company hopes to officially resolve the status of the plant by mid-year. In the meantime, operations are expected to continue as normal until the deactivation date.

Zilka isn't holding out much hope that the decision will be reversed.

In addition to the Avon Lake plant, seven other GenOn plants are slated for deactivation in Ohio, Pennsylvania and New Jersey between June 2012 and May 2015.

See more Avon Lake news at cleveland.com/avon-lake.

Higley is a freelancer from Avon Lake. Contact her at ***chigley4sun@gmail.com.***

Senator CARPER. With that, Mr. Alford, very nice to see you again. Welcome. Thanks for coming back and joining us. You are welcome to proceed for 5 minutes.

STATEMENT OF HARRY ALFORD, PRESIDENT/CEO, NATIONAL BLACK CHAMBER OF COMMERCE

Mr. ALFORD. Thank you, Mr. Chairman, and thanks to Ranking Member Barrasso, Senator Barrasso, and to the other distinguished members of this very important Subcommittee.

My wife and I founded the National Black Chamber of Commerce back in 1993, based on a need of there being a national voice for the Black business community. At the time we founded the Chamber, according to the Census Bureau there were 300,000 Black-owned businesses in the United States, doing about $38 billion a year in annual revenue. Today I am happy to report there are more than 2.1 million Black-owned businesses doing over $138 billion a year, according to the U.S. Census Bureau.

We have evolved to be the largest Black business association in the world. I am happy to say that we are spinning out a sister organization to take care of the international policies out there.

I have an affinity for clean air and a big appreciation for the Clean Air Act. I grew up in Los Angeles, California, the area of Ventura County. And I know what smog, I know what dirty air is. Los Angeles had dirty air beyond any comparison to mankind.

It was hard, it was hard playing football, eyes running, skin burning, you can't take a full breath but you know the only way you are going to get a college education is to get a scholarship. So you played through it anyway. All the while, someone 250 pounds is trying to break your back.

We got through that. L.A. started to get its act together, thanks to the Clean Air Act. Today it thrills me to fly into LAX and to see the clear skies. We get it. Other cities in the United States did, too.

But I went to Mexico City, and there was that black smoke again. I went to Sao Paulo, Brazil and there was that black smoke again. Last November I went to Addis Ababa, Ethiopia, and there it was, just like Los Angeles back in the 1960s and 1970s. The point I am making, we can pay the pain here in the United States and do all the things we should be doing. But unless there is a global solution and a global coordination, it is all for naught. It is all for naught. And that is why we were successful in defeating the Kyoto Treaty, and I am glad to say that we convinced this body to vote 97 to 1 against it. Because China, India, Brazil, and other nations, Indonesia, were rapidly developing with reckless abandon. So what good does it do for the United States to retreat, to retract when others are moving ahead?

The NACS issue, we were successful there. I am happy to say, cap and trade was defeated, thanks to the U.S. Senate. But somehow, cap and trade is sneaking back. It is coming in little forms, and one of those forms is called MATS.

There is so much at risk, so very much at risk. Coal mines, I count 32 utility plants, 1.4 million jobs, and pricing increases going sky high. What is going to happen to Corey Walker, who has a limousine service in Decatur, Illinois? What is going to happen to the people he employs? Gas is sky high already. We are looking at the

end of the rope. We are suffering, and we don't need another hammer on our head. This MATS is going to take a lot of my constituents out.

Like Anna Henderson in Atlanta, Georgia, HA Office Furniture, when the schools, when Coca-Cola, when Lockheed Martin, some of her prime customers, will retract, in buying new furniture, adding to their existing assets. What is going to happen to Arnold Baker, Baker Ready-Mix, in New Orleans, Louisiana? Here is a guy who was knocked down from Katrina, went down to two employees and one truck. Today he has 70 trucks and over 200 employees. Price of utilities and gasoline is going to kill his business.

I could talk about millions. Silver Gallery in a mall in Jackson, Mississippi. People aren't going to buy costume jewelry any more. So this family owned business is going to be out of whack, it is going down. So that is where we are. Unless we have some global solutions and start looking at this thing from who is paying the cost. Because a disproportionate amount of that cost is going to the African-American community, and we cry foul. We will do everything we legally can to fight this rule.

Thank you.

[The prepared statement of Mr. Alford follows:]

NBCC | National Black Chamber of Commerce®

Where Business Begins | www.NationalBCC.org

Review of the Environmental Protection Agency's MATS Rule for Power Plants

Testimony before the

Subcommittee on Clean Air and Nuclear Safety,
Committee on Environment and Public Works,
United States Senate

of

Harry Alford,
President/CEO,
National Black Chamber of Commerce®

March 20, 2012

National Black Chamber of Commerce®
1350 Connecticut Ave. NW Suite 405
Washington, DC 20036
202-466-6888

Chairman Carper, Ranking Member Barrasso, and members of the Subcommittee, thank you for holding this hearing today and for inviting the National Black Chamber of Commerce, of which I am President/CEO, to speak on an issue of vital importance to the Black business community and the overall economy. Black-owned businesses are one of the fastest growing segments of the economy, accounting for significant job creation and economic activity. According to the U.S. Census Bureau, there are 1.9 million Black-owned businesses today doing over $137 billion in business annually, a four-fold gain over when the NBCC was founded in 1993. With over 140 local chapters, the NBCC is the leading representative of Black-owned businesses in the United States and one of the largest Black business associations in the world. We advocate directly on behalf of more than 100,000 businesses.

It is their concerns that I will share with you today. Black-owned businesses, no less than businesses generally, depend on one resource that has always been plentiful in America: reliable, affordable electric service. Electricity is a basic input for just about every American business—to keep the lights on, to keep the registers running, and to operate every kind of equipment. When electricity rates rise, so does the cost of doing business, putting investment, economic growth, and jobs at risk. And when the power goes out, business does too.

This isn't just talk. EPA's own numbers show that its MATS rule will force the shutdown of numerous power plants and require many others to undertake

expensive upgrades to continue in operation. EPA projects that forcing plants offline and requiring expensive upgrades will cause electricity prices to rise.

The causation here is straightforward. EPA's MATS rule will force the retirement of a number of coal-fired power plants—indeed, many retirements have already been announced in the time since EPA issued its proposed rule. This will reduce electricity supply, with the effect of raising rates. Some coal-fired plants that satisfy base load demand will be replaced with more expensive or price-volatile technologies, with the effect of raising rates. Utilities will have to undertake significant upgrades and other measures to meet the MATS rule's requirements—EPA estimates costs of about $10 billion per year, while other estimates are almost double that—and that too will have the effect of raising rates. The bottom line is that you cannot impose new burdensome requirements on electricity producers without expecting electricity rates to go up.

The only open questions are the amount of the increase and the collateral damage that it inflicts on jobs and the economy. EPA projects that its MATS rule will boost retail electricity prices by 3.1 percent across the contiguous United States in 2015, but those price increases are not distributed uniformly. Hardest hit will be the Upper Midwest and the middle part of the country from northern Texas up through Nebraska. But if you look at all the different estimates that have been made by various parties, EPA's are definitely at the low end of the spectrum. For example, an analysis from NERA, an economics consultancy, shows average price

increases of 12.1 to 23.5 percent in 24 states, with the worst increases in the Midwest and the South. Other projections are in a similar range.

But let's just assume that EPA's low-ball numbers are correct—what does even a 3 percent increase in the cost of electricity do to a business? It is, of course, a cost increase, crowding out other expenditures. It raises the cost of production, putting pressure on profits. It decreases the productivity of capital, because it now costs more to make the same amount of product or to provide the same amount of services. It may force the business to raise prices on products and services. For a business in a competitive market, it will force the business owner to cut other costs, such as labor expenses, by reducing hours or laying off employees. In the worst case, an energy-intensive business like a factory may be forced out of business due to rising electricity prices and competition from foreign countries that do not artificially inflate energy prices with inefficient environmental regulations. And when a business like a manufacturer closes, that injures the entire community, not just those workers who previously held good jobs. There is a ripple effect that impacts families, local businesses, the local real estate market, and so on. These are the human costs of regulation, and I do not see that EPA has even attempted to account for them.

Although a number cannot fully capture the human costs of a layoff on the worker, his family, and their community, we do at least have numbers—albeit only from sources other than EPA. NERA projects the loss of 1.44 million job-years through 2020, with the greatest losses concentrated in the South and industrial

Midwest. EPA, as I said, did not even attempt to estimate job losses. It did, however, put out an estimate claiming that compliance with the MATS rule would boost employment by 46,000 job-years. This is astounding: EPA counts the enormous cost and burden of its rule as a benefit, because it will require utilities to temporarily hire workers to comply, while ignoring the far larger and longer-lasting impact on electricity consumers. At a time when millions of Americans are unemployed, have exited the labor force entirely, or are worried about keeping their jobs, this cynical approach to estimating the job-impact of a major regulation is disrespectful and insulting. A disproportionate number of those struggling today are African-Americans, and this rule will therefore harm them disproportionately.

Rising rates aren't the full extent of the problem, because the MATS rule will also impact the reliability of electric service. Reports by the Federal Energy Regulatory Commission and the North American Electric Reliability Corporation, which are together responsible for ensuring the reliability and resiliency of our electric system, conclude that the MATS rule will put reliability at risk, particularly due to its accelerated implementation schedule of just three or four years.

The evidence on this point could not be clearer. In its most recent annual reliability assessment, NERC identified EPA rulemaking as "the number one risk to reliability over the next 1 to 5 years." It also identified the MATS rule's implementation timeline as the primary cause of this risk. According to NERC, "the loss of reliability support functions provided by coal-fired generation [that is forced

to retire] may not be easily replaced given the time constraints." As a result, "the nation's power grid will be stressed in ways never before experienced."

These findings echo those of FERC's Office of Electric Reliability. OER found that EPA's MATS rule will threaten "adequacy," which is "the ability of the electric system to supply the aggregate electric power . . . at all times, taking into account scheduled and reasonably expected unscheduled outages of system components." It will also threaten operating reliability, which is "the ability of the electric system to withstand sudden disturbances," the "deliverability" of remaining energy resources to customers. In testimony before FERC, representatives of several utilities and grid operators made these same points.

The reports by NERC, FERC, and other organizations are highly technical, and that's not my area of expertise, but I can tell you what they mean in terms of business. We know that EPA's MATS rule will cause more blackouts of greater severity and greater duration. To a business owner, a blackout is a business interruption, and that means more expenses and lost revenues and profits. For some businesses, this means we have to start thinking about mitigation—for example, do you buy a generator, do you relocate?—and that means we have to make trade-offs, usually cutting other costs and delaying investments. For others that cannot afford to make their own arrangements, they will just have to absorb the loss, and that is not something that every business will be able to do. An extended blackout of one week—which isn't common today, but is also not unheard of, following a major storm—can be enough to push a new or struggling business

over the edge. An entrepreneur who has tapped all of his credit just to get the doors open cannot afford to close them for a week because the power's out. So those doors may close for good, or he'll have to lay off workers. This is what happens when you can't depend on flipping the switch and having the lights come on.

There are solutions to these problems. The best, although it may be unlikely to occur, is for EPA to withdraw its MATS rule and go back to the drawing board. As I understand it, nothing in the law requires EPA to subject power plants to Section 112 requirements, and EPA can address pollution just as effectively through other Clean Air Act programs, at far lesser cost and economic impact. You, Members of Congress, should make EPA explain why it has chosen to adopt Section 112 regulations rather than proceed under more flexible programs. To date, it has never adequately answered this question.

But let's assume that EPA does not do the sensible thing—what then? In that case, Congress should act. Here are three possibilities:

First is to disapprove EPA's MATS rule under the Congressional Review Act, sending a signal to the public, to EPA, and to the President that Congress places economic growth and job creation ahead of environmental extremism. Sure, the President may veto the disapproval in the end, but that's not a foregone conclusion, given the political cost. He should have to bear that cost, and should not be allowed to evade it.

Second is to enact a "safety valve" to ensure that reliability-essential power plants can remain in service where they are needed to protect against outages.

EPA, of course, has no particular expertise in electric reliability. FERC and NERC do—it is their statutory responsibility. It makes no sense that EPA should be able to claim the authority to wreak havoc on our electric system, while FERC and NERC stand idly by. We should leverage our existing reliability infrastructure here by empowering FERC, NERC, and the regional entities to carve out exceptions from rules that put reliability at risk. A proposal that is carefully targeted at the reliability issue should not be controversial—after all, no one opposes reliable electric service and no one seriously believes that FERC, NERC, and the regional entities would abuse this type of targeted authority. While a safety valve would not address the affordability issue, it would at least give businesses greater peace of mind.

Third is to amend the Clean Air Act to make perfectly clear Congress's intentions. There is no indication that Congress ever intended to hand over the keys to the nation's power grid to EPA. But it did intend that EPA can and should achieve environmental goals with a light touch, using the least burdensome regulation possible to meet those goals in a cost-effective fashion. Today, EPA interprets the Clean Air Act precisely backwards, claiming that it is required to implement the most burdensome and expensive requirements, and to do so in ways that achieve little additional benefit over less onerous options. We ought to be able to fix this.

Let me conclude with an observation. Everybody knows that this isn't really about the environment or public health, because EPA has the tools to address any

problems under other sections of the Clean Air Act, without imposing Section 112 requirements on power plants. The real motivation here is the current Administration's war on coal and policy goal of raising energy prices across the board. If the Congress does not take a stand now, that would be strong evidence to the business community that the Congress has bought in to the Administration's job-destroying energy agenda.

Again, I thank you for holding this hearing and for inviting me to testify. I look forward to answering any questions you may have.

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April 20, 2012

RE: Questions from Chairman Barbara Boxer and Ranking Member James M. Inhofe

Dear Chairman Boxer and Ranking Member Inhofe:

Thank you again for inviting me to appear before the Committee on Environment and Public Works to discuss EPA's MATS Rule and its devastating impact on businesses and job creation. This is, as I explained in my testimony, a crucially important issue for the Black business community that I represent.

Senator Inhofe's thoughtful questions for the record demonstrate a deep and correct understanding of this issue. My answers to his questions are as follows:

1. The National Black Chamber of Commerce warned that "cap-and-trade" legislation could drive up unemployment across an area where 76% of African-Americans live. Are you concerned that Utility MACT could have a similar effect?

Yes, there is not a dime's worth of difference between cap and trade and the MATS Rule in terms of the kinds of impacts that they will have on Black businesses and employment. The fundamental similarity is that both policies will drive up energy prices at all levels. Energy is an essential input to all business activity, and when it costs more to keep the lights on, a business has only three options: pass those price increases onto customers, cut back on other inputs, or close because the business is no longer economical. These responses cause a ripple effect, because those who are affected have less money to spend in their communities, and that leads to

more stress on more businesses and more lay-offs. This is why even relatively small increases in energy prices are projected to cause enormous numbers of job losses.

It is virtually certain that Black communities will be disproportionately injured, for several reasons. First, due to the weak economy, unemployment among African-Americans is already near record highs, with an unemployment rate in March 2012 of 14.0 percent. By reducing job opportunities, EPA's MATS Rule will stop many already unemployed workers from returning to the workforce or limit their opportunities to lower-wage jobs. Second, a disproportionate number of African-Americans live in those parts of the country that are projected to suffer the greatest increases in energy prices. Indeed, the NERA consulting firm projects the greatest number of job losses to be concentrated in the South and industrial Midwest. Third, Blacks are disproportionately represented in the energy-intensive industries—such as transportation, boiler operation, and appliance manufacturing—that will bear the brunt of job losses.

Unfortunately, because EPA has never seriously evaluated the impact of its MATS Rule on jobs, I am unable to provide a precise answer as to what percentage of African-American communities will be impacted. Having seen the damage that overzealous regulation can do to communities, I agree with proposals that would require federal agencies to perform detailed and realistic estimates of job losses as part of the rulemaking process. It would be prudent, in this instance, for Congress to insist that EPA delay the MATS Rule until it undertakes such an analysis—otherwise, neither EPA nor Congress can even begin to evaluate whether the rule's benefits truly outweigh its costs.

2. What are some of the unique challenges that minority-owned businesses face when confronting regulations that raise energy prices like Utility MACT?

Although minority-owned businesses will be disproportionately harmed by regulations like the MATS Rule that raise energy prices, the challenges they face are not unique. As even EPA concedes, the MATS Rule will force the retirement of power plants, and this will, in turn, push up electricity rates. For a business, a rate hike is a cost increase. It raises the cost of production, putting pressure on profits. It decreases the productivity of capital, because it now costs more to make the same amount of product or to provide the same amount of services. It may force the business to raise prices on products and services. For a business in a competitive market, it will force the business owner to cut other costs, such as labor expenses, by reducing hours or laying off employees. In the worst case, an energy-intensive business like a factory may be forced out of business due to rising electricity prices and competition from foreign countries that do not artificially inflate energy prices with inefficient environmental regulations. And when a business like a manufacturer closes, that injures the entire community, not just those workers who previously held good jobs.

These effects are common to all businesses, not just those owned by minorities. The MATS Rule is bad for business.

3. EPA claims that the Utility MACT contains "several flexibilities" that will "lower costs" for small businesses. How do you respond?

My response is simple: nonsense. This rule imposes requirements on electric utilities, not small businesses, and so no amount of "flexibility" in the rule will help small businesses unless it keeps energy rates low and electric service reliable. But that is the exact opposite of EPA's approach, which is to quickly ratchet up the cost of coal-fired electricity generation and force long-running plants to retire. Enormous compliance costs and widespread retirements can only boost energy prices and impair reliability, and those effects are amplified when compliance is mandated within just a few short years.

For EPA to "lower costs" for small businesses, it would have to abandon its MATS Rule altogether, start over from scratch, and craft a rule that targets hazardous air pollutants without attempting to reconfigure the entire energy industry in the process—something that Congress never intended and that is not even implied by the Clean Air Act. That is what EPA *should* do.

4. Job loss or inability to pay electric bills surely impacts one's health. Are you concerned that Utility MACT disproportionally impacts the health of minority populations?

EPA trumpets its projections of the health benefits of its MATS Rule, but it plain ignores the direct and immediate health consequences that are certain to result as a result of unemployment and impaired electric reliability. There is an undeniable link between unemployment and adverse health outcomes that is not reflected in EPA's lopsided estimates of the costs and benefits of its MATS Rule. Sociological, economic, and public health research indicates that unemployment itself dramatically increases the risk of poor health.

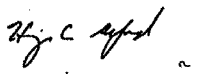
This is consistent with what I have witnessed over the years as an entrepreneur and business advocate, and it is just common sense. The unemployed earn less income. This may lead to economic strain and make it difficult for them to lead healthy lifestyles. They may have impaired access to preventative health care services. They are more likely to experience stress—which has its own effects on health—as well as depression. Unemployment is a major shock and a major stress, not just for the individual but also for his family.

Those consequences will disproportionately impact minorities and their communities. How could they not, given the job impact of the MATS Rule? But once again, we have no numbers or analysis on this from the EPA, which chooses simply to ignore the problem. That is unjustifiable and inexcusable. No agency should rush forward with a major regulation that is intended to benefit public health when it has never even studied the impact on public health.

This is just more evidence that EPA's goal is not reasonable environmental regulation but to shut down disfavored technologies, no matter the consequences.

Again, I thank you for the opportunity to provide information to the Committee on this crucially-important issue and appreciate your interest in my views.

Sincerely,



Harry C. Alford
President/CEO

Senator CARPER. Mr. Alford, thanks very much for your presence and your testimony today.

I am pleased to present Vickie Patton, who has joined us from the Environmental Defense Fund.

Welcome; thank you for joining us.

STATEMENT OF VICKIE PATTON, GENERAL COUNSEL, ENVIRONMENTAL DEFENSE FUND

Ms. PATTON. Thank you, Chairman Carper, Ranking Member Barrasso, members of the Committee.

On February 16th, 2012, the Environmental Protection Agency published long overdue protections for our families and for our children to address the most toxic air pollutants in our communities from the largest single sources of mercury and acid gases and arsenic. It is not surprising that over 800,000 Americans submitted comments strongly encouraging EPA to take this action. And it is based on a very strong foundation; a number of States across our country have adopted mercury pollution control standards, long before EPA took action, States such as Delaware and New Jersey and Colorado and Oregon and Illinois and Maryland and Montana have led the way in establishing a strong State policy foundation to help us solve these problems.

We are incredibly grateful for the entrepreneurs, the innovators across American who help deliver smart solutions to help us solve these problems, companies like ADA Environmental Solutions in my home State of Colorado, which has kind of pioneered the advances in mercury pollution control technology. In 2009 the General Accounting Office said our Nation has solutions to mercury, we can achieve a 90 percent reduction of all coal types, in large part due to the innovation of companies across America. There are power companies who have been leading the way and preparing for these standards for many years. And they show us that this can all be achieved.

There are also just concerned citizens who have lent their voices to this issue and helped encourage policymakers to carry out what are long overdue protections. It is all about voices across America working together to solve big problems.

There has been a lot written and a lot said about the Mercury and Air Toxics Standards. But I would like to focus on the standards that were actually adopted and the standards that are actually in place, and what has been said about those. When the Environmental Protection Agency completed its work on these standards, the American Public Health Association, the American Lung Association, the American Heart Association, the League of United Latin American Communities, the NAACP, the Consumers Union, Small Business Majority, voices across America said thank you very much, Administrator Lisa Jackson, for leading the way and finally ending this delay in protecting Americans from this very serious toxic air pollution.

There are a number of power companies that have responded to these standards since they were in fact adopted. Xcel Energy, one of the Nation's largest investor-owned utilities with service territory across the Midwest and the Southwest, said, we are well positioned to comply. There are a number of companies, power compa-

nies, major power companies who have said, we are well positioned to comply. It includes rural co-ops, it includes municipal utilities, it includes independent power producers.

Duke Energy, on February 16th, briefed investors, and it said, we are adjusting our estimations of the costs. They are going to be on the low side of what we have previously sort of communicated to the public. As you indicated, Senator Carper, the Bank of America, Merrill Lynch, issued some analysis on March 15th, just a few days ago, indicating that Southern Company is prepared to comply by 2016, within the 4 years that EPA has provided for with its adaptive compliance framework.

One of the biggest detractors and critics of this rule has been American Electric Power. It has been sort of long, sort of critical of EPA's efforts here. Well, on February 10th, the President and CEO of American Electric Power briefed investors, and Nick Akins said that, in Ohio, the cost of compliance will be a small fraction of what we previously predicted. Instead of $1.1 billion, it will cost $400 million for us to comply in Ohio. He also indicated that he could count on his hand, a single hand the units that might need additional time to comply. And his executive vice president, Mark McCullough, indicated EPA's final rule are much more manageable than we previously have indicated.

This is not surprising. The time-tested history of the Clean Air Act has been delivering cleaner, healthier air at a small fraction of the predicted cost. We have seen this time and time again. It is a great American success story.

And Senator Carper, we are here today in many respects due to your steadfast leadership. On behalf of moms across America, you have challenged Americans to work together to find solutions to this very serious problem. You have helped remind us that this is not a red State issue, this is not a blue State issue, these are shared American values in protecting our children's health. You have helped us realize these final standards that give meaning to the Clean Air Act's vision that every child be raised in a community, in a home free of the most toxic pollutants in our environment, so they can realize their full potential.

Thank you for all you have done.

[The prepared statement of Ms. Patton follows:]

Before the United States Senate
Subcommittee on Clean Air and Nuclear Safety

"Oversight: Review of the Environmental Protection Agency's Mercury and Air Toxics Standards (MATS) for Power Plants"

Testimony of Vickie Patton
General Counsel
Environmental Defense Fund
March 20, 2012

Chairman Carper, Ranking Member Barrasso, and members of the Subcommittee, thank you for the opportunity to testify about the U.S. Environmental Protection Agency's Mercury and Air Toxics Standards.

My name is Vickie Patton. I serve as General Counsel of Environmental Defense Fund, a national non-partisan, non-profit environmental organization. I previously served as an attorney in the U.S. Environmental Protection Agency's Office of General Counsel under the George H.W. Bush and William Clinton administrations where I worked on a variety of Clean Air Act matters.

OVERVIEW

In 1990, the 101st Congress charted the course for our nation to address the most toxic airborne contaminants. The 1990 Clean Air Act Amendments, forged into law with strong bipartisan support (passing the United States Senate 89-10 and the House of Representatives 401-25) and signed into law by President George H.W. Bush, identified the most hazardous air pollutants as warranting the maximum achievable reductions including: mercury, arsenic, chromium and acid gases such as hydrochloric acid and hydrofluoric acid. The law also singled out the hazardous air pollution from power plants instructing EPA to assess the reasonably anticipated public health hazards and, in turn, directing EPA to determine if regulation is "appropriate and necessary." Coal- and oil-fired power plants are the nation's single largest manmade source of major toxic air contaminants, responsible for approximately 50 percent of mercury pollution, 77 percent of acid gases, and 62 percent of arsenic emissions.

On February 16, 2012, more than two decades after the enactment of the 1990 Clean Air Act Amendments, EPA published the *Mercury and Air Toxics Standards* containing final national emission standards limiting the mercury, arsenic, chromium, acid gases and other toxic airborne contaminants discharged from coal- and oil-fired power plants. The standards will provide healthier and longer lives for millions of Americans and protect our most vulnerable population, America's children, from profoundly dangerous air pollution.

When implemented, the *Mercury and Air Toxics Standards* will annually prevent as many as 11,000 deaths, 4700 heart attacks, 130,000 asthma attacks, over 500,000 missed work days due to illness, and over 3 million unhealthy air days. The standards will deliver vital human health protections valued at $37 billion to $90 billion each year, deploying commonly available and widely implemented cost-effective clean air solutions. The nation's investment in healthier air for our children will mobilize jobs across the country. The Economic Policy Institute projects these clean air standards will create 85,000-117,000 jobs between now and 2015.[1]

Over a dozen states -- including Colorado, Delaware, Illinois, Maryland, Michigan, Minnesota, Montana, New Jersey, Oregon and Wisconsin -- adopted state protections to limit mercury from coal-fired power plants well before the *Mercury and Air Toxics Standards* were finalized. Numerous power companies contracted for the installation of advanced mercury controls before federal protections were adopted, bookings in October 2011 tallied 175 electric generating units reflecting 55,000 megawatts of coal-fired capacity combusting all coal types.[2]

The final standards provide an adaptive compliance framework that will secure the vital life-saving benefits under these clean air standards while addressing any source-specific reliability issues that could potentially arise. The Congressional Research Service recently examined the final standards through the lens of reliability concerns expressed by industry finding: "Furthermore, to address the reliability concerns expressed by industry, the final rule includes provisions aimed at providing additional time for compliance if it is needed to install pollution controls or add new capacity to ensure reliability in specific areas. As a result, it is unlikely that electric reliability will be harmed by the rule."[3]

Many companies -- including investor owned utilities, rural electric cooperatives, municipal utilities and independent power producers -- have indicated they are prepared to comply with the final standards. Xcel Energy one of the nation's largest electricity providers, serving 3.4 million customers in Colorado, Michigan, Minnesota, New Mexico, North Dakota, South Dakota and Texas, recently stated it is "well positioned to comply with a number of new environmental standards and regulations, like this one, thanks to early actions we have taken to modernize our generation and mitigate future environmental compliance costs."[4]

The leaders of PG&E, Calpine, NextEra, Public Service Enterprise Group, National Grid USA, Exelon, Constellation Energy Group, and Austin Energy explained in the pages of

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[1] Josh Bivens, *The 'Toxics Rule' and Jobs: The job-creation potential of the EPA's new rule on toxic power-plant emissions,* Economic Policy Institute (Feb. 7, 2012).

[2] Institute of Clean Air Companies, *Commercial Mercury Specific Bookings,* as of Oct. 24, 2011, http://www.icac.com/files/public/Commercial_Installations_Public_%20October_2011.pdf

[3] Id. at *Summary.*

[4] Chris Hubbbuch, "Dairyland, Xcel prepared for mercury rules," LaCrosse Tribune, Dec. 22, 2011.

the *Wall Street Journal* that many companies have long prepared for these clean air standards:

> The electric sector has known that these rules were coming. Many companies, including ours, have already invested in modern air-pollution control technologies and cleaner and more efficient power plants. For over a decade, companies have recognized that the industry would need to install controls to comply with the act's air toxicity requirements, and the technology exists to cost effectively control such emissions, including mercury and acid gases.[5]

The public support for EPA's final *Mercury and Air Toxics Standards* is extensive, encompassing public health associations, organizations representing African-Americans and Latino-Americans, consumer affiliations, and small business groups, including the following: the American Heart Association, American Lung Association, American Public Health Association, League of United Latin American Citizens, NAACP, the Small Business Majority, and Consumers Union. The Executive Director of the American Public Health Association heralded the health protections for Americans: "Implementing these critically needed standards could mean the difference between a chronic debilitating, expensive illness or healthy life for hundreds of thousands of American children and adults."

Mercury, one of the toxic contaminants addressed by these standards, is a bioaccumulative neurotoxin that imperils the brain development of infants and children. Over 400,000 infants are born each year with mercury contamination exceeding safe levels. Full compliance with EPA's *Mercury and Air Toxics Standards* for coal- and oil-fired power plants will be required more a quarter century after the adoption of the 1990 Clean Air Act Amendments, during which time millions of infants will have been exposed to unsafe mercury levels.

On February 16, 2012, Senator James Inhofe introduced S.J. Res. 37, a Joint Resolution to disapprove these fundamental safeguards. Under the plain terms of the Congressional Review Act, enactment of S.J. Res. 37 would prohibit EPA from adopting new emission standards for mercury and other air toxics discharged by power plants that are "substantially the same" thereby preventing EPA from acting under our nation's clean air laws to address the largest source of hazardous air contaminants such as mercury, arsenic and acid gases.[6] S.J. Res. 37 would not only prolong the tragic delay in protecting

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[5] Letter to the Editor, Wall Street Journal, "We're OK With EPA's New Air-Quality Regulations," Dec. 8, 2010.

[6] The CRS report quotes a joint statement by the Congressional Review Act's principal sponsors:

> If the law that authorized the disapproved rule provides broad discretion to the issuing agency regarding the substance of such rule, the agency may exercise its broad discretion to issue a substantially different rule. If the law that authorized the disapproved rule did not mandate the promulgation of any rule, the issuing agency may exercise its discretion not to issue any new rule. Depending on the law that authorized the rule, an issuing agency may have both options. *But if an agency is mandated to promulgate a particular*

America's infants and children from toxic mercury but it would forever relegate generations of American children to lives poisoned by mercury, thwarting the bipartisan vision forged into law in 1990 for a healthier, stronger and more prosperous America.

MERCURY IS A BIOACCUMULATIVE NEUROTOXIN THAT HARMS HUMAN HEALTH AND THE ENVIRONMENT

Mercury is a toxic heavy metal that contaminates water bodies across the nation and threatens the brain development of infants and children.

Mercury vented into ambient air returns to Earth in precipitation or attached to particles, and through runoff or deposition can end up in lakes, rivers and the ocean. Toxic methylmercury results from the transformation of mercury by microorganisms in the sediments of water bodies. The methylated mercury readily accumulates in the aquatic food chain with the concentrations increasing at each level in the food chain.

According to EPA, the concentrations of mercury and other bioaccumulative contaminants in fish tissue far exceed the concentrations found in the waterbodies: "top predators in a food chain (e.g., largemouth bass, walleye) may have concentrations of bioaccumulative contaminants in their tissues that are often orders of magnitude higher than the concentrations found in the water."[7]

All Fifty States Have Mercury Fish Consumption Advisories

Humans are exposed to methylmercury predominantly through the "[c]onsumption of contaminated fish."[8] As of 2010, 50 states have mercury fish consumption advisories. An estimated 3,710 total advisories for mercury have been issues at water bodies across the nation encompassing 16.4 million lake acres and 1.1 million river miles.

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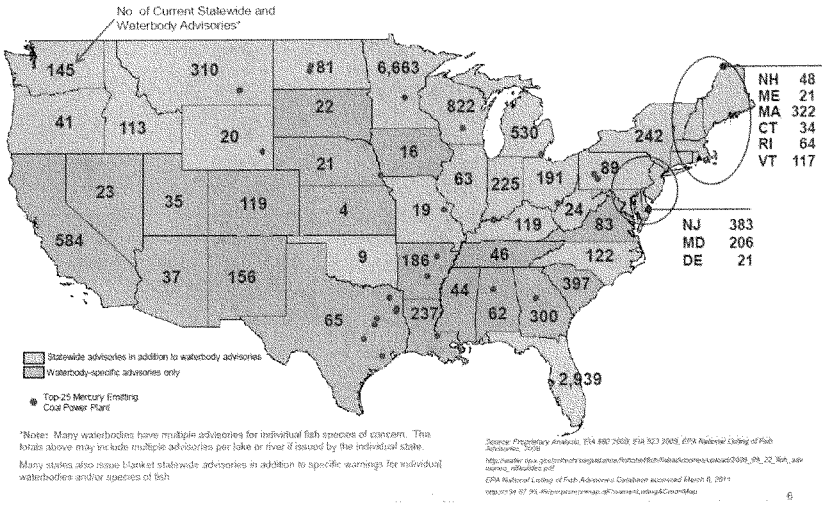
rule and its discretion in issuing the rule is narrowly circumscribed, the enactment of a resolution of disapproval for that rule may work to prohibit the reissuance of any rule.

Morton Rosenberg, Congressional Research Service, Congressional Review of Agency Rulemaking: An Update and Assessment of The Congressional Review Act after a Decade (May 2008) (citing Joint Explanatory Statement of House and Senate Sponsors, 142 Cong. Rec. E 571, at E 577 (daily ed. April 19, 1996); 142 Cong. Rec. S 3683, at S 3686 (daily ed. April 18, 1996)) (emphasis added).

[7] U.S. EPA, 2010 Biennial National Listing of Fish Advisories, Fact Sheet, EPA-820-F-11-014 (Nov. 2011), at p. 3.

[8] Leonardo Trasande, Philip J. Landrigan, and Clyde Schechter, *Public Health and Economic Consequences of Methyl Mercury Toxicity to the Developing Brain*, Environmental Health Perspectives, Vol. 113, No. 5 (May 2005).



Mercury Threatens the Neurological Development of Newborns and Young Children

Methylmercury is known to cause severe damage to growing nerves and impede brain development, particularly in infants and children. Exposure to methylmercury in the womb can impact development of the central nervous system, and cause children to have lower IQs leading to difficulty thinking and learning. Each year, over 400,000 American newborns are exposed to unsafe levels of methylmercury in utero. The risks from contamination do not disappear after birth, as methylmercury can also be transferred from breastfeeding mothers to their infants.[9]

The developing brain of infants and young children is distinctly vulnerable to exposure of methylmercury:

> The vulnerability of the developing brain to methyl mercury reflects the ability of lipophilic methyl mercury to cross the placenta and concentrate in the central nervous system (Campbell et al. 1992). Moreover, the blood-brain

[9] Bose-O'Reilly et al, *Mercury Exposure and Children's Health*, Curr Probl Pediatr Adolesc Health Care. 2010 September; 40(8): 186–215. doi:10.1016/j.cppeds.2010.07.002. [hereinafter Bose-O'Reilly 2010].

> barrier is not fully developed until after the first year of life, and methyl mercury can cross this incomplete barrier (Rodier 1995).[10]

The National Academy of Sciences' National Research Council found that the brain development of infants and young children is threatened by chronic, low-dose environmental exposures to methylmercury:

> Chronic, low-dose prenatal [methylmercury] exposure from maternal consumption of fish has been associated with more subtle end points of neurotoxicity in children. Those end points include poor performance on neurobehavioral tests, particularly on tests of attention, fine-motor function, language, visual-spatial abilities (e.g., drawing), and verbal memory.[11]

In its toxicological assessment of methylmercury-related health effects in 2000, the National Research Council concluded that neuro-developmental impacts from prenatal methylmercury exposures are the most sensitive and well-documented health endpoint.[12] In children, low-dose exposures to methylmercury may produce deficits in vision and hearing, delayed walking and speech development, and other developmental delays.[13]

Mercury has no biologically beneficial function. In a recent letter to President Obama, leading mercury scientists explained the biochemical mechanism associated with mercury's toxicity: "Mercury is such a potent toxin because it bonds very strongly to functionally important parts of proteins including enzymes, antibodies and nerve growth-cones that keep cells alive, 'intelligent' and safe. Target enzymes, organs, or metabolic pathways vulnerable to mercury poisoning may change from cell to cell, person to person and in the same individual over time. Regardless, minimizing all mercury exposure is essential to improving human, wildlife and ecosystem health because *exposure to mercury in any form places a heavy burden on the biochemical machinery within cells of all living organisms.*"[14]

MERCURY IS ASSOCIATED WITH DEPOSITION HOT SPOTS AND BIOLOGICAL HOT SPOTS

Scientists at the University of Michigan and EPA conducted an extensive mercury monitoring and source apportionment study to evaluate the potential connection between local and regional coal plants and mercury deposited in the Ohio River Valley. The study was based on a two-year record of mercury deposition monitored in Steubenville, Ohio at

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[10] Leonardo Trasande, Philip J. Landrigan, and Clyde Schechter, *Public Health and Economic Consequences of Methyl Mercury Toxicity to the Developing Brain*, Environmental Health Perspectives, Vol. 113, No. 5 (May 2005), at p. 50.

[11] National Academy of Sciences National Research Council, *Toxicological Effects of Methylmercury* 4 (2000), *available at* http://www.nap.edu/catalog/9899.html.

[12] *Id.*

[13] Castoldi, Coccini, Ceccatelli, & Manzo, *Neurotoxicity and molecular effects of methylmercury*, 55 Brain Res. Bull. 197, 203 (2001).

[14] Letter of 23 leading mercury scientists and physicians to President Barack Obama, Dec. 13, 2011(http://grist.files.wordpress.com/2011/12/mercury_scientists_in_support_of_the_mats.pdf)

the campus of Franciscan University. Seventeen coal plants are located within 100 kilometers of the monitoring site. The study found that local and regional coal plants accounted for an estimated 70% of the mercury deposited during precipitation events:

> Results of multivariate statistical analysis (~70% of the Hg in the wet deposition at Steubenville coal combustion sources), and meteorological analysis (highlighting the importance of local regional sources), consistently point toward the dominant influence by local and regional coal-burning sources.[15]

Another major field study examined the potential for biological mercury hot spots, defined as areas with elevated concentrations of mercury in biota (e.g., fish, birds, mammals) that exceed established human or wildlife health criteria as determined by a statistically adequate sample size.[16] The study assessed over 7,000 observations of mercury concentrations for seven species including yellow perch and the common loon while also considering factors such as surface water chemistry and land cover.

The Merrimack River watershed was identified as a biological hot spot, and further investigation revealed both the potential for local emission sources to amplify the adverse biological effects of mercury in the watershed and, conversely, the benefits of measures to reduce emissions from large local sources of mercury. Modeling analysis, for example, suggested "that emissions from coal-fired power plants in the study region account for a large fraction of the total Hg deposited in the Merrimack River watershed hotspot."[17] The data also showed biological exposure to mercury "can change rapidly in response to changes in atmospheric emissions and deposition from local and regional sources."[18] Protective emission limitations on the mercury from local incinerators substantially reduced overall mercury in the region. The field data revealed "consistency between the timing and magnitude of Hg emissions reductions and the declines in Hg concentrations in common loons, fish, and zooplankton."[19]

Measures to reduce mercury in southern Florida similarly revealed the close nexus between large local sources of mercury and local impacts. Mercury emissions in south Florida were reduced by about 90 percent largely due to rigorous mercury emission limitations on incinerators. The mercury in the fish and wildlife of the Everglades, in turn, declined by about 75 percent.[20]

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[15] Gerald J. Keeler, Matthew S. Landis, Gary A. Norris, Emily M. Christianson, and J. Timothy Dvonch, *Sources of Mercury Wet Deposition in Eastern Ohio, USA*, Environ. Sci. Technol., Article 10.1021/es060377q S0013-936X(06)00377-4 (published on web Sept. 8, 2006).

[16] David C. Evers, Young-Ji Han, Charles T. Driscoll, Neil C. Kamman, M. Wing Goodale, Kathleen Fallon Lambert, Thomas M. Holsen, Celia Y. Chen, Thomas A. Clair, and Thomas Butler, *Biological Mercury Hotspots in the Northeastern United States and Southeastern Canada*, BioScience, Vol. 57, No. 1 (Jan. 2007) at pages 29-30.

[17] *Id.* at p. 41.

[18] *Id.* at p. 38.

[19] *Id.* at p. 39.

[20] Florida Dept. of Environmental Protection, *South Florida Mercury Science Program*, available at: http://www.dep.state.fl.us/labs/mercury/index.htm.

In Massachusetts, a multi-year monitoring program found that substantial declines in mercury concentrations in yellow perch and largemouth bass were consistent with substantial reductions in mercury pollution from several local incinerators.[21]

Field studies demonstrate that deposition and bioaccumulative effects of mercury emissions can have a cascade of local impacts. Conversely, empirical data show that measures to reduce nearby sources of industrial mercury pollution can secure rapid, real-world results in cooling hot spots and protecting human health and the environment.

THE MERCURY AND AIR TOXICS STANDARDS PROVIDE VITAL HEALTH PROTECTIONS FOR MILLIONS OF AMERICANS

Coal- and oil-fired power plants are the nation's single largest manmade source of major toxic air contaminants, responsible for approximately 50 percent of mercury pollution, 77 percent of acid gases, and 62 percent of arsenic emissions. When implemented, the *Mercury and Air Toxics Standards* will annually prevent as many as 11,000 deaths each year, 4700 heart attacks, 130,000 asthma attacks, over 500,000 missed work days due to illness, and over 3 million unhealthy air days, delivering vital human health protections valued at $37 billion to $90 billion each year they are carried out.

NUMEROUS EXPERTS HAVE DETERMINED THE MERCURY AND AIR TOXICS STANDARDS WILL NOT IMPAIR THE RELIABLE FLOW OF ELECTRICITY

Analyses by the U.S. Department of Energy, the Congressional Research Service, the North American Electric Reliability Corporation, and M.J. Bradley & Associates/the Analysis Group address concerns that the Mercury and Air Toxics Standards would impair the reliable flow of electricity. The findings of these various assessments are summarized below:

Congressional Research Service (January 2012). In the principal analyses available since the rule was finalized, the Congressional Research Service reviewed reliability issues observing that other analyses did not account for adjustments made in the final rule: "Both the EEI and NERC analyses discussed above assumed requirements that appear to be substantially more stringent that what EPA has promulgated."[22] The final rule also provided for an adaptable compliance framework that was not accounted for in previous analyses: "Furthermore, to address the reliability concerns expressed by industry, the final rule includes provisions aimed at providing additional time for compliance if it is needed to install pollution controls or add new capacity to ensure reliability in specific areas. As a result, it is unlikely that electric reliability will be harmed by the rule."[23]

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[21] Massachusetts Dept. of Environmental Protection, *Freshwater Fish in Mass. Lakes Show Reductions in Mercury*, available at: http://www.mass.gov/dep/public/publications/mercury.htm.
[22] Congressional Research Service, *EPA's Utility MACT: Will the Lights Go Out?* R42144, January 2012, at p. 11.
[23] Id. at *Summary*.

M.J. Bradley & Associates and the Analysis Group. A November 2011 report issued by Michael J. Bradley & Associates and the Analysis Group found the US power generation fleet has significant excess capacity. The NERC Electric Reliability Regions in the U.S. have projected reserve margins ranging from 28% to over 40%, well above margins needed to maintain electric grid reliability. This reserve margin equates to an estimated 145 gigawatts of excess capacity. An additional 38 GW of generation capacity is currently under construction.[24]

U.S. Department of Energy. In December 2011, the Department of Energy's assessment of reliability determined the standards would not disrupt the reliable flow of electricity:

> Our review, combined with several other studies, demonstrate that new EPA rules – which will provide extensive public health protections from an array harmful pollutants – should not create resource adequacy issues. Any local reliability challenges that could arise should be manageable with timely cooperation and effective coordination among all relevant stakeholders. Working together, we can and will provide safe, reliable electricity to American consumers.[25]

The North American Electric Reliability Corporation (NERC). NERC establishes standards to ensure the reliability of the North American bulk electric system. It issued a report at the end of the year, preceding the final EPA standards, finding a number of available tools to mitigate potential reliability impacts:

> NERC identifies a number of tools that industry has available to mitigate potential reliability impacts from the implementation of EPA regulations. NERC's expectation is that industry and regulators will use these tools to ensure that bulk power system reliability is maintained as EPA regulations are finalized and implemented.[26]

THE FINAL STANDARDS WERE ACCOMPANIED WITH AN ADAPTABLE COMPLIANCE FRAMEWORK

As examined above, a body of studies concludes the *Mercury and Air Toxics Standards* will not impair reliability. Further, EPA made adjustments in the final standards incorporating an adaptable compliance framework to ensure grid reliability is protected while pollution controls are installed and modern, cleaner replacement generation is

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[24] M.J. Bradley & Associates and the Analysis Group, "Ensuring a Clean, Modern Electric Generating Fleet while Maintaining Electric System Reliability," November 2011.
[25] US Department of Energy, "Energy Department Releases Study of Electricity System Ahead of Proposed EPA Air Quality Standards," December 1, 2011. Available at: http://energy.gov/articles/energy-department-releases-study-electricity-system-ahead-proposed-epa-air-quality
[26] North American Electric Reliability Corporation, "2011 Long-term Reliability Assessment," November 2011 at 120. Available at: http://www.nerc.com/files/2011LTRA_Final.pdf .

constructed. Only the January 2012 CRS report considered these adjustments to EPA's final standards.

EPA's framework will ensure that the life-saving benefits of the rule will accrue rapidly while addressing any plant-specific reliability issues that could potentially arise.

3 Year Statutory Compliance: As specified under the Clean Air Act, all power plants will have three years to comply.

4th Year: A fourth year compliance extension will be "broadly available" to sources that require extra time to install controls and to address any local reliability issues. The rule states that under § 112(i)(3)(B) state "permitting authorities have the discretion to use this extension authority to address a range of situations," including "staggering installations for reliability reasons," to address "source-specific construction, permitting, or labor, procurement or resource challenges," and to allow "the installation of replacement power at the site." The rule also notes that the development of off-site replacement generation, transmission upgrades, and continued operation of a retiring plant while other plants install controls "may provide reasonable justification" for a fourth year extension where necessary to address a local reliability concern.

5th Year: In the rare situation where four years are insufficient, "reliability critical units" will be able to obtain "expeditious" administrative orders providing a 5th year to come into compliance. Under the compliance planning pathway developed by EPA's Office of Enforcement and Compliance Assurance, power companies will develop compliance plans; engage the relevant grid operator, FERC, and the public utility commission or service commission; analyze any reliability risk with the relevant grid authority; and apply for expeditious extensions under § 113(a) where necessary.

Beyond 5 Years: Sources needing a compliance pathway beyond 5 years to ensure reliability will be addressed on a case-by-case basis.

THE POWER INDUSTRY IS WELL-POSITIONED TO COMPLY WITH THE MERCURY AND AIR TOXICS STANDARDS

Numerous power companies have been preparing for more rigorous clean air protections and are well positioned to comply with the *Mercury and Air Toxics Standards* including municipal utilities, investor owned utilities, independent power companies, and rural electric cooperatives. Statements by a variety of power companies are summarized here:

- In Minnesota, **Rochester Public Utilities** noted that its "Silver Lake Plant has been prepared for the new mercury rules over the past two years with [an] emissions reduction project installed on Unit 4 in 2009."[27]

- The **Lower Colorado River Authority** says it is "well-positioned" to comply with the new EPA rules. LCRA says it has been "evaluating control technologies and will be installing appropriate technologies to ensure compliance within the established compliance timeframe."[28]

- **Dynegy** has stated that Illinois' Hennepin and Havana plants are expected to remain operating and in compliance – indeed, most of the upgrades have already been done in order to comply with Illinois' already "stringent" regulations, with which they have been complying since 2009. Kay Sullivan, Dynegy director of public relations, explained, "We anticipated the changes and saw the need to make an investment there. We're where we need to be."[29]

- **Public Service of New Hampshire's** mercury pollution controls at its coal-fired Merrimack Station power plant puts the state's largest utility in good stead to meet new federal pollution rules. PSNH said, "The really good news for New Hampshire is the mercury reduction law that the Legislature passed in 2006 put us on a path of compliance that synchs up very well with this new federal standard."[30]

- **Kansas City Power & Light** has already made extensive investments to control pollution of toxic metals, and as a result has said that it is "relatively well-positioned to meet the compliance deadlines of these new rules."[31]

- **Midwest Generation** has been developing and installing mercury emission controls at its plants since 2008, nearly all of the company's generating units are

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[27] Christina Killion Valdez, "Silver Lake Plant prepares for new mercury rules," The Post-Bulletin, December 24, 2011. http://www.postbulletin.com/news/stories/display.php?id=1480070

[28] Brenham Banner Press, "LCRA to comply with new EPA rules," December 23, 2012. http://www.brenhambanner.com/articles/2011/12/23/news/news01.txt

[29] Jeff Dankert, "Hennepin coal plant expects to comply with EPA regulation," News Tribune, December 23, 2011. http://www.newstrib.com/articles/news/nci/default.asp?article=31437&aname=Hennepin+coal+plant+expects+to+comply+with+EPA+regulation

[30] Denis Paiste, "PSNH Says Bow scrubber already meeting standards," New Hampshire Union Leader, December 23, 2011. http://www.unionleader.com/article/20111223/NEWS02/712239971

[31] William Seay, "KCP&L Responds to New EPA Power Plant Standards," The St. Joe Channel, December 23, 2011. http://stjoechannel.com/fulltext/?nxd_id=246487

already reducing mercury emissions by more than 90 percent and already comply with the USEPA's regulation of mercury emissions.[32]

- **Dairyland Power Cooperative** in Wisconsin says it is prepared to comply with the new rules. Dairyland has already implemented about half of its $400 million plan to install pollution controls on coal-fired plants in Genoa and Alma. "We have anticipated a rule like this," said spokeswoman Katie Thomspon. "We're well prepared to be in compliance with it."[33]

- **Xcel Energy** said "we are well positioned to comply with a number of new environmental standards and regulations, like this one, thanks to early actions we have taken to modernize our generation and mitigate future environmental compliance costs."[34]

- **PSEG**'s Vice President of policy and environment, Eric Svenson, said the MATS rules were "overdue" and praised the EPA for adopting a pragmatic approach. Mr. Svenson noted that, despite the outcry from some interest groups, much of the industry was already compliant with the new standards. PSEG has already spent about $1.6 billion on upgrading three of its power plants. [35]

Further, some companies, such as American Electric Power, have significantly lowered their estimated cost of compliance since the standards were finalized. In a February meeting with investors, AEP announced it had "cut its estimate for complying with EPA's mercury rule in Ohio to $400 million from last summer's estimate of $1.1 billion."[36]

PUBLIC SUPPORT FOR THE MERCURY AND AIR TOXICS STANDARDS IS EXTENSIVE

The public support for the *Mercury and Air Toxics Standards* is extensive. Leading public health associations, organizations representing African-Americans and Latino-Americans, consumer groups, and small business consortium support these clean air standards. Some statements of support are set out below:

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[32] Business Wire, "Midwest Generation completes installation of additional pollution controls," December 22, 2011. http://www.businesswire.com/news/home/20111222005573/en/Midwest-Generation-Completes-Installation-Additional-Pollution-Controls

[33] Chris Hubbuch, "Dairyland, Xcel prepared for mercury rules," LaCrosse Tribune, December 22, 2011. http://lacrossetribune.com/dairyland-xcel-prepared-for-mercury-rules/article_b612f370-2c50-11e1-aac7-0019bb2963f4.html#ixzz1hGiDoi58

[34] Id.

[35] Jeremy Lemer, "EPA toughens rules on US power emissions," Financial Times, December 21, 2011. Available online: http://www.ft.com/intl/cms/s/0/93e363ae-2e17-11e1-98bc-00144feabdc0.html#axzz1p7zFrFOI (accessed March 14, 2012)

[36] Martinson, Erica, "AEP: Costs of meeting power plant rule decline," *Politico*, February 24, 2012.

American Heart Association, Robert D. Brook, MD:
"This historic action taken today by the EPA will mean that all of us now and in the future can expect to suffer fewer cardiovascular problems caused by breathing harmful air pollutants from power plants, and also see a reduction in other health issues related to mercury and fine particulate matter. Though much progress has been made in cleaning our nation's air over the past few decades, these added safeguards should help to further reduce cardiovascular disease, the No. 1 killer in the United States. With these standards in place, generations of Americans will now be able to breathe even cleaner air, a fact we should all be proud of as a nation." American Heart Association, *American Heart Association Applauds New EPA Rule Limiting Power Plant Emissions*, Dec. 21, 2011.

American Lung Association, Albert A. Rizzo, MD, National Volunteer Chairman
"Since toxic air pollution from power plants can make people sick and cut lives short, the new Mercury and Air Toxics Standards are a huge victory for public health." American Lung Association, *Obama Administration Finalizes Life-Saving Mercury and Air Toxics Standards*, Dec. 21, 2011.

American Public Health Association, Alan Baker, Executive Director (Interim):
"Exposure to air pollution and toxic chemicals can cause asthma and heart attacks, harm those suffering from respiratory illness and in some cases lead to death. Implementing these critically needed standards could mean the difference between a chronic debilitating, expensive illness or healthy life for hundreds of thousands of American children and adults." American Public Health Association, *Air quality standards for coal-burning power plants offer long-awaited protections to public health, says American Public Health Association*, Dec. 21, 2011.

League of United Latin American Citizens (LULAC), Brent Wilkes, Executive Director:
"We support the new mercury and toxic air pollution rule announced today because it means that the health of our communities and families everywhere across the U.S. will face decreased risks for serious diseases associated with these pollutants. One of the most harmful effects of mercury pollution are birth defects and other developmental issues and with 39 percent of Latinos living near a power plant, we could not be happier to have this important new protection in place. The increased health costs and other expenses associated with these pollutants is also too heavy a burden to ask future generations to bear. These safeguards should be implemented immediately and without question by Congress." *Latino Groups Support Long Awaited Health Protections for Mercury and Air Toxics*, Dec. 21, 2011.

NAACP, Benjamin Todd Jealous, President and CEO:
"This rule is a smart, sensible and overdue step to limit the dangerous effects of these toxins and address the racially disparate impact of air pollution. The standards will save millions of dollars in medical expenses by helping to prevent new cases of asthma attacks and other respiratory diseases that often strike families that can least afford it, while advancing a healthier quality of life for families across the nation." NAACP, "*NAACP Applauds EPA's Mercury and Air Toxics Standards*," Dec. 20, 2011.

Consumers Union, Shannon Baker-Branstetter, Policy Counsel:
"The health risks that mercury exposure poses are serious, especially since those most at risk are children and other vulnerable populations. Mercury from large industrial sources contaminates the air we breathe and common foods that many Americans eat. Regulating mercury emissions is just a common sense way to protect consumers from these health hazards and today's announcement is a critical step towards that goal." Consumers Union, *New Mercury Rules Help Lower Pollution, Save Lives*, Dec. 21, 2011.

Small Business Majority, John Arensmeyer, Founder and CEO:
The Mercury and Air Toxics Rule is "supported by small business owners across the political spectrum, and on that will create much-needed jobs." Small Business Majority, "*MATS Rule Can Create Opportunities for Small Businesses*," February 16, 2012.

CONCLUSION

More than two decades after the passage of the 1990 Clean Air Act Amendments, EPA has adopted final national emission standards addressing the hazardous air pollutants from coal- and oil-fired power plants, including neurotoxic mercury.

The National Research Council's assessment of the toxicological effects of methylmercury found that young children bear profound health risks that can, tragically, prevent a child from realizing his or her full potential:

> The population at highest risk is the children of women who consumed large amounts of fish and seafood during pregnancy. The committee concludes that the risk to that population is likely to be sufficient to result in an increase in the number of children who have to struggle to keep up in school and who might require remedial classes or special education.[37]

The *Mercury and Air Toxics Standards* are long overdue safeguards to protect the most vulnerable in our society, our infants and children, from the largest sources of toxic air pollution through proven, cost-effective solutions.

[37] National Research Council, *Toxicological Effects of Methylmercury* at p. 9.

U.S. Senate Committee on Environment and Public Works

Questions Following Hearing on March 20, 2012
"Oversight: Review of the Environmental Protection Agency's Mercury and Air Toxics Standards (MATS) for Power Plants"

Vickie Patton
General Counsel
Environmental Defense Fund
April 2012

Responses to Questions from Senator Thomas R. Carper

1) You testified about the support for EPA's Mercury and Air Toxics Standards. Can you provide the Subcommittee with a more complete list of the organizations and experts that support these clean air measures?

- **23 of the country's leading scientific experts on mercury** stated in a letter to EPA Administrator Jackson, "We, the undersigned physicians and scientists studying mercury in our biological and physical environment, write to affirm our belief that the Mercury and Air Toxics Standards (MATS) will protect the health of thousands of Americans each year. . . . [M]inimizing all mercury exposure is essential to improving human, wildlife and ecosystem health because exposure to mercury in any form places a heavy burden on the biochemical machinery within cells of all living organisms."[1]

- Roberto Carmona of **Voces Verdes** stated, "Voces Verdes applauds the Obama Administration's important new standard to control and curb mercury and other toxic air pollution from power plants. This historic rule will benefit our nation as a whole and Latino families everywhere preventing the harmful effects of these pollutants, such as respiratory diseases, developmental problems and heart attacks in our communities. This rule protects our health while also creating thousands of jobs from the manufacturing, engineering, installation and maintenance of pollution controls to meet these standards, potentially including 46,000 short-term construction jobs and 8,000 long-term utility jobs. This is an important move to protect the public health while ensuring a brighter future for our communities."[2]

- Albert A. Rizzo, M.D., National Volunteer Chair of the **American Lung Association** stated, "Since toxic air pollution from power plants can make people sick and cut lives short, the new Mercury and Air Toxics Standards are a huge victory for public health."[3]

- A diverse group of business leaders representing over 125,000 businesses through the **American Businesses for Clean Energy, American Sustainable Business Council, Ceres, Environmental Entrepreneurs, Main Street Alliance and the Small Business Majority** stated in a letter to the President, "Our experience has shown that the Clean Air Act yields substantial benefits to the economy and to businesses, and that these benefits

consistently outweigh the costs of pollution reductions. We believe the finalization of MATS is a meaningful step towards economic recovery and growth."[4]

- James Salt, Executive Director for **Catholics United** said, "Catholics and people of faith from across the political spectrum welcome the EPA's new public health standards on Mercury pollution because they will protect the lives of children."[5]

- Robert D. Brook, M.D. at the **American Heart Association** and the **University of Michigan** stated of the MATS rule, "This historic action taken today by the EPA will mean that all of us now and in the future can expect to suffer fewer cardiovascular problems caused by breathing harmful air pollutants from power plants, and also see a reduction in other health issues related to mercury and fine particulate matter. Though much progress has been made in cleaning our nation's air over the past few decades, these added safeguards should help to further reduce cardiovascular disease, the No. 1 killer in the United States. With these standards in place, generations of Americans will now be able to breathe even cleaner air, a fact we should all be proud of as a nation."[6]

- Benjamin Todd Jealous, the President of **NAACP** stated, "This rule is a smart, sensible and overdue step to limit the dangerous effects of these toxins and address the racially disparate impact of air pollution. The standards will save millions of dollars in medical expenses by helping to prevent new cases of asthma attacks and other respiratory diseases that often strike families that can least afford it, while advancing a healthier quality of life for families across the nation."[7]

- Kenneth Kimmell of the **Massachusetts Department of Environmental Protection**, in discussing the need for the MATS rule, said, "Extensive scientific research shows widespread mercury pollution across New England, largely due to air deposition of mercury from upwind states. Because of high mercury levels, all New England states warn against eating certain types of locally caught fish."[8]

- More than 50,000 members have joined the **Moms Clean Air Force** to support clean air protections. The Moms Clean Air Force recently thanked EPA Administrator Jackson for her "leadership in finalizing the historic Mercury and Air Toxics rule, which for the first time will require many of America's oldest and dirtiest power plants to slash toxic air emissions like mercury, arsenic, dioxin, acid gases, and other dangerous air emissions. These reductions will prevent thousands of premature deaths every year and will significantly reduce our children's exposure to highly toxic mercury. Mercury exposure can cause brain damage in infants and experts estimate that hundreds of thousands of babies are born each year with potentially unsafe levels of mercury in their blood."[9]

- Alan Baker of the **American Public Health Association** said of the MATS rule, "The dangerous health risks associated with coal-burning power plants is no longer an elusive, distant threat. Exposure to air pollution and toxic chemicals can cause asthma and heart attacks, harm those suffering from respiratory illness and in some cases lead to death. Implementing these critically needed standards could mean the difference between a

chronic debilitating, expensive illness or healthy life for hundreds of thousands of American children and adults."[10]

- Rev. Fletcher Harper at **GreenFaith** stated, "The EPA's new rule is a vital step forward morally and religiously. The great religious traditions to which so many U.S. citizens belong – from Judaism, Christianity and Islam to Hinduism, Buddhism and more – are overwhelmingly clear that protecting life and the environment represent a moral responsibility, and that we are called to steward and protect an earth which, ultimately, does not belong to us. By saving thousands of lives – many of them from our nation's most vulnerable communities – and by preventing toxic emissions, this rule will help ensure that future generations inherit a healthier, cleaner planet."[11]

- Shannon Baker-Branstetter from the **Consumers Union** said, "The health risks that mercury exposure poses are serious, especially since those most at risk are children and other vulnerable populations. Mercury from large industrial sources contaminates the air we breathe and common foods that many Americans eat. Regulating mercury emissions is just a common sense way to protect consumers from these health hazards and today's announcement is a critical step towards that goal."[12]

- Jeff Levi, PhD, Executive Director of **Trust for America's Health** said, "This new standard, over twenty years in the making, is a critical addition to the Clean Air Act to protect the public's health."[13]

- **New York City Mayor Michael Bloomberg** said of the rule, "Today, the President has done the right thing by ignoring the false claims of a narrow special interest and siding with the public health and the public good. The new EPA mercury standards will save countless lives and improve the quality of life for millions. The new rules will also accelerate the country's move away from heavily polluting coal power plants to cleaner energy sources that will continue to stimulate investment and economic activity long into the future."[14]

- Howard Learner of the **Environmental Law & Policy Center** said, "These standards mean power plants will invest in modern pollution controls, and that investment will create jobs, cleaner air and better public health. Illinois adopted mercury pollution reduction standards in 2006 and modern control equipment has been installed at almost all coal plants in the state. The technology works, the lights have stayed on, mercury pollution has been reduced and children's health is better protected. It's time for the holdout utilities to stop crying wolf, stop stalling and clean up their pollution to protect children's health and our rivers and lakes."[15]

- **Chicago Mayor Rahm Emanuel** stated, "I commend the U.S. Environmental Protection Agency (EPA) for introducing new standards to reduce levels of dangerous toxins in our air. Limiting emissions of mercury and other pollutants from coal and oil-fired power plants will save thousands of lives, protect public health, and create jobs for Americans. Our experience in Illinois has shown that mercury emissions can be dramatically reduced without any impact on reliability, cost, or quality of service. We must continue to clean

our air and clean up this industry across the country, to create opportunities for Americans and allow all Americans to lead healthier lives."[16]

- Rev. Canon Sally G. Bingham, President of **Interfaith Power & Light**, said, "This is good news for the religious community across America. The finalization of the Mercury and Air Toxics Standards shows us that the 40-year old Clean Air Act is still an invaluable tool to carry out our call to be stewards of God's Creation and to serve the least among us."[17]

- Ilan Levin, Associate Director of the **Environmental Integrity Project,** said of the MATS rule, "The only thing more shocking than the large amounts of toxic chemicals released into the air each year by coal- and oil-fired power plants, is the fact that these emissions have been allowed for so many years... There is no reason for Americans to continue to live with unnecessary risks to their health and to the environment."[18]

2) Since the Mercury and Air Toxics Standards have been finalized, changes in compliance plans have been reported for some power companies. Please provide the Subcommittee with up-to-date and documented information about the compliance plans (including timetable, compliance strategy and costs) announced for power companies since the standards were finalized.

Duke Energy Q4 2011 Earnings Call February 16, 2012 10:00 AM ET
Lynn Good, Group Executive and Chief Financial Officer

"Turning to Slide 9. I'll now discuss our expectations for capital expenditures. In 2011, we spent approximately $4.5 billion and we expect 2012 CapEx to be fairly consistent, at $4.3 billion to $4.5 billion. In 2013, CapEx is expected to trend down slightly as we complete our remaining modernization projects and a significant number of renewable projects later this year. Over the 3-year period, from 2012 to 2014, we expect to deploy about 80% of our forecasted CapEx into our regulated businesses, consistent with our overall business mix. Overall, annual capital expenditures at FE&G are expected to range between $3.2 billion and $3.5 billion. Of this, approximately $2 billion is related to ongoing maintenance capital and nuclear fuel for our regulated fleet. The remaining $1 billion to $1.5 billion is targeted toward growth investments, such as completing our major construction projects, our grid modernization program and environmental compliance spending. Our nuclear fleet is also performing a series of upgrades, which will add additional net capacity of around 100 megawatts when completed in 2014. These upgrades are expected to be completed at a cost of less than $2 million per megawatt. As we enter 2013 and 2014, we expect to begin increasing our environmental spending. ***After the recent finalization of the utility mercury rules, we refined our CapEx estimates. To comply with the new regulations, as well as potential rules, which have not yet been finalized, including air emissions, coal ash and water intake, we could spend around $5 billion over the next 10 years. This is at the low end of our previous $5 billion to $6 billion range. Over the next 3 years, we expect to spend about $1 billion for environmental compliance***." (emphasis added)

FirstEnergy Q4 2011 Earnings Call February 29, 2012 8:15 AM ET
James H. Lash - President of FirstEnergy Generation Corp

"The strategy that we're using in complying with the MATS rule involves a least capital approach model. What we're doing is using current emissions, and then stack data -- additional stack data that we will take in the first quarter of this year. And with that information, we plan to deploy numerous low-cost -- lower-cost technologies to ensure compliance. And we're viewing compliance on a plant basis versus a unit basis. We are also exploring co-firing some of our units with natural gas and coal. We'll consider additional dispatch approaches, and we'll even consider derating units considering this marketplace in order to ensure compliance.

"Now last year, I told you that our spend -- our capital spend was $2 billion to $3 billion to comply with this rule when it was MACT. Now that we understand the rule and we've dug into it and analyzed the situation more deeply, we are right now looking at a $1.3 billion to $1.7 billion spend to comply. And we continue to work further to reduce that cost. And we will be in compliance by the spring of 2015. To ensure that our plan holds up, we've engaged a well-known independent engineering contractor to validate our approach and make sure that we -- our plan is solid when we start its implementation later this year."

After hosting investor meetings with **Southern Company** (SO) management, Bank of America Merrill Lynch reported:

"Of its 20,000MWs of coal plants, SO expects to close 4,000MWs and repower with nat gas another 3,200MWs in response to EPA's MATs rule. ***The remaining 12,000MWs+ require some retrofits, but the company now believes that these can be done for $0.5b to $1.0b less than its initial $2.7b estimate. Moreover, the company now believes it can meet EPA's 2016 time line.*** As a result of the lower potential capex, SO may not need all of the $1.5b of new equity in 2013/2014disclosed in its year end forecast. "[19]

3) The actual compliance costs of clean air measures under the Clean Air Act have often been lower than predicted as businesses find innovative, cost saving solutions to meet new standards. Please provide the Subcommittee with documented examples over the history of the Clean Air Act in which the actual cost of the clean air solutions to meet clean air standards has been less than predicted.

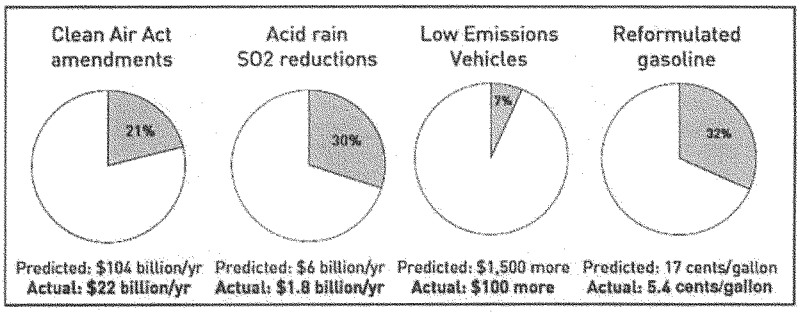
In 1997, Senator Max Baucus observed: "Air quality standards have always been met with claims of economic demise. But then technology catches up. Innovative programs are implemented. Further research bolsters the initial decision. In the end, costs are a fraction of initial claims, and everyone breathes cleaner air."[20]

EPA's March 2011 prospective analysis of the costs and benefits of the 1990 Clean Air Act Amendments found that benefits will exceed costs by more than 30 to 1 between 1990 and 2020.[21] The benefits of MATS are projected to outweigh costs by at least 3-to-1, and up to as much as 9-to-1. If history is any guide, the actual costs will likely be lower than predicted. A

Resources for the Future 2010 paper finds that "EPA and other regulatory agencies tend to overestimate the total costs of regulations… These exaggerated adjustment costs are often attributable to underestimates of the potential that technological change could minimize pollution abatement costs."[22]

Industry cost predictions have also overestimated predicted compliance costs. When Congress was considering the 1990 Clean Air Act Amendments, industry groups estimated the legislation would cost $104 billion per year.[23] In 1995, five years after the amendments became law, EPA estimated the actual annual costs to be $22 billion.[24] The graphic and chart below illustrate how actual costs compare with initial predictions in three other cases: acid rain SO_2 reductions; low emissions vehicles; and reformulated gasoline.

Predicted vs. Actual Costs of Clean Air Protections in the U.S.



Predicted vs. Actual Costs of Clean Air Act Protections

Program	Predicted costs	Actual costs
1990 Clean Air Act Amendments	**1990:** "The study we are releasing today estimates that the cost of the various proposed amendments...could be as high as $104 billion per year"[25]	**1995:** Five years after implementation EPA estimated that implementation of the 1990 CAA protections cost $22 billion per year—79% less than predicted.[26]
Acid rain	**1990:** EPA estimated that Phase II implementation would cost $6 billion per year.[27] **1990:** The Edison Electric Institute estimated that reducing SO_2 would cost the electric utility industry $3.6-4.5 billion per year.[28]	**2005:** The Office of Management and Budget estimated that the annual cost of reducing SO_2 is $1.1-1.8 billion—70% less than predicted.[29]
Low emissions vehicles	**1994:** Auto manufacturers estimated that low emission vehicles would cost $1,500 more than comparable car models.[30] **1990:** The California Air Resources Board estimated the average incremental cost of a	**1995:** One year after the manufacturers' estimate, Honda placed a Civic subcompact model on the market that emitted less than half of what was permitted under California law. This vehicle cost only $100 more

	low emissions vehicle to be $170. Industry estimates in California were $788.[31]	than comparable models.[32] **1998:** The actual incremental cost of low emission vehicle technology was $83, fully 93% less than predicted.[33]
Reformulated gasoline in California	**1991:** The California Air Resources Board predicted that reformulated gas would lead to a price increase of 12-17 cents per gallon.[34]	**1998:** The actual price differential was 5.4 cents per gallon—68% less than predicted.[35]

A Closer Look at Cost-Effectively Reducing SO2 Pollution

EPA's program to control SO_2 pollution from power plants and reduce acid rain offers a prime example of a clean air policy that has achieved important results at significantly lower costs than predicted. Peabody Coal and the Edison Electric Institute (EEI) initially estimated the costs of reducing 10 million tons of SO_2 (approximately the amount required by Phase I of EPA's Acid Rain Program) would be $3.9 billion and $4-5 billion per year, respectively.[36] The U.S. Congressional Office of Technology Assessment projected Phase I compliance costs of $3-4 billion per year.[37]

EEI predicted even higher compliance costs for Phase II reductions – at least $7.5 billion per year (Y2000$). EPA's first estimate for annual Phase II costs was $6.1 billion.[38]

However, with American innovation, actual costs were a small portion of the initial projections. The U.S. Energy Information Administration's 1995 official calculation of costs found that actual annualized costs of compliance with Phase I were $836 million. In 1998, the Electric Power Research Institute and Resource for the Future estimated total costs of implementation would be $1.7 and $1.1 billion, respectively, in 2010.[39] Similarly, the U.S. Office of Management and Budget estimated costs of the entire SO_2 program at $1.1 to $1.8 billion (Y2000$) – a fraction of what was projected.[40, 41]

In large part, industry was able to realize lower-than-expected compliance costs due to advances in scrubber pollution control technology. A March 2010 Resources for the Future report explains how technological innovation reduced compliance costs: "Estimates before regulation assumed that scrubbers operate at 85 percent reliability and remove 80 to 85 percent of the sulfur. In fact, scrubbers typically run in excess of 95 percent reliability, removing 95 percent of the sulfur. The original estimate of opportunities to blend low- and high-sulfur coal in older boilers was a 5/95 mixture. In fact, industry was able to achieve a much more efficient 40/60 mixture."[42]

Breakthrough advances in pollution abatement technology and low cost clean air solutions continue to happen today, driven by American ingenuity and innovation. With smart clean air policies in place, further advancements in American-made pollution controls can simultaneously clean the air and strengthen the economy.

Advances in Mercury Emissions Reductions

The U.S. has also made important progress in the efficacy of mercury pollution controls. In 2005, a large coal-based power company claimed it would be 2018 before Activated Carbon

Injection (ACI) could be feasibly installed at most power plants.[43] EPA's 2005 standards largely reflected a similar perspective.

But, through innovation, U.S. firms have propelled ACI technology more quickly and at lower cost than initially predicted. ACI technology has turned out to be an efficacious pollution control, and the cost of capturing mercury from power plants has dropped substantially. According to the Department of Energy's National Energy Technology Laboratory, the cost of capturing a pound of mercury in 2008 was 1/6 the 1999 price.[44] Advances in the sorbents used to remove mercury have allowed ACI to be used for a wider range of coal types than was expected in 2005, and ACI systems now cost a fraction of other air pollution control devices.[45]

4) In your written testimony, you mention that in south Florida there are studies that have found a correlation between the mercury found in the fish and wildlife in the Everglades and the levels of mercury emissions reduced from industry. Can you provide the Committee for the record the studies that show these correlations?

As requested, I have attached the following studies for the record:

- The relevant chapter from the 2011 South Florida Environmental Report, entitled "Mercury and Sulfur Monitoring, Research, and Environmental Assessment in South Florida." The study found that in the 1980s, "the mercury sourced to the Everglades was almost entirely (> 95 percent) from wet (rain) and dry (particulate mercury) atmospheric deposition" and that "in the early 1990s, pollution controls were implemented on emissions to the atmosphere from South Florida municipal waste combustors and medical waste incinerators. Mercury levels in fish subsequently declined substantially[.]"

- A study undertaken by the Massachusetts Department of Environmental Protection entitled "Massachusetts Fish Tissue Mercury Studies: Long-Term Monitoring Results, 1999-2004." The study found "significant decreases in edible fish tissue mercury concentrations, in particular from waterbodies located in a mercury deposition hotspot area, that occurred within 36-48 months of the adoption and implementation of comprehensive state and regional plans that effectively reduced emissions of mercury." The study concluded that "these results suggest that mercury levels in fish from temperate water bodies can be significantly reduced over a relatively short timeframe if emission sources are effectively controlled."

- The Hubbard Brook Foundation study entitled "Mercury Matters." The study team "evaluated mercury deposition patterns in southern New Hampshire and northeastern Massachusetts and estimated that mercury deposition is 10 to 20 times higher than pre-industrial conditions" and that "nearby coal-fired power plants produce more than 40 percent of this locally derived mercury deposition."

- A study entitled "Biological Mercury Hotspots in the Northeastern United States and Southeastern Canada," which found "consistency between the timing and magnitude of Hg emissions reductions and the declines in Hg concentrations in common loons, fish, and zooplankton."

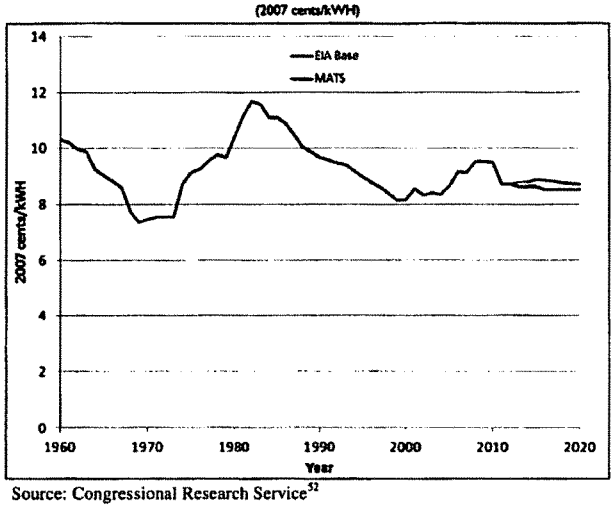
Responses to Questions from Senator James M. Inhofe

1) The U.K. Department of Energy and Climate Change released a report concluding that a lack of affordable energy in the U.K. – in part due to government policies – is a "factor driving" thousands of British deaths each year. Are you concerned that EPA did not similarly attempt to assess the public health impact that could result from increasing energy prices?

The public health risks due to toxic air pollution from power plants are serious. Power plants emit 84 different Hazardous Air Pollutants[46] and are responsible for nearly half of all manmade mercury emissions, 75% of acid gases, and 20–60% of many toxic metal emissions in the United States.[47] Mercury exposure can cause pre-natal brain damage and in infants, and it is estimated that hundreds of thousands of infants are born each year in the U.S. with potentially unsafe levels of mercury in their blood.[48] Acid gases are corrosive gases that can severely irritate the nose, throat, and respiratory tract and contribute to acid rain.[49] Many of the other toxic pollutants controlled by these rules – such as chromium, arsenic, and dioxin – are known or probable carcinogens and can attack the brain, lung, liver, and kidney.[50] By substantially reducing emissions of these harmful pollutants, the health benefits of the Mercury and Air Toxics Rule will be extensive. For every dollar spent reducing pollution Americans will receive $3-9 in health benefits, totaling $37-90 billion annually. Every year it is in full effect the rule will prevent up to 11,000 premature deaths; 4,700 heart attacks; 130,000 asthma attacks; 5,700 hospital and emergency room visits; and 540,000 missed work or school days.[51]

Evidence indicates that these toxic air pollution protections will not have a significant impact on electricity prices. The Environmental Protection Agency completed a rigorous analysis of the impacts of MATS which is documented in its Regulatory Impact Analysis. In the RIA, EPA projects that average retail electric prices will rise by about 3.1% as a direct result of MATS in 2015, declining to 2% in 2020, as illustrated in the graph below from the Congressional Research Service and "within the normal range of historical price fluctuations."

Figure 1. Average U.S. Total Electricity Prices
Historical to 2010 & Projections With and Without MATS
(2007 cents/kWH)



Source: Congressional Research Service[52]

CRS found:

- "[E]lectricity prices have declined more than 20% in real terms since 1980. The impact of price changes would be relatively small compared to this downward trend, and well within the normal range of historical price fluctuations."

- "The average consumer will see an increase of 3.1% ($3-$4 per month) in the cost of electricity in 2015 due to the rule, according to EPA, falling to less than 1% by 2030."[53]

Critics Have Overestimated Potential Electric Rate Increases from Prior Clean Air Rules

When EPA finalized acid rain rules in the early 1990s, some in industry claimed that electric rates would go up by 20 percent.[54] In fact, the cost of compliance was substantially lower than predicted and average electricity rates declined or stayed flat over the past 20 years.

In response to an AEP assertion that EPA's clean air protections would cause a "sudden increase in electricity rates and impacts on state economies will be significant at a time when people and states are still struggling,"[55] Deutsche Bank stated:

> " [O]ur research runs contrary to AEP's assertion. As we showed earlier, we see the potential for existing gas-fired generation to make up for as much as ~96% of the loss in coal-fired generation in the MISO and SERC regions that are most impacted by EPA regulation with very modest incremental infrastructure costs...

Finally, we would note that we continue to think the market broadly underestimates the potential for significant reductions in electricity consumption due to demand side management and energy efficiency programs and the soup to nuts ramifications of the shale gas revolution, which is likely to put a lid on natural gas prices and therefore power prices. When all is said and done the net impact to the consumer and to the economy of coal retirements on electricity prices and jobs is not likely to be as dire as the coal industry would have one believe. Lew Hay, Chairman and CEO of Next Era Energy, a leading natural-gas and renewables power generator has a similar view as illustrated by comments on the company's first quarter 2011 earnings call.

> *"I don't believe that replacing 50-year old fossil plants with new, more efficient units will be the train wreck we have been hearing so much about. Nor do I believe that putting pollution controls on many of the remaining plants is all that terrible. As an aside, it is interesting to note that two-thirds of our nation's coal fleet is without meaningful pollution controls. While there is no free lunch, the cost of this upgrade to that nation's generation fleet is likely to be far less than the costliest predictions."*[56]

Please also see my response to Question 3 from Senator Carper above for further information.

Energy Efficiency Policies Can Help Minimize Rate Increases

As noted above, investment in demand-side management and energy efficiency can reduce or offset potential rate impacts. Recognizing the crucial role energy efficiency can play, EPA conducted an energy efficiency policy sensitivity analysis in the Regulatory Impact Analysis for the Proposed Rule. EPA's analysis, based on Department of Energy and Lawrence Berkeley National Lab research, examined the impacts of federal appliance standards and increased deployment of ratepayer-funded energy efficiency programs consistent with recent state policy trends. EPA found that with these relatively straight forward energy efficiency policies, industry compliance costs for MATS would fall by $0.3 billion and $1.1 billion in 2015 and 2020, respectively.[57] Under the energy efficiency scenario retail electricity prices would be reduced by 0.04 cents/kWh and 0.38 cents/kWh in 2015 and 2020, respectively (see table below).

Table 8-17. Projected Contiguous U.S. Electricity Prices Including Energy Efficiency Costs (2007 cents/kWh)

	2015	2020	2030
Base Case	9.01	8.94	10.16
Base Case w/ Energy Efficiency (EE)	8.95	8.54	9.72
Toxics Rule Case	9.35	9.17	10.35
Toxics Rule Case w/ Energy Efficiency (EE)	9.31	8.80	9.93
Incremental Price Changes			
Base to Base w/EE	-0.07	-0.40	-0.44
Toxics Rule to Toxics Rule w/EE	-0.04	-0.38	-0.42
Base to Toxics Rule	0.33	0.23	0.19
Base with EE to Toxics Rule w/EE	0.36	0.26	0.21
(Base to Toxics Rule) to (Base w/EE to Toxics Rule w/EE)	0.03	0.02	0.02

Source: Integrated Planning Model run by EPA. 2011.

The scenarios EPA examined are conservative – greater deployment of energy efficiency measuresby states and industry would likely further reduce potential impacts on electricity impacts.

Working together, our nation can provide cleaner, healthier air for those especially vulnerable to harmful air pollution while also ensuring a steady flow of low cost electricity.

2) **The U.K. Department of Energy and Climate Change released a report warning that government policies leading to higher prices will have a regressive impact on the poor. Are you concerned that energy price increases resulting from EPA regulations – projected by Deutsch Bank to be as high as 1,700% - will disproportionately impact the health and safety of low-income families?**

My response to Question 1 addressed claims regarding electricity price increases. In addition, our nation must work together to reduce the vulnerability that Americans living on low incomes face due to electricity rate changes of any genesis. States and the federal government have worked together on the Low-Income Heating Energy Assistance Project (LIHEAP) and the Weatherization Assistance Project (WAP). These are important programs and can provide an effective means of protecting low-income families from electricity rate increases due to any factors. In order to be effective, however, such programs must be funded.[58]

Low-income, minority, and Tribal communities are also disproportionately impacted by air pollution.[59] According to the American Lung Association:

- over 20 million people living in poverty reside in counties that are failing to meet national ozone standards;
- over 9.3 million people living in poverty reside in counties not meeting the short term particulate matter (PM) standard; and

- 3 million people living in poverty reside in counties with unhealthy year-round PM levels.[60]

Exposure to fine particulate matter can lead to premature death – and contribute to heart attacks, asthma attacks, emergency room visits and other harmful impacts that can be particularly challenging for parents who may have to miss work because of personal illness or a family member's illness.[61] Low-wage employees may not have paid sick days, and risk losing their jobs if they are absent frequently due to personal health issues or a family member's illness. Additionally, those Americans without access to affordable health insurance may have no access to quality health care, or find their savings consumed by the costs of treating these illnesses.

A report by the NAACP found that "coal power plants tend disproportionately to be located in low-income communities and communities of color."[62] The report further noted that the 8.1 million people that live within three miles of a coal power plant have an average per capita income of $18,594–significantly lower than the U.S. average. The impacts of power plant pollution on these communities are profound.

Additionally, a recent report found that 39% of Latinos live within 30 miles of a power plant and that Latino children have higher levels of mercury than non-Hispanic white children.[63] According to the Centers for Disease Control and Prevention, nearly 50% of all Hispanic Americans living in areas that often violate ozone health standards.[64] The report also noted that groups representing more than five million Latinos have called on Congress and the President to defend the Clean Air Act and to protect their health from polluters.[65]

Representatives of minority and Tribal communities have been vocal supporters of the Mercury and Air Toxics Standards and have gone to great lengths to explain the burdens their communities face from toxic air pollution from power plants. Juan Cofield, President of the NAACP New England Conference, submitted the following to EPA in support of MATS:

> Approximately 71% of African Americans live in areas in violation of air pollution standards. Race rather than income, is the #1 predictor of whether a person is located near a polluting facility. Pollution from power plants is an issue of racial disparity as people of color are most likely to be exposed to the toxins coming from these plants and the impact is obvious from our health outcomes. At least 1 in 12, and as many as 1 in 6 American women of childbearing age have enough mercury in their bodies to put a baby at risk for mercury poisoning. Mercury and other dangerous air pollutants are connected to extreme health problems: brain damage, learning disabilities, birth defects, heart disease, cancer and even pre-mature death. We finally have a chance to end the cycle.
>
> The rates of infant mortality, low birth weight, and premature births are much higher among African Americans who, again, are more likely to be located next to these polluting power plants which spew toxins that scientists have linked to poor birth outcomes. African American infant mortality rates are 2.4 times that of white Americans.[66]

The Little River Band of Ottawa Indians submitted comments to EPA in support of MATS as well:

> The Environmental Protection Agency (EPA) must protect both Michigan and national Tribal communities from the harms caused by mercury and particulate matter (PM2.5) from toxic air pollutants emanating from coal and oil fired power plants, or Electrical Utility Steam Generating Units (EGUs).
>
> We believe that the rules proposed by the EPA to reduce emissions of toxic air pollutants from power plants and Electrical Utility Steam Generating Units have a material impact on Tribal Communities who will bear a disproportionate share of the pollution burden from those toxic air emissions from power plants.
>
> Mercury is a neurotoxin that causes neurological delays and damage. Mercury is of special concern to Tribal children and women of childbearing age. The risk to women is the impact of mercury on babies in the womb. In utero exposure to mercury, via contaminated fish eaten by expectant mothers, can impair thinking, memory, attention, language, and fine motor and visual spatial skills. Similarly, children who eat mercury-contaminated fish are at risk for decreased brain function.[67]

Here are some quotes of support that I reference above in response to Senator Carper's Question 1:

- Shannon Baker-Branstetter from the **Consumers Union** said, "The health risks that mercury exposure poses are serious, especially since those most at risk are children and other vulnerable populations. Mercury from large industrial sources contaminates the air we breathe and common foods that many Americans eat. Regulating mercury emissions is just a common sense way to protect consumers from these health hazards and today's announcement is a critical step towards that goal." [68]
- Benjamin Todd Jealous, the President of **NAACP** stated, "This rule is a smart, sensible and overdue step to limit the dangerous effects of these toxins and address the racially disparate impact of air pollution. The standards will save millions of dollars in medical expenses by helping to prevent new cases of asthma attacks and other respiratory diseases that often strike families that can least afford it, while advancing a healthier quality of life for families across the nation."[69]
- Roberto Carmona of **Voces Verdes** stated, "Voces Verdes applauds the Obama Administration's important new standard to control and curb mercury and other toxic air pollution from power plants. This historic rule will benefit our nation as a whole and Latino families everywhere preventing the harmful effects of these pollutants, such as respiratory diseases, developmental problems and heart attacks in our communities. This rule protects our health while also creating thousands of jobs from the manufacturing, engineering, installation and maintenance of pollution controls to meet these standards, potentially including 46,000 short-term construction jobs and 8,000 long-term utility jobs. This is an important move to protect the public health while ensuring a brighter future for our communities."[70]

These communities, which have borne a heavy burden due to the toxic air pollution from power plants, are strong supporters of the Mercury and Air Toxics Standards.

3) The U.K. Department of Climate Change released a report citing a number of health concerns related to reduced access to affordable energy including poor mental health, social isolation, and cardiovascular and respiratory problems, especially for children or the elderly. Are you concerned about the health impacts that high energy prices have on vulnerable populations?

As detailed previously, electric rate increases, if any, due to MATS are projected to be diminutive, and I strongly support programs like LIHEAP that can effectively protect vulnerable populations from increases in electricity prices that stem from any cause. Furthermore, Americans living on low incomes, children, people with asthma or other respiratory conditions, and the elderly are particularly at risk from the dangerous air pollution that will be reduced as a result of the Mercury and Air Toxics Standards.[71] Because the health benefits of this rule are so compelling and urgent, numerous health groups including the American Academy of Pediatrics, the American Lung Association, the American Heart Association, and the American Nurses Association have expressed their strong support for MATS and have urged members of Congress to oppose any efforts to undo the rule.[72] Please also see my responses to Questions 1 and 2, above.

4) At the recent FERC Reliability Conference, National Association of Regulatory Utility Commissioners President David Wright asked, "if [rate-payers] can't pay the bill, and they're living without power,...at what point does it become a health and safety issue for commissions and for utilities?" Do you believe access to affordable energy is a public health issue? If not, when is it a public health issue – Deutsch Bank projects Utility MACT could increase electricity capacity prices by 1,700% - how about then?

As discussed above, EPA and Deutsche Bank project that *electric rates* will be minimally impacted by MATS if at all. Transmission constraints in localized load pockets can create very high capacity prices, but this does not usually translate into significantly higher rates simply because the effect of capacity prices, in the aggregate, are very small when compared with overall energy prices, which dominate the rates that customers pay. Please see my written testimony and response to Senator Carper's Question 2 for more information.

5) Surely there are public health and safety issues resulting from lost jobs, lost tax revenue for local schools and municipal services, and lack of affordable energy. What have you and the Environmental Defense Fund done to investigate those concerns?

The vital clean air protections under MATS will not only protect human health, including the health of vulnerable members of our community, but will also create a stronger, more efficient economy. MATS is an example of how smart policies can achieve all of these goals.

MATS will mobilize American innovation to cut harmful air pollution and create jobs for hard-working Americans. MATS provides power companies with an adaptable compliance

framework, allowing a companies to choose from a variety of pollution reduction options in order to comply with the rule. For example, the construction, installation, and operation of pollution control equipment will create jobs. Wisconsin Power & Light Co. (WP&L) is currently installing air pollution scrubbers on its Columbia Energy Center in Wisconsin. WP&L has stated that "During the peak of construction, there will be about 600 workers on site and, through the course of the project, we will average about 300-400 workers daily."[73] Moreover, according to the Wisconsin Governor's office, the project will also boost the state's economy by creating work for contractors and suppliers that will provide materials to the project.

Other studies have also shown that MATS will propel job creation. Dr. Josh Bivens of the Economic Policy Institute found that MATS would likely lead to the creation of 28,000 to 158,000 jobs between now and 2015.[74] Dr. Charles Cicchetti, senior advisor to Navigant Consulting, projected that MATS will create more than 115,000 jobs.[75]

Dr. Cicchetti's study also shows that far from detracting from tax revenues, MATS will add $2.689 billion in tax receipts nationally, and will contribute an additional $7.17 billion annually to GDP.[76] Moreover, pollution control projects such as those described above at the Columbia Energy Center have the potential to increase tax revenues to local communities.

The responses to previous questions have addressed concerns regarding electricity prices. Furthermore, as I have outlined in response to Senator Carper's questions above, both EPA and industry have repeatedly and significantly overestimated the costs of compliance with Clean Air Act protections. In fact, power companies are already reducing their estimated of compliance costs for MATS. For example, as noted above, Southern Company has revised its compliance cost estimates – and now believes compliance for its fleet will cost between *$500 million and $1 billion less* than it had originally anticipated; AEP announced that its revised estimate for the cost of compliance for its Ohio units is *60% less* than what it originally projected.[77]

My support of MATS is consonant the imperatives of securing healthy air and a stronger America.

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Chapter 3B: Mercury and Sulfur Monitoring, Research and Environmental Assessment in South Florida

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SUMMARY

As a highly toxic form of mercury that bioaccumulates in food chains, methylmercury (MeHg) is a risk to wildlife and humans that consume Everglades fish. Sulfur in the form of sulfate increases the rate of MeHg production and may promote phosphate releases from sediments; sulfur in the form of sulfide is toxic to aquatic plants and animals. Regional effects of elevated mercury and sulfur concentrations are evident — and the Everglades has among the highest mercury levels in fish in Florida. Options for reducing these levels include mercury and sulfur source reduction, although the predominant remaining mercury source to the Everglades may be atmospheric deposition from international sources.

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[7] DB Environmental, Inc., Rockledge, FL
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To address these concerns, the Florida Department of Environmental Protection (FDEP) and the South Florida Water Management District (SFWMD or District) are continuing coordinated efforts to better understand the regional sources, transformations, and toxicity of mercury and sulfur. In addition, the Florida Fish and Wildlife Conservation Commission has complementary fish and wildlife programs that monitor for mercury. This chapter updates the status of mercury and sulfur science in South Florida and highlights the progress on research findings. In addition to largemouth bass (LMB) (*Micropterus salmoides*) monitoring, this year's chapter looks more broadly at historical mercury levels and related trends in wildlife including the American alligator (*Alligator mississippiensis*), the Florida panther (*Puma concolor coryi*), and the invasive Burmese python (*Python molurus bivittatus*). In combination with Appendices 3B-1 and 5-6 of this volume, this chapter meets the Everglades Forever Act (EFA) requirement that the District and the FDEP shall annually issue a peer-reviewed report that summarizes all data and findings of mercury research and monitoring in South Florida. Additional detailed scientific information can be found in mercury chapters of the 1999 Everglades Interim Report, 2000–2004 Everglades Consolidated Reports, and 2005–2010 South Florida Environmental Reports.

KEY FINDINGS OF RESEARCH AND MONITORING

- In the Water Conservation Areas over the past 20 years, there has been a significant decline in annual median total mercury concentration in largemouth bass, based on annual monitoring. Mercury in LMB declined 62 percent from a peak level of 1.6 parts per million [(ppm) or milligrams per liter (mg/L)] in 1991 to 0.6 ppm in 2009. Over the past decade, median mercury levels in LMB have varied little, ranging from 0.4 to 0.6 ppm. Still, present concentrations in LMB average twice the U.S. Environmental Protection Agency's recommended human health criterion for fish consumption.
- In the Shark River Slough region of Everglades National Park over the past 20 years, there has been no significant trend in annual median mercury concentration in LMB. This indicates continued favorable conditions for MeHg production and bioaccumulation. In 2010, the median mercury concentration in LMB was 1.4 ppm, which markedly exceeds both federal wildlife protection and human health criteria.
- About 60 percent of the Everglades marsh area has sulfate concentrations that exceed the restoration goal of 1 ppm in surface waters; 1 to 2 ppm of sulfate may represent a threshold level below which mercury methylation rates are relatively low. Further research is needed to quantify sulfur sources and better understand sulfur-related effects on the Everglades ecosystem.
- A regional sulfur mass balance study is under way to quantify the exchange of sulfur between Lake Okeechobee, the Everglades Agricultural Area (EAA), and Water Conservation Areas 1 and 2. Preliminary results suggest that during periods of normal or high rainfall, the EAA is a key source of sulfur to the downstream Everglades, mostly due to sulfur release from soil oxidation, as well as agricultural sulfur application and runoff.

MERCURY IN EVERGLADES WILDLIFE AND FISH

HISTORICAL MONITORING OF MERCURY IN BIOTA

The highly bioaccumulative form of mercury, methylmercury (MeHg), is a concern due to the neurotoxic threat it poses for Everglades wildlife and humans who consume Everglades fish. Elevated levels of mercury (Hg) in biota in Florida were first reported by Ogden (1974) for the Everglades National Park (ENP or Park), and by Bigler et al. (1985) for peninsular Florida. In 1988, reports of mercury levels in largemouth bass (LMB) (*Micropterus salmoides*) in the Everglades Protection Area's (EPA) Water Conservation Areas (WCAs) exceeding 1 part per million (ppm) [1 ppm = 1 milligram per kilogram (mg/kg) or 1 microgram per gram (µg/g)], prompted expanded sampling of fish and wildlife by state environmental and health agencies.

Statewide sampling determined that mercury in LMB was highest in the Everglades, and mercury levels in American alligators (*Alligator mississippiensis*), softshell turtles (*Apalone ferox*), and the endangered Florida panther (*Puma concolor coryi*) were also elevated (Ware et al., 1990).

Since then, mercury has remained a chronic water quality problem in the EPA, the Greater Everglades, and for the remainder of Florida, impacting humans and fish-eating wildlife. High mercury concentrations in fish have not only been documented in the freshwater reaches of the EPA (Loftus et al., 1998; Gabriel et al., 2010a), but also downstream in Florida Bay (Strom and Graves, 2001; Evans et al., 2003) and the Gulf of Mexico (Adams et al., 2003).

In response to findings that mercury concentrations in sport fish exceeded human health criteria, the Florida Department of Health (FDOH) issued fish consumption advisories for Florida Bay, the Gulf of Mexico, the Atlantic, and the fresh waters of the ENP, WCAs, and numerous lakes and rivers (FDOH, 2009). In addition, one wildlife species, the pig frog (*Rana grylio*), has a limited-consumption advisory (FDOH, 2008), and the Florida Fish and Wildlife Conservation Commission (FWC) has banned the sale of alligator meat harvested from the Francis S. Taylor Wildlife Management Area (Francis S. Taylor WMA), which overlaps Water Conservation Area 3B.

Fish and wildlife monitoring is necessary to (1) assess human and wildlife risks from consumption of mercury-contaminated fish, (2) describe spatial and temporal trends in mercury bioaccumulation, and (3) gain a better understanding of the ecological significance of mercury bioaccumulation in fish and wildlife. The following are summaries of research on the status and trends of mercury in the American alligator, Florida panther, and the nonindigenous invasive Burmese python (*Python molurus bivittatus*) (**Figure 3B-1**). In addition, this chapter reports on fish sampling activities within the Greater Everglades.

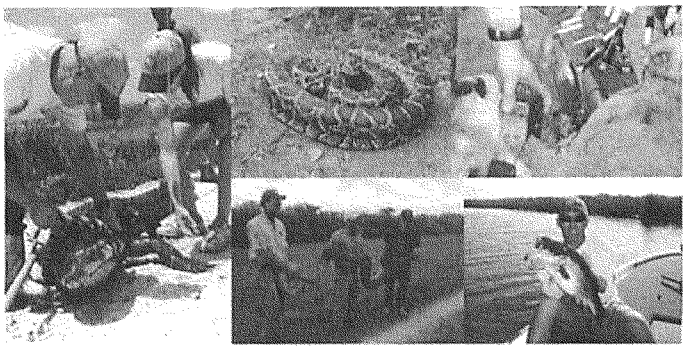


Figure 3B-1. Fish and wildlife species in the Everglades region, including (clockwise from left) the native American alligator (*Alligator mississippiensis*), invasive Burmese python (*Python molurus bivittatus*), Florida panther (*Puma concolor coryi*), and largemouth bass (LMB) (*Micropterus salmoides*) that are the focus of research on mercury bioaccumulation [photos by the South Florida Water Management District (SFWMD) and the Florida Fish and Wildlife Conservation Commission (FWC)].

AMERICAN ALLIGATOR

The first report of total mercury (THg) in wild-caught American alligators (*Alligator mississippiensis*) from Florida waters was made by Ogden et al. (1974), who reported on levels in eggs collected from Shark River Slough in the ENP (the southern end of the EPA). They found concentrations of THg in alligator eggs greatly exceeded levels observed in the eggs of their estuarine counterpart, the American crocodile (*Crocodylus acutus*), collected from Florida Bay.

Measurements of THg in tail muscle from wild-caught alligators from Florida waters were first reported by Delany et al. (1988). They found that average concentrations in 32 alligators collected from eight lakes in 1984 ranged from 0.04 to 0.61 ppm. In 1989, responding to findings of elevated levels of THg in fish, the Florida Fish and Wildlife Conservation Commission (FWC) collected 29 harvestable-size alligators from the WCAs and tested for THg in tail muscle (**Table 3B-1**). THg levels were well in excess of previous findings from non-Everglades water bodies, with a system-wide range in individual alligators of 0.46 to 3.88 ppm and an average concentration of 2.38 ppm (Hord et al., 1990).

During the same time period, the FWC obtained samples of tail muscle (n = 19) collected by a nuisance-alligator hunter from alligators captured in urban canals on the eastern boundary of WCAs 2 and 3 in the Fort Lauderdale area. For comparison, an additional 58 samples of tail muscle were collected from licensed meat processors from north, central, and South Florida (Hord et al., 1990). Results for nuisance alligators from the Fort Lauderdale area during May 1989 revealed a wide range of values — individual concentrations ranged from 0.17 to 2.52 ppm with an overall mean of 0.74 ppm. The lack of precise location data for sample harvesting and the close proximity to the WCAs with their relatively high fish mercury concentrations were likely responsible for the highly variable THg concentrations in alligators. The results for alligators collected from meat processors from north, central, and South Florida (non-WCA locations) revealed lower THg concentrations with a range in county means of 0.13 to 0.90 ppm. The highest county mean, 0.90 ppm (n = 1), was from Franklin County in the panhandle, indicating that problematic levels of THg were not limited to the WCAs.

Table 3B-1. Range of total mercury (THg) concentrations in tail muscle from American alligators collected from Water Conservation Areas 2 and 3 (WCA-2 and WCA-3) by the FWC during two sampling events on February 2 and June 7, 1989 (adapted from Hord et al., 1990).

		THg (ppm)		
Canal Site	N	Average (± SD)	Min	Max
C123	5	2.68 (0.82)	1.60	3.50
L35B	7	2.52 (0.82)	1.23	3.88
L38E	2	0.73 (0.38)	0.46	1.00
L67A	8	2.29 (0.72)	1.50	3.20
Miami	7	2.70 (0.97)	0.78	3.58
Both WCAs	**29**	**2.38**	**0.46**	**3.88**

N = number of alligators collected
SD = standard deviation
ppm = parts per million or milligrams per kilogram (mg/kg)

Further validation of the differences in bioaccumulation rates between the Everglades and the rest of the state came during a September 1989 survey of THg in alligator tail muscle conducted by the FWC. The average concentration of THg in 60 tissue samples collected from 12 peninsular lakes was 0.43 ppm (range, 0.05–1.40 ppm) (FWC, unpublished data). Testing of five randomly selected individuals of various sizes revealed that nearly all of the mercury (91 percent) in alligator tail muscle was methylmercury (MeHg), a highly toxic form of the element.

Results from these initial surveys clearly demonstrated that mercury was a state-wide water quality problem, with particular significance in the Everglades where bioaccumulation of mercury could have long-term ecological and human health impacts. The FWC had initiated a recreational alligator harvest in the Francis S. Taylor WMA in 1988; however, the finding of elevated levels of THg in wild alligators from the Everglades resulted in the closure of the 1989 and 1990 recreational alligator harvest in WCAs 2 and 3 based on Florida Department of Health and Rehabilitative Services' [now the Florida Department of Health (FDOH)] human consumption criteria. The criteria were that where mercury levels in fish or wildlife exceeded 1.5 ppm, the fish or wildlife should not be consumed by any segment of the population, while fish or wildlife with mercury levels exceeding 0.5 ppm should only be consumed in limited quantities. Based on those criteria and the mercury data, alligators from Francis S. Taylor WMA were placed in the "do not eat" category.

When open, the recreational alligator harvest quota for the Francis S. Taylor WMA was about 585 alligators per year, with a total economic loss of $27,000 during each year of closed harvest (Hord et al., 1990). The FWC re-opened the recreational harvest of alligators from the area in 2000. However, all specimens harvested were marked with a special color-coded tag identifying the alligator as taken from a mercury-contaminated area, and that the harvested meat could not be sold. Furthermore, it was highly recommended that the meat not be consumed by the hunter or anyone else. These protocols remained in effect at the time of this report.

Additional alligator tissue sampling was conducted by the FWC during the 1996 state-wide alligator harvest within 23 Alligator Management Units (AMUs) to define the spatial and temporal gradients in THg concentrations. Results again confirmed elevated levels of mercury in alligators collected from the WCAs (**Table 3B-2**). Within each AMU, between 10 and 12 individual tail muscle samples were composited for analyses of THg. Concentrations from 22

non-WCA AMUs ranged between 0.05 and 0.75 ppm (mean: 0.28 ppm), while the two composites from WCA-3A had concentrations of 1.62 and 1.90 ppm, respectively.

Table 3B-2. Range of THg concentrations in parts per million (ppm) in composite samples of American alligator tail muscle collected from select Alligator Management Units (AMUs) in 1996.

AMU	Location	Number in Composite	Composite THg (ppm)	Average Carcass Length (feet)	Range Carcass Length (feet)	Female	Male
104	Lake Hatchineha	12	0.34	6' 5"	4'2"-11'3"	5	7
107	Kiss. R. Pool B	12	0.67	7' 10"	6'4"-11'1"	3	9
201	St. Johns R. N.	11	0.19	6' 10"	5'0"-10'2"	11	
501	St. Johns R. 1	12	0.20	5' 9"	4'5"-7'11"	7	5
502	St. Johns R. 2	11	0.23	6' 5"	5'0"-8'9"	3	8
504	St. Johns R. 4	12	0.30	6' 1"	5'3"-8'3"	5	7
505	Lake Harney	11	0.30	7' 1"	4'11"-11'2"	2	9
508	Crescent Lake	12	0.15	5' 2"	4'1"-6'6"	7	5
509	Lake Griffin	10	0.15	9' 6"	8'0"-12'9"	4	6
511	Lake Harris	12	0.17	9' 11"	8'7"-12'0"		12
513	Lake Eustis	12	0.13	7' 7"	6'1"-9'3"	4	8
518	Lake Rousseau	12	0.27	6' 9"	4'3"-10'3"	5	7
601	Okeechobee W.	12	0.23	6' 3"	5'4"-7'3"	6	6
602	Okeechobee N.	10	0.20	8' 1"	6'8"-9'7"	1	9
711	Lake Hancock	12	0.05	8' 5"	6'3"-13'2"	6	6
722	Orange Lake	12	0.38	8' 10"	5'4"-11'1"	2	10
734	Lake Seminole	10	0.29	7' 8"	4'1"-11'7"	5	5
741	Lake Trafford	10	0.63	7' 11"	6'2"-10'4"	4	6
751	Lake George	10	0.14	7' 10"	5'11"-9'6"	3	7
110	Lake Kissimmee	11	0.75	8' 7"	6'3"-12'10"	1	10
515	L. Panasoffkee	12	0.13	4' 11"	4'2"-6'2"	6	6
517	Withlacoochee S.	12	0.31	5' 6"	4'1"-7'8"	8	4
	Non-Water Conservation Area (WCA) Average		**0.28**				
403	WCA-3A North	11	1.62	5' 3"	4'1"-6'4"	4	7
401	WCA-3A South	11	1.90	6' 4"	4'0"-9.6"	4	7
	WCA Average		**1.76**				

Similarly, Heaton-Jones et al. (1997) reported that THg concentrations in various tissues from alligators collected during 1992–1993 from non-Everglades locations in Florida varied widely with geographic origin but were between those collected from alligator farms (low THg concentrations) and the WCAs (high concentrations). Alligators collected from the Everglades (in WCA-2 and WCA-3), were significantly higher in THg than farm-raised animals for a number of tissues, including tail muscle. Mean THg concentrations in farm-raised, non-WCA, and WCA alligators were 0.10 ± 0.06 ppm, 0.33 ± 0.28 ppm, and 2.61 ± 0.91 ppm, respectively. During this study, an alligator size-dependence in THg bioaccumulation was noted; however, other datasets have been inconsistent in demonstrating increased THg concentration with alligator size. The levels of THg found in WCA alligators were not unprecedented; Yanochko et al. (1997) found similar levels in other mercury-enriched locations in the southeastern United States.

Concentrations of THg in alligator muscle collected through the 1990s clearly demonstrated THg levels exceeding the existing criteria established for the protection of human health by the FDOH and U.S. Environmental Protection Agency (USEPA, 2001a). The USEPA human health criterion for fish consumption for MeHg of 0.3 ppm was exceeded by all WCA alligators and also by alligators from several AMUs sampled during the mid-1990s.

Although many fish from the WCAs continue to exceed the USEPA human health fish tissue MeHg criterion, recent declines have been evident (Gabriel et al., 2010b). It is not known if concurrent declines in alligator mercury levels have occurred because samples have not been collected from the WCAs since 1996.

The FWC is interested in conducting a human health risk assessment to determine the viability of allowing sale and consumption of meat from recreationally caught alligators from the WCAs. Alligator sampling in several areas adjacent to the WCAs has occurred in recent years. In consideration of establishing alligator hunts in several Stormwater Treatment Areas (STAs), collections of 12 harvestable size alligators were made from both Stormwater Treatment Area 1 West (STA-1W) and Stormwater Treatment Area 5 (STA-5) in 2008, and from Stormwater Treatment Area 3/4 (STA-3/4) in 2010 by the FWC and the SFWMD. THg concentrations in STA alligators were much lower than previous findings from the adjacent WCAs, with average concentrations less than the USEPA MeHg criterion for human consumption. Average concentrations of 0.084 ppm (0.032 to 0.266 ppm), 0.113 ppm (0.048 to 0.329 ppm), and 0.277 ppm (0.110 to 0.771 ppm), and were observed in STA-1W, STA-5, and STA-3/4, respectively.

Whether these results include data from alligators that move in and out of the adjacent WCAs is unknown; the STAs typically have fish populations with significantly lower THg levels than the WCAs (Gabriel et al., 2010c). In 2010, 12 alligators were harvested from the Holey Land Wildlife Management Area (Holey Land WMA) when establishment of a hunt on the property was being considered. Long-term monitoring of fish from the Holey Land WMA has revealed increasing concentrations in THg during the past decade with only recent declines (Axelrad et al., 2009; Gabriel et al., 2010a). Not unexpectedly, THg levels in alligators were elevated with an average concentration of 1.16 ppm (range: 0.54–2.56 ppm). Again, there is the potential for alligators to forage within the adjacent wetlands of WCA-3 and STA-3/4. Current mercury levels in the WCAs are unknown.

The FWC and the FDEP plan to reassess the need for the human health protection guidance presently in place for the WCA-2 and WCA-3 recreational alligator harvest by collecting and analyzing up to 200 alligators (150 from the Francis S. Taylor WMA AMU and 50 from other state-wide AMUs) during the 2011 state-wide recreational alligator harvest. Results are expected to be used for human health risk assessments specifically for each AMU.

FLORIDA PANTHER

The Florida panther (*Puma concolor coryi*) is a state and federally listed endangered species. Environmental stressors (including environmental contaminants), low genetic variability, and habitat loss have all contributed to the decline of this species. Mercury contamination has been suggested as a causative factor in the low densities, poor reproduction, and some reported deaths of panthers from portions of South Florida (Roelke et al., 1991; Facemire et al., 1995); however, factors such as prey abundance and consumption, panther diseases, genetics, and demographic issues are difficult to separate from the influence of mercury when measuring panther fitness and mortality. During a survey of various tissue, blood, and hair samples collected from 52 live and dead free-ranging panthers from 1978–1991, Roelke et al. (1991) found detectable levels of THg in all tissues as well as strong spatial gradients. Similarly, MeHg was present in all panther hair samples collected from museum specimens dating back to the 1890s (Newman et al., 2004), with significantly higher levels observed in the 1990s than in the late 1800s.

Roelke et al. (1991) reported that the highest mercury concentrations were found in panthers from the Shark River Slough of the ENP (hair = 56.4 ppm; blood = 0.794 ppm) and the lowest concentrations were from north of Alligator Alley (hair = 1.66 ppm; blood = 0.094 ppm), which included northern Fakahatchee Strand, Florida Panther National Wildlife Refuge (FPNWR), and portions of Big Cypress National Preserve (BCNP). Differences were likely influenced by the ambient levels of mercury in the environment as well as prey selection, with panthers feeding on non-hoofed, fish-eating species [i.e., raccoons (*Procyon lotor*)] exhibiting the highest tissue THg concentrations. [Note: Animal tissue (fish, panther, etc.) are usually reported as mg/kg (ppm); blood is mg/L (ppm).]

It was noted that raccoons comprised 70 percent or more of the diet of panthers foraging within Shark River Slough. These panthers also had the highest muscle and liver THg concentrations. Panthers foraging north of Alligator Alley had lower mercury levels and fed primarily on white-tailed deer (*Odocoileus virginianus*) and feral hogs (*Sus scrofa*) — species not tied to the aquatic food web. During the late 1980s, adaptive management strategies by the FWC to modify the prey base available to panthers foraging within the Fakahatchee Strand resulted in declines in panther THg levels, as panthers transitioned from a diet dominated by raccoons to one comprised largely of deer and hogs (Roelke et al., 1991). At that time, raccoons within Fakahatchee Strand had THg values 10–100 times higher than those in deer.

More recently, declines in THg levels in Everglades fish (Lange et al., 2000, 2005; Gabriel et al., 2010a), birds (Rumbold et al., 2001; Frederick et al., 2002), and alligators from certain regions of the Everglades (Rumbold et al., 2002) have been reported. This led Barron et al. (2004) to conclude that current risks to panthers from mercury exposure are low. Based on a dietary exposure model, pre-1992 levels of mercury in panther prey suggested a 46 percent probability of exceeding chronic dietary thresholds for MeHg. Based on an estimated 70–90 percent decline in mercury exposure to panthers during the subsequent decade, panthers in 2002 faced a less than 4 percent probability of exceeding dietary thresholds. Barron et al. (2004) further concluded that under a worst-case scenario, panthers consuming raccoons only faced a 4.5 percent risk of developing clinical symptoms of mercury exposure that could lead to death. However, there is evidence that mercury hot spots in the Everglades continue to exist or could develop in response to restoration activities, increasing risks to panthers through dietary exposure.

From 2000–2007, the FWC gathered a total of 272 blood samples and 384 hair samples from panthers for mercury analysis. Preliminary results for these collections were reported by Brandon et al. (2009). Blood samples (n = 158) had measurable amounts of mercury, with concentrations ranging from 0.009 ppm to 5.3 ppm. Likewise, hair samples (n = 321) also had measurable concentrations of mercury, with values ranging from 0.086 ppm to 100 ppm. During this period, the panther with the highest mercury concentrations in blood and hair (from samples collected

post-mortem), identified as FP 85, was first caught in the Southern Glades Wildlife Management Area in 2003 and then found dead in the ENP in 2004. The cause of death for FP 85 was listed as "unknown" (FWC, 2010).

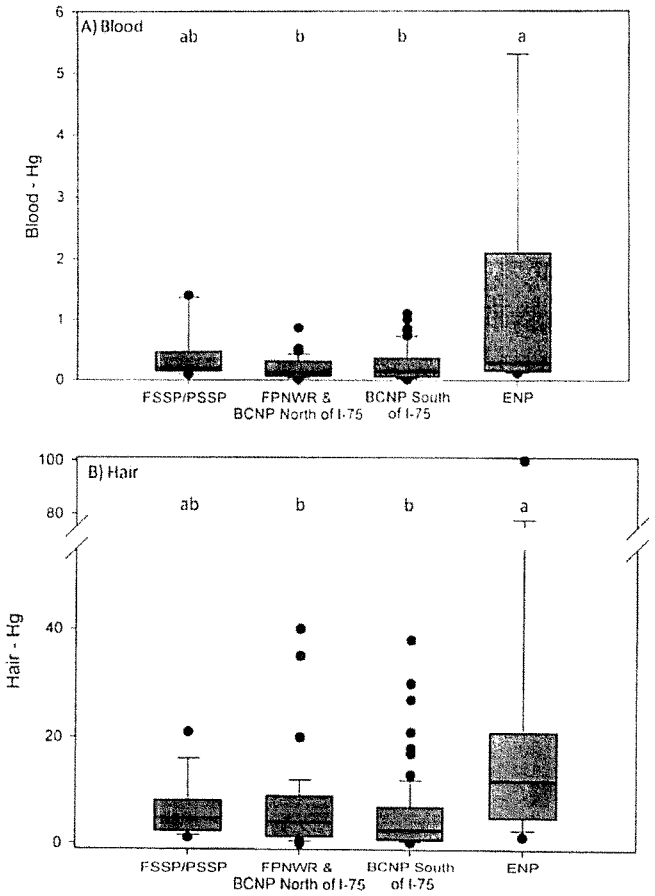
Average mercury concentrations in the hair and blood of Florida panthers has decreased in most geographic regions (Roelke et al., 1991) with the possible exception of areas north of I-75, including north BCNP and the FPNWR, where concentrations have remained relatively unchanged (**Table 3B-3**). Spatial gradients in the panther mercury levels persisted for the 2000–2007 period, with the highest mean concentrations in hair and blood of the four regions originally identified by Roelke et al. (1991) found in the ENP (**Figure 3B-2**). Differences among these regions were statistically significant as indicated in **Figure 3B-2** in blood (Kruskal-Wallis One Way Analysis of Variance on Ranks, $h = 13.541$, $df = 3$, $p = 0.004$; Dunn's Method for pairwise multiple comparison $p = < 0.05$) and in hair ($h = 16.765$, $df = 3$, $p = < 0.001$; Dunn's Method for pairwise multiple comparison $p = < 0.05$). Roelke et al. (1991) suggested that panthers inhabiting areas with less dense ungulate populations, like the ENP, may rely more heavily on fish-eating wildlife, such as raccoon and alligators, thereby increasing their potential for mercury accumulation through trophic transfer.

Table 3B-3. Variation in blood Hg and hair Hg (ppm) between periods of intensive sampling among geographic regions. Data from 1978–1991 and geographic regions from Roelke et al. (1991), table adapted from Brandon et al. (2009).

	Florida Panther Mercury Levels					
	1978–1991			2000–2007		
Assay (ppm)	N	Mean	SE	N	Mean	SE
Florida Panther National Wildlife Refuge & Big Cypress National Preserve, North of I-75						
Blood	42	0.1	1.15	38	0.13	0.03
Hair	43	1.66	1.23	48	3.26	1.13
Fakahatchee & Picayune						
Blood	12	0.38	1.35	11	0.25	0.14
Hair	7	7.18	1.62	14	4.46	1.39
Big Cypress National Preserve, South of I-75						
Blood	2	0.62	1.26	50	0.14	0.04
Hair	2	42.3	1.63	90	2.65	0.75
Everglades National Park & East Everglades*						
Blood	7 & 14	0.23–0.79	1.2–1.6	15	0.57	0.46
Hair	8 & 8	10.9–56.4	1.24–1.35	17	11	6.4

N – northern
SE – southeastern

*Note: Roelke et al. (1991) subdivided this region into two smaller areas, which could not be duplicated with any certainty for this assessment. Animal tissue (fish, panther, etc.) are generally reported as mg·kg (ppm); blood is mg·L (ppm).



Note: Box plots represent the median, 25th and 75th percentiles; whiskers the 10th and 90th; points are outliers. Sites with similar letter designations (e.g., a and ab) did not differ significantly. Sites from Roelke et al. (1991) include Fakahatchee and Picayune State Parks (FSSP & PSSP), Florida Panther National Wildlife Refuge (FPNWR), Big Cypress National Preserve (BCNP), and Everglades National Park (ENP) (figure from Brandon et al., 2009).

Figure 3B-2. Geographical variations in (A) blood Hg and (B) hair Hg (ppm) from 52 free-ranging Florida panthers collected 2000–2007.

Although average mercury concentrations in Florida panther blood and hair generally declined between study periods (1978–1991 and 2000–2007) at Big Cypress National Preserve (BCNP) south of I-75, increasing mercury levels in blood and hair were observed in recent years (**Figure 3B-3**). Mean concentration of mercury in blood rose from 0.259 ppm (n = 6) in 2006 to 0.568 ppm (n = 8) in 2007 and more than doubled in hair from 4.518 ppm in 2006 (n = 9) to 10.847 ppm (n = 13) in 2007. This difference between years was not statistically significant for blood or hair, but because of the few animals left in the wild, any data indicating elevated panther mercury levels are cause for concern.

It appears that maximal mercury concentrations in panthers were evident in the late 1980s and early 1990s, with subsequent declines across much of the Everglades landscape. The possible recent increase in mercury levels in panthers from certain areas, especially the Big Cypress region (BCNP), is cause for concern due to the concentration of animals inhabiting this area. Because the Florida panther is an endangered species, mercury exposure levels remain a concern.

It is evident that the majority of the current Florida panther population occupies an area where mercury bioaccumulation in aquatic ecosystems remains a significant concern. The FWC continues to collect blood and hair samples for mercury analysis. Current efforts focus on filling the data gap from 1992 through 1999, and on more in-depth analysis of existing data, including the 1978–1991 and 2000–2007 datasets. Analyses will focus on developing a better understanding of potential influential variables contributing to mercury exposure (such as panther age and sex, and regional hydrology). Moreover, correlation analyses of mercury levels with health metrics such as body condition, blood chemistry, and reproductive success should be conducted on the expanding dataset and compared to literature-derived critical tissue concentrations to elucidate the direct and indirect effects of mercury on individuals and regional sub-populations. Finally, special consideration should be given to regional and individual maximum exposure levels observed in panthers due to their endangered status.

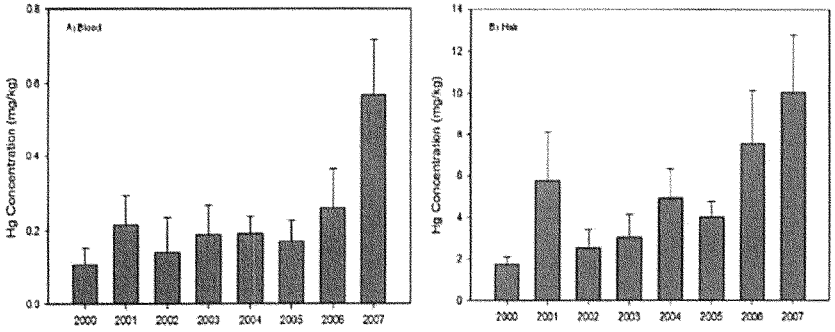


Figure 3B-3. Temporal variation in mercury concentrations [mean ± 1 standard deviation (SD), mg/L = ppm for blood; mg/kg = ppm for hair] in (A) blood and (B) hair of Florida panthers collected from 2000–2007 in Big Cypress National Preserve (BCNP), south of I-75 (figure from Brandon et al., 2009).

BURMESE PYTHON

The Burmese python (*Python molurus bivittatus*) is native to Southeast Asia and has been exported to the United States for the pet trade and ultimately released into the wild. These snakes thrive in the subtropical South Florida climate. Other species of pythons have been found in Florida, but the Burmese python is the only species that has been confirmed to breed in the wild (Harvey et al., 2008). Due to increases in their populations, state and federal agencies are working to control pythons. The Burmese python is a priority invasive species under the Research Coordination Verification and Assessment program of the Comprehensive Everglades Restoration Plan (see Chapters 6 and 9 of this volume). In January 2008, the FWC established a list of Reptiles of Concern (ROC) for nonnative species which includes pythons. In July 2009, a permit program was initiated to allow hunting of ROCs in FWC-managed areas. There is concern, however, that hunters may consume the python meat, which has high concentrations of mercury.

Mercury data were collected from 24 Burmese pythons in the ENP from 2006–2009 by the U.S. Geological Survey (Krabbenhoft, unpublished data). The mean THg concentration in muscle tissue of 3.6 ppm (range: 0.14–10.75 ppm) was significantly higher than in fish and alligators within the ENP (**Figure 3B-4**) and showed no relationship to python size. Most of the mercury burden in pythons appears to be in the methylated form, with an average MeHg fraction of 80 percent in 11 co-sampled individuals (range: 67–96 percent). Analysis of the digestive tracts of captured pythons in Florida show some of the species consumed are raccoons, wading birds, and alligators (Snow et al., in press), which could account for the high concentrations of mercury since all of these species are fish-eating. Continued monitoring of mercury in captured pythons is planned by the National Park Service (NPS) and FWC.

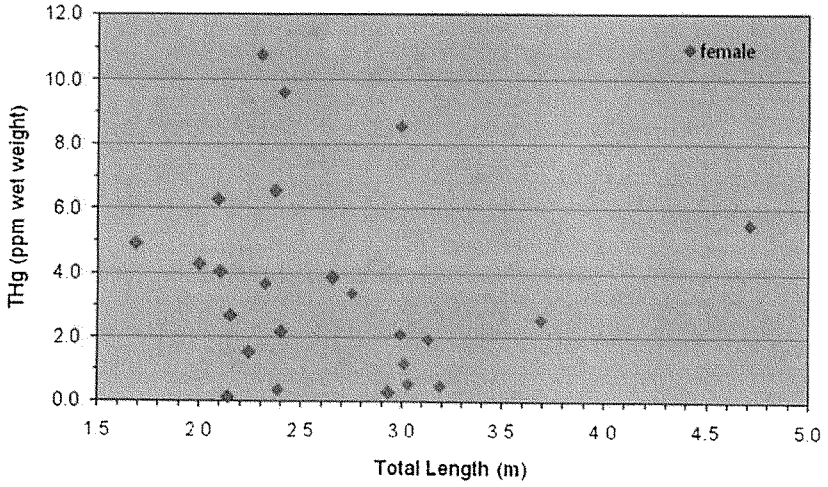


Figure 3B-4. Mercury concentrations (ppm) with size (total length) in Burmese pythons collected in Everglades National Park (ENP or Park) from 2006–2009 (figure from D. Krabbenhoft, U.S. Geological Survey, personal communication).

FISH IN THE EVERGLADES PROTECTION AREA

Largemouth bass (LMB) (*Micropterus salmoides*) were collected from the EPA and other South Florida sites during the current-year sampling period from July 2009 through June 2010 using direct-current electro-fishing equipment (**Figure 3B-5**). The same methods were used to collect LMB from downstream receiving waters of the EPA and STAs and are reported in Appendices 3B-1 and 5-5 of this volume, respectively.

In the laboratory, LMB were weighed, measured, sexed, and the sagittal otoliths were removed for determination of age as described by Taubert and Tranquilli (1982). An entire skinless axial muscle fillet was homogenized and an aliquot submitted to the FDEP Central Laboratory in Tallahassee where THg determinations were made using USEPA Method 245.6 (Mercury in Tissues by Cold Vapor AAS). The minimum detection limit (MDL) was 0.02 ppm.

A subset of samples was analyzed by the SFWMD using USEPA Method 7473 (Mercury in Solids and Solutions by Thermal Decomposition, Amalgamation, and Atomic Absorption Spectrophotometry). The MDL was 0.005 ppm. A portion of the samples were analyzed by both methods and evaluated to determine comparability. All results are reported as THg on a wet-weight basis as micrograms per gram (µg/g) (1 µg/g = 1 ppm). Because more than 85 percent of the mercury found in top-level predatory fish such as LMB is in the form of MeHg (Grieb et al., 1990; Bloom, 1992). The assumption is made that THg is equal to MeHg concentration in LMB samples.

Figure 3B-5. Fish collections within the Everglades Protection Area (EPA) typically are conducted in open marsh, along airboat trails, and in canals using direct-current electro-fishing equipment mounted either on an airboat or jon boat (photos by the FWC).

Monitoring of mercury in LMB tissue from the Everglades integrates spatial and temporal exposure to MeHg. This is particularly relevant where LMB can move over large areas in response to changes in hydroperiod, with prey selection varying between habitats (i.e., canal or marsh). Mercury levels in LMB are also reflective of variations in fish size and age, population turnover, trophic position, and trophic exchange rates. Using relatively long-lived LMB as a monitoring tool is a distinct advantage because these fish accumulate high concentrations of mercury over their life span, thus allowing detection of concentration gradients within their feeding ranges. LMB are also readily available throughout the Everglades, have well understood feeding ecology and life histories, and are directly relevant to public health policy.

To eliminate redundancy, regional trends in LMB THg concentrations are reported and site-specific trends are referenced when necessary from Appendices 3B-1 and 5-6 of this volume. The only exception is that trends from the Holey Land WMA, represented by only one site, are reported in this chapter (see Appendix 3B-1).

From July 2009 through June 2010, 183 LMB were collected from the WCAs, 40 were collected from Shark River Slough in the ENP, 20 were collected from Holey Land WMA, 20

from STA site, STA1WC3, and 40 from the Kissimmee Chain of Lakes (KCOL). Data for 5,281 LMB collected from 1989–2010 are summarized by region to compare and contrast trends in mercury concentrations within the EPA, STA-1W, and the Northern Everglades (represented by the KCOL). Single-year data (2009–2010 sampling period) are briefly summarized in the *Fish in the Greater Everglades* section of this chapter and in Appendix 3B-1 of this volume.

Comparisons were made among five regions, from south to north, including Shark River Slough in the ENP (SHARK region); WCA-1, WCA-2, and WCA-3 within the EPA (WCA region); STA-1W, Cell 3 (STA1W region); Holey Land Wildlife Management Area (HOLEY region); and from the Northern Everglades, three lakes within the KCOL, including Lakes Kissimmee, Tohopekaliga, and East Tohopekaliga (KISS region) (**Table 3B-4**). Site locations for long-term monitoring sites are presented in **Figure 3B-6**.

Table 3B-4. Description and period of record (POR) for fish collection sites within each region. Sampling events typically represent one collection each year per region, but may vary.

Region	Site Names	Description	Site POR	Sampling Events	# LMB
Stormwater Treatment Area 1 West (STA-1W)	ENR012	Both sites located within Cell 3 of STA1W	1995–2009	15	492
	ENR302		1995–2009		
Holey Land WMA	HOLEY (in the north borrow canal)	Holey Land Wildlife Management Area	1990–2009	15	284
Shark River Slough	ENPNP	Both sites are within Shark River Slough in ENP	1993–2010	19	529
	L67X		1989–2009		
Water Conservation Areas	WCA-1	11 canal and marsh long-term monitoring and 42 random sites within WCAs 1, 2, and 3	1989–2009	21	3,173
	WCA-2		1989–2009		
	WCA-3		1989–2009		
Northern Everglades [Kissimmee Chain of Lakes (KCOL)]	LK Kissimmee	Lake samples	1989–2006	21	803
	LK Tohopekaliga		1989–2010		
	E. LK Tohopekaliga		1989–2010		

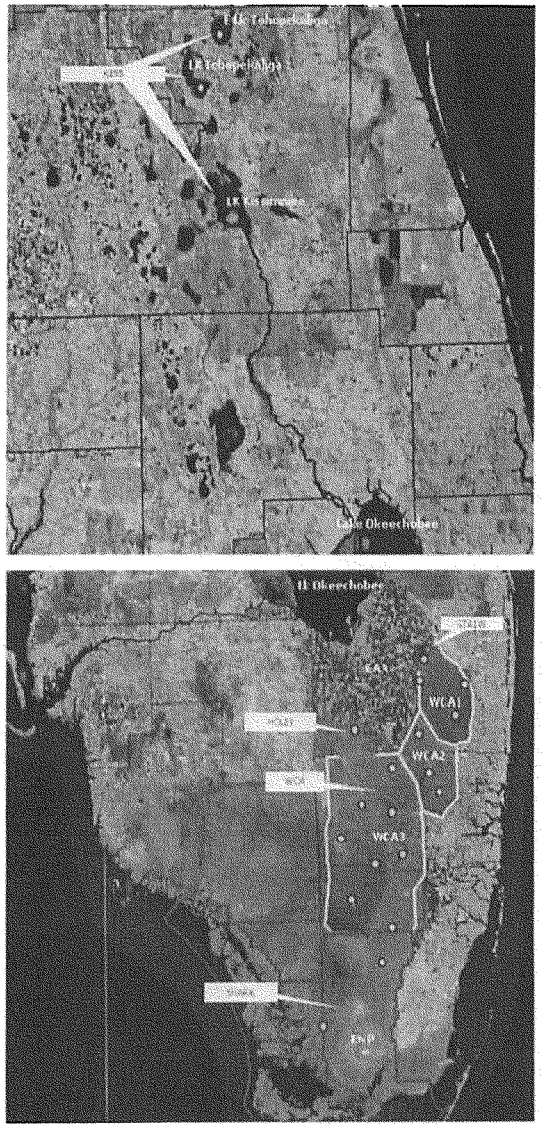


Figure 3B-6. Regional boundaries for annual LMB median THg concentrations indicating location of long-term monitoring sites (o) for region KISS in the Northern Everglades (top) and regions STA-1W, HOLEY, WCA, and SHARK in the Southern Everglades (bottom). [Note: Less frequently sampled locations are not shown.]

Regional LMB THg concentrations were normalized to a standard fish length in this year's report. Because THg concentrations in LMB vary with size and age (Wiener et al., 2006; Lange et al., 1994) and because size distributions, sex, and collection date vary among sites, THg concentrations in individual LMB were normalized by dividing the THg value by fish total length (TL) in millimeters (mm). Moreover, in order to relate the resultant concentration to a human health end-point, the value (ppm/mm) was multiplied by 356 mm (14") to represent the upper range of the legal LMB size range available for harvest by anglers. In the Everglades region, anglers are allowed to harvest up to five LMB up to 14" TL as well as one fish exceeding 14" per day; however, most LMB exceeding 14" are voluntarily live-released.

For previous SFERs, normalization of mercury concentrations by fish age proved to be a successful method to assess spatial and temporal distributions of LMB THg concentrations in Florida (Lange et al., 1993 and 1994; Gabriel et al., 2010b), because this reduced the influence of sexually dimorphic growth on mercury bioaccumulation rates between male and female LMB (Lange et al., 1994). Normalization by regressing mercury with age is desirable when assessing trends among individual sites, but TL data were both more readily available and better for assessing trends. Using TL enables use of all available data to assess trends across multiple sites within a region where age-standardization would not provide a link to size-specific human health criteria. While annual medians for TL normalized data were highly correlated with non-normalized data (**Figure 3B-7**), TL normalized data provide a link to a measurable human health end-point and better describe differences in THg concentrations among regions.

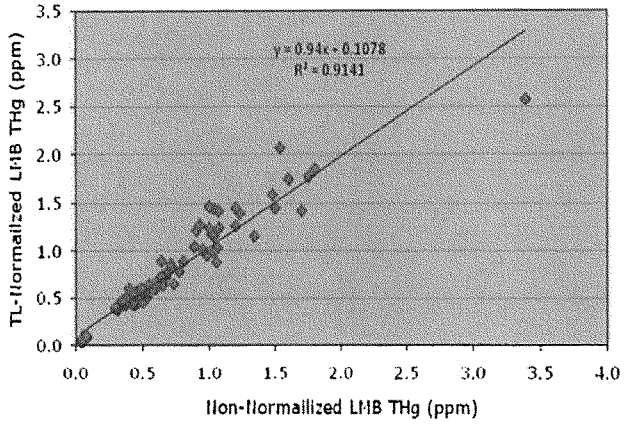


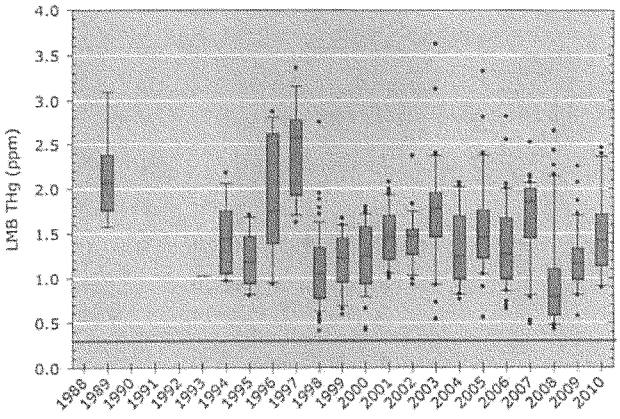
Figure 3B-7. Relationship between annual regional median non-normalized and normalized THg concentrations for largemouth bass (LMB) (*Micropterus salmoides*) collected during sampling events from 1989–2010.

LMB have been collected for mercury analyses from two sites, L67F1 and ENPNP in Shark River Slough almost yearly since 1989 (**Figure 3B-8**). Regional medians in the slough remain elevated over other areas within the EPA, making Shark River Slough a significant mercury hot spot; levels continue to exceed the 0.3 ppm USEPA MeHg criterion for the protection of human health. The median THg concentration peaked in 1997 at 2.58 ppm (range: 1.63–3.36 ppm; n = 14) and was 1.43 ppm (range: 0.89–2.46 ppm; n = 20) in 2010; however, the 2010 median represents a short-term (two-year) increase of 80 percent from a median of 0.79 ppm in 2008. Although annual median LMB mercury concentrations have varied over the short term in Shark

River Slough, seasonal Kendall analysis found no significant ($r = -0.018$; $p = 0.9164$) trends over the entire period of record (POR) indicating continued conditions favorable to MeHg production and bioaccumulation.

Similarly, across the EPA, near maximal cumulative mean THg concentrations in mosquitofish (*Gambusia holbrooki*), sunfish (*Lepomis* spp.), and LMB have been found at site L67F1 in the upper reaches of Shark River Slough (see Appendix 3B-1 of this volume). Maximal mosquitofish THg concentrations occurred in central Shark River Slough during wet seasons in 1995 and 2005 (USEPA, 2001b; Scheidt and Kalla, 2007). In contrast, aqueous MeHg concentrations in Shark River Slough tend to be lower than most other areas of the EPA (USEPA, 2001b; Scheidt and Kalla, 2007). While across much of the EPA, mercury levels in epiphytic periphyton were strongly related to mercury uptake in mosquitofish, in a core area of Shark River Slough, a strong relationship was found between aqueous MeHg and uptake in mosquitofish (Kalla et al., 2008) suggesting a mechanism for the high bioaccumulation factors in this area (USEPA, 2001b).

Within the wetlands of Shark River Slough, dissolved organic carbon (DOC) concentrations are variable in response to dry/rewet cycles (Scheidt and Kalla, 2007); however, DOC levels are generally low compared with the rest of the EPA. Dry/rewet cycles, common seasonally in the region, have been demonstrated to temporarily increase production of sulfate (Orem et al., 2008) and release labile carbon and sediment-bound inorganic mercury (Krabbenhoft and Fink, 2001) to stimulate MeHg production. Wet season deposition of inorganic mercury would additionally increase substrate for MeHg production and perhaps provide the seasonal pulses of bioavailable MeHg necessary to drive short-term variations in LMB THg concentrations. Although LMB integrate MeHg over a protracted period of time [LMB here normalized to TL = 14" (356 mm), mostly age class 2 and 3 in the ENP], pulses of aqueous MeHg have been shown to move quickly (< 1 yr) through the food web into high trophic level fish (Krabbenhoft and Fink, 2001; Rumbold and Fink, 2006).



Box plots represent the median, 25th and 75th percentiles, whiskers the 10th and 90th percentile; and points are outliers. The 0.3 ppm U.S. Environmental Protection Agency (USEPA) methylmercury (MeHg) criterion is indicated in red.

Figure 3B-8. Annual summaries of mercury concentrations [normalized to total fish length = 356 millimeters (mm)] for LMB collected from sites L67F1 and ENPNP in Shark River Slough within the ENP from 1989–2010.

In addition to LMB, several other species of fish found within Shark River Slough exceeded the USEPA MeHg criterion for the protection of human health (USEPA, 2001a). The FDOH continues to issue no-consumption advisories for LMB, common snook (*Centropomus undecimalis*), spotted sunfish (*Lepomis punctatus*), and yellow bullhead (*Ameiurus natalis*). The FDOH further recommends limited consumption of redear sunfish (*L. microlophus*), bluegill (*L. macrochirus*), and the nonindigenous Mayan cichlid (*Cichlasoma urophthalmus*) from Shark River Slough waters (FDOH, 2009). Mercury bioaccumulation in Shark River Slough appears to be elevated over other areas of the ENP (Axelrad et al., 2009), but the entire Park is subject to advisories urging limited consumption of fish. The impacts of mercury on estuarine species in downstream reaches of Shark River Slough and into the Gulf of Mexico are uncertain because the processes affecting bioaccumulation of mercury are not well understood.

In the WCAs, a total of 3,173 LMB were collected from 53 sites over the POR (1989–2009) (see **Table 3B-4**). Long-term monitoring locations within the WCAs are shown in **Figure 3B-6**. Annual mercury medians in LMB have varied over the POR but have generally declined from a maximum of 1.59 ppm in 1991 to a minimum of 0.40 ppm in 2001, representing a 75 percent decline (**Figure 3B-9**). By 1998, median concentrations in LMB across the WCAs stabilized, and have varied little since then (range: 0.40–0.61 ppm). Over the entire POR, seasonal Kendall analyses indicate a significant ($r = -0.63810$; $p < 0.001$) decline in THg levels in LMB with an overall decline of 62 percent since 1991.

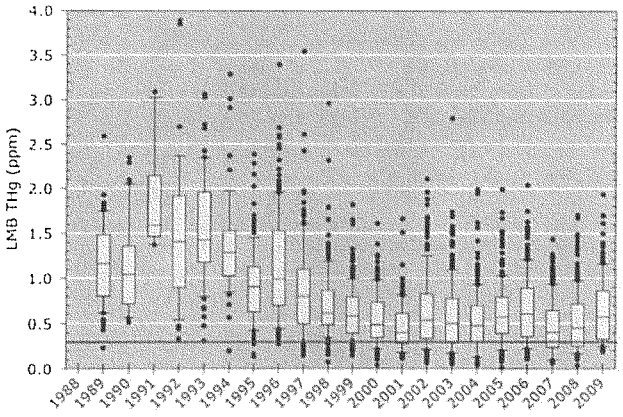
Based on extensive surveys in 1995 and 1996, the USEPA (1998) identified several hot spots where THg levels in mosquitofish were almost twofold higher than the Greater Everglades basinwide average. One of these MeHg hot spots, site CA315 within WCA-3A, received focused attention for a decade in order to better understand system controls on MeHg production and bioaccumulation.

Declines in sulfate concentrations in the WCAs during the late 1990s likely resulted in rapid declines in MeHg production and concomitant declines in fish THg concentrations (USEPA 2001b and 2007; Kalla et al., 2010; Krabbenhoft et. al, 2010). However, other factors affecting temporal and spatial patterns of MeHg production and THg bioaccumulation in fish are likely important in explaining the smaller variations in LMB mercury levels detected since 1998.

For example, spatial patterns of fish THg concentration within the WCAs have shifted as concentrations in fish representing three distinct trophic levels (mosquitofish, sunfish, and LMB) from site WCA2U3 (farther upstream) now exceed those from CA315 (see Appendix 3B-1 of this volume). In addition, within WCA-2, divergent trends in fish THg are evident. At site WCA2U3 (farther downstream), these three fish species have shown recent THg increases, while at the same time declines were observed for the same species at site CA2NF. These divergent trends occurred within WCA-2, but at sites with different nutrient inputs, hydrologic regimes, and food web structures. The influence of food web dynamics, water quality, sediment parameters, and hydrologic regimes on MeHg production and bioaccumulation are slowly being resolved (USEPA, 2007; Kalla et al., 2010; Krabbenhoft et al., 2010) to further elucidate their influence on MeHg production and bioaccumulation in fish.

Not only have median LMB THg concentrations declined as a whole across the WCAs, but the number of individual LMB exceeding 2 ppm decreased from 56 for POR 1988–2000 to only three for POR 2001–2009 (**Figure 3B-9**). The maximum LMB mercury concentration in individual, legally harvestable fish has decreased over time, ranging from 3.89 ppm (from canal site L67A in 1992) to 2.8 ppm (from canal site L35B in 2003). Nonetheless, median concentrations of mercury in LMB continue to exceed the USEPA human-health fish tissue criterion (USEPA, 2001). From 2001–2009, over 58 percent of all LMB ($n = 1,306$) exceeded that criterion in the WCAs (**Figure 3B-10**). The WCAs provide important fishing opportunities within the Francis S. Taylor WMA (WCA-2 and WCA-3) and within Arthur R. Marshall

Loxahatchee National Wildlife Refuge (which contains WCA-1) for both LMB and other sport fish. The FDOH has issued advisories for LMB and eight other species of fish, recommending limited or no consumption of fish caught from the WCAs (FDOH, 2009). Due to (1) continued high rates of atmospheric deposition of mercury, (2) the rich, organic soils, and (3) sulfate enrichment, mercury remains a water quality concern in the WCAs.



Notes: Box plots represent the median, 25th and 75th percentiles; whiskers the 10th and 90th; and points are outliers. The 0.3 ppm USEPA MeHg criterion is indicated in red.

Figure 3B-9. Annual pooled summaries of Hg concentrations (normalized to total fish length = 356 mm) in LMB collected from canal and marsh sites in WCA-1, WCA-2, and WCA-3 from 1989–2009.

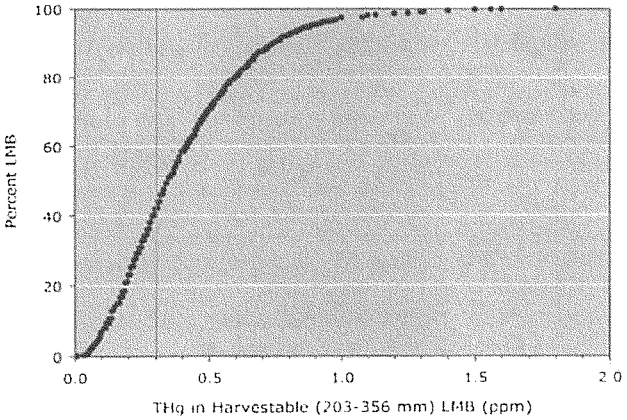


Figure 3B-10. Cumulative distribution of harvestable size LMB [203–356 millimeter (mm) length] collected from WCAs 1, 2, and 3 during 2001–2009. Fifty-eight percent of all LMB exceeded the USEPA human health criterion of 0.3 ppm (red line).

FISH IN THE GREATER EVERGLADES

LMB THg concentrations trends outside the EPA have been determined for sites in STA-1W (Cell 3), Holey Land WMA, and the KCOL (see **Figure 3B-6**). Sites in STA-1W and the Holey Land WMA are located interior to hydrologically managed wetlands adjacent to the WCAs, while the KCOL represent three long-term datasets from the Northern Everglades.

The two sample sites representing STA-1W (sites ENR003 and ENR012; see Gabriel et al., 2009 for site descriptions) were not significantly different in LMB THg concentrations when compared among years (paired t-test, $p > 0.05$); therefore, data were pooled to represent STA-1W, Cell 3. In general, LMB from the interior cells of STA-1W have had the lowest concentrations of THg among all of the STAs since inception. Of a total of 492 LMB collected for POR 1995–2009, only five exceeded the USEPA criteria for the protection of human health. Median THg concentrations varied little during the POR with annual medians ranging from 0.04–0.11 ppm and no trends evident (**Figure 3B-11**). There were concerns that the Everglades Nutrient Removal Project, the precursor to STA-1W, would promote high rates of mercury methylation and bioaccumulation due to inundation of organic-rich soils, suggested by previous studies of newly created reservoirs (Abernathy and Cumbie, 1977; Bodaly et al., 1984; Verdon et al., 1991). Ultimately, the man-made wetland functioned as a mercury sink, removing about 70 percent of the inflow mass (Miles and Fink, 1998; Rumbold and Fink, 2006).

In contrast, in 2000, Cell 1 in the newly constructed STA-2 exhibited anomalously high MeHg concentrations in fish and water soon after start-up (Rumbold and Fink, 2006). Water flow rate and depth were managed as a means to alter sediment biogeochemistry and reduce in situ mercury methylation. Management included drying the marsh to prevent bioaccumulation in predatory fish and to reduce foraging by wading birds, followed by maintaining deeper water levels to reduce oxygen levels in bottom waters, reducing the production of sulfate and mercury methylation within surficial sediments. The exact biogeochemical mechanisms surrounding these anomalously high MeHg concentrations in STA-2, Cell 1, are not fully understood, but the series of operational steps taken highlight the difficulties of managing the STAs for MeHg.

Trends within the Holey Land WMA are represented by a single canal site that is hydrologically connected to wetlands where average wet season water levels have been maintained approximately 0.3 meters lower than they were in the early 1990s when LMB collections began (see Appendix 3B-1 of this volume).

Although median THg concentrations have not changed drastically over the POR at site HOLEY, a strong upward gradient occurred during 1998–2006, when median LMB THg concentrations increased from 0.40 ppm (range: 0.11–0.80 ppm, $n = 20$) to 0.96 ppm (range: 0.67–1.30 ppm, $n = 20$) (**Figure 3B-12**). The effects of decreased water depths and more frequent drying and re-flooding cycles on bioaccumulation of mercury are unknown; however, median LMB THg concentrations have decreased in each of the last three years (2007–2009), while water level regimes have not changed. Similarly, mosquitofish and sunfish THg concentrations decreased 49 and 6 percent, respectively, from 2008 to 2009 (see Appendix 3B-1 of this volume).

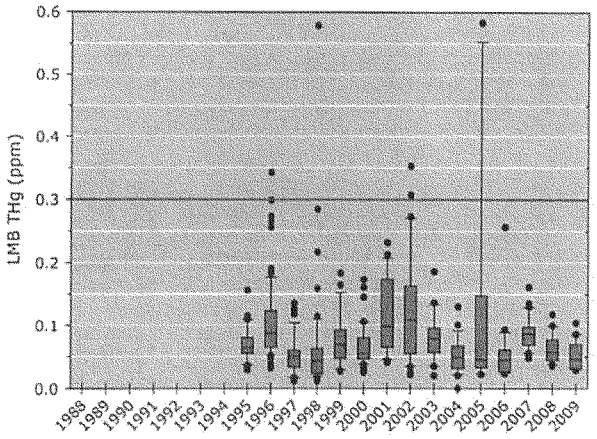


Figure 3B-11. Annual summaries of mercury concentrations (normalized to total fish length = 356 mm) in LMB collected from sites ENR003 and ENR012 in STA-1W, Cell 3, from 1995–2009.*

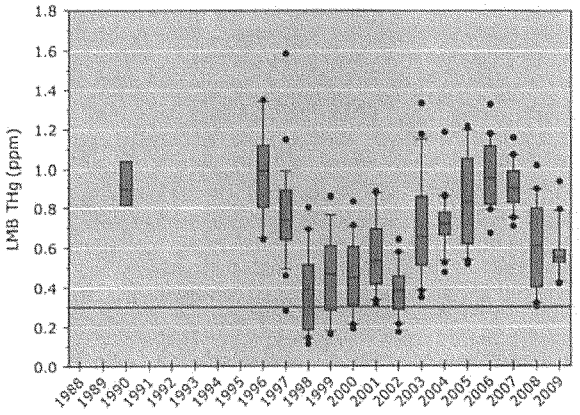
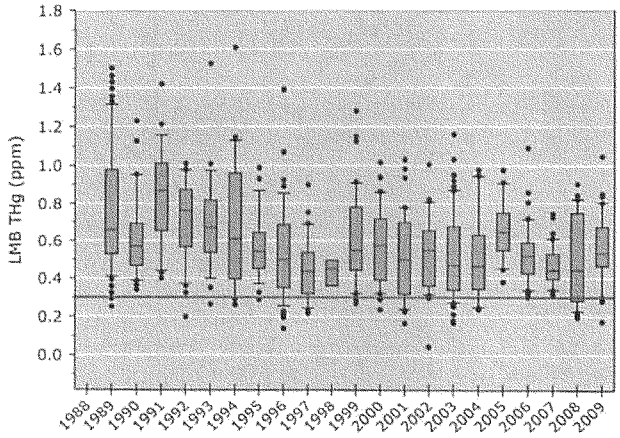


Figure 3B-12. Annual summaries of mercury concentrations (normalized to total fish length = 356 mm) in LMB collected from the north borrow canal (site HOLEY) within Holey Land WMA from 1990–2009.*

*Box plots represent the median, 25th, and 75th percentile; whiskers the 10th and 90th; and points are outliers. The 0.3 ppm USEPA MeHg criterion is indicated in red.

In the Northern Everglades region, mercury continues to be a significant water quality issue. The FDEP lists 11 water bodies within the Kissimmee Basin as impaired due to mercury, and the FDOH (2009) has advisories recommending limited consumption for 12 species of fish in the KCOL. The FDOH further advises that anglers not consume LMB from several lakes not part of the KCOL but that are within the Kissimmee Basin, including the Kissimmee River. Previous SFERs (e.g., Gabriel et al., 2010a) listed a range of THg data for various sport fish from 13 lakes and the Kissimmee River. For this year's report, data from 803 LMB collected in 21 sampling events from 1989–2010 are summarized as pooled annual medians for Lakes Kissimmee, Tohopekaliga, and East Tohopekaliga (part of the KCOL) to provide insight into temporal trends and to contrast to mercury concentration levels within the (downstream) EPA.

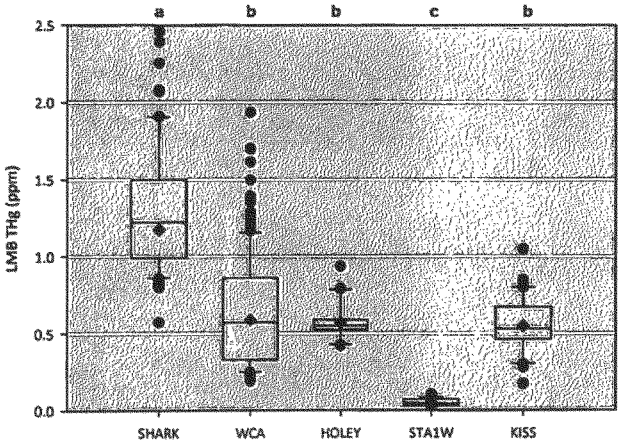
Median THg concentrations were maximal during initial sample collections within the Northern Everglades region. In 1991, the median was 0.87 ppm (range: 0.40–1.42 ppm, n = 29) and declined steadily to the lowest level in 2008 with a median of 0.44 ppm (range: 0.20–0.90 ppm, n = 40), a 49 percent decrease (**Figure 3B-13**). A seasonal Kendall analysis indicated a significant (r = -0.448; p = 0.005) 14 percent decline in THg concentrations in LMB. Although this trend seems promising, as of 2009, THg levels in LMB and other large-bodied piscivorous fish remain at or above the USEPA MeHg criterion for the protection of human health throughout the entire Kissimmee Basin.



Box plots represent the median, 25th and 75th percentile; whiskers the 10th and 90th; and points are outliers. The 0.3 ppm USEPA MeHg criterion is indicated in red.

Figure 3B-13. Annual pooled summaries of mercury concentrations (normalized to total fish length = 356 mm) in LMB collected from Lakes Kissimmee, Tohopekaliga, and East Tohopekaliga from 1989–2009.

Shark River Slough in the ENP has replaced site CA315 as the most significant Everglades mercury hot spot (see the *Fish in the Everglades Protection Area* section of this chapter). In spite of Shark River Slough having aqueous MeHg concentrations up to 60 times lower than in areas to the north in the WCAs (USEPA, 2001b), Shark River Slough LMB were significantly higher in THg ($p < 0.05$) than LMB in all other regions in 2009. Similar to previous years, a south-to-north, high-to-low gradient in THg in LMB was evident with significant differences [analysis of variance (ANOVA); $F_{4,298} = 59.40$; $p < 0.001$] observed among regions within the Greater Everglades (**Figure 3B-14**). Shark River Slough had significantly higher (t-statistic = 6.750 to 15.098; $p < 0.001$; df = 4) and STA-1W, Cell 3, significantly lower (t1 = 7.230 to 15.098; $p < 0.001$; df = 4) THg in LMB than the WCA and Holey Land WMA regions. The lakes tested within the Northern Everglades region were intermediate in THg levels.



Note: Adjusted least square means are indicated in red and are not significantly different when letter designations are the same (analysis of variance).

Figure 3B-14. LMB median mercury concentrations from Shark River Slough (SHARK), WCAs 1, 2, and 3 (WCA), Holey Land WMA (HOLEY), STA-1W, Cell 3 (STA1W), and Northern Everglades (KISS) regions during the 2009–2010 sampling period.

EVERGLADES SULFUR LEVELS, SOURCES AND EFFECTS

Elevated concentrations of both mercury and sulfur are evident in the Everglades, with mercury sourced predominantly from atmospheric deposition, and sulfur probably from agricultural activities. Excessive mercury levels in high trophic level Everglades fish are related to elevated sulfur concentrations; naturally occurring sulfate reducing bacteria convert inorganic mercury into MeHg.

Evaluating the efficacy of reducing sources of sulfur to the Everglades as a means of reducing mercury in fish is an important step in water quality restoration efforts. Mercury atmospheric deposition to South Florida remains high relative to that for most of the United States. (NADP, 2010); however, this deposition is now predominantly from global (international) rather than local (within Florida) sources (Atkeson et al., 2005; Axelrad et al., 2007 and 2008; Pollman et al., 2007). Since reducing global mercury sources is not feasible in the short term, reducing sulfur loading to the Everglades from agricultural activities (Axelrad et al., 2007 and 2008; Gabriel et al., 2008 and 2010a; Orem et al., in press), may be the most practical means of lowering MeHg levels in Everglades fish.

Sulfate originating from the Everglades Agricultural Area (EAA) may be stimulating MeHg bioaccumulation in EPA fish. Beyond mercury methylation, sulfur is a concern because (1) as sulfate or sulfide it affects the biogeochemical cycling of numerous elements, and may promote the release of phosphorus (a nutrient of concern) from sediments; and (2) as sulfide, it is toxic to aquatic plants and animals.

EVERGLADES MERCURY CONCENTRATIONS LINKED TO SULFUR

In the 1980s, Florida state agencies monitoring mercury levels in freshwater fish state-wide, were surprised to find that of 80 Florida water bodies monitored for mercury through LMB sampling, the Everglades had the highest mercury concentrations. Largemouth bass in the central Everglades (WCA-3) had mean values of 2.7 ppm THg (Ware et al., 1990). For water bodies without direct input of mercury from industrial activity or mining runoff, this mercury level in Everglades fish was among the highest reported in fresh waters worldwide.

At the time, this finding of high mercury concentrations was puzzling because the Everglades is relatively distant from industrial activity. However, it was quickly determined that the mercury sourced to the Everglades was almost entirely (> 95 percent) from wet (rain) and dry (particulate mercury) atmospheric deposition (Landing et al., 1995; Pollman et al., 1995; Stober et al., 1996, 1998, and 2001; Guentzel, et al., 1998 and 2001).

Consequently, in the early 1990s, pollution controls were implemented on emissions to the atmosphere from South Florida municipal waste combustors and medical waste incinerators. Mercury levels in fish subsequently declined substantially (about 60 percent to date) in Everglades WCAs (Gabriel et al., 2010a; see also the *Fish in the Everglades Protection Area* section of this chapter). To date, mercury levels in Everglades LMB remain generally higher than the USEPA MeHg fish tissue criterion (0.3 ppm MeHg) for protection of human health from consumption of fish. In addition, mercury levels in Everglades fish also pose risks to fish-eating wildlife (Rumbold et al., 2008; see also the *Mercury in Everglades Wildlife and Fish* section of this chapter).

Despite some mercury concentration declines, mercury-in-fish hot spots (THg > 1 ppm in LMB) remain, and these areas have shifted around in the Everglades over time, possibly more as a consequence of changing biogeochemistry than a changing rate of atmospheric deposition of mercury (Axelrad et al., 2005).

A second surprise regarding Everglades water quality was the discovery of high levels of sulfur in surface waters and sediments (Orem et al., 1997). U. S. Geological Survey (USGS) investigators sampling at a site in WCA-2A in the mid-1990s were struck by the strong "rotten egg" odor of hydrogen sulfide. High concentrations of hydrogen sulfide are unusual for freshwater wetlands — this is more characteristic of marine or estuarine systems with low dissolved oxygen concentrations. It was also evidence of microbial sulfate reduction.

Because sulfate-reducing bacteria (SRB) are important biomethylators of mercury, microbial sulfate reduction is clearly linked to mercury levels in fish (Compeau and Bartha, 1985; Ekstrom et al., 2003; Gilmour et al., 2004). Methylation of mercury produces MeHg, which is more toxic and bioaccumulative than inorganic mercury (Driscoll et al., 2007; Munthe et al., 2007). Therefore, the rate of mercury methylation by naturally occurring SRB is an important determinant of MeHg levels in fish. The MeHg in fish represents the dominant mercury threat to humans and wildlife that eat fish.

The balance between sulfate and sulfide is a key control on net mercury methylation rate in most ecosystems, including the Everglades. Sulfate stimulates methylation of mercury by SRB, but sulfide created from the reduction of sulfate leads to the formation of mercury-sulfur complexes that are less bioavailable for uptake and methylation by SRB (Benoit et al., 1999a; 1999b; King et al., 2001).

When sulfate is the limiting factor for sulfate reduction (as it is in the Everglades), the activity of SRB and the concomitant production of sulfide is a linear function of sulfate supply. However, most of the sulfide produced from sulfate reduction is rapidly bound up in organic matter and/or iron sulfides in sediments. Therefore, porewater sulfide concentrations are generally well below porewater sulfate concentrations. In the Everglades, organic matter is the main sink for sulfide. The balance between the activity of SRB and the resultant concentration of free sulfide in porewaters in an important control on MeHg production. The activity of SRB increases linearly with sulfate supply, while the bioavailability of mercury decreases with increasing sulfide (Munthe et al., 2007). Studies have shown positive correlations between MeHg production and surface water sulfate concentrations in the WCAs up to 20 ppm sulfate (Gilmour et al., 2007a); at porewater sulfide concentrations >1 ppm, sulfide becomes inhibitory to MeHg production (Orem et al., in press.) Raising sediment porewater sulfide concentrations beyond this in order to repress mercury methylation is, however, not an acceptable strategy, as sulfide may be toxic to Everglades flora and fauna (Li et al., 2009; Orem et al., in press; USEPA, 1986).

ENVIRONMENTAL SULFUR EFFECTS

The existing high level of sulfate loading to the Everglades is important because sulfur has myriad impacts on the ecosystem beyond stimulating the production of MeHg. Sulfide is toxic to aquatic plants (Mendelssohn and McKee, 1988; Koch and Mendelssohn, 1989) and animals (National Research Council, 1979). Because SRB are primarily responsible for producing MeHg from atmospherically deposited inorganic mercury, sulfur contamination has increased MeHg levels in Everglades fish (Axelrad et al., 2007; Gilmour et al., 2007b, Gabriel, 2009). Concerning plants, Li et al. (2009) hypothesized that sulfide toxicity could, in part, be responsible for the replacement of sawgrass (*Cladium jamaicense*) by cattail (*Typha* spp.) in the Everglades. Further research is being conducted on this topic (see the *Phosphorus Mobilization and Plant Toxicity Effects in Mesocosms Amended with Sulfate, Calcium and Alkalinity* subsection of this chapter).

Sulfate, via internal eutrophication, may cause the release of phosphorus and nitrogen from wetland soils (Axelrad et al., 2007; Lamers et al., 1998; Smolders et al., 2006). There is preliminary evidence of sulfate-induced internal eutrophication in the Everglades (Gilmour et al., 2007a), and further research is being conducted on this topic (see the *STA/WCA Internal Eutrophication Study: Interim Findings* section of this chapter).

Recent data (Orem et al., 2010) from northwest WCA-2A indicate that surface water levels of undissociated hydrogen sulfide are many times higher than the USEPA's water quality criterion [2 micrograms per liter (µg/L) or parts per billion (ppb)] for protection of fish and other aquatic life (USEPA, 1986). This is consistent with hydrogen sulfide data from surface waters from WCA-2A as reported in 1997 by Orem et al.

Of these detrimental environmental effects of sulfur, it is likely that increased MeHg production occurs at lower sulfate concentrations than does sulfide toxicity or internal eutrophication. Accurate estimates of Everglades sulfur sources, fate, and transport are needed to determine if it is feasible to reduce sulfur loading to a level that would bring lower MeHg in Everglades fish (to acceptable levels).

THE EVERGLADES AGRICULTURAL AREA AS SULFUR SOURCE TO THE EVERGLADES PROTECTION AREA

The EAA is adjacent to and directly south of Lake Okeechobee, and borders the Water Conservation Areas to the south and southeast (see **Figure 3B-6**). The EAA comprises approximately 700,000 acres, with about 430,000 acres in crop production; 350,000 acres of this is sugarcane, the remainder is made up of vegetables, sweet corn, rice, sod, and plant nurseries (UF/IFAS, 2006). Historically, the EAA was part of the Greater Everglades, but has been farmed since the partial drainage of the Everglades in the early 1900s (UF/IFAS, 2006). In 1948, the EAA was specifically designated for agricultural use, under the U.S. Army Corps of Engineers' (USACE) Central and South Florida Flood Control Project.

Due to its hydrological connection to the Everglades, the EAA is now managed to minimize the effects of some agricultural activities on the ecosystem. The 1994 Florida Forever Act (Section 259.105, Florida Statutes) requires farming practices that minimize phosphorus levels in water discharged from farmland to the Everglades (see Chapter 4 of this volume). Phosphorus, while an essential nutrient for crop growth, in excess amounts can be harmful to the Everglades, perhaps most notably by eliminating calcareous periphyton and causing the replacement of native sawgrass with invasive cattails. In addition to EAA farming best management practices to minimize phosphorus pollution, 40,000 acres of constructed wetlands, the STAs, have been developed to remove phosphorus from farmland runoff before it can enter the Everglades (see Chapter 5 of this volume).

Agricultural Sulfur and Regional Concentration Gradients

Like phosphorus, sulfur is a plant nutrient, and it has several roles in EAA agriculture. Possibly the greatest use of sulfur in the EAA is as a soil amendment for pH adjustment (Boswell and Friesen, 1993). Elemental sulfur acidifies soil, and by reducing soil pH, it increases the availability of phosphorus and micronutrients (trace metals) for crops. When soil pH exceeds 6.6 standard units (SU), recommendations are to apply 500 pounds per acre (lbs/acre) for muck and sandy mucks, 300 lb/acre for mucky sands, and no sulfur for sands (Rice et al., 2006). Actual sulfur use in the EAA is estimated to be 30–100 lbs/ac every three years (Wright et al., 2008).

Concentration gradients across the Southern Everglades implicate the EAA as the dominant source of sulfur to the ecosystem, though better identification and quantification of the underlying and proximate sources of sulfur in the EAA is needed. Everglades surface water sulfate concentrations follow a north-to-south gradient from the EAA to the freshwater ENP, with sulfate levels nearer the EAA often exceeding 100 times those in parts of the ecosystem further south and away from canal discharges (Bates et al., 2002; Gilmour et al., 2007b; Weaver et al., 2007).

Sulfate discharged from the EAA is not efficiently removed by the STAs since these constructed wetlands were created to reduce phosphorus entering the EPA (in large part through

uptake of phosphorus by plants). The STAs were neither intended nor designed to remove the much higher levels of sulfate from EAA runoff, so while STA removal efficiency for phosphorus is about 70 percent, it is only about 10 percent for sulfate (Pietro et al., 2009). This is because the mass of inflow of sulfate/sulfur to the STAs exceeds that of total phosphorus by 1,000 to 1, while as nutrients, sulfur and phosphorus are required by plants — such as those in STAs — in about a 1-to-1 ratio (Beaton, 1966; Tabatabai, 1984).

The disparity in sulfate versus phosphorus loading to the Everglades through the STAs is evident. While about 30 percent of the area of surface waters in the Everglades marsh exceed the 10 ppb total phosphorus water quality standard, about 60 percent of the Everglades marsh exceeds the 1 ppm (1,000 ppb) sulfate/sulfur Comprehensive Everglades Restoration Plan goal (Scheidt and Kalla, 2007).

Sulfur concentration gradients and the extent of Everglades sulfur contamination have been documented by the USGS, the USEPA, and the SFWMD (Orem et al., 1997; Stober et al., 2001; Bates et al., 2001 and 2002; Scheidt and Kalla, 2007; Payne et al., 2009). Surface water sulfate concentrations in northern Everglades marshes can reach from about 40 to 70 mg/L in WCA-2 compared to $\leq$ 0.1 mg/L in parts of the ecosystem farther south and away from canal discharges (Bates et al., 2002; Orem, 2004; Gilmour et al., 2007a; Scheidt and Kalla, 2007). Sulfide in Everglades soil porewater shows a north-to-south gradient similar to that for sulfate in surface water, with extremely high sulfide concentrations in sediment porewater (up to 12,000 ppb) in the north and low concentrations (0.1 ppb) in the south.

Everglades Agricultural Area Sulfur Mass Balance and Soil Subsidence

There have been recent attempts at determining an EAA sulfur mass balance. Regarding agricultural applications of (elemental) sulfur in the EAA, Gabriel (2009) estimated that applications averaged 20 lbs/acre per year, based on a weighted mean of sulfur applied to various crop types. Wright et al. (2008) estimated agricultural applications at 33 lbs/acre per three years, based on the estimates of Schueneman (2001), which were derived from interviewing several EAA growers, as well as sellers of fertilizer in the EAA region. Oxidation of agricultural sulfur applied to EAA soils allows sulfate to be transported into EAA canals during rain events (Bates et al., 2002) from where it moves downstream to the EPA.

Another source of sulfur is oxidation of EAA soil (soil subsidence). Soil subsidence in the EAA occurs at an accelerated rate because these soils are highly organic and composed largely of decomposed sawgrass which accumulated under flooded, low-oxygen conditions over thousands of years. With the EAA being pumped dry to allow crop production (UF/IFAS, 2006), the resultant aerobic conditions led to the relatively rapid loss of organic matter in EAA soils via microbial oxidation, compared with the rate of soil loss in flooded and anoxic Everglades soils (Wright and Snyder, 2009). Gabriel (2009) reported that the EAA soil oxidation rate resulted in soil losses ranging from 0.5 to 1.5 inch/year, while Wright et al. (2008) and Wright and Snyder (2009) reported recent EAA soil oxidation rate to be about 0.5 inch/year. Schueneman (2001) also used the 0.5 inch/year soil oxidation rate for sulfur mass balance estimates. Similar to agricultural sulfur applications, soil subsidence (microbial oxidation of soil organic sulfur) also releases sulfate to the EPA via EAA canals during rain events.

Several EAA sulfur mass balance estimates vary as to their assessments of the relative importance of soil oxidation versus agricultural sulfur application as sources of sulfur to the Everglades. Gabriel (2009) estimated that sulfur released from EAA soil oxidation exceeded sulfur from agricultural application by a factor of 5, while Wright et al. (2008) estimated that ratio at 11, and Schueneman (2001) estimated the ratio at 15 (Gabriel et al., 2010a). Estimates vary

greatly because of uncertainties in the actual amounts of all forms of sulfur added to EAA soils, average sulfur contents, and oxidation rates of EAA soils.

The source of the sulfur in EAA soils has a bearing on potential options for reducing sulfur loading to the Everglades. Gabriel (2009) notes that total sulfur concentrations range from 0.1–5 percent in soils across the EAA. Organic sulfur, the largest fraction of the total sulfur in peat soils from the freshwater Everglades, accounts for 50–85 percent of the total sulfur at most locations (Altschuler et al., 1983; Bates et al., 1998; Ye et al., 2010a). Organic sulfur forms through the reaction of sulfide with soil organic matter, and thus it is plausible that some or even most of the organic sulfur in EAA peat soils results from the reaction of agricultural applications of sulfur with soil organic matter (Bates et al., 2002).

Results of isotope and other studies are consistent with the conclusion that agricultural sulfur applied to EAA soils is an important source of sulfur to the EAA soil organic sulfur pool. Sulfate from agricultural sulfur and soil oxidation (soil subsidence) enter the Everglades through canal discharge (Bates et al., 2002; Orem, 2004; Axelrad et al., 2007; Gilmour et al., 2007a; Gabriel et al., 2008).

In addition to agricultural sources within the EAA that create a high sulfur load in the region, Lake Okeechobee is a significant source of sulfur to the EAA (Gabriel et al., 2010a) even though it has annual average sulfate concentrations less than half of those in EAA canals (Bates et al., 2002). The lake receives sulfur from EAA backpumping, as well as from surface water runoff from upstream and adjacent agricultural lands (McCormick and James, 2008). Sulfur loading to the EAA from rainfall and groundwater are estimated to be low (Axelrad et al., 2007 and 2008; Gabriel et al., 2010; Gilmour et al., 2007a; Orem et al., in press).

Existing data support the hypothesis that the EAA is the principal source of sulfate to the Everglades, and that sulfur sourced from EAA agriculture, which includes new sulfur soil amendments plus sulfate released via oxidation of EAA soils (soil subsidence), is the principal source of sulfate to EAA canals that discharge to the EPA.

IMPACTS OF SULFATE LOADING TO NORTHWESTERN WATER CONSERVATION AREA 2A AND EVERGLADES NATIONAL PARK

In 2008, the USGS and other partners began examining the interactions of sulfate, mercury, and dissolved organic carbon (DOC) in northwestern WCA-2A and the ENP. This section describes the sampling and overall findings of these recent efforts.

Northwestern Water Conservation Area 2A

One area of the Everglades where sulfate loading has changed dramatically over the last decade is northwestern WCA-2A. Garrett and Ivanoff (2008) documented increased sulfate loading to this area due to the opening of STA-2 in July 2001. Historically, the northwest section of WCA-2A received water via the S-10E structure, but the structure was closed in 1997, causing rainfall to be the primary source of water to the northwest section of WCA-2A. Beginning in July 2001, treated water from STA-2 was released into the northwest section of WCA-2A. Prior to this opening, sulfate concentrations in northwestern WCA-2A ranged from 5–17 ppm, but concentrations since then have averaged about 61 ppm (Garrett and Ivanoff, 2008).

In 2009–2010, the USGS began an examination of the impacts of sulfate loading from canal water releases in the WCA (Orem et al., 2010). Sampling of surface water, porewater, and soil was conducted in August–September 2009 and February 2010, at the same sites used by Garrett and Ivanoff (2008). The observed sulfate levels ranged from 60–80 ppm in surface waters at the 10 sites, which is similar to values observed by Garrett and Ivanoff (2008). Sulfide levels in porewaters ranged from 7–6,000 ppb.

Sulfate loading stimulates microbial sulfate reduction, which results in increased sulfide levels in sediment porewater. The sulfide levels observed in northwestern WCA-2A were not high enough to be toxic to sawgrass (Li et al., 2009), but sulfide may increase to levels toxic to plants if the high sulfate loading rates to this area are maintained. Total sulfide levels in surface water ranged from 7–307 ppb, which is equivalent to about 3.5–153 ppb of undissociated hydrogen sulfide at the observed field-measured surface water pH (between 7 and 8 SU). All sites sampled in northwestern WCA-2A exceeded the USEPA surface water standard (2 ppb undissociated hydrogen sulfide) recommended to protect aquatic fauna and flora (USEPA, 1986).

THg levels in surface water ranged from 0.8–4.3 nanograms per liter (ng/L), typical of surface water levels throughout the ecosystem (Scheidt and Kalla, 2007). In contrast, MeHg levels in surface water in northwestern WCA-2A in 2009–2010 were elevated at some sites. MeHg levels ranged from 0.04–1.1 ng/L (mean and median of 0.33 and 0.22 ng/L, respectively), but with a number of sites having levels of MeHg > 0.4 ng/L. These high values likely reflect the production of MeHg due to enhanced rates of sulfate reduction. Sites with lower levels of MeHg tended to have higher sulfide levels, indicative of the balance between stimulation of mercury methylation by sulfate and inhibition by sulfide (Axelrad et al., 2007).

High levels of DOC are also present in northwestern WCA-2A, with concentrations in surface water ranging from 27–47 ppm. High DOC levels may be partly linked to the discharge of DOC-enriched canal water from STA-2, and partly due to sulfate enhancement of microbial organic matter decomposition. High DOC may enhance the methylation of mercury by complexing mercury, making it more bioavailable to methylating microbes. Studies are ongoing.

Everglades National Park

In October 2008 and 2009, the USGS and the NPS collaborated to sample 76 sites across the ENP for sulfur and mercury (Krabbenhoft et al., 2010). The objective was to examine whether there was any evidence to link canal water releases from the S-12 canal and the L67 terminus along the northern ENP boundary with water quality changes in the ENP. Since surface water releases generally follow the Shark River Slough, the hypothesis was that several water quality indicators would be correlated with canal water releases.

At each site, surface water and small fish were collected. Water samples were analyzed for general water quality parameters, sulfate, DOC, THg, and MeHg. Results from both years were similar. Compared to the other analytes, THg concentrations exhibit relatively little variability across the ENP, with modestly higher concentrations seen in the S-12 and L-31W canals and Shark River Slough. The relatively small amount of THg variability is likely due to the uniform deposition pattern of atmospheric mercury that occurs across the Everglades, as evidenced by the Mercury Deposition Network data (http://nadp.sws.uiuc.edu/mdn/; Krabbenhoft et al., 2008).

Methylmercury showed a different pattern, with elevated levels (generally 0.25–1.0 ng/L) observed in Shark River Slough. Much lower MeHg concentrations (generally less than 0.1 ng/L) are seen in areas of the ENP where the presence of canal water is not apparent (determined by sulfate and fluoride markers), such as the Rocky Glade area. Samples collected from the S-12/L-31W region generally show MeHg concentrations that are between levels from Shark River Slough and Rocky Glade. One of the most striking results from these two sampling efforts were those from the lower C-111 canal, which revealed some of the lowest MeHg levels ever observed by the USGS, and appear to be the result of abnormally (for the Everglades region) low DOC levels observed at this location. Much like the results from northwestern WCA-2A, there is a sulfate concentration optimum for mercury methylation in the ENP, though this occurs at lower sulfate concentrations than for WCA-2.

For the ENP dataset, low sulfate concentrations (less than 1 ppm) were associated with a substrate limitation response (meaning that mercury methylation by SRB was limited by the amount of sulfate), and high sulfate concentrations (greater than about 5 ppm) were associated with an inhibition effect, presumably due to sulfide accumulation in porewater, causing reduced mercury bioavailability. At mid-level sulfate concentrations (1–5 ppm), MeHg production appears to be maximal in the ENP. MeHg in mosquitofish tissue exhibited a spatial pattern that agreed very closely with the aqueous MeHg results.

In summary, results from this study suggest that MeHg production in the ENP reacts to sulfate loading similarly to previously studied regions of the Everglades, but with a different range of optimum sulfate concentrations (compared with WCA-1, WCA-2, WCA-3, and BCNP). Restoring water flow to the southern portions of the Everglades is a key goal of the restoration effort in South Florida, but surface water quality also needs to be considered when conducting a complete environmental benefit analysis.

ELEMENTAL SULFUR USE FOR SUGARCANE PRODUCTION IN THE EVERGLADES AGRICULTURAL AREA

As a result of the conversion of EAA lands from seasonally flooded wetlands to agricultural use, soil subsidence has occurred and continues at a rate of about 0.6 inches/year (Shih et al., 1998; Wright and Snyder, 2009). In 1912, much of the EAA had soils thicker than 120 inches. By 1988, only 17 percent of the EAA had soil thicker than 51 inches, while 53 percent had soils less than 36 inches thick, and 11 percent had soils less than 20 inches thick (Scheidt and Kalla, 2007).

After almost a century of farming in the EAA, the depth of soil has declined in some areas to the point where cultivation, specifically tillage, has resulted in the incorporation of EAA limestone-bedrock into peatland EAA soils. Sugarcane lands especially require multiple tillage applications before and during the growing season.

The limestone bedrock that underlies EAA soils is composed of calcium carbonate ($CaCO_3$), which has high pH when dissolved in deionized water. Incorporation of EAA $CaCO_3$ bedrock into EAA soils through tillage and as a result of declining soil depths has increased the soil pH over time (Snyder, 2005; Gabriel et al., 2008). These soil pH increases have decreased phosphorus and micronutrient availability to crops and may require new fertilizer management practices (Ye et al., 2010a, b).

Application of elemental sulfur (agricultural sulfur) to EAA soils has long been recommended as a means to reduce soil pH when it exceeds 6.6 SU, for purposes of lowering pH and improving the availability of soil phosphorus and micronutrients (trace metals) to sugarcane (Anderson, 1985; Schueneman, 2001). Recommendations are 300–500 lbs/acre of agricultural sulfur for highly organic EAA soils (Rice et al., 2006), although actual use is estimated at much lower rates (see the *Everglades Agricultural Area Sulfur Mass Balance and Soil Subsidence* section of this chapter). The natural microbial oxidation of the added elemental sulfur produces sulfate, reduces soil pH, and enhances phosphorus and micronutrient release from soil. This, in turn, increases phosphorus and micronutrient availability to crops, increasing plant productivity.

In response to increasing soil pH, elemental sulfur application to EAA soils is being evaluated for its current influence on soil chemical and microbiological properties (Ye et al., 2010a). During the first two months after application, sulfur additions at the highest rate, 400 lbs/ac, did increase phosphorus concentrations in the iron-aluminum-bound phosphorus fraction by 55 percent compared to unamended soils (Ye et al., 2010b). The stimulatory effects of this elemental sulfur addition on phosphorus release were quite limited however, possibly because the iron-aluminum-bound phosphorus fraction averaged only 4 percent of soil total phosphorus. Furthermore, the stimulatory effects did not last beyond two months. Similar to labile

phosphorus, water-extractable potassium and acetic-acid-extractable zinc increased by 71 and 134 percent, respectively, only during the first two months after adding elemental sulfur at the highest rates, then the stimulatory effects ceased (Ye et al., in press).

Similar to the effects on soil chemical properties, elemental sulfur promoted short-term changes in soil microbial activities. The activities of phosphatase and glucosidase in soils receiving 400 lbs/acre were 115 and 560 percent higher, respectively, than in unamended soils at two months (unpublished data). Microbial respiration and nitrogen and phosphorus mineralization rates were not affected by elemental sulfur amendment, suggesting that application under the current recommendations would not enhance soil subsidence and release rates of nitrogen and phosphorus.

Extractable sulfate in soils receiving 400 lbs/acre was 36, 131, 201, and 270 percent higher than unamended soils at 2, 6, 9, and 13 months, respectively (Ye et al., 2010a). Both extractable sulfate and dissolved organic sulfur decreased throughout the growing season, likely due to uptake by sugarcane, but also potentially by runoff or leaching through the shallow soils. Elemental sulfur was not detected in unamended soils, and its concentration in amended soils gradually decreased throughout the growing season, but it was still detected in soil at 13 months after application (Ye et al., 2010a).

Agricultural sulfur application in a Dania series soil using current recommended guidelines (up to 400 lbs/ac) did not increase sugarcane yield. There may be a need for greater agricultural elemental sulfur application rates in some EAA soils to overcome the soil's buffering capacity, and thus release phosphorus. Sulfur application rates above 400 lbs/acre could continue to reduce soil pH and cause releases of phosphorus from the calcium-bound fraction (Gessa et al., 2005). Calcium-bound phosphorus comprises 32 percent of total phosphorus and more than 80 percent of total inorganic phosphorus in EAA soils.

It is important to note that the EAA sulfur amendment recommendations were developed many years ago, before the occurrence of widespread increases in soil pH due to soil subsidence. Thus, the effectiveness of elemental sulfur amendment for the higher pH soil conditions in the EAA has been questioned (Schueneman, 2001; Ye et al., 2010b). Additional evaluation of the effectiveness of elemental sulfur use for sugarcane grown on various soil types with higher pH values within the EAA is ongoing.

INFORMATION NEEDS AND RECOMMENDATIONS

Information needs and recommendations regarding Everglades sulfur source determination and management include:

1. Better estimating Everglades, Lake Okeechobee, and EAA sulfur mass balances, including quantifying agricultural application of sulfur to soils in the EAA and applications previously not measured [e.g., addition of gypsum ($CaSO_4$) for EAA soil erosion control].
2. Accurately determining the rate of oxidation of EAA soil organic sulfur, for dry and submerged-soil conditions.
3. Determining the relative contributions of natural and agricultural sulfur to organic sulfur in EAA soils.
4. Determining the time for sulfur release from EAA soils to reach a steady-state value after cessation of agricultural applications of sulfur.
5. Assessing soil depths across the EAA and total sulfur stocks within the EAA.
6. Measuring groundwater sulfur inputs to the EAA.
7. Implementing high-resolution spatial sampling frameworks over various time periods to capture particular meteorological conditions (i.e., dry, wet, and intermediate seasons) with

more frequent measurement of sulfur flux occurring at water structures in the Everglades to better determine sulfur inputs to various areas of the ecosystem (Gabriel, 2009).

8. Modeling the response of mercury levels in Everglades fish to sulfate concentrations to estimate the reduction in sulfate loading to the ecosystem necessary to achieve desired fish mercury reductions.
9. Reviewing options for restoring the Everglades hydropattern while minimizing sulfur effects:
    - The delivery of sulfate-contaminated water through the Everglades canal system to protected areas such as the ENP and the Refuge — areas that previously did not have elevated levels of sulfur — may cause environmental harm. In contrast to transporting water though the canal system, moving water as sheetflow over expansive marsh areas may allow for sequestration of reduced sulfur in soils and thus reduce the sulfate loads delivered to these protected areas (Orem, 2007).
    - Current management practices have altered the Everglades natural drying and rewetting cycles: soil drying results in the oxidation of reduced sulfur to sulfate; upon rewetting, pulses of sulfate reduction and MeHg production occurs (Gilmour et al., 2004; Orem, 2007).
    - Reviewing the potential effects of Aquifer Storage and Recovery on Everglades sulfur loading (Krabbenhoft et al., 2007).
    - Estimating the cost and effectiveness of sulfur Best Management Practices for the EAA and the Lake Okeechobee Watershed.
    - Continuing to evaluate effectiveness of agricultural sulfur application for enhancing crop production, and alternatives to sulfur application to EAA crops so as to maintain high crop production rates while minimizing environmental impact (e.g., phosphorus addition; alternative means of lowering soil pH).

RESEARCH PROGRESS

The following research needs were identified in peer-review comments from previous Everglades Consolidated Reports (ECRs) and *South Florida Environmental Reports* (SFERs) – *Volume* I for the mercury chapter. Updates on progress follow. These projects address sources, toxicity, and biogeochemistry of mercury and sulfur, as well as prediction (modeling) of the effects of implementing mercury or sulfur source reduction on the ecosystem.

1. **Quantify the no-effect level for Greater Everglades fish-eating bird dietary exposure to MeHg to support development of a water quality criterion (2000 ECR).**

   Experimental exposure of white ibis (*Eudocimus albus*) to MeHg through diet significantly reduced reproduction. These effects were seen over a concentration range from the very high MeHg levels that existed in the Everglades in the early 1990s and in the ENP at present, down to current ambient MeHg levels in the WCAs. The main loss of reproduction was due to a high rate of MeHg-induced white ibis male-male pairings (up to 55 percent of males), an effect which was dose-related in two of the three study years (Frederick and Jayasena, 2008).

   Following the FDEP's initial support for research on MeHg effects on white ibis (Frederick et al., 2005, 2007; Axelrad et al., 2008, 2009), the U.S. Fish and Wildlife Service and the U.S. Army Corps of Engineers (USACE) provided continuing funding. The final report to the USACE was submitted in December 2008 (Frederick and Jayasena, 2008).

   In this study, experimental groups of 40 white ibises (even sex ratios) were exposed to 0.05, 0.1, and 0.3 mg MeHg/kg wet weight in diet from 90 days of age through three breeding seasons. No effects were found of MeHg on mass, size, survival, appetite, juvenile hormone levels, or the ability to learn to feed in novel situations.

   However, all of the mercury-dosed groups had significantly lower reproductive success than the control group in all years, with up to 30 percent reduction in reproductive success. The main loss of reproduction was due to nests not producing eggs, and this stemmed directly from a high rate of male-male pairings (up to 55 percent of males), an effect which was dose-related in two of the three years.

   The male-male pairings showed nearly all of the characteristics of male-female pairings, including phenology, courtship, copulation, nest construction, nest attendance, mate defense, and socially monogamous behavior. Male-male pairs were often of longer duration than male-female pairings, and dosed groups all had significantly more time (pair-days) spent in male-male pairings than did the control group. In all years, the majority of the reproductive deficits in dosed groups were attributable to male-male pairing (2006: 75–85 percent, 2007: 82–100 percent, 2008: 50–100 percent).

   Male-male pairings were not a result of location effects, sex ratio, or constrained mating opportunities. Additionally, male-male pair bonds in all groups were formed relatively early in the breeding season at a time when there were unpaired females available in breeding condition.

   Males that were dosed, and especially those that later paired with males, had significantly lower display rates than control males (Frederick and Jayasena, 2010). It seems likely that although females approached them for courtship, the displays of these males may have been substandard. Some homosexual males later formed heterosexual pair bonds in the same or subsequent seasons, and had fertile eggs in all of those situations, demonstrating that they were competent mates. Male-male pairings declined over the three breeding seasons, suggesting that birds were switching mates because of poor reproductive success.

   Expression of sex steroids (estradiol and testosterone) were also affected by MeHg exposure, showing a dose-dependent response (Frederick, UF, personal communication). The pattern of altered expression was exaggerated within any group among homosexual males, suggesting

that MeHg-induced changes in hormone expression affected sexual behavior such as display rates and pairing preference, and through that mechanism, reproduction was affected. While this experimental evidence strongly links hormones, mercury exposure, and behavior, the physiological mechanisms involved are unknown.

This study suggests that MeHg can function as an endocrine disruptor, resulting in altered sexual behavior and reduced reproductive success. The reduction in reproduction was not trivial — if the normal sex ratio in the wild is 1:1, the reduction in success could be up to 55 percent (the proportion of males pairing with males in this study). In many studies, effects seen in the lab (or aviary) are exaggerated in the field because of additional stressors in the wild; it is unclear whether effects documented in the aviary would be exacerbated in the Everglades.

At minimum, the implications of this study are that MeHg exposure at ambient levels in the Greater Everglades in the early 1990s could have been enough to affect breeding behavior to the extent that measurable demographic change may have been realized. As mercury exposure declined in the late 1990s, the numbers of breeding pairs of wading birds increased by 3–5X. While some of this increase was clearly due to better hydrological conditions, hydropattern does not explain all of the increase, and mercury is an explanatory variable in nearly all models of population response during this period (Frederick and Jayasena, 2008). While these results are merely correlational, the experimental research demonstrates an effect and a mechanism by which mercury affected populations.

In addition, it is worth noting that the lowest effects level (0.05 mg MeHg /kg in diet) from this study is still commonly encountered by birds in the Greater Everglades today, while the highest effects level (0.3 mg MeHg/kg in diet) may presently be encountered by birds in the ENP. A CERP goal is to restore wading bird numbers in the ENP — historically the area of highest bird numbers in the Everglades — via hydrological restoration of the ENP. MeHg, however, appears to have a potentially powerful effect on reproduction in birds, and the effects research indicates it could strongly interact with other variables (e.g., hydrological restoration) to produce both masking and additive effects.

2. **Quantify "global versus local" atmospheric Hg sources to South Florida to better define options for reducing mercury levels in Everglades biota (2002 ECR).**

   See the *State-wide Mercury Total Maximum Daily Load Program* section of this chapter.

3. **Revise the Everglades Mercury Cycling Model (E-MCM) to include relationships between sulfur concentrations and mercury dynamics (2001 ECR).**

   The FDEP and the SFWMD have supported efforts to capture the biogeochemical relationships between the mercury and sulfur cycles in the Everglades Mercury Cycling Model (E-MCM), a mechanistic simulation model that runs on Windows™-based computers (Tetra Tech, 1999a, b; 2002). Results are reported in the 2010 SFER and by Gilmour et al. (2008). Additional statistical analyses using R-EMAP data to better elucidate the non-linear role of sulfate on methylation and mosquitofish mercury concentrations (and the migration of the so-called "sulfate Goldilocks region," which results in mercury-in-fish hot spots) have been proposed by the FDEP.

   A study funded by the Electrical Power Research Institute (EPRI) to improve the treatment of several processes in the lake version of the MCM (D-MCM) continues (see the 2010 SFER). EPRI also has approved funds to extend D-MCM to be more generalized so that users can simulate single-cell or multi-cell scenarios without having to modify or manipulate the source code in the model. In addition to having the ability to simulate lakes, rivers, and large water bodies, the new version of D-MCM is expected to be able to simulate large complex systems like the Everglades that contain both wetland and more purely aquatic cells.

4. **Research biogeochemical controls on mercury methylation (2001 ECR).**

   ACME Phase III Research: Significant progress has been made in understanding biogeochemical controls on mercury methylation through Aquatic Cycling of Mercury in the Everglades (ACME) Phase I and II research conducted by the USGS and the Smithsonian Environmental Research Center (SERC), through support by the USGS, the FDEP, and the SFWMD. Findings are detailed in USGS (2010).

   This research, begun in 2008, focused on the ENP, BCNP, and the Loxahatchee National Wildlife Refuge and has been extended at least until the end of 2011, with additional cruises planned in the Shark River Slough and the offshore marine zone.

   This project seeks to expand the knowledge of the factors controlling MeHg production in the Everglades, with specific attention to geographic areas where Everglades restoration may affect MeHg production and bioaccumulation. Because work under ACME Phases I and II was largely conducted in the WCAs, efforts for ACME Phase III will be in Everglades areas where less research has been conducted, particularly on federally managed lands.

   The overall objective of this next phase of research is to extend the understanding of interactions between mercury, sulfate, and DOC as they influence MeHg production in areas of the Everglades that are anticipated to receive increased water delivery from sulfate-rich EAA runoff or high-sulfate Aquifer Storage and Recovery waters.

   ACME Phases I and II Database and Data Synthesis: The FDEP contracted with SERC for completion of compilation and synthesis of ACME Phases I and II data. The SERC data compilation will include a detailed assessment, through time, of the biogeochemistry of core ACME Phase I and II sites across the full length of the Everglades ecosystem and compile data from field mesocosm experiments designed to test cause-and-effects hypotheses.

   This project is planned to compile data from all ACME researchers in one central database where it can be queried and studied as controls on sulfur inputs to the Everglades are debated; a text report on the synthesized dataset is also planned. As part of that report, a synthesis of the literature on MeHg production with a detailed focus on studies of the relationship between sulfate, sulfide, and MeHg will be produced. The literature summary will help to put the ACME datasets into a larger context, and provide information to decision makers. Metadata will also be included. The dataset is slated for public accessibility (as well as submitted to the USGS for consideration for publication as an open file report).

5. **Determine sulfur sources to and effects on the Everglades (2006 SFER).** See the *Sulfur Levels, Sources and Effects on the Everglades* and *Regional Sulfur Mass Balance Study* sections of this chapter.

STATE-WIDE MERCURY TOTAL MAXIMUM DAILY LOAD

By 2012, the FDEP is required to develop a draft mercury Total Maximum Daily Load (TMDL) for mercury-impaired fresh waters of the state for review by the USEPA. In 2008, the FDEP initiated a multiyear statewide mercury TMDL study for fresh water that includes both atmospheric and aquatic field monitoring and modeling components. The mercury TMDL study is described in the 2010 SFER – Volume I, Chapter 3B.

MERCURY IN COASTAL WATERS

On a national scale, Americans are exposed to MeHg almost exclusively through the consumption of fish. Approximately 5 percent of women of childbearing age in the United States have blood MeHg levels that pose an increased risk to fetal brain development (Mahaffey et al., 2009). Many states are implementing mercury TMDLs to mitigate exposure to MeHg, but currently these TMDLs are being derived predominantly for fresh waters. The entire Atlantic and Gulf of Mexico (Gulf) coasts of the United States are under limited or no-consumption advisories for fish. Florida alone lists over 60 fish species of commercial or sport-fishing interest from the Gulf as under these advisories because of mercury content (FDOH, 2009). Marine and estuarine fish (finfish, shellfish, and crustaceans) make up more than 90 percent of the total fish consumption and MeHg exposure, indicating an obvious need for marine TMDL development. Less than 10 percent of fish eaten are from fresh waters (Degner et al., 1994; Sunderland, 2007).

The FDEP is initially addressing mercury in the Gulf because it is a very significant fishery — accounting in 2008 for 15 percent of the nation's marine commercial fishing, and 42 percent of the marine recreational fish catch (NOAA, 2010a, b). Because MeHg levels in a high proportion of fish in the Gulf exceed the proposed USEPA fish tissue criterion for human consumption, the Gulf is a significant source of human exposure to MeHg.

Determining the feasibility of reducing elevated MeHg concentrations in Gulf fish requires an understanding of which sources are the most important for MeHg bioaccumulation in fish. This involves determining:

- The sources of mercury to the Gulf
- Where and at what rate inorganic mercury is converted to MeHg by naturally occurring bacteria
- How MeHg cycles and bioaccumulates through the marine food web

While mercury data are limited for the Gulf, a screening-level model has been used to examine this question. Mercury cycling and bioaccumulation has been simulated by the Navy Coastal Ocean Model, coupled to the Gulf of Mexico Dynamic Mercury Cycling Model, previously used for USEPA-funded pilot mercury TMDLs in Florida and Wisconsin.

The FDEP funded initial runs of both models and has received U. S. Department of Commerce National Oceanic and Atmospheric Administration funds for research on (1) MeHg exposure to Gulf states' residents from Gulf fish, (2) total and MeHg inputs to the Gulf from rivers, and (3) Gulf fish trophodynamics.

REGIONAL SULFUR MASS BALANCE STUDY

The objectives and methods of the Regional Sulfur Mass Balance Study are described in the 2010 SFER. Thus far, three separate years have been investigated in mass balance calculations: a high precipitation year (2004 [556 cm]), a drought year (2007 [393 cm]), and an intermediate scenario (2003 [472 cm]). To date, the major findings are as follows:

- Canal transport is the largest TS mass transfer mechanism for each land-use area.
- Total sulfur source/sink characteristics vary considerably for each area per year, particularly for WCA-1 and the EAA.
- For the WCAs, the smallest total sulfur mass transfer mechanisms are total sulfur biogenic emissions and atmospheric deposition.
- Agricultural sulfur applications and total sulfur release through soil oxidation are similar in mass transfer magnitude for the EAA during years with higher precipitation.
- Lake Okeechobee shows the least variation in source/sink characteristics.

The next steps of the study are to (1) include the years 2000, 2001, 2002, 2005, 2006, 2008, and 2009 in mass balance calculations, (2) further explore biogeochemical total sulfur oxidation and reduction processes using chloride mass balance data, (3) investigate the source for sulfur that contributed to the high sulfate concentration at sampling locations, and (4) further explore sulfur source delineation for the South Florida ecosystem.

SOUTH FLORIDA MERCURY HOT SPOT STUDY: DATA COLLECTION PHASE

This study consists of sampling multiple biogeochemical parameters within porewater, surface water, sediment, mosquitofish, and periphyton at locations that exhibit contrasting fish mercury levels (see **Figure 3B-15**). Future data evaluation will involve statistically comparing parameter levels between selected locations to help identify the processes causing the large differences in fish mercury levels. Potential environmental factors could include differences in porewater carbon quantity and quality, sediment sulfur speciation levels, and sediment phosphorus levels. Two sites (ENR302 and WCA2F1) selected for data collection have demonstrated relatively low mercury concentrations in several fish species for the POR (1998–2010) [average levels range from 0.006–0.010 ppm in sunfish and 0.016–0.172 ppm in LMB (Axelrad et al., 2008; Gabriel et al., 2009)]. Sites WCA2U3 and CA315 were selected for relatively high mercury levels in all fish species for the POR (1998–2010) [average levels range from 0.175–0.324 ppm in sunfish and 0.418–0.997 ppm in LMB (Axelrad et al., 2009; Gabriel et al., 2009)]. Results and discussion are anticipated for inclusion in future SFERs.

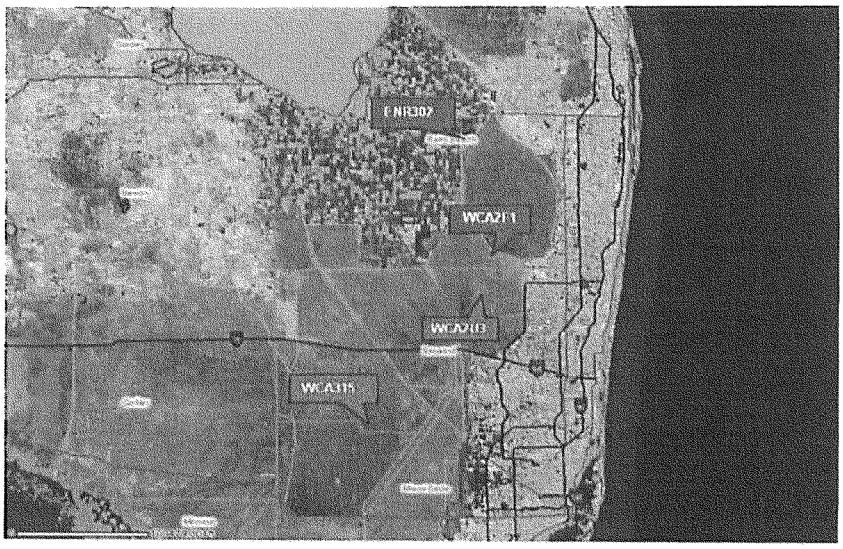


Figure 3B-16. Sampling locations within WCA-2, WCA-3, and STA-1W. Red boxes indicate high fish mercury concentration areas and blue boxes indicate low fish mercury concentration areas.

EVALUATION OF SULFUR IMPACTS IN SOUTH FLORIDA WETLANDS

The *Evaluation of Sulfur Impacts in South Florida Wetlands* is a three-year project planned for completion in 2011. The principal objectives are to determine the effects of elevated water column sulfate levels on phosphorus cycling and vegetation health in natural wetlands and the STAs. This study is detailed in 2010 SFER – Volume I, Appendix 3B-2, with the results of the first set of lab incubations on soil slurries amended with sulfate. WY2010 results are presented here.

The following sections summarize the results of field monitoring and laboratory experiments performed to assess the effects of elevated water column sulfate levels on phosphorus release from soils collected from unimpacted and impacted (with respect to sulfur) South Florida wetlands. Updates on other research platforms, including field-scale mesocosms, intact laboratory core incubations, and chemical gradient analyses in STAs, are also presented.

Porewater Concentrations and Soluble Reactive Phosphorus Release from Intact Soil Cores in the STAs

This task comprised two major efforts. The first was a field study where porewater equilibrators ("peepers") were deployed on one occasion in the central flow paths of STA-5, Cells 2A and 2B, and STA-3/4, Cells 2A and 2B, and on three occasions in STA-2, Cell 1 (**Figure 3B-16**).

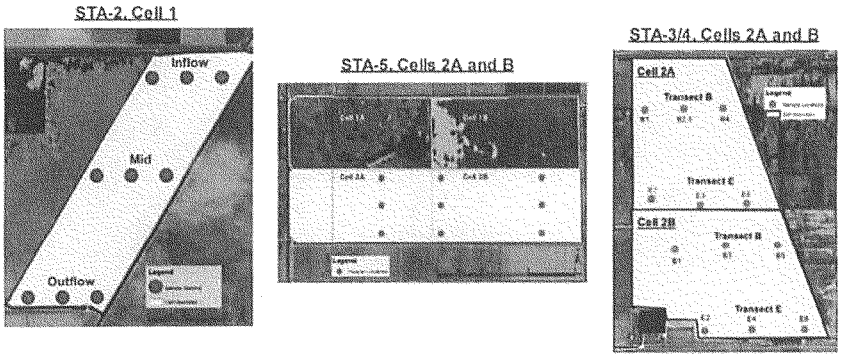


Figure 3B-16. Porewater measurement locations within the STAs.

The second effort entailed six-week lab incubations of intact soil cores collected from the porewater measurement locations. Duplicate cores from each sampling location were flooded with unamended (typically low sulfate) water from the STA flow path. Two additional cores were amended with sulfate at a concentration comparable to the highest levels observed for each STA flow path over a five-year period (2004–2009). All of the field collection and laboratory experiments for this task have been completed, and final data analyses are under way.

Preliminary findings are:

- For STA-2, Cell 1, and STA-3/4, Cells 2A and 2B, field-measured porewater soluble reactive phosphate (SRP) levels and Fickian diffusion rates from the soils to the overlying water generally were highest for the soils nearest to the inflow culverts. By contrast, porewater SRP and diffusion rates were higher along the

outflow transect of in STA-5, Cell 2B, than for the mid- and inflow-transects of the flow path. A comparable spatial trend in SRP release was also observed for the intact soil cores that were incubated in the laboratory for six weeks.

- For STA-2, Cell 1 (sampled on three occasions), porewater chemistry varied in response to seasonal and antecedent hydrologic conditions. During the June 2009 deployment, performed after a prolonged drydown–reflooding event, sharply elevated sulfate, SRP, and dissolved organic phosphorus concentrations were observed along the mid-cell transect. Porewater sulfide levels were generally low at this time for this sampling location.
- No correlation was found between porewater sulfide and SRP concentrations in soil cores retrieved from STA-2, Cell 1, and STA-3/4, Cells 2A and 2B; very weak correlations ($r^2 \leq 0.23$) were found between porewater sulfide and porewater SRP concentrations in soil cores retrieved from STA-2, Cell 1, and STA-3/4, Cells 2A and 2B, at the end of a six-week wet incubation; a stronger correlation ($r = 0.57$) was observed in soils from STA-5, Cells 2A and 2B.

Phosphorus Mobilization and Plant Toxicity Effects in Mesocosms Amended with Sulfate, Calcium and Alkalinity

Three mesocosm platforms have been constructed to address the effects of sulfate amendments on phosphorus mobilization and plant toxicity. Two experiments are being conducted at the Port Mayaca lock, adjacent to Lake Okeechobee. The first study tests the potential toxicity of sulfate amendments to emergent (cattail and sawgrass) and submerged [southern naiad (*Najas guadalupensis*)] plants. Four groups of triplicate containers containing each plant type are being fed Lake Okeechobee waters. Two groups are receiving waters with ambient sulfate levels of ~ 40 ppm. The others are being fed lake waters spiked to a sulfate concentration of ~ 90 ppm. One set of ambient-sulfate tanks and one set of high-sulfate tanks are also having the lake water pre-treated to remove available phosphorus forms (**Figure 3B-17**). Plants are harvested periodically and measurements are performed on aboveground and belowground tissues to assess potential sulfate/sulfide impacts on morphology and physiology.

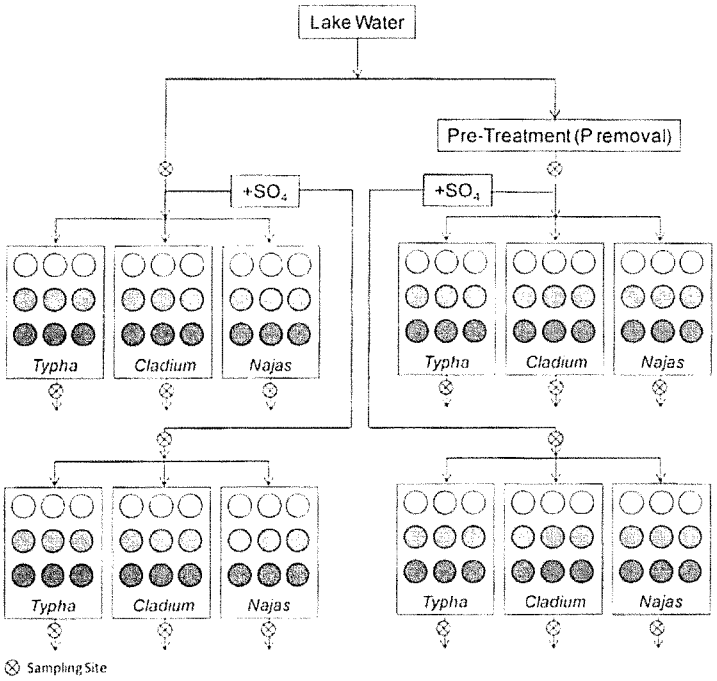


Figure 3B-17. Experimental design for the mesocosm toxicity experiments receiving sulfate amended and unamended Lake Okeechobee waters. One mesocosm group also receives pre-treated lake water. The colored circles represent containers of cattail (*Typha domingensis*), sawgrass (*Cladium jamaicense*), or southern naiad (*Najas guadalupensis*).

A second mesocosm platform at Port Mayaca is designed to test the effects of sulfate on phosphorus mobilization under a typical STA configuration (i.e., front-end emergent followed by back-end submerged communities) (**Figure 3B-18**). An additional treatment that involves increasing the calcium and alkalinity concentrations in conjunction with sulfate amendments is also being evaluated. To date, sulfate amendments (to ~ 90 ppm) to Lake Okeechobee source water have not impaired the phosphorus removal performance of the STA process trains.

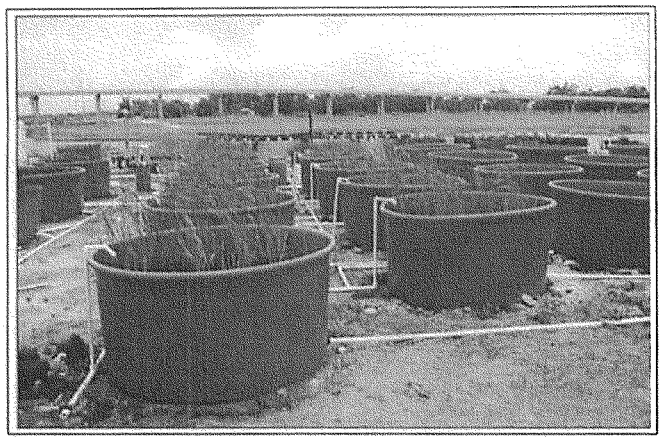


Figure 3B-18. Front-end emergent (cattail) mesocosms in the STA platform at Port Mayaca (photo by DB Environmental, Inc.).

A mesocosm platform has also been deployed in a relatively pristine (low phosphorus, low sulfate) area of WCA-3A (**Figure 3B-19**). Construction of the facility has been completed, and initial vegetation and soil measurements have been performed. The mesocosms will be operated in a batch mode where outside surface water will be exchanged with the inside water on a biweekly basis. A system of underwater ports and valves will facilitate the water exchange and also minimize the hydrostatic "head" difference between the inside and outside enclosures.

During each water exchange, selected mesocosms will receive sulfate amendments to final concentrations of 12, 24, and 48 ppm. In addition, a triplicate set of mesocosms will receive 40 ppm of calcium as a final concentration, while another set of triplicate mesocosms will be amended with 40 ppm of calcium plus 48 ppm of sulfate as final concentrations. The remaining triplicate set of mesocosms will remain unamended (controls). Amendments and water exchanges began in August 2010.

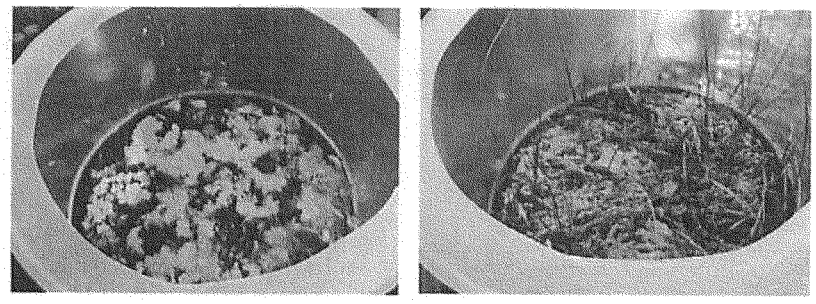


Figure 3B-19. Typical ridge-and-slough vegetation communities of floating periphyton (left) and floating periphyton interspersed with sawgrass and spikerush (*Eleocharis* spp.) (right) in WCA-3A mesocosms (photo by DB Environmental, Inc.).

MERCURY AND SULFUR IN SOUTH FLORIDA WETLANDS WORKSHOP

Organized by the SFWMD, FDEP, and USGS, the Third Annual Workshop on Mercury and Sulfur in South Florida Wetlands was held on February 2, 2010. In attendance were representatives from USGS, NPS, USEPA, FDEP, Smithsonian Institute, Aqua Lux Lucis, Inc., University of Florida, DB Environmental, Inc., and Syracuse University. The purpose of this workshop was to discuss research conducted since the second annual workshop related to mercury and sulfur biogeochemistry and ecological effects in South Florida wetlands. This workshop was intended to support activities under the SFWMD's Sulfur Action Plan, the USGS South Florida Ecosystem Program, and the FDEP South Florida Mercury Science Program. Through these programs, the three agencies investigate the effects of elevated mercury and sulfur levels throughout the Greater Everglades with research emphasis placed on mercury and sulfur interactions, internal eutrophication (sulfate-induced nutrient release from sediments), sulfide toxicity, agricultural applications of sulfur, and sulfur mass balance. Another workshop is planned for June 2011.

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MASSACHUSETTS FISH TISSUE MERCURY STUDIES:

LONG-TERM MONITORING RESULTS, 1999 - 2004

by

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2006

PREFACE

In 1994, the first comprehensive Massachusetts statewide examination of mercury in freshwater fish was conducted (MassDEP 1997). This study was followed in 1999 by an investigation of fish mercury concentrations in a region of the state predicted to have regionally high atmospheric deposition of mercury (MassDEP 2003b). That study was complemented by a study of historical mercury deposition into one lake in this region through the analysis of a sediment core using radioisotope dating techniques (Wallace et al. 2004). Additional work addressing mercury emissions and deposition is ongoing.

A number of additional studies have been conducted as part of the Department's continuing efforts to better elucidate the status of the Commonwealth's freshwater fish populations and environments with respect to mercury contamination.

A long-term monitoring network of lakes was established in 2001 to provide temporal tracking of changes in the mercury contamination status of fish in the Commonwealth, particularly as comprehensive mercury use and emissions reductions efforts have been implemented in Massachusetts and regionally. Results from these lakes will also provide a perspective on the scale of natural variability in tissue mercury concentrations for comparison with other sources of variation. The results from the first 5 years of this effort are contained in this report and in particular highlight the changes in fish tissue mercury concentrations which have taken place in the high mercury deposition area during a period when emissions from major point sources of mercury to the atmosphere have declined substantially in Massachusetts and across the region.

Other studies completed as part of our overall effort include one of seasonal variation in fish tissue mercury concentrations, which was conducted to provide perspective on the magnitude of this source of variance in fish tissue mercury concentration measurements (MassDEP 2005). This information is intended to help more efficiently design monitoring studies. Another study was performed to help elucidate the ecological basis for varying fish mercury patterns seen in different lakes. This comparative food web mercury study was conducted in two similar lakes in close proximity, which have different levels of mercury in top predator fish (MassDEP 2003a).

Wildlife are integral parts of pond ecosystems. Piscivorous birds in particular are at risk from mercury exposure via the food chain. Loons have been a focus of attention in New England for aesthetic and ecological reasons. A first step in the process for addressing threats of mercury to wildlife in Massachusetts is to have an understanding of the state of knowledge of mercury in indigenous non-fish vertebrates in the Commonwealth. A compilation of information on the state of knowledge on mercury in wildlife in the Commonwealth was performed as part of our overall program (Pokras and Tseng 2001).

The data generated from these studies on mercury concentrations in edible tissues of popular freshwater fish also permit more widespread screening of the Commonwealth's lakes for potential human health risks posed by eating mercury-contaminated fish from

these lakes. These health hazards are addressed through the issuance of fish consumption advisories by the Massachusetts Department of Public Health.

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ABSTRACT

This report describes the establishment of a network of lakes in Massachusetts for the long-term monitoring of temporal changes in mercury concentrations in edible tissues of two species of freshwater fish. This network provides environmental indicator data to help evaluate the effectiveness of state and regional mercury reduction programs overall and in a modeled mercury deposition "hotspot".

Fourteen lakes were identified as the core lakes for this program. They are located across the Commonwealth in order to give a breadth of geographic coverage. The monitoring plan calls for seven of these lakes to be sampled each year on a rotating basis so that all are sampled every two years. Additional lakes in an area of specific interest, northeast (NE) MA[1], were added in some years to give a total of 17 lakes addressed in this report. Largemouth bass (LMB; *Micropterus salmoides*) and yellow perch (YP; *Perca flavescens*) are sampled because they are known to accumulate mercury and they are caught and consumed by recreational and subsistence anglers. On each spring sampling visit to a lake, approximately 30 YP and 12 LMB are caught and analyzed using a statistically-based sampling design. This report covers data returns from 17 lakes for the years 1999 through 2004.

Over this period consistent and substantial statistically significant decreases in YP and LMB fish tissue mercury concentrations occurred in most lakes sampled. Of seventeen lakes with at least two years of YP data, mean mercury concentrations in YP decreased significantly in 13 of the waterbodies between the earliest and latest dates sampled. Nine of the lakes were located in northeastern Massachusetts (NE MA). In 8 of the 9 waterbodies in this area significant decreases in YP mercury were observed, ranging from -26.0 to -61.9%. The mean change for all 9 lakes was -32.4%. Five of the remaining eight lakes around the rest of the state also had statistically significant, but not as large, decreases in YP mercury, ranging from 20.1 to 28.0%, with an overall mean change for all 8 lakes of -15.4 %.

LMB mercury concentrations followed a similar pattern with 11 of 17 lakes throughout the state decreasing in tissue mercury concentrations. Eleven of the lakes sampled were in NE MA and mercury levels in LMB from 7 of those decreased significantly, ranging from -16.0 to -55.2%. Mercury levels in 3 of the 4 other lakes also decreased, but the changes were not statistically significant. The mean change in LMB mercury among all 11 of these lakes was -24.8 %. Four of the remaining six lakes located around the rest of the state also had statistically significant but smaller decreases in LMB tissue mercury concentrations. The range of these changes was 15.9 - 36.4%, with an overall mean for all six lakes of -19.0%.

[1] *This area was a former mercury deposition "hotspot" in the 1990s that has experienced a very substantial decline in mercury emissions from local point sources since 1999. Recent preliminary deposition modeling and monitoring indicate that these emission reductions have resulted in similarly large decrements in mercury deposition in the area as well.*

Although reduced, it is important to note that the overall mean mercury concentrations in YP and LMB in many of the sampled lakes, in particular those in the northeast part of Massachusetts, still exceed the level deemed as safe for consumption by pregnant women, nursing mothers and children. On an individual lake basis, even after the noted reductions, many continued to have fish containing unsafe levels of mercury.

The temporal pattern of fish tissue mercury concentration decreases was consistent. No significant decreases were seen over a period of one year. Decreases were observed in some waterbodies over a period of 3 years and were consistently observed at 4 years. The first year of monitoring occurred prior to substantial reductions in mercury emissions from Massachusetts, regional and local mercury point sources that occurred through the Massachusetts Zero Mercury Strategy (MAZMS) and the New England Governors and Eastern Canadian Premiers (NEG-ECP) Mercury Action Plan. In particular, mercury emissions in the NE MA deposition hotspot area are estimated to have decreased by about 87% between the late 1990's and 2004 due to new pollution controls on municipal solid waste combustors (MSWC) and the closure of medical waste incinerators (MWIs) and a MSWC in the area.

In conclusion, the study results are notable for the significant decreases in edible fish tissue mercury concentrations, in particular from waterbodies located in a mercury deposition hotspot area, that occurred within 36-48 months of the adoption and implementation of comprehensive state and regional plans that effectively reduced emissions of mercury. These reductions were achieved primarily through the imposition of stringent mercury emissions controls on MSWCs and MWIs, as well as reductions from other regional sources. These results suggest that mercury levels in fish from temperate water bodies can be significantly reduced over a relatively short timeframe if emission sources are effectively controlled. However, although reduced, overall average mercury concentrations in fish from many of the waterbodies sampled still exceed the recommended safe consumption level. As discussed in the Massachusetts TMDL Alternative Proposal[2] submitted to the USEPA in 2004, significant reductions from out-of-state mercury sources will likely be needed to achieve water quality and public health objectives in Massachusetts.

MassDEP will continue to monitor mercury concentrations from these waterbodies to assess the environmental results of mercury reduction efforts targeting coal-fired utilities as well as mercury pollution from consumer and industrial products and from dental offices, that are currently underway in Massachusetts and the northeastern U.S. and Canada. MassDEP is also working to address the contribution of upwind, out-of-state sources to mercury deposition in Massachusetts through additional monitoring and modeling.

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[2] *A TMDL Alternative Regulatory Pathway Proposal for the Management of Selected Mercury-Impaired Waters: A Supplementary Document to the Massachusetts Year 2004 Integrated List of Waters*
http://www.mass.gov/dep/water/resources/mercalt7.doc

1.0 INTRODUCTION

The Commonwealth of Massachusetts has monitored fish contaminants, including mercury, since 1984. The primary goal of much of the early work was to identify fish populations that might pose unacceptable health risks to those consuming the fish. Sampling sites were not often revisited in subsequent years, methods and procedures had not been fully standardized until more recent years, and the level of sampling intensity was not sufficient to optimally support statistically-based comparisons between samples.

Starting in the autumn of 1994, a more rigorous and comprehensive approach to the study of fish tissue mercury concentration processes in Massachusetts was implemented in response to increased concern about mercury inputs to the environment and possible adverse human health effects as a result of consuming mercury contaminated fish. A statewide study was first performed to determine the distribution of mercury in the edible tissues of several freshwater fish species and the relationships of those concentrations to environmental characteristics (Rose et al. 1999). Based upon limited data collected for fish consumption advisory purposes showing signs of high mercury levels in fish and recognition of the presence of several likely sources of high atmospheric emissions of mercury in the northeast region of the state, a targeted, intensive study of the degree of mercury contamination of two species of freshwater fish was performed in the spring of 1999 (MassDEP 2003b). These two studies also provided the first good assessment of the degree of variability in mean fish tissue mercury concentration estimates which served as a basis for statistically-based designs of subsequent fish mercury studies. This information highlighted the importance of a number of factors contributing to variability in fish mercury concentrations estimates. If uncontrolled or unaccounted for, these sources of variability can mask the variation of interest (e.g., change due to controlling the source of the mercury). In order to better understand the magnitude of the contributions of these factors to variance in the data, several follow-on studies were designed and executed. One examined whether tissue moisture content was a significant source of variance in the data (MassDEP 2005); a second examined seasonal and fish reproductive state-related variance (MassDEP 2005) and a third, reported in this document, sought to document the scale of interannual variation, both in relation to natural factors, and also to changes in mercury inputs to the environment.

This report describes the establishment of a long-term monitoring network of lakes for fish tissue mercury monitoring in Massachusetts. The data from this effort are intended to provide several pieces of valuable information to help understand temporal edible fish tissue mercury concentration trends. This information will firstly provide a consistent, long-term record of mercury concentrations in fish across the state. The data will represent an indicator of the responses of the environment to changes in mercury inputs as a result of regional and national mercury emissions control efforts. The information will also address random year-to-year variation in fish mercury concentrations. In cases where data collected in different years are compared to evaluate the influence of some other variable (e.g., comparisons between urban and rural lakes), knowledge of the magnitude of random interannual variation would assist with the determination of the significance of differences attributed initially to other factors. The species monitored in

our program are largemouth bass (LMB; *Micropterus salmoides*) and yellow perch (YP; *Perca flavescens*).

Interannual variation of mercury in fish can reflect changes in mercury inputs to lake ecosystems, variation in internal processes such as mercury methylation rates, and biological and statistical variation. Interannual variation has been documented in fish tissue mercury concentrations in largemouth bass (LMB) between some, but not all years in some published studies. Lange et al. (1994) observed ~34% differences in yearly means in LMB in Florida. Jeremiason (2000) documented approximately 40% decreases in northern pike (*Esox lucius*) lake mean mercury concentrations over a >5 year period in Minnesota. Another study in remote Canadian Shield lakes did not detect interannual variation in LMB, northern pike, walleye, and cisco tissue mercury concentrations over a 3-year study period (Bodaly et al. 1993). The presence of this type of variation in a multi-year study would seem to be a function of the locale of the study, so that one generalization cannot apply to all situations. The limited information summarized above shows differences from 0-40% between years at the same location, likely reflective of year-to-year variability in environmental parameters and changes in mercury inputs. In the Everglades, multiyear monitoring data document a trend of decreasing mercury in biota. Overall, LMB and bird (great egret nestlings) monitoring data from the Florida Everglades document a significant decrease in mercury concentrations from 1990-2000 (Atkeson et al. 2003). These interannual reductions correlate with reductions in local mercury emission rates in South Florida of more than 90% since peaks in the late 1980s and early 1990s. However, the generalizability of these observations to temperate waterbodies is unclear.

The objectives of this work have been to establish a long-term monitoring network that will allow interannual variation and trends in mercury levels in fish to be assessed in temperate waterbodies and potential associations with changes in mercury emissions and deposition to be explored. In particular we have focused on a subset of lakes located in proximity to a number of historically large point sources of mercury emissions and in a predicted high mercury deposition area. This report evaluates early data returns on mercury concentrations in the two target species, spanning the 1999-2004 timeframe. Samples from a total of 17 lakes are assessed, including a subset from the predicted high mercury deposition area.

2.0 MATERIALS AND METHODS

2.1 PROGRAM DESIGN

The program objective is to document the magnitude and direction of year-to-year and long-term changes in edible muscle total mercury concentrations in LMB and YP in the designated monitoring lakes. Approximately half the lakes are to be sampled on a rotating annual cycle. Dependent upon the degree of interannual variation observed between years in the initial stages of the program and available financial resources, the duration between repeat samplings may be changed from two years in subsequent years

of the program. To date, in some years, additional numbers of lakes were sampled in regions of the state of particular interest, specifically the predicted high deposition area encompassing the northeast part of MA, in order to give more temporal and spatial resolution.

Fourteen lakes throughout the state (Figure 1) have been designated long-term fish tissue mercury monitoring sites. Figure 1 also shows additional lakes that have been sampled to augment the sampling effort at the 14 program lakes as well as any lakes initially started and then dropped for various practical reasons. Lakes were chosen using several criteria:

- lakes previously sampled;
- locations in representative ecoregions of the state;
- lakes in the predicted high mercury deposition area in northeast MA;
- lakes spanning the West–to-East distance across the state to reflect possible out-of-state long-range transported atmospheric inputs with prevailing winds;
- lakes positioned in urban and rural areas of the state;
- lakes recommended by Massachusetts Basin Team leaders;
- lakes having protected watersheds;
- heavily fished lakes;
- lakes providing habitat for species higher on the food chain.

2.2 FIELD SAMPLING

The protocols for collecting fish and water samples in the field and subsequent processing in the laboratory are shown in Figure 2 and Figure 3. Fish were collected in the spring of each year to control for the variability which can be introduced by seasonal changes in fish tissue mercury concentrations (MassDEP 2005).

Fish were collected with box nets, gill nets, trot lines, electroshocking and rod and reel. They were removed from the water, rinsed with ambient water, wrapped individually in aluminum foil, placed in polyethylene Ziploc© bags and placed on ice for delivery to the laboratory within 24 hours of collection.

In order to provide robust size/age ranges of LMB, a size spectrum of fish was collected. We sought to obtain YP greater than 20-25 cm total length to represent those consumed by anglers.

Required numbers of replicate fish were determined using sample size calculation algorithms in Statistica©. Estimates of variance in the data from our previous studies were used along with a desired confidence level of 0.10 and power of 80% to calculate required sample sizes. Our calculations and consideration of practical issues including analytical costs and concerns over potential overharvesting of resident fish populations, led us to seek 30 replicate YP per lake per sampling event and 12-15 LMB. Based on the variance values from our previous studies, these sample sizes were estimated to have an ability to identify differences in means of approximately 40-50% in LMB and 15-20% in

YP. In practice, there were occasions when it was not possible to obtain the desired numbers of fish.

Basic water quality measurements were obtained at one station at the deepest part of each lake at 1 m depth intervals with multiprobe field instruments. Temperature, pH, dissolved oxygen concentration and conductivity were measured. Dependent upon whether or not the water column was stratified at the time of sampling, either mid-epilimnion and hypolimnion water samples were taken or a single mid-depth sample was taken for analysis of major cations and anions (Na, K, Ca, Mg, Fe, Mn, SO_4, Cl), dissolved organic carbon content (DOC), total organic carbon content (TOC), nitrate+nitrite nitrogen, total phosphorus, and ammonia. The analytical techniques used for each and associated detection limits are provided in Table 1 and MassDEP (2005).

2.3 LABORATORY PROCEDURES

Fish were processed for analysis of mercury in lateral muscle in accordance with US EPA procedures (U.S. Environmental Protection Agency 1993). Total fish lengths and wet weights were recorded. The sex and reproductive condition of each fish was assessed by visual examination of gonads and classification as: Immature; Developing; Ripe; and Spent. Gonad wet weights were determined. Scales were removed from the fish for age analysis. Tissue moisture contents were determined on the 2001 fish for calculation of the dry weight basis of the mercury content of the tissues. These data are presented and analyzed in MassDEP (2005). Other details of handling and sample preparation are identical to those described in Rose et al. (1999). Mercury in tissues was analyzed using US EPA Method 245.6. A Perkin Elmer Flow Injection Mercury System was used for total mercury analysis. The method detection limit was 0.01 mg/kg and the reporting limit was 0.03 mg/kg. Recovery for mercury- spiked fish samples and precision of the analyses were 96.0 ± 11.1% and 5.5 ± 5.5 % (means ± 1 std. dev.). The reference standard for mercury in fish tissue was freeze-dried tuna tissue (BCR ref. std #463). The accuracy of analyses of that standard was 102.1 ± 12.7%. Mercury in all laboratory reagent blanks was less than the method detection limit.

The data presented for the spring of 2001 were a subset of a larger data set of results from 7 of the long-term monitoring lakes sampled in the spring, summer, and fall of 2001 and winter and spring of 2002. The larger seasonal dataset is presented and analyzed for seasonal variability in MassDEP (2005).

2.4 DATA ANALYSIS

Bivariate plots of individual fish mercury concentrations versus total fish length for each species for each lake in each year were examined to determine if there were any outliers. Outliers were either corrected if representing a data entry error or excluded if outlying the sphere of the remainder of the data. The criterion for exclusion was a subjective determination that a data point(s) fell well outside the range of others in the data set

and/or represented a mercury size relationship at odds with all the other data. Only one record was struck from the original data set. The anomalous mercury concentration value was set due to a lab fish processing error. Some fish were noted as "outliers" during data analysis and have been identified as such in the text. An examination of the bivariate plots revealed that in almost all cases, there was a positive linear correlation of fish length with tissue mercury concentrations. In order to adjust for the effects of this covariate prior to testing for mercury concentration differences between years, either an ANCOVA was performed for data sets consisting of greater than two years, or individual fish mercury concentrations were adjusted to the concentration of a standard-sized fish of that species and a t-test was performed for situations where two years were being compared. The first phase of an ANCOVA involved testing for individual lakes regression line slopes of mercury concentrations versus lengths for parallelism between different years (Sokal and Rohlf 1995). If there was no interaction between the covariate and the independent variable (length) and the classification variable (year), the second part of an ANCOVA analysis (an ANOVA) was performed, testing for between- year differences in mercury concentrations with an adjustment for length. In cases where there were significant differences between years, a Duncan's post hoc multiple range test was performed to identify which means differed from each other.

In those cases where there was a differential relationship between years of the mercury concentrations-length regression slope, the size effect was controlled for by deriving a predicted mercury concentration for a "standard-sized fish", defined as the arithmetic mean fish length over all fish sampled (339 mm for LMB; 243 mm for YP) in our study of mercury concentrations in fish from northeastern Massachusetts (MassDEP 2003a). In subsequent analyses for comparing data between lakes, the predicted mercury concentration of a standard-sized fish for a lake was used as a basis for comparison. This value was determined by regressing individual fish mercury concentrations on total body lengths for the fish species from a lake in a year, and then solving the regression equation for the predicted tissue mercury associated with the length of the standard-sized fish. Prior to running the regression analysis, plots of these two variables were examined for linearity: most of the mercury – length relationships approximated linearity. In order to retain individually-based fish data in analyses, thereby getting maximal statistical benefit out of the sample size "n" for the lake, individual fish mercury concentrations were also size-adjusted to the mercury concentration of a standard-sized fish. The rationale behind this adjustment is that the mercury-size relationship for each individual fish in the lake would follow the same relationship (slope of regression line) as that determined for all fish (least squares regression line). Lines having the same slope as the overall regression positioned to cross through each data point will have different intersection points with a vertical line at the standard-sized fish length (representing tissue mercury concentrations). This set of new size-adjusted data points for each fish for each lake was then available for use in subsequent analyses testing for interannual differences using either a one-way ANOVA or a t-test.

The fish tissue mercury concentration data or size-standardized mercury concentrations for ANCOVAs and ANOVAs for each species for each year for a lake were examined for the following characteristics to determine if they met the assumptions implicit in using parametric statistics for analysis of the data: normal distribution of the data; homogeneity

of error variances; independence of the means and variance. Normality was assessed through: generation of frequency histograms of individual fish tissue mercury concentrations and application of the Kolmogorov-Smirnov test for goodness of fit to normal distribution at $\alpha = 0.05$ (Sokal and Rohlf 1995); and generation of normal probability plots of these mercury concentrations for each lake. Homogeneity of error variances between lake tissue mercury concentrations was assessed with Levene's test (Sokal and Rohlf 1995). Plots of lake mean tissue mercury concentrations or size-standardized mercury concentrations versus associated standard deviations were examined to determine if means were correlated with errors. Violations of these assumptions of normality and errors for any species were addressed by applying $\log_{10}$ transformations to the individual fish tissue mercury concentration data prior to additional testing. For t-tests, the test was run on both the size-standardized value and a log-transformed value as a time-saving measure, rather than making all the determinations above. The same test outcome occurred in all cases except one.

All statistical evaluations in this study were performed with the Statistica/W©, Version 5.0 software package (StatSoft, Tulsa, OK, USA).

3.0 RESULTS

Lake physical and chemical variable data is presented in Appendix Table A-3, but is not analyzed in this report. Summarized lake means and standard deviations for fish mercury concentrations for each year of sampling are provided in Table 2 and plotted in Figure 4 for YP and Figure 5 for LMB. Slopes of the linear regressions of mercury concentration versus total lengths are also presented. In order to guide the reader in the types of tests performed to test for significant differences between annual means for a species at each monitoring lake, a checklist of tests performed is presented in Appendix Table A-2.

Annual means throughout the state ranged from 0.061 – 0.966 mg/kg (size-standardized values were 0.169-0.847 mg/kg) for YP and 0.070 – 1.633 mg/kg (size standardized values were 0.198 – 1.678 mg/kg) for LMB.

Of the 17 lakes having at least 2 sampling times with sufficient numbers of YP for comparison throughout the state, mercury concentrations in 13 of them decreased significantly between the first value in either 1999 or 2001 and the most recent values in 2004 (Table 3). Nine of the lakes were located in NE MA and 8 of those had significant decreases ranging from 26.0 – 61.9% with a mean change over all the lakes of –32.4%. Five of the remaining 8 lakes around the remainder of the state had mercury concentration decreases between the earliest and latest measurements (range: 20.1 – 28.0 %). The overall mean change across all of the eight lakes was –15.4%. Although a smaller percentage decrease, this mean was not significantly different ($\alpha = 0.05$) from that for the NE lakes.

The data trends for LMB were similar. Of the 17 lakes having at least 2 sampling times for comparison throughout the state, mercury concentrations in 11 of them decreased

significantly between the first value in either 1999 or 2001 and the most recent values in 2004. Eleven of the lakes were located in NE MA and 7 of those had significant decreases ranging from 16.0 to 55.2 %. The mean of the changes over all these lakes was –24.8%. Four of the remaining 6 lakes around the remainder of the state had mercury concentration decreases between the earliest and latest measurements (range: 15.9 – 36.4%). The mean change over all those lakes was –19.0%; not statistically significantly different from the NE MA mean ($\alpha > 0.05$).

The data sets for several lakes received closer, post analysis examinations as a result of their anomalous mercury concentrations in relation to predominant trends observed in all other lakes.

A fish kill of unknown origin in Pomps Pond in the spring of 2001 substantially reduced the fish populations in that lake. The few fish caught that year represented small young-of-the-year or year class 1+ fish. The YP from that lake 3 years later in 2004 were of intermediate size, representing primarily year class 3+ fish, while LMB were year class 2+ or 3+. Because of the relatively uniform sizes of these post fish kill fish, their mercury concentrations shown in Table 2 were not size standardized, nor were the interannual changes analyzed further because of the unique event which took place in this pond in the middle of our monitoring program.

YP from Johnsons Pond in NE MA initially had an apparent large temporal increase in tissue mercury concentrations between 1999 and 2004. On closer examination of the size and mercury distributions of the fish in the 1999 group and the 2004 group from this lake, it was apparent that size-standardization to a 243 mm fish wasn't appropriate, since all the fish in both years were smaller than the 243 mm size standard. There was therefore no practical basis for extrapolating to a larger fish beyond the range of measured lengths. In this case, for comparing the temporal differences between 1999 and 2004, a different approach was taken than for the rest of the data because all but one fish represented a narrow size range (210-234 mm total length) with mercury concentrations showing no relationship with size over this narrow interval. Size standardization of the 2004 group was therefore performed to the mean length of the 1999 group (221 mm). The 1999 unadjusted mercury concentration mean and the size-adjusted 2004 group mean were then compared with a t-test and were not significantly different (t-test, $p>0.05$), even though they differed by 8.3%. These data are presented in Table 2, Table 3 and Figure 4.

The LMB from Haggetts Pond exhibited a statistically significant decrease in size-adjusted tissue mercury concentration from 1999 to 2003. However, the 2004 sample represented a slight increase over the 1999 value (Figure 5). This anomalous pattern is not readily explainable. The 2005 sample, which has yet to be analyzed, will hopefully shed light on the mercury dynamics in this lake. The percentage changes in mercury concentrations presented in Table 3 for Haggetts Pond LMB are based on the 1999 – 2004 comparison, yet should be viewed cautiously. The values are reflected in the summary change value shown in Table 3.

The mean mercury concentrations for YP for Buckley Dunton Lake (2003 and 2004) in Table 2 on first examination were anomalous. Upon closer examination, the mercury concentrations of 5 of the 30 fish in 2003 fell well outside of the range of values for the other 25 fish (3 fold lower than expected concentrations based upon the mercury – size relationship exhibited by the other fish). These 5 fish were treated as outliers, removed from the regression of mercury concentration versus fish length for the 2003 fish and new size adjusted values generated based upon the new regression, the 2003 and 2004 size-adjusted data sets can be compared without the influence of these outliers. This slope based on censored data is the one shown in Table 2. The means (values shown in Table 2 were significantly different (t-test, $\alpha = 0.01$) and the direction of the change was an increase of 20.7% between 2003 and 2004 (Table 3).

4.0 DISCUSSION

Once released into the environment mercury persists and does not break down into harmless components like many other pollutants. It also bioaccumulates, or concentrates, into fish to levels up to a million times higher than in water. Although mercury is a natural element, the amount of this toxin circulating in portions of the biosphere, which interact with man today, is much higher than it was 100 years ago.

Mercury's potentially harmful health effects to humans received widespread international attention in the mid to late 1950s as a result of mass human poisonings from ingestion of contaminated fish and shellfish from Minamata Bay, Japan. Other subsequent poisoning episodes came from maternal consumption of breads made from methylmercury contaminated grains made into flour in Iraq in the early 1970s (Bakir et al. 1973) and from consumption of pork fed methylmercury-treated grains by a family in New Mexico in 1969 (Davis et al. 1994). These tragic events were the catalyst for efforts to address mercury as a global pollutant.

Mercury is a potent toxin that adversely affects people and wildlife. It can adversely affect the neurological system, kidneys, immune system and cardiovascular system. The brain and developing neurological system of the fetus and children are particularly sensitive to mercury and can be damaged by fairly low levels of exposure. Based on recent data from the United States (US) Centers for Disease Control, which measured mercury levels in the blood of women across the country, several hundred thousand newborns each year are at risk of mercury toxicity in the US because of their mother's exposure to mercury. This equates to over 10,000 newborns at risk each year in the Commonwealth. Human exposures to mercury are largely attributable to the consumption of contaminated fish, in which mercury has bioaccumulated.[3]

[3] *Wildlife can also be adversely affected by mercury, including loons, otters and fish eating mammals and even some songbirds. Data indicates that mercury exposures to loons may be high enough in the northeast to reduce their ability to reproduce and can even reach lethal levels in mink.*

Based on data from MassDEP's fish monitoring program, fish consumption advisories have been issued for over 100 specific waterbodies in MA. Overall, about 60% of all tested waterbodies have one or more species of fish with mercury concentrations that necessitate fish consumption advisories for sensitive subgroups including women of childbearing age, pregnant women, nursing mothers and children. More than 40% of the tested waterbodies require fish consumption advisories for the general public.

Mercury's serious environmental impacts, documented in the 1996 Mercury in Massachusetts Report (MassDEP 1996) and in the 1998 Northeast Regional Mercury Study[4], led MA, the other New England States and the Eastern Canadian Provinces to develop a regional strategy, the New England Governors and Eastern Canadian Premiers (NEG-ECP) Mercury Action Plan (MAP) targeting mercury pollution. The goals of the NEG-ECP MAP are to reduce New England and Eastern Canadian mercury emissions by 50% as of 2003 and by 75% as of 2010, with a long-term goal of virtual elimination. To further the goals of the regional MAP, Massachusetts adopted its own multi-agency Zero Mercury Strategy in 2000.

Under the umbrella of these initiatives mercury pollution in Massachusetts and the region has been dramatically reduced and a number of monitoring and research projects designed to evaluate progress and manage state priorities were implemented. These include collaborative efforts to establish mercury emission source inventories; measure emission reductions; monitor mercury deposition rates; model mercury deposition from local and distant sources; and track mercury levels in fish. Some of these activities have been completed, others are underway[5]. Monitoring these environmental indicators allows MassDEP to evaluate the effectiveness of policies and regulations to eliminate mercury pollution.

In order to help assess the effectiveness of mercury pollution reduction programs and to better document conditions in a region predicted to have had experienced elevated mercury deposition MassDEP focused considerable effort on the northeastern region of the state because of the following findings:

1. **Modeled atmospheric deposition rates of mercury for that region were the highest of those predicted for the northeastern U.S.,** in part attributable to a number of point sources of mercury emissions the area. As part of the regional effort in the mid to late 1990s to better understand mercury cycling in the region, the northeast states and eastern Canadian provinces conducted a computer modeling analysis of mercury deposition in the region (Northeast States/Eastern

[4] *This study provided important evidence of the need for concerted and coordinated actions to address mercury and was a key factor behind the decision to pursue a regional mercury action plan.*

[5] *MassDEP is collaborating with the; Northeast States for Coordinated Air Use Management (NESCAUM); US Environmental Protection Agency New England (EPA-NE); Environment Canada; University of Massachusetts (UMASS); University of Michigan; Northeast Waste Management Officials' Association (NEWMOA); New England Interstate Water Pollution Control Commission (NEIWPCC); New England Governor's Conference (NEGC); and Secretariate of the Eastern Canadian Premiers on a number of projects.*

Canadian Provinces 1998). Total predicted annual wet and dry deposition rates for the region of northeast Massachusetts and southern New Hampshire bounded by a 40 x 40 km grid cell from the model were greater than 100 ug Hg/m^2 (Figure 6). This rate was the highest modeled in the region and was greater than measured rates (21 – 83 $ug/m^2/yr$) across a variety of lakes in Vermont and New Hampshire (Kamman and Engstrom 2002).

2. **A geochronological history of mercury deposition to lake sediments in the area revealed augmented twentieth century deposition relative to other regional locations and especially increased deposition in the last two decades of that century.** Data from two lake bottom sediment cores provided an initial comparative picture of historical mercury deposition in the area (Figure 7) (Wallace et al. 2004). Lake Cochichewick located approximately 5-6 km to the east or southeast of the cluster of incinerators, which were operating in northeastern Massachusetts in the late 1990s, provided the picture for the predicted high deposition area. Echo Lake data came from unpublished work by Luce and Wallace and provide a comparative picture of historic mercury deposition in a more pristine, rurally-located lake approximately 45 km west southwest of downtown Boston. There are no local point sources of mercury emissions to the atmosphere in the region so that the mercury in the lake should reflect generalized atmospheric deposition of mercury to the lake and its watershed. Mercury concentrations in the sediments of the two lakes were similar from about 1850 through 1910 (with the exception of an unexplained spike in mercury content of the Echo Lake sediments in the early 1900s). Thereafter, mercury concentrations in Lake Cochichewick sediments increased about six times faster than those of Echo Lake. As of about 2001, the surface sediment concentrations in Lake Cochichewick were about 2.6 times those in Echo Lake (Wallace et al. 2004). Northeastern Massachusetts has an important history of industrialization dating back into the nineteenth century with the extensive burgeoning of textile mills and associated cities along major rivers such as the Merrimack River and subsequent urbanization through the twentieth century. Associated with urbanization have been activities associated with mercury emissions such as manufacturing, generation of domestic and industrial wastes, generation of combustion products to the atmosphere from widespread burning of coal for domestic heat, for coal gas production, for firing industrial boilers in the late nineteenth and first half of the twentieth centuries, and municipal-level solid waste combustion. The monotonic increase in the flux of mercury to the sediments of Lake Cochichewick throughout the twentieth century is shown in Figure 8 and approached an annual deposition rate of 90 ug $Hg/m^2/yr$ in recent years, in concordance with the model-predicted value noted above.

3. **Early (1980s) limited sampling of various freshwater fish species from some lakes in the area suggested a fairly consistent picture of elevated mercury concentrations, sufficient to be of public health concern.**

4. **Lastly, the early data suggesting that the fish in this region had higher concentrations of mercury than those from other regions of the state, which led MassDEP to focus further sampling in this region, was confirmed by a statistically-based intensive sampling program of YP and LMB from 21 lakes in NE MA (MassDEP 2003b).**

The long-term monitoring effort, which started in 1999, focused on a number of waterbodies in this hotspot deposition area to investigate the magnitude and time course of possible reductions in response to the emission reductions set to occur in MA, New England and in the local area as a result of upcoming regulatory activities under the NEG-ECP MAP and MAZMS. By the early 2000s after the imposition of tighter incinerator mercury emissions limits, only two of three MSWCs were still in operation and no MWIs continued to operate in that part of MA. Concomitantly, better emissions controls were installed on remaining facilities in the area and across Massachusetts and New England. Overall, mercury emissions in New England and the Eastern Canadian Provinces decreased by about 54% between 1998 and 2003. During this period emissions in Massachusetts decreased by about 70% and those in the study area by about 87%. Although the exact timing of the pollution reductions over this period cannot be precisely evaluated due the large number of differing sources and regulatory requirements in play, the largest fraction occurred after 2000 when new regulations came into effect limiting emissions from MSWCs and MWIs in the New England states and MA.

The results for fish tissue mercury concentration changes over this timeframe were notable. Over the period 1999 through 2004, mean edible tissue mercury concentrations in YP and LMB exhibited fairly consistent decreases with 13 of 17 lakes across the state showing statistically significant decreases (Figure 4, Figure 5 and Table 3). The presentation of the lakes data has been segregated into two categories for interpretative purposes: (1) those lakes in northeastern Massachusetts subject to local atmospheric inputs of mercury from several large point sources of mercury; (2) those lakes throughout the rest of the state subject to more diffuse sources of mercury emissions to the atmosphere.

Within NE MA, YP had the largest overall decreases in mercury. The mean decrease over all 9 lakes sampled in that region was 32.4% and 8 of those had statistically significant decreases.

The picture for LMB was similar but not as complete because of smaller sample sizes due to difficulties capturing sufficient numbers of fish (or any fish in some cases). The variation was also greater between lakes for LMB than YP (Table 3). Four out of eleven lakes had no statistically significant changes (Figure 9). The statistically significant decreases ranged from 16 to 55.2% of the initial value. The average change was –24.8%.

For lakes around the remainder of the state, a fairly consistent picture of decreases in tissue mercury concentrations in both species was apparent (Figure 4 and Figure 5). Five out of eight had statistically significant decreases in YP tissue mercury concentrations

(Figure 9). The average change in tissue mercury concentrations for all lakes in the remainder of the state was -15.4%.

Tissue mercury concentrations in LMB in lakes around the rest of the state decreased by an average of 19.0% and statistically significant decreases occurred in four out of the six lakes sampled (Table 2, Table 3, Figure 9).

Comparison of the temporal changes in fish tissue mercury concentrations between those lakes from NE MA and those from the rest of the state should be performed cautiously because the starting points for both groups are somewhat different. Because of logistical and budget constraints, 1999 baseline testing was focused on the northeast deposition hotspot area. Thus, pre-incineration emissions reductions values (1999) were available for many of the NE MA lakes but not for lakes around the rest of the state. The first data point for these other statewide lakes was usually 2001, so that those lakes had a different baseline value for calculation of amount of change than the NE MA lakes. However, for those few lakes where a baseline mean was available in 1999, the 2001 value was not statistically different from the 1999 value (YP: Lake Cochichewick, Kenoza Lake; LMB: Lake Cochichewick, Stevens Pond) (Figure 5 and Table 2). Therefore, the 2001 values may not be bad representations of conditions in the lakes in 1999.

The timing of fish tissue mercury decreases is similar to the timing of mercury emissions reductions. The YP tissue mercury yearly means for Lake Cochichewick in NE MA plotted in Figure 10 were representative of the trends seen from most lakes (Figure 4 and Figure 5). Total statewide MSWC and MWI mercury emissions are plotted on the same time scale. The baseline level of emissions in the late 1990s prior to imposition of emissions controls is represented by the data through 2000 (approximately 3000 kg mercury per year). By 2003 after the emissions controls had been operational for 3 years, total emissions levels dropped by about an order of magnitude to approximately 300 kg per year. Fish tissue mercury concentrations showed a similar pattern. Means in 1999 and 2001 were statistically the same. In 2002 they decreased significantly ($\alpha = 0.01$) and they decreased even further in 2004. Overall, the concentrations decreased 47.4% between 1999 and 2004. The magnitude of reductions in mercury emissions is more significant in NE MA than in the remainder of the state because of the concentration of local major point sources in NE MA before 2000 and subsequent reductions in numbers of operating facilities and substantial reductions in the mercury emissions of those remaining.

The time scale over which fish tissue mercury concentration changes have been observed in relation to changes in anthropogenic mercury inputs is notable. While the closest samples that we have for comparison with post-2000 samples were from 1999, 12 months before the imposition of the emissions controls in 2000, we think that the 1999 samples were likely representative of fish tissue mercury concentrations at the time of imposition of the controls. We draw this conclusion for the same reason discussed in earlier paragraphs that we concluded that the 2001 samples were likely reflective of 1999 conditions in those lakes where we did not have 1999 samples: we cited data from 4 lakes with 1999 and 2001 data showing no differences between 2001 and 1999. Therefore we

reference our conclusions about the timing of mercury decreases to the 2000 date. The majority of the decreases occurred 36-48 months after the implementation of new emissions controls and accompanying decreases in mercury emissions. Until recently, the prevailing view has been that it would be many years (tens of years) before fish tissue mercury concentrations reflected any decreases in inputs of mercury into the environment through emissions and use reductions efforts. This perspective probably has come from the fact that mercury cycling in the environment is a complex process and substantial historical stores of mercury exist in the sedimentary environment. These stores would presumably serve as a reservoir for mercury to be reintroduced back into the aquatic ecosystem even after present day inputs are reduced.

Recent data from the Florida Everglades have recast the thinking on this issue. Fish (LMB) and birds (great egret nestlings) have more rapidly reflected decreases in local atmospheric mercury inputs than was previously anticipated (Atkeson et al. 2003). Greater than 80% decreases in the mercury content of these two species were documented over the decade from 1990-2000. Local mercury emission rates in South Florida decreased by more than 90% since peaks in the late 1980s and early 1990s. More stringent emissions control regulations for incinerators came into effect in mid 1992, which led to decreases in mercury emissions rates and closures of some incineration facilities in Florida. From the time emissions started to decrease, it took from 6-36 months before decreases in LMB tissue mercury concentrations were detected. Modeling indicated that changes in atmospheric deposition, inferred from sediment core data, may account for the recent changes in LMB mercury concentrations. The generalizability of these observations to temperate waterbodies is, however, unclear due to the rather unique attributes of the Everglades ecosystem.

The relative importance of old reservoir sources of mercury such as aquatic sediments versus newer mercury inputs has been elucidated by the results of experiments from isotopic mercury tracer field studies. They have indicated that newly deposited atmospheric mercury is more reactive (and bioavailable) than old mercury in lake systems (Hintelmann et al., 2002; Babiarz et al., 2003). These results indicated that mercury cycling in aquatic systems responds rapidly to changes in recent depositional inputs of mercury. This empirical field data and data from Florida lend support for the preliminary conclusion that decreases in fish tissue mercury concentrations seen in northeastern Massachusetts may be reflecting recent large decreases in the levels of mercury emissions to the atmosphere and subsequent deposition to aquatic ecosystems.

Our results for YP versus LMB in NE MA are concordant with the theory of preferential accumulation of recent mercury. YP in NE MA exhibited greater tissue mercury concentration decreases than did LMB (– 32.4 % versus – 24.8 % (Table 3). YP feed lower on the food web and would be more directly and quickly the recipients of smaller prey lower on the food chain, closer to benthic habitats where methylation of mercury probably takes place. LMB feed on small fish and therefore are at least one step further removed from the trophic levels where changes in mercury inputs would be see most quickly. Given also their longevity, perhaps their tissue stores of mercury are less labile than those of YP and would more strongly reflect the longer-term accumulation dynamics

of mercury than would the YP. This comparison does not hold for these two species in lakes from the remainder of the state, where the changes in recent mercury inputs were not as dramatic as those in NE MA.

While it is encouraging to see distinct, measurable environmental benefits associated with reduced mercury pollution, it should be noted that a potential human health hazard from ingestion of mercury-containing fish from many of the lakes sampled still exists because tissue concentrations have universally not decreased below the concentration limit of 0.5 mg Hg/kg (see Figure 4 and Figure 5) used by the state's Department of Public Health for issuing fish mercury consumption advisories. This situation is particularly the case with LMB, which tend to have higher tissue mercury concentrations than YP because of their higher trophic position.

In conclusion, the study results are notable for the significant decreases in edible fish tissue mercury concentrations, in particular from waterbodies located in a mercury deposition hotspot area, that occurred within 36-48 months of the adoption and implementation of comprehensive state and regional plans that effectively reduced emissions of mercury. These reductions were achieved primarily through the imposition of stringent mercury emissions controls on MSWC and MWI, as well as reductions from other regional sources. These results suggest that mercury levels in fish from temperate water bodies can be significantly reduced over a relatively short timeframe if emission sources are effectively controlled. However, although reduced, overall average mercury concentrations in fish from many of the waterbodies sampled still exceed the recommended safe consumption level. As discussed in the Massachusetts TMDL Alternative Proposal submitted to the USEPA in 2004, significant reductions from out-of-state mercury sources will likely be needed to achieve water quality and public health objectives in MA.

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TABLES

Table 1. Analytical Methods for Water Quality

Analyte	Method Reporting Limit, mg/L	Method
Na	0.02	EPA 200.7
K	0.07	EPA 200.7
Ca	0.01	EPA 200.7
Mg	0.005	EPA 200.7
SO_4	0.06	EPA 300
Cl	0.07	EPA 300
Fe	0.01	EPA 200.7
Mn	0.005	EPA 200.7
TOC	0.2	EPA 415.1
DOC	0.2	EPA 415.1
Alkalinity	0.25	EPA 310.1
NO_2	0.003	EPA 300.0
NO_3	0.002	EPA 300.0
NH_3	0.001	Standard Methods. 4500-NH_3 F
Tot. P	0.001	Standard Methods. 4500-P E

Table 2. Annual Lake Mean Fish Tissue Mercury Concentrations and Size-Adjusted Means.

AREA	SPECIES	LOCATION	YEAR	Mercury Concentration (m/kg)			slope*	Size Adjusted Hg Mean	
				Mean	n	Std.Dev.		Mean	Std.Dev.
NE MA	LMB	Baldpate Pond	1999	1.333	9	0.158	0.004	1.401	0.112
	LMB	Baldpate Pond	2004	0.421	15	0.173	0.003	0.696	0.126
	LMB	Chadwicks Pond	1999	1.170	12	0.288	0.000	1.172	0.288
	LMB	Chadwicks Pond	2004	0.986	15	0.442	0.005	1.054	0.277
	LMB	Lake Cochichewick	1999	0.579	9	0.186	0.004	0.554	0.163
	LMB	Lake Cochichewick	2001	0.699	12	0.458	0.006	0.626	0.191
	LMB	Lake Cochichewick	2004	0.363	14	0.219	0.002	0.416	0.095
	LMB	Haggetts Pond	1999	0.894	8	0.539	0.007	0.664	0.263
	LMB	Haggetts Pond	2003	0.180	12	0.127	0.001	0.260	0.091
	LMB	Haggetts Pond	2004	0.578	15	0.612	0.005	0.764	0.193
	LMB	Johnsons Pond	1999	0.607	9	0.149	0.004	0.563	0.069
	LMB	Johnsons Pond	2004	0.316	15	0.116	0.001	0.473	0.037
	LMB	Kenoza Lake	2001	1.104	5	0.254	0.003	0.948	0.207
	LMB	Kenoza Lake	2004	0.719	13	0.436	0.004	0.814	0.155
	LMB	Lake Attitash	1999	1.011	9	0.252	0.004	0.575	0.152
	LMB	Lake Attitash	2004	0.353	12	0.208	0.003	0.428	0.102
	LMB	Lake Saltonstall	1999	0.514	9	0.187	0.004	0.655	0.057
	LMB	Lake Saltonstall	2003	0.341	12	0.255	0.003	0.427	0.094
	LMB	Lowe Pond	1999	1.112	9	0.284	0.002	1.078	0.229
	LMB	Lowe Pond	2004	0.833	3	0.051	0.001	0.775	0.044
	LMB	Pomps Pond	1999	1.321	9	0.498	0.005	1.200	0.283
	LMB	Pomps Pond	2001	0.070	9	0.020	-	-	-
	LMB	Pomps Pond	2004	0.232	6	0.056	-	-	-
	LMB	Rock Pond	1999	1.633	9	0.212	0.007	1.678	0.170
	LMB	Rock Pond	2004	0.834	14	0.538	-0.001	0.752	0.530
	LMB	Stevens Pond	1999	0.612	9	0.165	0.002	0.571	0.125
	LMB	Stevens Pond	2001	0.427	11	0.355	0.003	0.561	0.208
	LMB	Stevens Pond	2004	0.318	9	0.141	0.002	0.404	0.056
	YP	Baldpate Pond	1999	0.606	9	0.228	-0.002	0.645	0.219
	YP	Baldpate Pond	2004	0.198	4	0.067	0.002	0.246	0.010
	YP	Chadwicks Pond	1999	0.664	9	0.208	0.001	0.674	0.208
	YP	Chadwicks Pond	2004	0.379	30	0.164	0.004	0.492	0.115
	YP	Lake Cochichewick	1999	0.321	9	0.093	0.000	0.321	0.093
	YP	Lake Cochichewick	2001	0.333	30	0.128	0.002	0.349	0.103
	YP	Lake Cochichewick	2002	0.235	26	0.137	0.002	0.226	0.074
	YP	Lake Cochichewick	2004	0.145	30	0.107	0.002	0.169	0.059
	YP	Haggetts Pond	1999	0.381	9	0.143	0.003	0.498	0.140
	YP	Haggetts Pond	2003	0.264	30	0.060	-0.001	0.238	0.058
	YP	Haggetts Pond	2004	0.233	30	0.063	0.001	0.310	0.057
	YP	Johnsons Pond	1999	0.301	9	0.059	-	-	-
	YP	Johnsons Pond	2004	0.177	34	0.126	0.004	0.326	0.085
	YP	Kenoza Lake	2001	0.790	29	0.370	0.009	0.535	0.164
	YP	Kenoza Lake	2002	0.966	27	0.279	0.009	0.497	0.149
	YP	Kenoza Lake	2004	0.411	30	0.221	0.003	0.396	0.141
	YP	Lake Attitash	1999	0.289	9	0.092	0.001	0.316	0.087
	YP	Lake Attitash	2004	0.150	30	0.076	0.001	0.208	0.065
	YP	Lowe Pond	1999	0.432	9	0.147	0.004	0.374	0.138
	YP	Lowe Pond	2004	0.286	30	0.132	0.002	0.268	0.096

Table 2 cont. Annual Lake Mean Fish Tissue Mercury Concentrations and Size-Adjusted Means.

AREA	SPECIES	LOCATION	YEAR	Mercury Concentration (m/kg)			slope*	Size-Adjusted Hg Mean	
				Mean	n	Std.Dev.		Mean	Std.Dev.
NE MA	YP	Pomps Pond	1999	0.536	7	0.180	0.003	0.474	0.175
	YP	Pomps Pond	2001	0.106	9	0.021	-	-	-
	YP	Pomps Pond	2004	0.121	9	0.046	-	-	-
	YP	Rock Pond	1999	0.859	9	0.180	-0.001	0.847	0.180
	YP	Rock Pond	2004	0.383	30	0.239	0.003	0.529	0.210
	YP	Stevens Pond	1999	0.457	9	0.085	-0.001	0.473	0.082
	YP	Stevens Pond	2001	0.061	1	0.000	-	-	-
	YP	Stevens Pond	2004	0.135	2	0.007	-	-	-
Rest of	LMB	Bare Hill Pond	1999	0.549	9	0.129	0.003	0.550	0.101
State	LMB	Bare Hill Pond	2004	0.533	12	0.423	0.004	0.536	0.244
	LMB	Echo Lake	2004	0.478	13	0.127	0.002	0.553	0.057
	LMB	Lake Lashaway	2003	0.522	12	0.385	0.004	0.594	0.126
	LMB	Massapoag Dunstable	1999	0.784	9	0.077	-0.001	0.742	0.057
	LMB	Massapoag Dunstable	2004	0.578	12	0.157	0.002	0.624	0.083
	LMB	Massapoag Sharon	2003	0.438	12	0.333	0.004	0.471	0.132
	LMB	Lake Nippenicket	2003	0.645	12	0.296	0.004	0.764	0.156
	LMB	North Watuppa Pond	2001	0.772	9	0.461	0.009	0.529	0.124
	LMB	North Watuppa Pond	2004	0.928	12	0.272	0.006	0.539	0.152
	LMB	Onota Lake	2001	0.241	21	0.106	0.001	0.300	0.063
	LMB	Onota Lake	2004	0.143	6	0.053	0.001	0.198	0.048
	LMB	Upper Reservoir	2001	0.716	5	0.111	0.000	0.727	0.111
	LMB	Upper Reservoir	2004	0.815	2	0.474			
	LMB	Lake Wampanoag	2001	0.856	14	0.395	0.004	0.805	0.201
	LMB	Lake Wampanoag	2004	0.511	14	0.264	0.003	0.587	0.114
	LMB	Wequaquet Lake	2001	0.554	30	0.297	0.003	0.612	0.129
	LMB	Wequaquet Lake	2004	0.842	12	0.351	0.005	0.389	0.156
	LMB	Wickaboag Pond	2003	0.291	12	0.336	0.003	0.423	0.202
	YP	Bare Hill Pond	1999	0.342	9	0.111	0.001	0.329	0.106
	YP	Bare Hill Pond	2004	0.190	30	0.057	0.002	0.263	0.041
	YP	Buckley Dunton Lake	2003	0.236	25	0.105	0.003	0.448	0.050
	YP	Buckley Dunton Lake	2004	0.212	29	0.083	0.004	0.541	0.055
	YP	Echo Lake	2004	0.253	18	0.135	0.002	0.376	0.043
	YP	Lake Lashaway	2003	0.227	15	0.110	0.001	0.299	0.093
	YP	Massapoag Dunstable	1999	0.428	9	0.157	0.004	0.418	0.109
	YP	Massapoag Dunstable	2004	0.253	30	0.119	0.002	0.327	0.084
	YP	Massapoag Sharon	2003	0.154	30	0.060	0.001	0.212	0.047
	YP	Lake Nippenicket	2003	0.344	30	0.079	0.002	0.416	0.064
	YP	North Watuppa Pond	2001	0.646	30	0.157	0.003	0.533	0.131
	YP	North Watuppa Pond	2002	0.388	30	0.089	0.001	0.375	0.074
	YP	North Watuppa Pond	2004	0.415	30	0.146	0.003	0.391	0.086
	YP	Onota Lake	2001	0.229	30	0.082	0.002	0.270	0.077
	YP	Onota Lake	2002	0.208	24	0.092	0.001	0.226	0.089
	YP	Onota Lake	2004	0.131	30	0.059	0.001	0.212	0.047
	YP	Upper Reservoir	2001	0.702	30	0.210	0.006	0.779	0.189
	YP	Upper Reservoir	2002	0.642	20	0.218	0.006	0.738	0.160
	YP	Upper Reservoir	2004	0.585	4	0.294	0.011	0.703	0.109

Table 2 cont. Annual Lake Mean Fish Tissue Mercury Concentrations and Size-Adjusted Means.

AREA	SPECIES	LOCATION	YEAR	Mercury Concentration (m/kg)			slope*	Size-Adjusted Hg Mean	
				Mean	n	Std.Dev.		Mean	Std.Dev.
Rest of State	YP	Lake Wampanoag	2001	0.720	30	0.236	0.006	0.797	0.174
	YP	Lake Wampanoag	2004	0.440	30	0.136	0.003	0.574	0.079
	YP	Wequaquet Lake	2001	0.489	30	0.129	0.004	0.413	0.094
	YP	Wequaquet Lake	2002	0.380	30	0.129	0.003	0.331	0.084
	YP	Wequaquet Lake	2004	0.296	30	0.091	0.002	0.330	0.048

* slope of regression line of mercury concentration versus length

Table 3. Mean Percent Changes in Mercury Concentrations in Species and Lake-Specific Tissue Mercury Concentrations Between First Monitoring Date and Latest Date

Area	Lake	Yellow Perch % Change[a]	Largemouth Bass % Change[a]
Northeast MA	Lake Attitash	**-34.3**	**-25.4***
	Baldpate Pond	**-61.9**	**-50.4**
	Chadwicks Pond	**-26.9**	**-10.0**
	Lake Cochichewick	**-47.4**	**-24.9**
	Haggetts Pond	**-37.9**	*15.1*
	Johnsons Pond	8.3	**-16.0**
	Kenoza Lake	**-26.0**	-14.2
	Lowe Pond	**-28.4***	**-28.1***
	Pomps Pond	-	-
	Rock Pond	**-37.5**	**-55.2**
	Lake Saltonstall	-	**-34.8**
	Stevens Pond	-	-29.3
	Group Mean:	**-32.4**	**-24.8**
Rest of State	Bare Hill Pond	**-20.1**	-2.5
	Buckley Dunton Lake	*20.7*	-
	Lake Massapoag- Dunstable	**-21.9***	**-15.9**
	North Watuppa Pond	**-26.6**	1.9
	Onota Lake	**-21.5***	**-34.1**
	Upper Reservoir	-5.3	
	Lake Wampanoag	**-28. 0**	**-27.1**
	Wequaquet Lake	-20.1	**-36.4**
	Group Mean:	**–15.4**	**-19.0**

[a] Bolded values represent statistically significant changes at $\alpha = 0.01$, unless noted with an '*' representing significance at $\alpha = 0.05$. Anomalous values noted in *italics*.

FIGURES

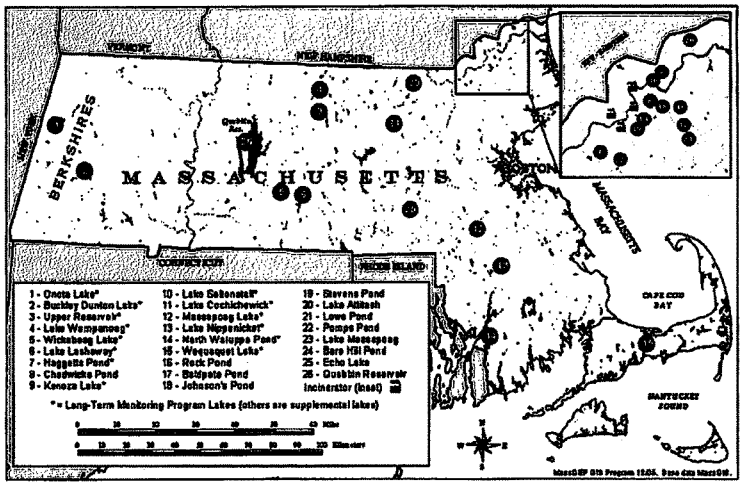


Figure 1. Locations of Long-Term Monitoring Lakes (Lake Saltonstall (#10) dropped in 2004 because of absence of YP and high LMB fishing pressure. Rock Pond (#16) substituted for it in 2005).

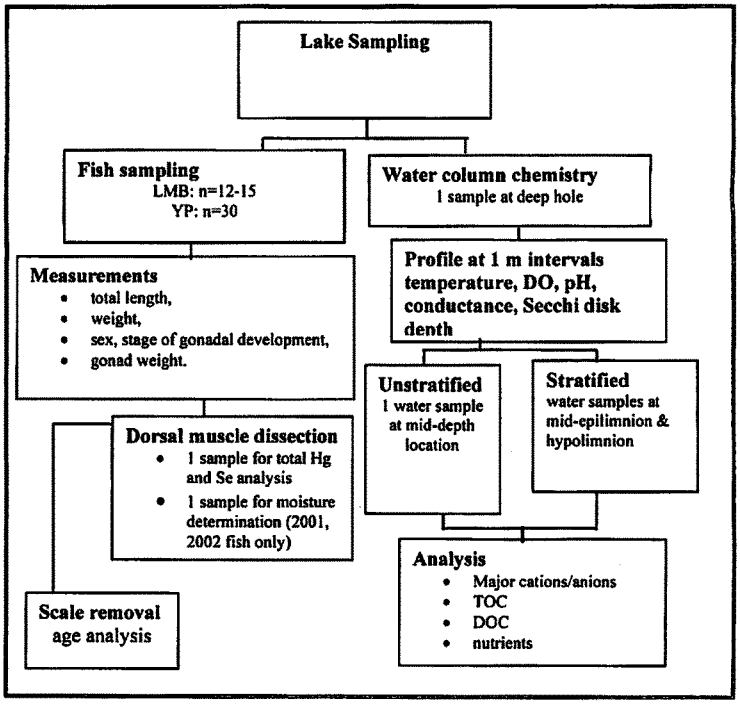


Figure 2. Field and Lab Handling Protocol.

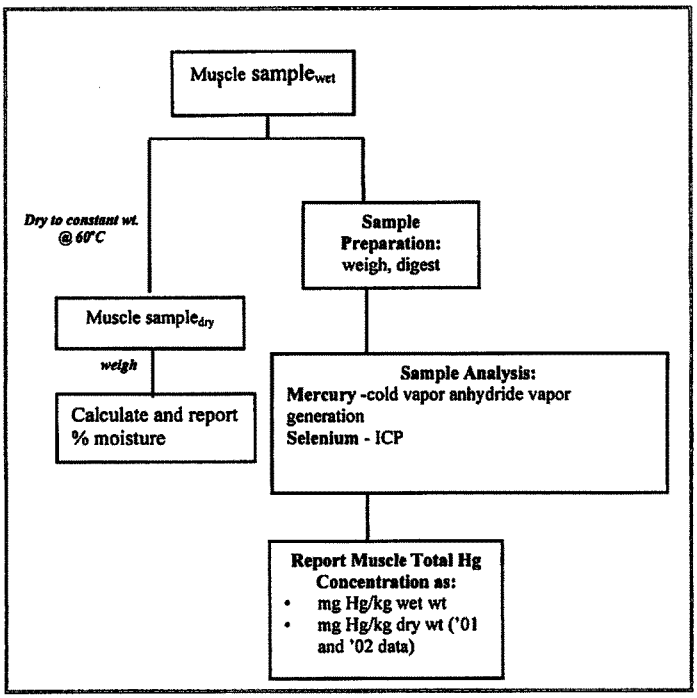


Figure 3. Fish Laboratory Processing Protocol

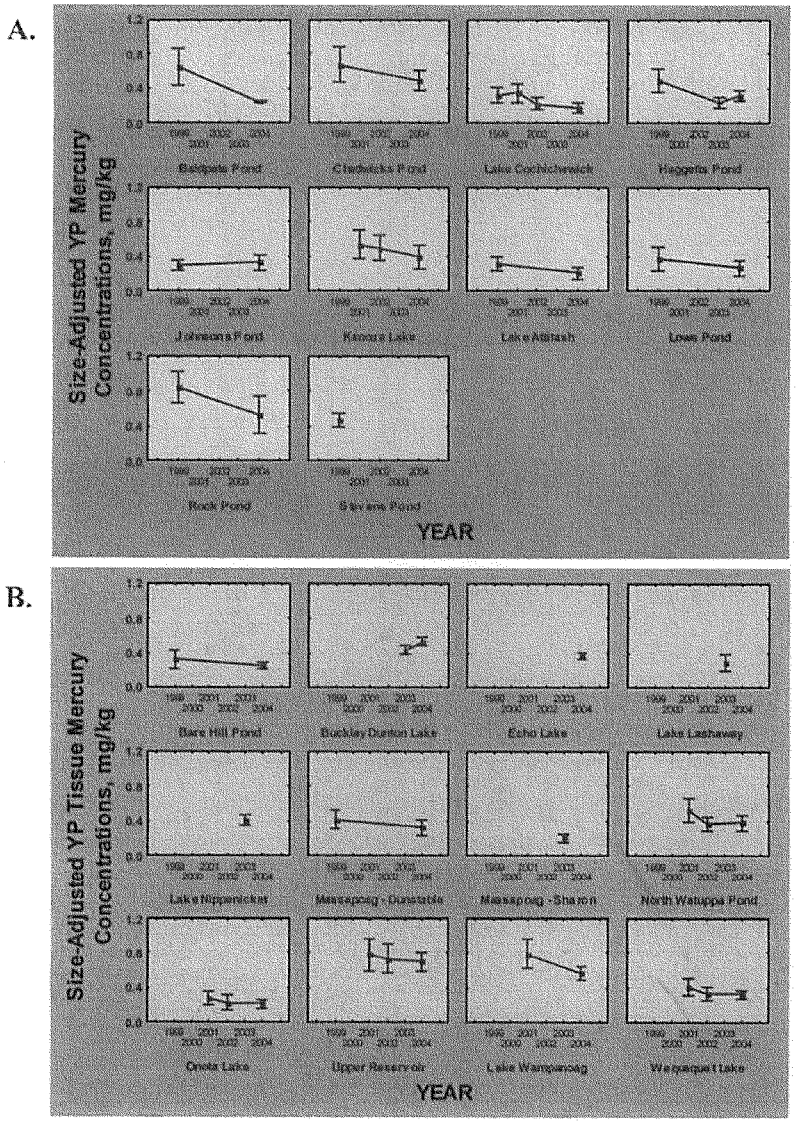


Figure 4. Size-Adjusted Annual Lake Mercury Concentration Means (± 1 std. dev.) for YP. A. Northeast Massachusetts Lakes; B. Statewide Lakes.

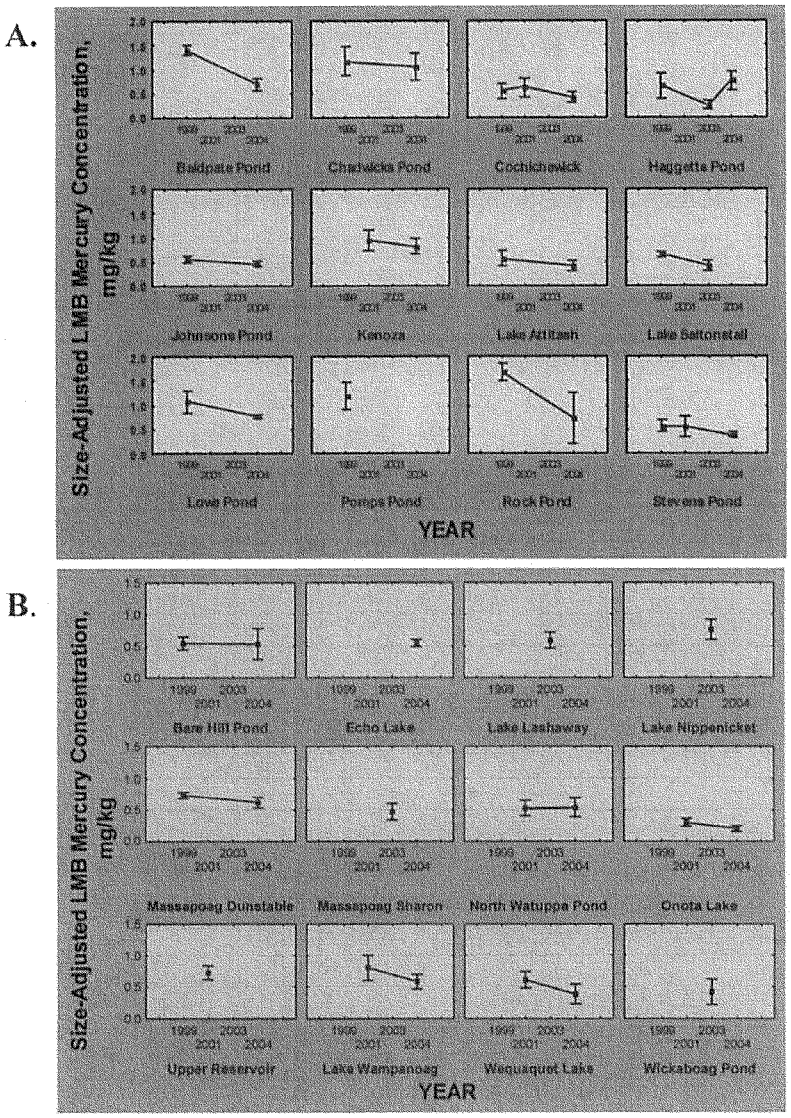


Figure 5. Size-Adjusted Annual Lake Mercury Concentration Means (±1 std. dev.) for LMB. A. Northeast Massachusetts Lakes; B. Statewide Lakes

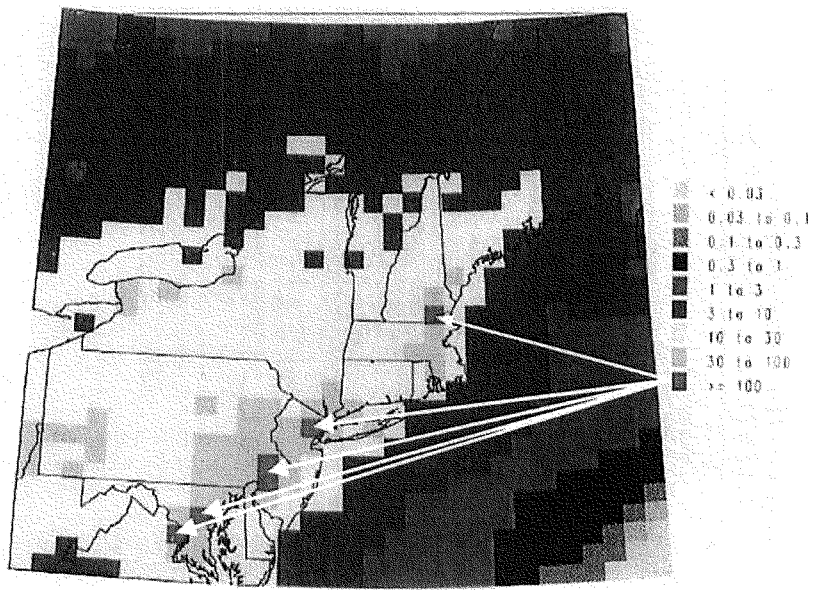


Figure 6. Predicted Annual Wet and Dry Mercury Deposition (ug/m2) from All U.S. Sources (Source: Northeast States/Eastern Canadian Provinces 1998)

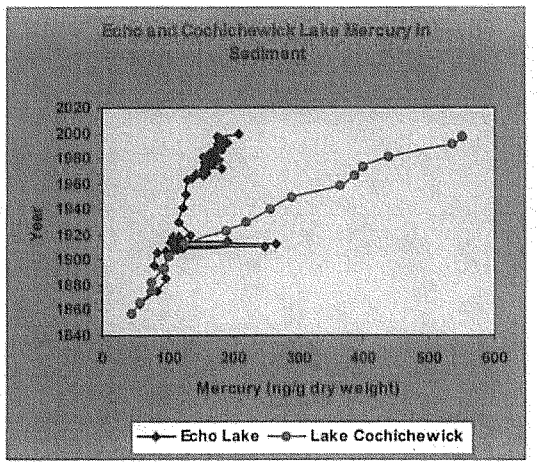


Figure 7. Sediment Core Mercury Concentration Versus Year for Echo Lake and Lake Cochichewick, MA. (Source: Wallace et al. 2004. Echo Lake Data from Wallace and Luce, unpublished data.).

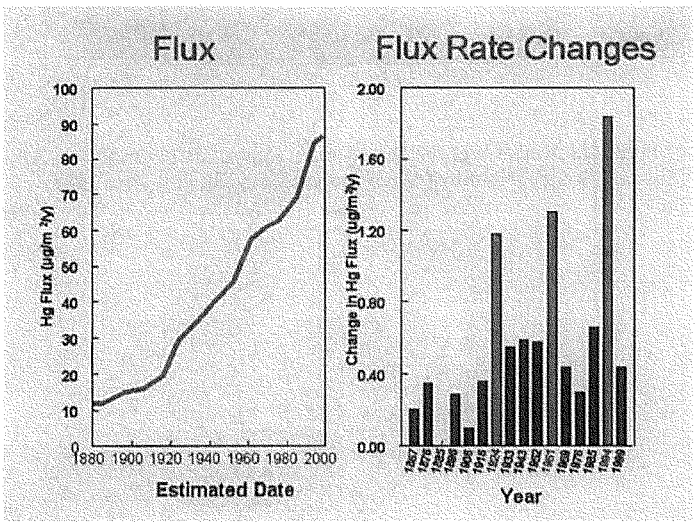


Figure 8. Mercury Fluxes Into Sediments of Lake Cochichewick Over The Last 120 Years (Source: Wallace et al. 2004)

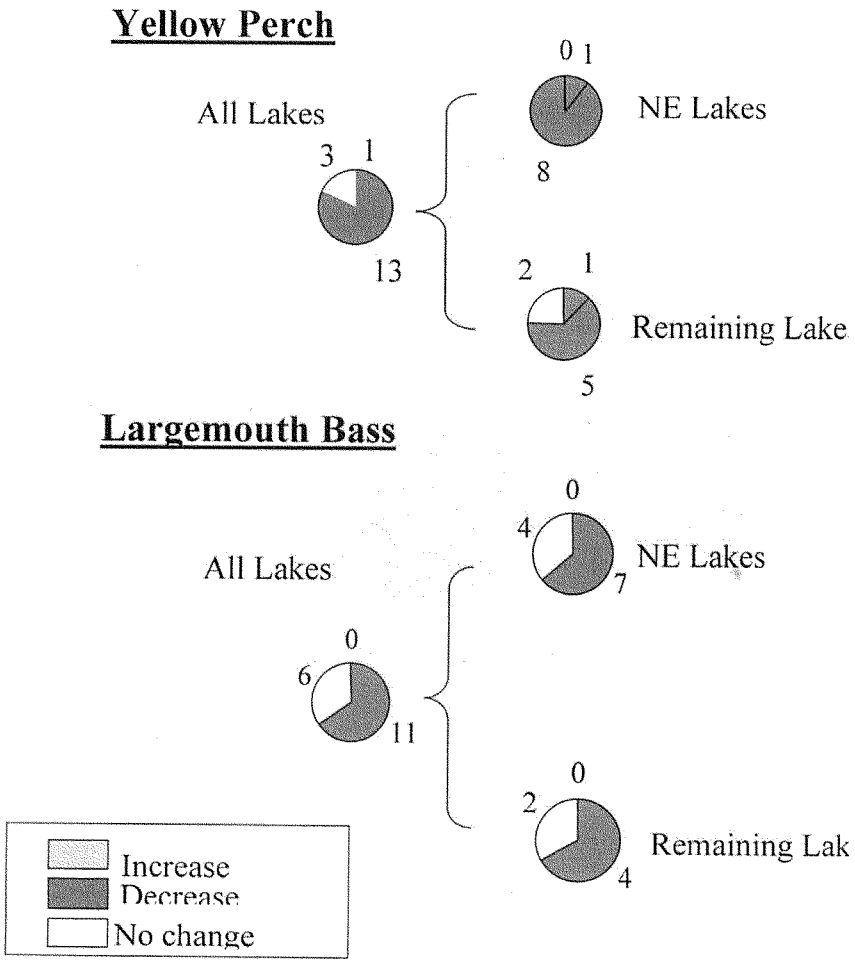


Figure 9. Numbers of Lakes Having Statistically Significant Increases, Decreases and No Significant Change in Fish Tissue Mercury Concentrations, 1999-2004. A. YP; B. LMB.

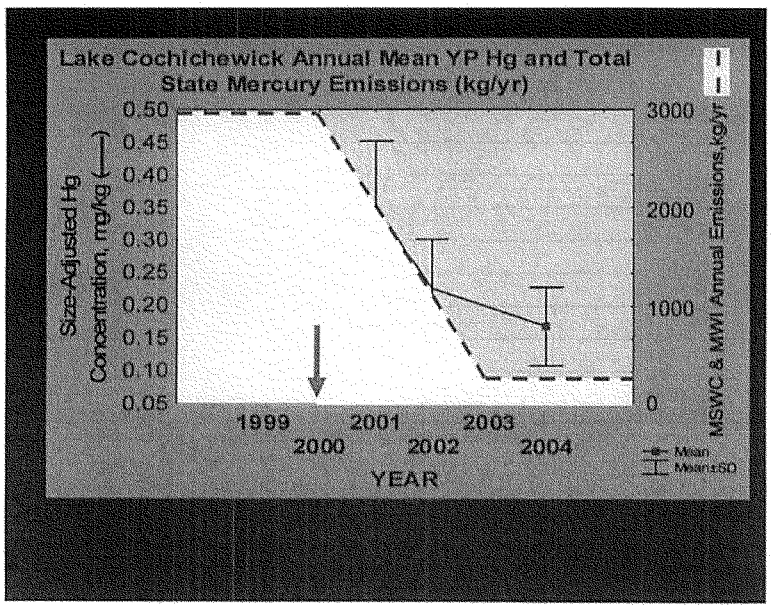


Figure 10. Representative Fish Tissue Mercury and Incinerator Emissions Changes Versus Time in NE MA.

APPENDIX

Table A-1. Long-Term Monitoring Lakes and Seasonal Variability Lakes (shown in bold)

Water Body	Acres	Town	Watershed	PALIS #	Year Sampled									
					1976	1995	1998	1999	2001	2002	2003	2004	2005	2006
Lake Wampanoag	218	Ashburnham Gardner	Nashua	81151		X			S,S,F	W		X		
Upper Reservoir	57	Westminster	Millers	35091		X				S		X		
North Watuppa Pond	1700	Fall River	Mount Hope Bay	61004		X		S,S,W	S,S	W,S		X	X	
Lake Cochichewick	555	North Andover	Merrimack	84008				X	S,S	W,S				
Kenoza Lake	287	Haverhill	Merrimack	84028					S,S,F	W,S		X		
Onota Lake	617	Pittsfield	Housatonic	21078	X				S,S	W,S	X	X		
Wequaquet Lake	654	Barnstable	Cape Cod	96333		X			S,S,F	W,S		X		
Lake Saltonstall	45	Haverhill	Merrimack	84059				X			X	*See note		
Rock Pond[#2]		Georgetown	Parker	91012				X				X	X	
Massapoag Lake	353	Sharon	Neponset	73030									X	
Buckley-Dunton Lake*	195	Becket	Westfield	32013		X						X		X
Haggetts Pond	214	Andover	Merrimack	84022				X		X	X	X	X	
Lake Nippenicket	354	Bridgewater	Taunton	62131						X			X	
Wickaboag Lake	320	West Brookfield	Chicopee	36166									X	
Lake Lashaway	270	North & East Brookfield	Chicopee	36079						X			X	
Baldpate Pond[#]	55	Boxford	Merrimack	91001				X		X X		X		

Table A-1 cont. continued. Long-Term Monitoring Lakes and Seasonal Variability Lakes (shown in bold)

Water Body	Acres	Town	Watershed	PALIS #	1976	1995	1998	1999	2001	2002	2003	2004	2005	2006
Chadwicks Pond[¥]	161	Haverhill, Boxford	Merrimack	84006				X				X		
Echo Lake[¥]	123	Milford, Hopkinton	Charles	72035								X		
Quabbin Reservoir[¥]	25,000	Multiple towns	Chicopee	36129	1989								X	
Massapoag		Dunstable						X				X		
Johnson's Pond[¥]		Groveland Boxford						X				X		
Stevens Pond[¥]		North Andover						X				X		
Bare Hill Pond[¥]		Harvard						X				X		
Lake Attatash[¥]		Amesbury						X				X		
Lowe Pond[¥]		Boxford						X				X		
Pomps Pond[¥]		Andover						X	X[1]			X		

S,S,F,W designation in some cells for Year Sampled indicated that fish were sampled in Spring, Summer, Fall or Winter.

[*] Dropped in 2004 because no YP previously caught and small LMB population with heavy fishing pressure.

[1] Part of Food web study

[2] Added to Long-Term Monitoring List in 2005 as substitute for L. Saltonstall

[*] Substituted Buckley Dunton Lake for Yokum Pond because no fish caught in Yokum Pond which was originally chosen.

[¥] Special sampling conducted in 2004. Not part of long-term monitoring group of 12 lakes.

Table A-2. Summary of Sampling Dates and Types of Interannual Means Difference Tests Performed

Water Body	1995	1998	1999	2001	2002	2003	2004	t-test YP	t-test LMB	ANOVA/ANCOVA YP	ANOVA/ANCOVA LMB
Lake Wampanoag	X			S,S,F	W		X	√	√	-*	-
Upper Reservoir	X			S,S,W	S		X	√ 01 v 02	-	-	-
North Watuppa Pond	X			S,S	W,S		X	√		√	
Lake Cochichewick			X	S,S	W,S		X			√	√
Keneza Lake				S,S,F	W,S		X		√	√	
Onota Lake				S,S	W,S		X		√	√	
Wequaquet Lake	X			S,S,F	W,S		X		√	√	
Lake Saltonstall			X			X	*See note		√		
Massapoag Lake -Sharon						X					
Buckley-Dunton Lake	X					X	X	√	-		-
Haggetts Pond			X			X	X			√	√
Lake Nippenicket						X		-	-	-	-
Wickaboag Lake						X		-	-	-	-
Lake Lashaway						X		-	-	-	-
Baldpate Pond			X				X	√	√		
Chadwicks Pond			X				X	√	√		
Echo Lake							X	-	-	-	-
Quabbin Reservoir							X(05)	-	-	-	-
Massapoag - Dunstable			X				X	√	√		

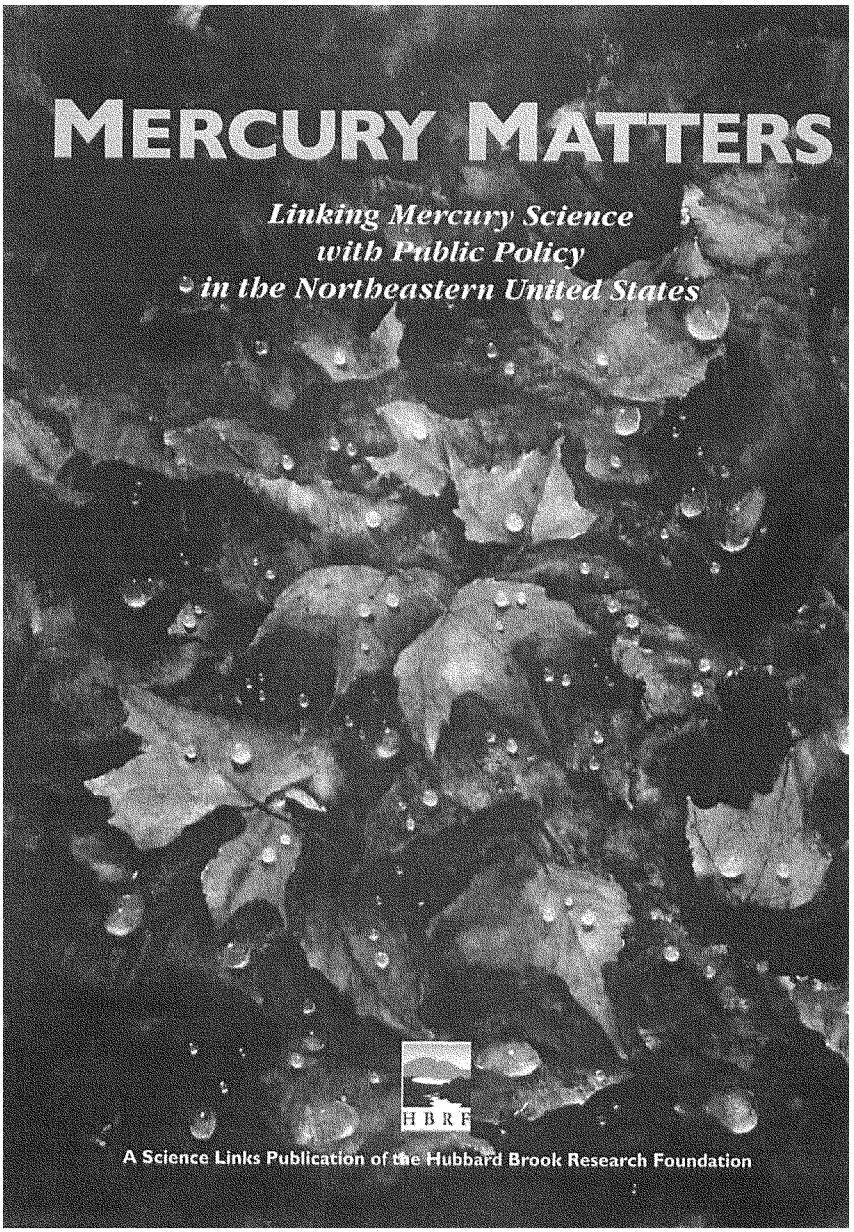
* not done because insufficient numbers of fish or samples.
* dropped in 2004 because no YP previously caught and small LMB population with heavy fishing pressure.

Table A-3. Physical/Chemical Parameters. All Units mg/L Unless Noted Otherwise

List of Chemical Symbols	
Alk	Alkalinity, as $CaCO_3$
Ca	calcium
Cl	chloride
DOC	dissolved organic carbon
Fe	iron
K	potassium
Mg	magnesium
Mn	manganese
Na	sodium
NH_3	ammonia nitrogen
NO_2	nitrite nitrogen
NO_3	nitrate nitrogen
SC	specific conductivity
SO_4	sulfate
TOC	total organic carbon
TP	total phosphorus

Location	Date	Season	T °C	DO	pH	SC, mS	Alk	Ca	Na	K	Mg	Mn	Fe
Kenoza Lake	2001	spring - prespawn	7.3	11.5		213.5							
Kenoza Lake	2001	spring	12.4	8.3	6.9	234.1	19.5	11.82	24.59	1.62	2.38	0.02	0.08
Kenoza Lake	2002	spring - postspawn	9.4	10.5	7.4	210.1							
Lake Cochichewick	2001	spring - prespawn	12.1	12.4		162.0							
Lake Cochichewick	2001	spring	17.7	121.6	7.5	106.4	14.4	7.61	17.04	1.68	2.04	0.13	0.12
Lake Cochichewick	2002	spring - postspawn	9.9	11.3	7.5	148.8							
Lake Wampanoag	2001	spring	16.2	8.1		106.2	0.2	2.16	14.57	0.44	0.48	0.13	0.26
North Watuppa Pond	2001	spring	16.6	8.8		75.9	1.6	2.58	8.49	0.39	0.81	0.03	0.07
North Watuppa Pond	2002	spring - postspawn	14.0	11.8	6.8	73.2							
Onota Lake Bottom	2001	spring	6.0	3.4	6.9	220.8	77.8	21.61	5.10	0.40	7.76	0.20	0.05
Onota Lake Top	2001	spring	7.5	9.5	7.7	189.8	65.1	18.80	4.45	0.33	6.60	0.01	0.03
Onota Lake	2002	spring - postspawn	9.5	5.3	8.0	208.0							
Upper Reservoir	2001	spring	16.6	4.3	4.6	64.0	-0.4	1.71	6.16	0.45	0.43	0.03	0.32
Upper Reservoir	2002	spring - postspawn	16.5	9.4	4.9	61.0							
Wequaquet Lake	2001	spring	17.6	5.1	6.6	109.1	3.3	1.22	12.37	0.96	2.00	0.01	0.08
Wequaquet Lake	2002	spring -postspawn	14.7	10.9	7.1	67.1							
Haggetts Pond	2003	spring	17.8	6.8	8.5	423.4	15.8	12.06	64.54	3.06	2.95	0.04	0.06
Lake Saltonstall	2003	spring	16.9	6.7	8.3	283.1	21.6	9.56	46.82	1.69	2.02	0.02	0.06
Lake Attitash	2004	spring	20.1	6.7	7.3	164.9	17.1	10.51	15.37	2.53	2.63	0.06	0.09
Baldpate Pond	2004	spring	12.7	7.2	8.2	194.9	21.4	10.89	29.63	1.87	3.03	0.07	0.20
Bare Hill Pond	2004	spring	19.2	6.7	7.1	193.3	8.9	6.97	21.18	1.29	1.70	0.11	0.21
Buckley Dunton Lake	2004	spring	20.8	8.7	6.8	26.3	2.1	3.23	2.15	0.48	0.56	0.03	0.25
Chadwicks Pond	2004	spring	15.8	10.9	7.8	154.3	24.3	11.10	16.02	1.69	2.78	0.17	0.08
Cochichewick	2004	spring	15.4	8.9	7.4	200.2	13.3	8.83	22.12	1.99	2.35	0.03	0.10
Johnsons Pond	2004	spring	15.2	5.2	6.7	134.7	26.6	11.39	13.15	1.97	2.66	0.19	0.12
Kenoza Lake	2004	spring	13.2	10.5	6.4	292.7	18.9	13.81	32.41	2.00	2.85	0.02	0.09
Massapoag Dunstable	2004	spring	13.8	6.5	6.6	103.3	20.9	14.39	19.01	2.21	2.05	0.16	0.17
Onota Lake epilimnion	2004	spring	20.0	8.6	8.7	156.8	69.6	22.16	5.18	0.44	7.10	0.01	0.04
Onota Lake hypolimnion	2004	spring	7.8	4.5	7.8	121.5	74.4	22.94	5.38	0.55	7.37	0.15	0.06
Rock Pond	2004	spring	17.6	5.0	6.5	223.8	19.1	11.09	23.17	1.56	2.67	0.12	0.64
Upper Reservoir	2004	spring	18.0	7.1	5.2	63.0	-0.6	1.92	7.37	0.56	0.46	0.02	0.43
Wampanoag	2004	spring	17.1	7.7	7.0	115.0	0.1	2.48	18.93	0.73	0.54	0.09	0.59
North Watuppa Pond	2004	spring	18.6	8.3	7.0	88.8	2.3	2.94	10.32	0.59	0.87	0.01	0.04
Wequaquet Lake	2004	spring	17.4	8.8	6.9	98.0	4.1	1.46	11.27	1.11	1.85	0.01	0.08

Location	Date	Season	Cl^-	$SO_4^{=}$	$NO3^-$	$NO_2^{=}$	NH_3	TP	DOC	TOC	Methods
Kenoza Lake	2001	spring - prespawn									* BDLs were entered as 1/2 DL.
Kenoza Lake	2001	spring	48.40	9.47	<.01		0.088	0.011	5.7	4.8	
Kenoza Lake	2002	spring - postspawn									* Anions- EPA method 300.0. DL in parentheses.
Lake Cochichewick	2001	spring - prespawn									(chloride=.07, sulfate=.06)
Lake Cochichewick	2001	spring	31.88	8.00		0.01	0.040	0.030	5.3	5.1	
Lake Cochichewick	2002	spring - postspawn									* Method 353.1 (.02). In 2003 they
Lake Wampanoag	2001	spring	25.78	4.40		0.005	0.040	0.010	4.8	3.1	were analyzed separately using
North Watuppa Pond	2001	spring	13.90	7.14		0.005	0.050	0.040	5.0	3.8	nitrite-N EPA Method 300.0
North Watuppa Pond	2002	spring - postspawn									MDL=2 ug/L.
Onota Lake Bottom	2001	spring	8.08	5.33		0.081	0.210	0.051	2.3	1.6	* Ammonia-N-Standard Methods 4500-NH3
Onota Lake Top	2001	spring	7.05	6.08		0.005	0.032	0.031	3.0	2.8	MDL=1 ug/L.
Onota Lake	2002	spring - postspawn									* TOC/DOC-EPA Method 415.1
Upper Reservoir	2001	spring	10.22	4.09		0.005	0.070	0.020	8.9	8.3	MDL=2 ug/L. Method for analysis for TOC/DOC.
Upper Reservoir	2002	spring - postspawn									is the same. The only difference is the method
Wequaquet Lake	2001	spring	20.00	7.16		0.005	0.010	0.030	3.9	2.4	of sampling. DOC is filtered, DOC is not.
Wequaquet Lake	2002	spring -postspawn									
Haggetts Pond	2003	spring	110.22	10.56	0.036	0.01	0.050	0.015	5.3	5.2	
Lake Saltonstall	2003	spring	77.12	5.44	0.034	0.012	0.022	0.014	4.2	4.2	
Lake Attitash	2004	spring	30.40	10.42	0.751	0.006	0.178	0.077	8.7	9.7	
Baldpate Pond	2004	spring	54.21	7.82	0.087	0.001	0.043	0.008	7.1	7.2	
Bare Hill Pond	2004	spring	41.31	5.60	0.029	0.001	0.429	0.010	5.8	5.8	
Buckley Dunton Lake	2004	spring	3.88	3.57	0.001	0.001	0.687	0.011	6.4	6.4	
Chadwicks Pond	2004	spring	30.77	6.24	0.001	0.001	0.014	0.010	8.2	8.2	
Cochichewick	2004	spring	42.37	9.43	0.001	0.001	0.021	0.011	6.4	6.8	
Johnsons Pond	2004	spring	25.80	6.65	0.002	0.001	0.076	0.018	9.2	9.2	
Kenoza Lake	2004	spring	64.66	10.99	0.002	0.001	0.011	0.008	8.3	8.1	
Massapoag Dunstable	2004	spring	44.05	5.98	0.071	0.001	0.291	0.007	4.8	4.4	
Onota Lake epilimnion	2004	spring	8.70	5.46	0.004	0.001	0.026	0.005	2.8	2.2	
Onota Lake hypolimnion	2004	spring	9.25	6.01	0.050	0.001	0.114	0.007	2.3	2.1	
Rock Pond	2004	spring	45.41	9.39	0.200	0.001	0.251	0.014	8.0	8.1	
Upper Reservoir	2004	spring	12.55	3.59	0.022	0.001	0.022	0.009	11.7	11.9	
Wampanoag	2004	spring	33.64	4.27	0.022	0.001	0.082	0.005	5.3	6.8	
North Watuppa Pond	2004	spring	17.95	6.84	0.002	0.001	0.309	0.008	4.0	3.8	
Wequaquet Lake	2004	spring	19.50	6.15	0.018	0.001	0.030	0.020	3.1	3.1	


MERCURY MATTERS
Linking Mercury Science
with Public Policy
in the Northeastern United States
HBRF
A Science Links Publication of the Hubbard Brook Research Foundation

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The mission of the **Hubbard Brook Research Foundation** (HBRF) is to promote the understanding and stewardship of ecosystems through scientific research, long-term monitoring, and education. HBRF was established to support the work of the Hubbard Brook Ecosystem Study. Since 1963, ecosystem experiments and continuous ecological monitoring have been conducted at the Hubbard Brook Experimental Forest, a 7,800-acre tract of land in central New Hampshire managed by the USDA Forest Service. The site is part of the National Science Foundation's Long Term Ecological Research (LTER) Network. Scientists participating in the world-renowned Hubbard Brook Ecosystem Study have made discoveries regarding the ecology of forested watersheds and the effects of timber harvesting, climate change, acid rain, and other natural and human-caused disturbances. HBRF is a nonprofit 501(c)(3) organization, supporting ecosystem science at Hubbard Brook by operating housing and other facilities and by conducting educational programs.

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MERCURY MATTERS

Linking Mercury Science with Public Policy in the Northeastern United States

A Science Links Publication
of the
Hubbard Brook Research Foundation
January 2007

SCIENCE LINKS
Leveraging Science for Public Policy

Executive Summary

Mercury pollution is a vexing environmental problem that leads to the contamination of forests, soils, lakes, streams, and oceans around the world. Today every part of the globe has been touched by mercury pollution. Even the remote Arctic, with no known sources of mercury, harbors polluted waters and contaminated fish. While mercury has been widely recognized as a global pollutant, new insights into emissions, deposition, and ecological effects also underscore its importance as a regional and local pollutant.

Historically mercury occurred at only trace levels in the environment, but mercury concentrations in fish and other animals in the northeastern United States (the Northeast) now routinely exceed human and wildlife health thresholds. State and federal fish consumption advisories blanket the nation, demonstrating that mercury pollution is widespread. Solutions to this complex problem have been hampered by conflicting information on the sources, transport, and accumulation of mercury in the environment. The Hubbard Brook Research Foundation (HBRF) convened a team of scientists to analyze mercury data in the region and address key questions facing decision-makers.

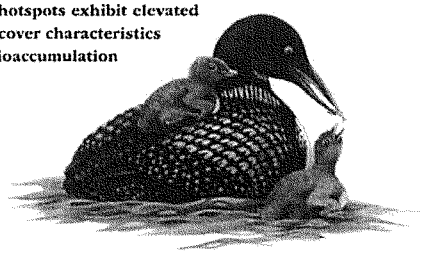
The HBRF team completed a new assessment of mercury in fish, birds, and mammals and identified five confirmed and nine suspected biological mercury hotspots in the northeastern United States and southeastern Canada.

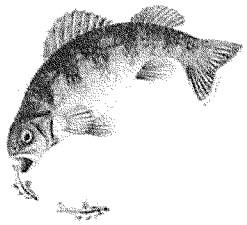
Key Findings

Mercury emissions to the atmosphere are the largest source of mercury pollution globally and in most areas of the Northeast. Watersheds throughout the nation receive mercury that is emitted from the smokestacks of coal-fired power plants and other sources and then deposited to the Earth. Some of the mercury eventually runs off into nearby rivers and lakes where, under the right conditions, it can bioaccumulate up to 1 million times as it passes from water to fish, wildlife, and people.

The HBRF team completed a **new assessment of mercury in fish, birds, and mammals and identified five confirmed and nine suspected biological mercury hotspots in the northeastern United States and southeastern Canada.** The primary causes of these biological mercury hotspots are airborne mercury emissions and deposition, which can be amplified by heightened watershed sensitivity, water-level fluctuations in reservoirs, or large local emission sources.

Scientists have long known that some watersheds are particularly sensitive to mercury pollution. Acidic waters draining forests and wetlands produce fish that are most likely to exceed the U.S. Environmental Protection Agency (EPA) human health criterion for mercury of 0.3 parts per million. **The HBRF team established chemical indicators of mercury sensitivity and determined that several of the confirmed and suspected biological mercury hotspots exhibit elevated mercury because their water chemistry and land-cover characteristics are particularly conducive to the transport and bioaccumulation of mercury.**





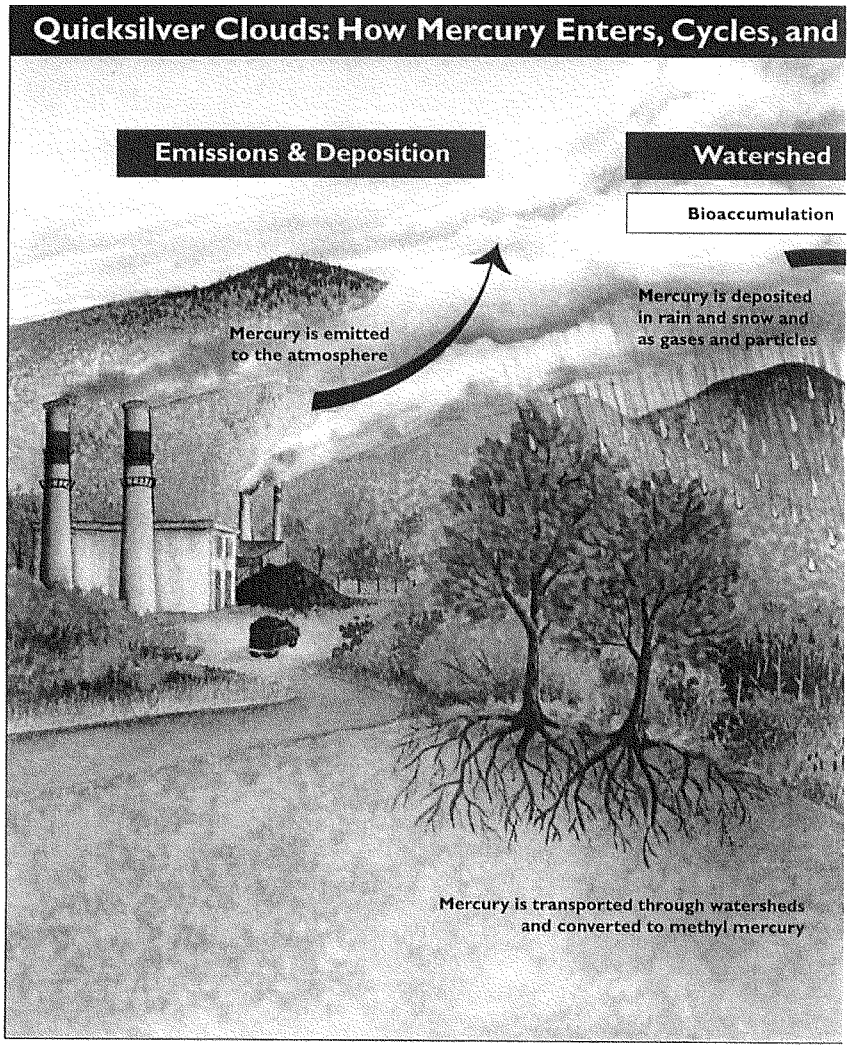
New data show that several of the biological mercury hotspots are linked to water level manipulation within reservoirs in the Northeast. Mercury deposited from the atmosphere can bioaccumulate to high levels in reservoirs with large draw downs that expose extensive shore land. Mercury levels in fish and loons are elevated in several Northeast reservoirs that fluctuate 10.5 feet or more annually.

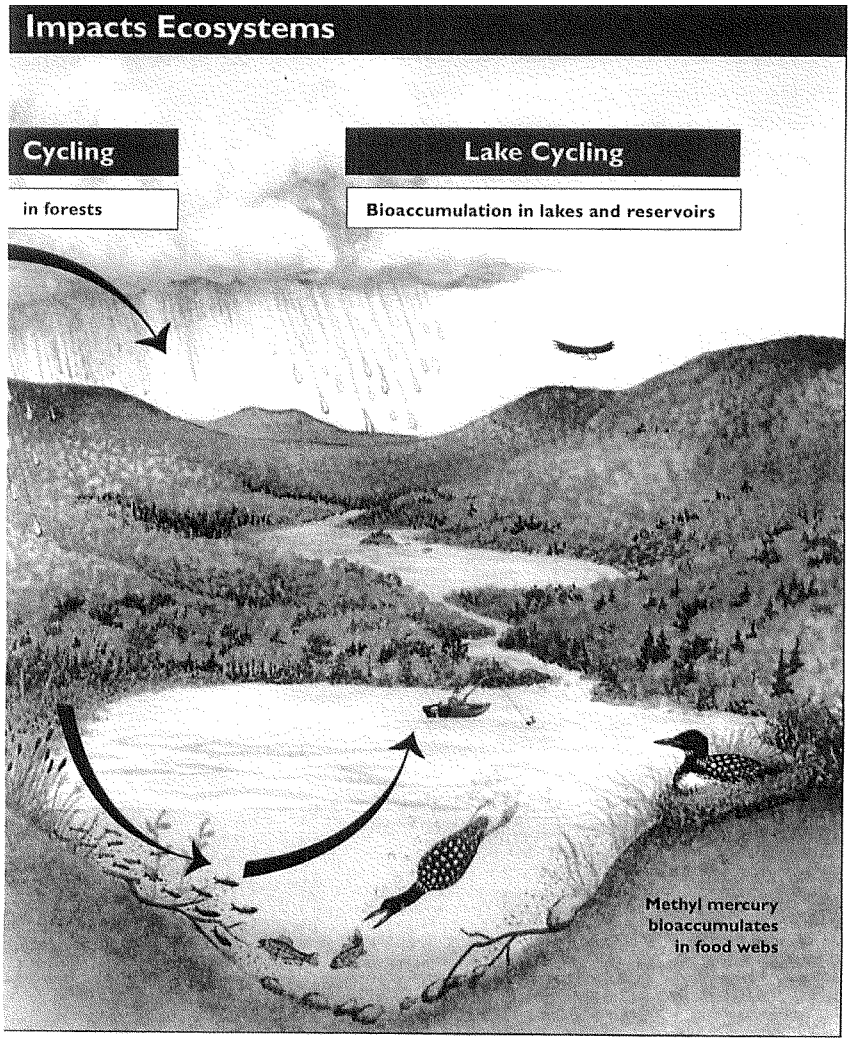
The HBRF team evaluated mercury deposition patterns in southern New Hampshire and northeastern Massachusetts and estimated that mercury deposition is 10 to 20 times higher than pre-industrial conditions, and four to five times higher than current EPA estimates. Local emission sources contribute approximately 65 percent of the mercury deposition in the study area, and nearby coal-fired power plants produce 40 percent of this locally derived mercury deposition. The results from this case study suggest that 1) EPA computer models can underestimate mercury deposition near large emission sources, and 2) the mercury cap-and-trade approach in the current U.S. Clean Air Mercury Rule (CAMR) could perpetuate or even exacerbate areas of high deposition and associated biological mercury hotspots if emissions continue unabated at coal-fired power plants.

The HBRF team also analyzed historical emissions and biological data to assess the prospects for recovery in the lower Merrimack River watershed of southern New Hampshire and northeastern Massachusetts. **Between 1999 and 2002, mercury levels in fish and common loon blood declined 32 and 64 percent respectively, following a 45 percent reduction in mercury emissions from local sources. These results suggest that fish and wildlife can respond rapidly and proportionally to further reductions in mercury emissions from large local sources in the Northeast.**

The continued widespread mercury contamination of fish and wildlife across the Northeast demonstrates that current mercury deposition is still too high to achieve recovery, despite recent control measures. Furthermore, the data presented in this report and the supporting peer-reviewed articles highlight the connection between airborne mercury emissions from United States sources and the existence of highly contaminated biological mercury hotspots. In addition to further reducing mercury emissions to the atmosphere, the United States and Canada must substantially improve mercury monitoring across the continent in order to track mercury pollution levels, further identify biological mercury hotspots, and assess the impact of policy decisions on mercury pollution.

The continued widespread mercury contamination of fish and wildlife across the Northeast demonstrates that current mercury deposition levels are still too high to achieve recovery, despite recent control measures.


Quicksilver Clouds: How Mercury Enters, Cycles, and
Emissions & Deposition
Watershed
Bioaccumulation
Mercury is deposited in rain and snow and as gases and particles
Mercury is emitted to the atmosphere
Mercury is transported through watersheds and converted to methyl mercury


Impacts Ecosystems
Cycling
in forests
Lake Cycling
Bioaccumulation in lakes and reservoirs
Methyl mercury
bioaccumulates
in food webs

What Is Mercury and Why Is It a Problem?

Mercury is a natural element existing in trace amounts in the Earth's crust. Through natural processes and human activities it can be mobilized into the environment and transformed into a toxic pollutant.

Mercury (Hg) is released naturally to the environment by volcanoes, the breakdown of rocks known as "weathering," and other processes (UNEP 2003). Human beings have extracted mercury for thousands of years for use in products such as paints and thermometers and processes such as gold mining. Prior to industrialization most of these uses released only small amounts of mercury into the environment. However, human activities in recent decades are responsible for a three-fold increase in global mercury deposition (UNEP 2003). That increase reaches four- to six-fold in the northeastern United States (the Northeast) as reflected in the increase in mercury deposited to sediments of lakes (Perry et al. 2005).

As a fundamental chemical element, mercury is persistent in the environment and does not break down or degrade. After mercury is released from ores or mineral deposits and emitted to the atmosphere, it is deposited to the Earth's surface, and some eventually flows into rivers and streams. Within watersheds and lakes, mercury is processed by specialized bacteria that convert it to methyl mercury – a form that is more readily absorbed in the digestive system of animals and magnified to high levels in the food web. Methyl mercury binds to proteins and can bioaccumulate through the food web in fish, birds, and other wildlife.

As a fundamental chemical element, mercury is persistent in the environment and does not break down or degrade.

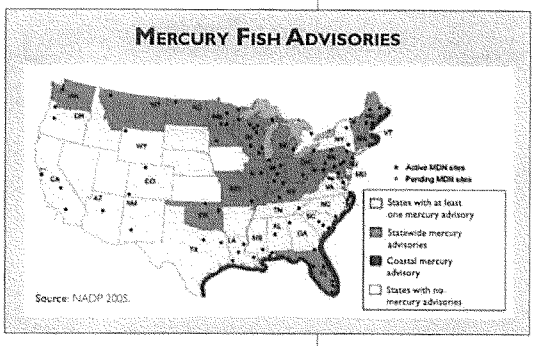


FIGURE 1: *In 2004, 44 states had one or more fish-consumption advisories warning consumers about the risk of eating fish that may be high in mercury.*

Most people and wildlife are exposed to methyl mercury by eating fish, an important source of animal protein. In human populations, the most at-risk and sensitive individuals include women of childbearing age who may become pregnant, nursing mothers, and children under 12 years of age. The most highly exposed people, due to fish-consumption habits, include: recreational fishers and their families, some Native American populations, Asians and Pacific Islanders, and individuals who fish to meet their or their families' nutritional needs (subsistence fishers).

A United States Environmental Protection Agency (EPA) scientist estimates that between 200,000 and 400,000 children are born each year in the United States with pre-natal exposure to methyl mercury sufficient to put them at risk for neurologic impairment due to fish consumption by the mother (Mahaffey 2005). These children can experience decreased ability to perform in school, declines in visual and spatial functions, deficits in ability to recall and process information, and a general decrease in intelligence (NAS 2000).

Several studies also point to a connection between mercury exposure through dietary consumption and cardiovascular disease in men. Dietary intake of fish and mercury were associated with a significantly increased risk of acute heart disease and death in men living in Eastern Finland (Salonen et al. 2000). Another study of men in Europe and Israel noted similar findings (Gaullar et al. 2002).

The impacts of mercury on fish and wildlife have been documented in numerous studies (see Evers 2005 and Chan et al. 2003 for comprehensive summaries and references). Research has linked elevated mercury in fish to decreased spawning success, increased embryo mortality in lake trout eggs, altered schooling movements, and at extreme levels, acute toxicity. In fish-eating birds, mercury exposure is

associated with reduced reproductive success, decreased chick survival, spinal cord degeneration, disrupted hormone levels, and difficulty flying, walking, and standing. Mammals have been studied to a lesser degree, but research shows that high mercury levels in mink and otter can cause impaired motor skills, weight loss, and acute toxicity.

To address growing concerns over fish contamination and human exposure to elevated mercury, the EPA and the U.S. Food and Drug Administration (FDA) established a human health criterion for methyl mercury in fish tissue of 0.3 parts per million (ppm), as measured in wet weight of fish fillets. The criterion represents the maximum advisable concentration of methyl mercury in freshwater and estuarine fish that protects the average consumer of fish and shellfish among the general population. Canada and the states of Maine and Minnesota have elected to set a stricter standard of 0.2 ppm to protect human health. Efforts are under way to address the impact of mercury on wildlife, including the development of wildlife criteria values for the protection of common loons, mink, and river otter in Maine (Evers et al. 2004).

In 2004, as shown in Figure 1, 44 states issued fish-consumption advisories for mercury, including 21 statewide advisories for fresh waters and 12 statewide advisories for coastal waters (EPA 2004). Through these advisories the FDA and EPA advise women who may become pregnant, pregnant women, nursing mothers, and young children to avoid some types of fish, and to eat fish and shellfish that are lower in mercury. The agencies further suggest that some types of fish should be avoided entirely (see complete details at www.epa.gov/mercury/advisories.htm).

Coal-fired power plants are the largest single source of anthropogenic mercury emissions in the United States, followed by industrial boilers and electric arc furnaces.

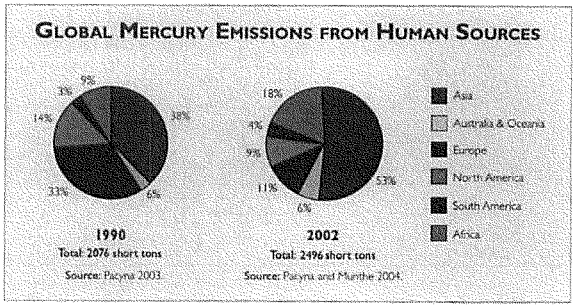
Where Does Mercury Pollution Originate?

Emissions from coal-fired power plants located within the United States are the largest source of human-caused mercury emissions in many areas of the Northeast.

Mercury is released to the global environment in several ways, but the dominant pathway is airborne emissions and deposition (UNEP 2003). Fossil-fuel combustion and waste incineration rank first and second among anthropogenic mercury emission sources worldwide (UNEP 2003). Coal-fired power plants are the largest single source of anthropogenic mercury emissions in the United States, followed by industrial boilers and electric arc furnaces (NEI 2002). Mercury is also released to lakes and streams from point and nonpoint sources. In the United States, direct discharges by wastewater treatment plants and chlorine production facilities top the list of waterborne point sources. Diffuse nonpoint sources include the leaching of mercury from contaminated soils associated with industrial facilities and landfills, as well as runoff from urban landscapes. Given the prevalence and impact of airborne emissions, the balance of this report will focus on atmospheric emissions and deposition of mercury.

The total amount of mercury released to the atmosphere worldwide is approximately 7,000 short tons, of which two-thirds originate from current and past human sources. The remaining third is emitted from volcanoes, mid-ocean ridges, and other natural sources. Global emissions associated with current human activities increased roughly 15 percent from 1990 to 2002, with a growing share contributed by Asia and Africa (Figure 2).

FIGURE 2:
Global mercury emissions from human sources increased 15 percent between 1990 and 2002. Large increases in Asia and Africa were responsible for this increase.



U.S. Mercury Emissions by Source

Source Category	US 1990 (ton/yr)[1]	US 1996 (ton/yr)	US 1999 (ton/yr)	US 2002 (ton/yr)	Northeast 2002 (ton/yr)
Coal-fired power plants	58.8	51	47.9	50.3	0.82
Medical waste incinerators	51	40.5	2.8	0.3	0.017
Municipal waste combustors	57.2	31.8	5.1	4.2	1.2
Industrial/commercial/institutional boilers and process heaters	14.4	12	12	11	0.36
Chlorine production	10	7.8	6.5	5.4	0
Electric arc furnaces	7.5	No Data	No Data	10.7	No Data
Hazardous waste incineration	6.6	4.5	6.5	4.6	0.001
Total (all categories)	245	185	120.3	113.8	5.2

Source: NEI 1999, NEI 2002

[1] Measurements are in short tons.

Mercury emissions in the United States have declined from 245 short tons in 1990 to 114 short tons in 2002, due largely to controls on municipal and medical waste incinerators. As shown in Table 1, emissions from coal-fired power plants did not change appreciably from 1990 to 2002 (NEI 1999; NEI 2002).

Regional studies show that mercury emission sources in the United States can play a disproportionately important role in mercury pollution, as demonstrated by studies in Ohio (Keeler et al. 2006), the Adirondack and Catskill Mountains of New York (Figure 3), and southern New Hampshire and northeastern Massachusetts (see case study on page 16). The substantial contribution by domestic emission sources to mercury pollution in the United States is corroborated by evidence from mercury accumulation in the sediments of lakes. Lake sediments tell the story of how mercury pollution has changed over time and where it may originate. A data set representing 39 lakes across the Northeast demonstrates that mercury deposition to lake sediments has been declining for the past two decades. The sediment pattern contradicts the global pattern of increasing global emissions, but closely tracks United States emissions trends, suggesting that mercury deposition in the Northeast is responsive to mercury emissions from within the United States.

TABLE 1:
Mercury emissions from some sources have declined substantially since 1990. Emissions from coal-fired power plants remain largely unchanged. Note that the individual source categories do not sum to the total because area sources and minor point source categories are not shown. (1 short ton equals 0.907 metric ton.)

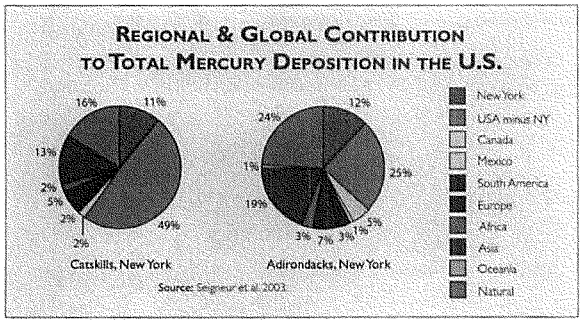


FIGURE 3:
Studies show that U.S. mercury emission sources play an important role in mercury pollution in the Catskill and Adirondack regions.

Where Does Mercury Go?

Emerging science suggests that mercury is not only transported globally, but is deposited regionally and locally to a greater extent than once thought.

Mercury was once considered a pollutant that, when emitted to the atmosphere, travels far from its source. For that reason, mercury has been considered a "global pollutant" with far-reaching impacts but minimal local effects. Emerging science has changed the dominant view of mercury from a strictly global pollutant to a global *and* regional and local pollutant.

The ultimate fate of mercury emissions is controlled in large part by the transport distances of different mercury "species" or forms. The three major forms of mercury in the atmosphere are gaseous elemental mercury, reactive gaseous mercury, and particulate mercury. Each form of mercury has specific physical and chemical characteristics that determine how far it travels in the atmosphere before depositing back to Earth (Figure 4).

Elemental mercury in the atmosphere is relatively inert and not easily dissolved in water. This form can be transported a considerable distance. Reactive gaseous mercury (also referred to as "oxidized mercury") is more chemically reactive and soluble than elemental mercury, and therefore deposits more rapidly and closer to the emissions source in precipitation (wet deposition) or on contact (dry deposition). Particulate mercury can travel short to moderate distances. The proportion of each mercury form emitted by specific sources in the United States is summarized in Table 2.

Scientists have identified two processes that enhance local and regional deposition of elemental mercury. The first is the conversion of elemental mercury to more reactive forms. This transformation occurs in the atmosphere and has been observed in areas where ground-level ozone is high and sea salt is prevalent in the air (such as coastal zones). Both of these situations are common in the Northeast. The second process is the direct deposition of elemental mercury to the foliage of trees and the subsequent transfer of this mercury to the land surface with leaf fall.

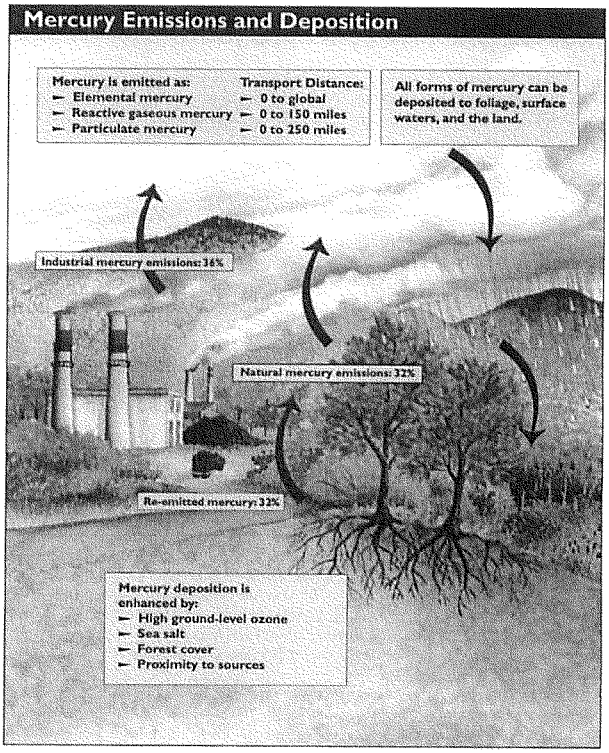


FIGURE 4:
Different forms of mercury can travel varying distances before depositing to foliage, surface waters, and the land. Also, certain conditions enhance mercury deposition.

Mercury Species by Source

Source Category	Elemental Mercury Average %	Reactive Gaseous Mercury Average %	Particulate Mercury Average %
Coal-fired electric utilities – U.S. average	50	40	10
Coal-fired electric utilities – the Northeast	30	68	2
Utility oil boilers	50	30	20
Municipal waste combustors	22	58	20
Pulp & paper production	50	30	20
Chlorine production	95	5	0
Hazardous waste incinerators	58	20	22
Municipal landfills	80	10	10

Sources: NEI 1999, Pacyna et al. 2003, NESCAUM 2005.

TABLE 2: *Different sources of airborne mercury emissions have varying percentages of the three main forms of mercury.*

Mercury emission and deposition are just two steps in a series of complex processes that convert mercury from an inert element in the Earth's crust to a pollutant harmful to fish, wildlife, and people. Most mercury deposited from the atmosphere occurs as inorganic mercury that generally exists at very low concentrations that pose no direct health risk. However, as this form of mercury is transported through the watershed, it can be processed by bacteria in soils, wetlands, and lake or river sediments and converted to a form known as methyl mercury. Methyl mercury occurs at low concentrations in water (less than 1 part per trillion), but then bioaccumulates through the aquatic food web and reaches toxic levels in fish (Figure 5). A compilation of data from across the Northeast illustrates that total mercury increases approximately 1 million times and methyl mercury can increase in concentration as much as 10 million times in the aquatic food chain, depending on the chemistry and ecosystem characteristics of a particular lake or river.

How Much Airborne Mercury Pollution Does the Northeast Receive?

Some areas in the Northeast receive mercury deposition 10 to 20 times higher than historical levels, with particularly high amounts in forests and areas near large emission sources.

Scientists use several methods to estimate how much mercury is deposited from the atmosphere to the Earth's surface. Wet and dry deposition together constitute *total* mercury deposition. Wet deposition in rain or snow is measured at a network of 92 mostly rural stations in North America known as the Mercury Deposition Network (MDN). The MDN is part of the National Atmospheric Deposition Program (NADP), which measures background mercury concentrations in areas generally distant from large sources, and is operated as a public-private collaborative, coordinated primarily by the federal government.

According to MDN measurements, the average wet deposition in the United States ranges from 2.0 to 20 micrograms per square meter per year ($\mu g/m^2$-yr). Wet deposition tends to be somewhat higher in the eastern portion of the nation, with the highest levels recorded in the Southeast. Wet deposition ranges from 6 to 10 $\mu g/m^2$-yr in the Northeast.

Dry deposition includes the deposition of mercury associated with gases and particles. It is not systematically measured in the United States due to technical challenges, but has been estimated at some research sites. In the Northeast, scientists

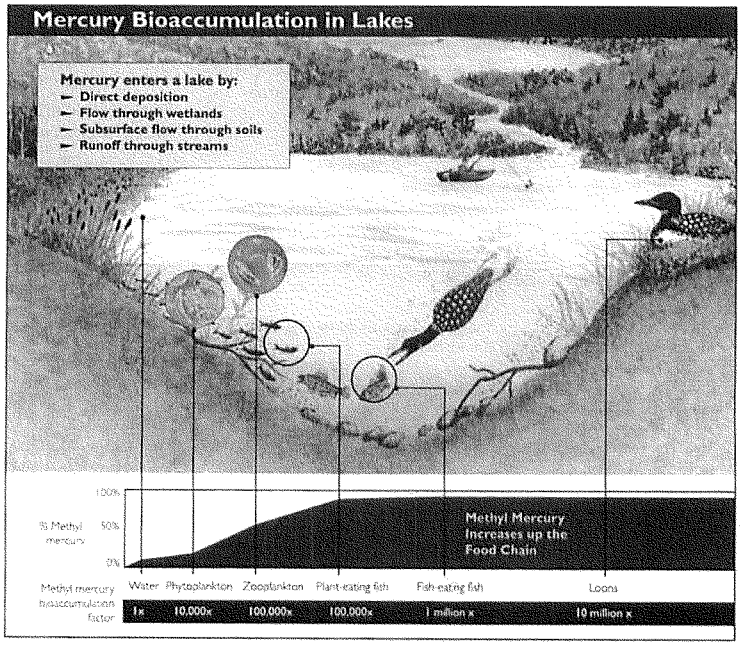


FIGURE 5:
Methyl mercury occurs at low concentrations in water, eventually bioaccumulating through the food chain, often reaching harmful levels in fish-eating fish and loons.

predict that dry deposition contributes 50 to 70 percent of total deposition in some forested areas.

Air quality models are useful tools for examining the impacts of air quality regulations or policies. There are many types of air quality models and each type has advantages and disadvantages for assessing air quality impacts from emission sources. There are three common types of models: plume models, trajectory models, and grid models. The EPA's large grid model, the Community Multi-Scale Air Quality model, predicts that total mercury deposition ranges from 5.0 to 40 $\mu g/m^2$-yr across the United States (EPA 2005a).

While large-scale models provide a picture of average mercury deposition across the United States, they often do not accurately depict local or regional variation. A regional model of total deposition in the Northeast which incorporates elevation and land cover, provides greater spatial resolution and generally predicts higher deposition in high-elevation forests and in southern New England (Miller et al. 2005).

Detailed local models demonstrate that total mercury deposition near large emission sources can be even greater than the levels predicted by national or regional models. The southern New Hampshire and northeastern Massachusetts case study on pages 16 and 17 shows that total mercury deposition near a coal-fired power plant can reach upwards of 70 $\mu g/m^2$-yr. Scientists and policymakers are only just beginning to understand and account for the wide variation in total mercury deposition, its linkage to biological mercury hotspots, and its implications for public policy.

What Are Biological Mercury Hotspots?

A biological mercury hotspot is a location on the landscape where mercury concentrations in fish, birds, or mammals exceed established thresholds for human or ecological health in a high number of samples compared to the surrounding landscape.

The definition above of a biological mercury hotspot is based on mercury concentrations in several biological indicators and is thus independent of the source of the mercury pollution. Areas of high mercury deposition have also been referred to as hotspots, but should more accurately be called "mercury deposition hotspots." In contrast, the EPA limits its focus to "utility hot spots" which it defines as a water body that is a source of consumable fish with methyl mercury tissue concentrations, attributable solely to utilities, greater than the EPA's human health criterion of 0.3 ppm (EPA 2005b).

There are three important considerations in defining biological mercury hotspots. First, many scientists agree that the definition of a biological mercury hotspot should not be constrained to one single mercury source, since ecosystems respond to the combined effects of mercury pollution from multiple sources.

Second, it is important to consider the possibility that given the range in sensitivity to mercury pollution, biological mercury hotspots can occur in diverse locations across the landscape, not only in areas of elevated mercury deposition.

Finally, the Clean Water Act has established national goals for water quality that appear to be at odds with the EPA's definition of what constitutes a mercury hotspot. Specifically, the Clean Water Act stipulates that states should strive to maintain or restore water quality in order to provide for "the protection and propagation of fish, shellfish, and wildlife" (CWA 1996). Therefore, a definition of mercury hotspots strictly limited to surface waters with *consumable* fish containing mercury levels exceeding the EPA human health criterion of 0.3 ppm from a single source would not appear to support the goals of the Clean Water Act.

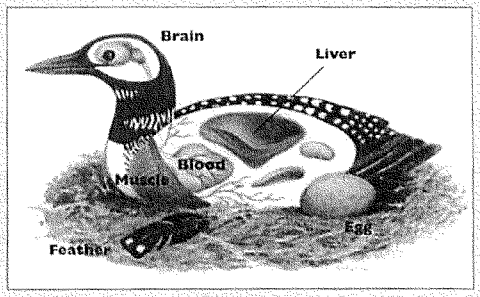
Many scientists agree that the definition of a biological mercury hotspot should not be constrained to one single mercury source since ecosystems respond to the combined effects of mercury pollution from multiple sources.

Mercury Effects on the Common Loon

Field and laboratory research show that common loons experience significant neurological, physiological, behavioral, and reproductive impacts from elevated mercury exposure. When loons ingest mercury by eating fish, the mercury is transported via the bloodstream to the birds' vital organs, including the brain.

Loons can naturally eliminate a portion of the ingested mercury from their bodies by transferring it to their feathers and eggs. They also attempt to reduce the toxicity of mercury by binding it as a nontoxic mercury compound and storing it in the liver, kidney, and spleen.

Despite these complex mechanisms, mercury still accumulates to high levels in loons, leading to adverse impacts such as brain lesions, spinal cord degeneration, difficulty flying and swimming, production of fewer and smaller eggs, lowered reproductive success, and higher body burdens of mercury over time (Evers et al. 2003, 2005). Comprehensive studies show that these effects are much more pronounced in "high risk" loons with mercury concentrations in blood above 3.0 ppm.



Mercury accumulates in the bodies of common loons and has adverse physiological, reproductive, and behavioral effects.

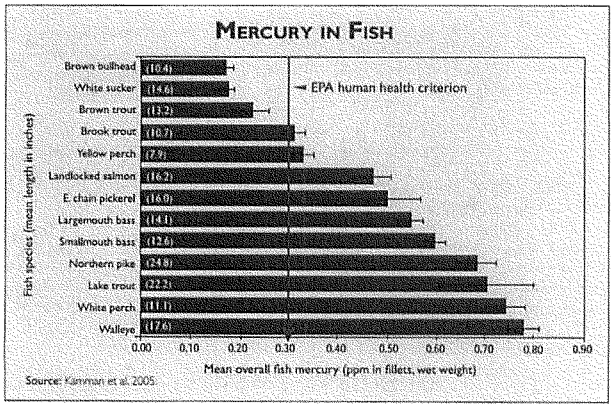


FIGURE 6:
Mercury measurements show that yellow perch tend to be low in mercury compared to species higher on the food chain. Ten of thirteen species exceed the EPA human health criterion of 0.3 ppm.

The HBRF team analyzed a data base with more than 6,800 observations for seven wildlife species to identify confirmed and suspected biological mercury hotspots. Several indicator species were chosen to reflect human and ecological health risks associated with mercury pollution. For each indicator species, an *adverse effects threshold* has been defined based on federal criteria and existing scientific research.

Yellow perch and common loon served as the primary indicator species in the biological hotspot analysis. Yellow perch was chosen as the primary indicator species for human health, using the EPA's recommended criterion of 0.3 ppm of mercury as the adverse effects threshold. Yellow perch are abundant in the region, have been widely sampled for mercury, and are regularly consumed by recreational fishermen. It is important to note, however, that yellow perch occupy a position in the middle of the aquatic food chain and are likely to have lower mercury concentrations compared to fish that are higher on the food chain such as pike, lake trout, and walleye (Figure 6).

TABLE 3:
The HBRF team used two primary indicator species to identify biological mercury hotspots and five secondary species to indicate "suspected" hotspots.

Biological Mercury Hotspot Indicators and Thresholds

Indicator Species	Threshold (ppm)	Tissue Type
Primary		
Common loon	3.0	Blood
Yellow perch	0.3[1]	Fillet
	0.16[2]	Whole body
Secondary		
Largemouth bass	0.3	Fillet
Brook trout	0.16	Whole body
Bald eagle	1.0	Blood
Mink	30.0	Fur
River otter	30.0	Fur

[1] Threshold based on EPA human health criterion.
[2] Threshold based on ecological impacts.

Source: Evers et al. 2007.

The common loon was chosen as the primary indicator for ecological health, using the population effect level of 3.0 ppm of mercury in blood as the adverse effects threshold. The common loon is a large, fish-eating bird, positioned high on the aquatic food chain, and it accumulates considerable mercury over its long lifetime. Common loons are ubiquitous in the Northeast and mercury exposure and effects are well characterized by a large regional data base of mercury in loon blood, eggs, and feathers. Consistent with its life history and position on the food chain, loons typically have high mercury levels compared to other aquatic and terrestrial birds.

The adverse effects threshold for loons is based on existing scientific research, which indicates that loon pairs with blood mercury levels of 3.0 ppm fledged up to 40 percent fewer young than pairs with blood mercury less than 1.0 ppm. The study further determined that when 25 percent or more of the loons in a given area exceed this blood mercury threshold, population levels are likely to decline.

Despite the extensive yellow perch and common loon data sets in the region, insufficient information exists to quantify mercury contamination levels in some areas. To address these gaps, the HBRF team used a set of secondary indicators to identify suspected biological mercury hotspots. The secondary indicator species include: brook trout, largemouth bass, bald eagle, mink, and river otter (see Table 3 for corresponding adverse effect thresholds).

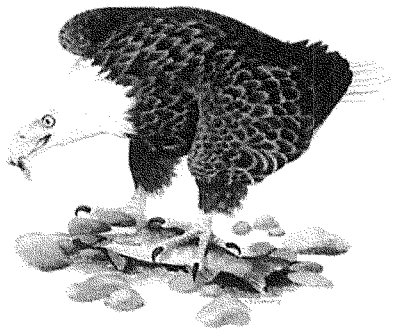
Where Do Biological Mercury Hotspots Occur?

Five confirmed and nine suspected biological mercury hotspots have been identified in the northeastern United States and southeastern Canada.

The HBRF team produced a map of the five confirmed and nine suspected biological mercury hotspots (Figure 7), which builds on a preliminary mercury hotspot analysis published by D.C. Evers (Evers 2005). The map pinpoints areas of especially high risk that emerge against the backdrop of fish consumption advisories in the region.

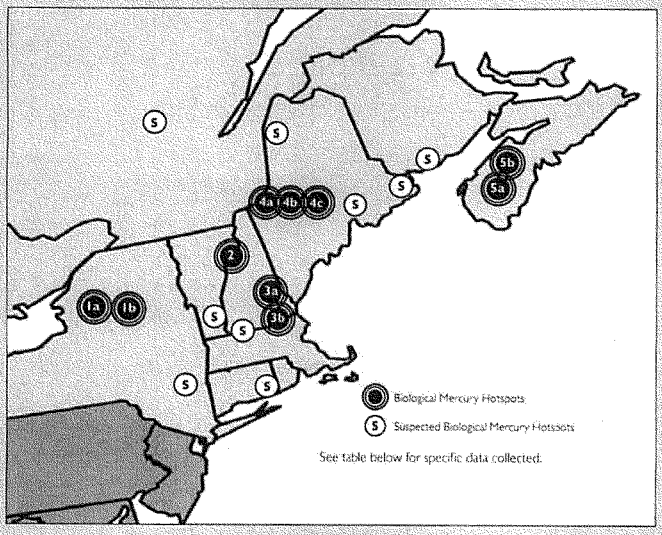
The five confirmed biological mercury hotspots span the region from Kejimkujik National Park in Nova Scotia to the Adirondacks of New York. Information on mercury concentrations in each hotspot is summarized in the table in Figure 7, shown on page 15. Nine suspected biological mercury hotspots were also identified in the region. Strong evidence of elevated mercury levels in fish and wildlife exists at these sites, but there is insufficient data at the present time to classify them as confirmed biological mercury hotspots. Additional sampling at these locations is needed to make a final determination as to their status

FIGURE 7: ←
The HBRF team identified five confirmed and nine suspected biological mercury hotspots in the Northeast.



Biological Mercury Hotspots

The HBRF team used a new method to determine biological mercury hotspots. In this method, a biological mercury hotspot of human health concern occurs where there are 10 or more independent sites with yellow perch concentrations above 0.3 ppm within grids that average 890 square miles in size (30 minutes by 30 minutes). A biological mercury hotspot of ecological concern emerges where 25 percent or more of the common loons sampled in a grid containing at least 14 samples have blood mercury levels above 3.0 ppm.



Mercury Levels in Biological Hotspots

Biological Hotspot	State/Province	Yellow Perch		Common Loon		
		Average (ppm)	Range (ppm)	Average (ppm)	Range (ppm)	% of loons > adverse effect level
1a. Adirondack Mountains – west	NY	0.73	0.57 - 0.96	1.5	1.1 - 2.1	0%
1b. Adirondack Mountains – central	NY	0.54	0.39 - 0.80	2.0	0.3 - 4.1	25%
2. Upper Connecticut River	NH,VT	0.35	0.14 - 0.58	1.1	0.1 - 2.9	0%
3a. Merrimack River – middle	NH	0.78	0.05 - 5.03	2.6	0.7 - 7.1	28%
3b. Merrimack River – lower	MA, NH	0.65	0.23 - 3.81	no data		
4a. Upper Androscoggin River	ME, NH	0.44	0.21 - 1.25	1.9	0.15 - 5.5	14%
4b. Upper Kennebec River – west	ME	0.40	0.24 - 0.52	3.1	0.6 - 14.2	43%
4c. Upper Kennebec River – east	ME	0.38	0.14 - 0.72	2.2	0.6 - 4.1	26%
5a. Kejimkujik National Park	NS	0.50	0.14 - 0.85	5.5	2.9 - 7.8	93%
5b. Central, Nova Scotia	NS	0.58	0.14 - 3.79	no data		

Source: Evers et al. 2007

Linking Biological Mercury Hotspots and Coal-Fired Power Plants: A Case Study

The biological mercury hotspot in southern New Hampshire and northeastern Massachusetts illustrates the important connections between emissions from local coal-fired power plants, areas of high mercury deposition, and elevated mercury in fish and wildlife. By focusing on one particular biological mercury hotspot, we were able to examine closely these connections and distill the implications for public policies, such as mercury emissions trading.

Mercury Deposition

The HBRF team produced a map of mercury deposition in New Hampshire using a computer model designed to capture the impacts of local emission sources[1]. With this plume model, we quantified how much airborne mercury pollution was deposited solely from sources within New Hampshire and adjacent counties in Maine, Massachusetts, and Vermont. We found that, in general, the average mercury deposition due to local sources is relatively low (7.0 $\mu g/m^2$-yr). However, we identified an area of intense deposition near Concord, New Hampshire, where we estimate that deposition reaches 70 $\mu g/m^2$-yr – four to five times higher than the EPA's estimate of 15 to 20 $\mu g/m^2$-yr for the same region (Figure 8).

Based on the data from the computer analysis, we determined that roughly 65 percent of all the mercury deposited to this area of high deposition near Concord, New Hampshire, is attributable to local (and some regional) sources, and that global sources therefore play a much smaller role. These results suggest that EPA may have underestimated total mercury deposition and the impact of domestic coal-fired power plants on mercury deposition in areas near large emission sources.

Mercury in Fish and Wildlife

Mercury levels are extremely high in fish and wildlife inhabiting waters within the biological mercury hotspot spanning southern New Hampshire and northeastern Massachusetts. The average mercury concentration in yellow perch reaches 0.78 ppm – more than 2.5 times higher than the EPA human health criterion, and twice the regional average. The loons that feed on these fish reflect the high mercury levels in their blood. Of the 39 loons we sampled in the hotspot area, 28 percent had blood mercury levels of 3.0 ppm, or higher. One loon found in Swains Lake in Barrington, New Hampshire, had a blood mercury level of 7.1 ppm – among the highest levels recorded in North America.

But the picture need not look so grim. Monitoring data show that as atmospheric emissions and deposition from local sources decline, mercury levels in fish and wildlife can improve rapidly. Mercury emissions from New Hampshire sources that are upwind of the biological mercury hotspot declined 45 percent between 1997 and 2002. Average loon blood mercury concentrations from ten study lakes in the hotspot decreased 64 percent between 1999 and 2002. Yellow perch from Massachusetts study lakes in the hotspot showed a 32 percent decrease during roughly the same period (Smith and Hutcheson 2006). These reductions in mercury in fish and wildlife were much greater than observations elsewhere in the Northeast.

[1] *Industrial Source Code Short Term (ISCST3) model.*

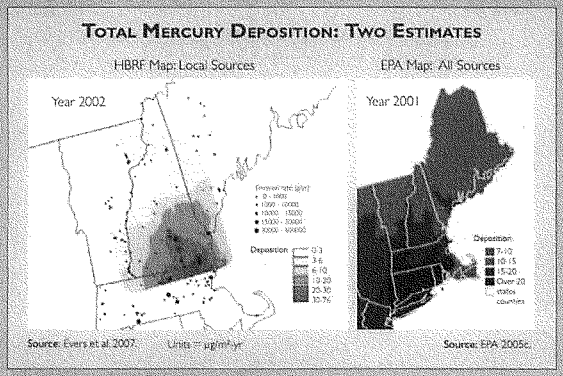


FIGURE 8: *A model used to quantify local sources of airborne mercury pollution (left) showed deposition levels four to five times higher than EPA estimates (right)*

Emissions Reductions from Coal Plants

Next, we used the same computer model to evaluate the impact of local coal-fired power plants on mercury deposition in New Hampshire. Using 2002 emissions data as a base case, we simulated the effect of cutting mercury emissions from four coal-fired power plants by 50 and 90 percent. The analysis showed that the greatest decrease in deposition would occur near Merrimack Station in Bow, New Hampshire – the largest coal-fired power plant in the study area. At this location, mercury deposition would decrease by 23 percent and 41 percent for the 50 and 90 percent emissions cuts respectively (Figure 9).

Based on this simulation, we determined that emissions from local coal-fired power plants account for roughly 40 percent of the total mercury deposition in this study area that is derived from local sources. This finding appears to contradict an EPA conclusion that coal-fired power plants in the United States contribute less than 5 percent of the total mercury deposition in the same area (EPA 2005c).

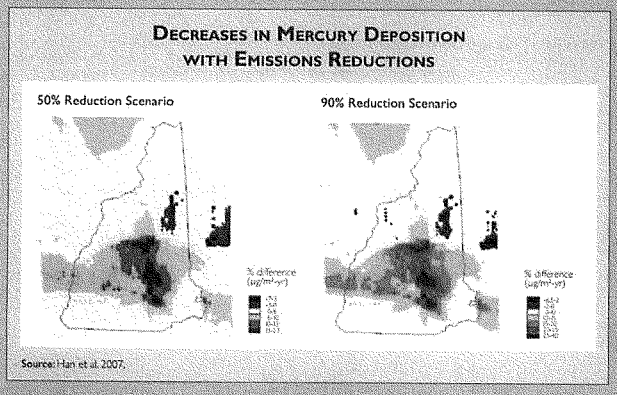
Pulling together the model results and biological trends data, we find that reductions in emissions from coal-fired power plants near this biological mercury hotspot would have a proportional impact on both mercury deposition and mercury in fish and wildlife.

Policy Implications

The case study findings are particularly important in light of recent federal policy. In May 2005, the EPA adopted the Clean Air Mercury Rule (CAMR) to reduce mercury emissions from the pool of coal-fired power plants by 70 percent by 2025. CAMR also includes a cap on national mercury emissions from coal-fired power plants, but allows individual facilities to buy and sell emissions credits to meet the cap rather than reduce actual emissions.

The New Hampshire case study holds important lessons for mercury policy. The results highlight the substantial role that local coal-fired power plants can play in local mercury deposition as well as fish and wildlife mercury levels. As such, these findings cast doubt on the effectiveness of unconstrained cap-and-trade programs that could allow emissions at some facilities to continue unabated.

The EPA has responded to concerns over mercury trading by using results from its own national-scale deposition model to conclude that mercury hotspots, as EPA defines them, will not occur as a result of CAMR (Federal Register 2006). The results of the New Hampshire case study suggest that by using a large-grid model, the potential effects of mercury trading may not be fully evident in the EPA analysis.



Source: Han et al. 2007.

Figure 9: *Mercury emissions scenarios from four New Hampshire power plants show that near the largest power plant in the area, mercury deposition would decrease by 23 percent under the 50 percent reduction scenario and 41 percent under the 90 percent reduction scenario.*

What Causes Biological Mercury Hotspots?

Biological mercury hotspots are associated with airborne mercury emissions and deposition that is amplified where local emissions are extremely high, ecosystems are particularly sensitive to mercury pollution, and/or reservoirs increase the availability of mercury.

Mercury pollution from atmospheric emissions and deposition is the primary driver for the biological mercury hotspots in the Northeast. The path by which mercury deposition leads to the formation of a biological mercury hotspot varies and includes: (1) extremely high deposition near large emission sources; (2) enhanced transport and bioaccumulation of mercury in sensitive watersheds; and (3) elevated production of methyl mercury in reservoirs that undergo substantial water-level fluctuations. In addition to atmospheric mercury deposition, one of the biological mercury hotspots is linked to leaching from contaminated soils at former industrial sites (Table 4).

1. High Mercury Deposition

Given the potential for mercury to deposit locally and regionally, it is not surprising that some biological mercury hotspots occur in proximity to large emission sources. The biological mercury hotspot in the lower Merrimack River watershed of New Hampshire and Massachusetts provides a clear example of a hotspot driven by elevated mercury deposition from local and regional mercury emission sources (see page 16).

2. Watershed Sensitivity

Biological mercury hotspots can occur in watersheds that receive average or even relatively low mercury deposition, but are sensitive to mercury pollution. These sensitive watersheds readily transport inorganic mercury, convert inorganic mercury to methyl mercury, and bioaccumulate this methyl mercury through the food web. The biological mercury hotspots linked to watershed sensitivity represent locations where moderate mercury deposition has generated high mercury concentrations in fish and loons compared to the surrounding landscape with similar mercury loading.

Mercury landscape sensitivity factors:

- Small lake to watershed ratio
- Waters impacted by acid deposition
- Shallow flowpaths
- Abundant shoreline wetlands
- Low nutrient inputs
- Forest cover
- Forest clearcutting
- Water-level manipulation

TABLE 4:
The primary causes of the five identified biological mercury hotspots in the Northeast are indicated. Locator numbers refer to the map on page 15.

Biological Mercury Hotspots: Primary Causes

	Regional & global atmospheric deposition	Water-level management	Landscape sensitivity	Local air emissions	Local soil contamination
1a. Adirondack Mountains – west	x		x		
1b. Adirondack Mountains – central	x		x		
2. Upper Connecticut River	x	x			
3a. Merrimack River – middle	x			x	
3b. Merrimack River – lower	x			x	
4a. Upper Androscoggin River	x	x			
4b. Upper Kennebec River – west	x	x			x
4c. Upper Kennebec River – east	x	x			
5a. Kejimkujik National Park	x		x		
5b. Central Nova Scotia	x		x		

Source: Evers et al. 2007.

The Adirondack Mountains of New York and Kejimkujik National Park in Nova Scotia are two examples of biological mercury hotspots in sensitive watersheds. While mercury deposition to these areas is moderate, the average mercury concentrations in yellow perch caught in these areas range from 0.5 to 0.78 ppm – up to 2.5 times the EPA human health criterion. Mercury in loon blood is also elevated in these two biological mercury hotspots, reaching 7.8 ppm in Kejimkujik National Park where 93 percent of all loons sampled exceed the 3.0 ppm threshold. The dense forest cover in these regions enhances atmospheric mercury deposition; shallow soils facilitate its transport to surface waters; extensive wetlands promote its conversion to methyl mercury; and acid-impacted and/or unproductive lake chemistry greatly enhances the bioaccumulation of methyl mercury to high levels in fish and wildlife.

The rate at which mercury is supplied to surface waters and converted to methyl mercury varies from watershed to watershed. Several characteristics are widely cited as important: small watershed to lake size ratio, shallow flowpaths with reduced groundwater inputs, extensive forest and wetland land cover, and land use disturbances such as forest harvesting. Where these conditions prevail, methyl mercury production and supply to surface waters are generally high.

Another component of mercury sensitivity is "surface water sensitivity" which affects the ability of aquatic ecosystems to bioaccumulate incoming mercury to high levels in fish and wildlife. Key factors controlling surface water sensitivity include: low nutrient levels and productivity; high surface water acidity (including areas impacted by acidic deposition); and the nature and structure of the food web. To help resource managers determine which surface waters are likely to have fish with high mercury levels, the HBRF team analyzed data from across the Northeast and identified four surface water characteristics that are indicative of sensitivity and are associated with fish mercury concentrations above the EPA human health criterion of 0.3 ppm (Table 5).

The HBRF team evaluated the chemistry in Northeast lakes and found that nearly 60 percent of lakes meet one or more of the sensitivity thresholds and are therefore considered relatively sensitive to mercury pollution. The 28 water bodies contained within the biological mercury hotspots in the Adirondacks and in Kejimkujik National Park have average water chemistry values that meet all the thresholds for the four indicators and are therefore considered highly sensitive to mercury pollution.

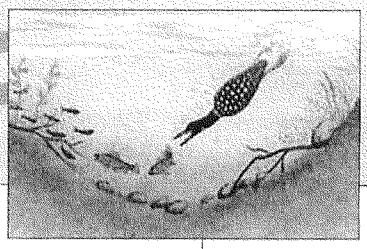
Given the potential for mercury to deposit locally and regionally, it is not surprising that some biological mercury hotspots occur in proximity to large emission sources.

Indicators of Surface Water Sensitivity

Indicators	Thresholds
Total phosphorus	< 30 µg/L
Dissolved organic carbon	> 4 mg/L
Surface water pH	< 6.0
Acid-neutralizing capacity	< 100 µequiv/L

Source: Driscoll et al. 2007.

TABLE 5:
Water quality indicators that coincide with elevated concentrations of mercury in fish. Sixty percent of lakes in the Northeast meet one or more of the sensitivity thresholds.



The Importance of Improved Mercury Monitoring

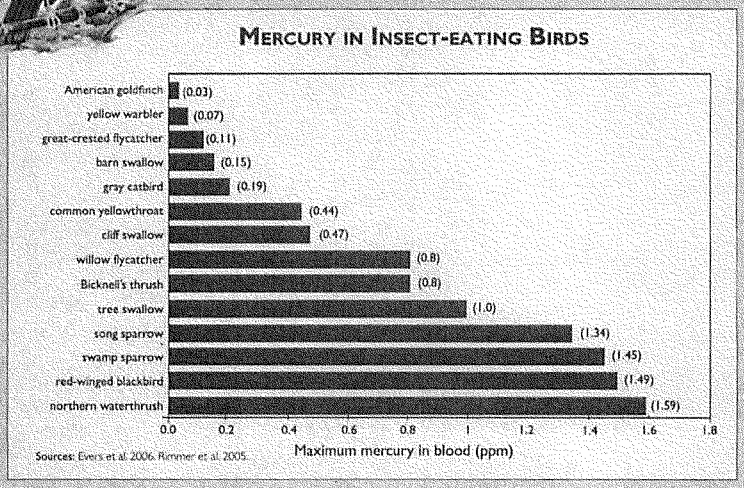
The biological mercury hotspots analysis presented in this report was made possible by an extensive data gathering effort supported by the Northeastern Ecosystem Research Cooperative (NERC), with funding from the USDA Forest Service's Northeastern States Research Cooperative. While the data and information generated by this project provide insights into the nature and extent of mercury pollution across the region, many data gaps remain and most other regions of the United States and Canada do not have such a large biological data set from which to evaluate biological mercury hotspots. In addition, the current Mercury Deposition Network is too sparse and limited by its focus on wet deposition in rural areas to provide a detailed understanding of deposition patterns and their connection to local sources in the United States.

The problem of insufficient mercury monitoring was recently echoed in a report by the EPA Inspector General which states, "Without field data from an improved monitoring network...'utility-attributable' hotspots that pose health risks may occur and go undetected." The reports goes on to say: "We recommend that EPA develop and implement a mercury monitoring plan to (1) assess the impact of Clean Air Mercury Rule (CAMR) on mercury deposition and fish tissue, and (2) evaluate and refine mercury estimation tools and models" (EPA 2006).

A comprehensive long-term mercury monitoring program focused on mercury deposition, watershed cycling, and biological effects would allow scientists to conduct a national scale assessment of biological mercury hotspots, and to link changes in emissions and deposition with ecosystem effects and response. At present, scientists must rely on limited information to make these important linkages. Increased mercury monitoring should extend to forest ecosystems where recent research revealed elevated mercury in insect-eating songbirds (Figure 10). Little information exists, however, to determine how mercury accumulates in terrestrial food webs and what levels are harmful to these birds.

A roadmap for a comprehensive national mercury monitoring program was developed by a team of scientists and is detailed in the 2005 paper "Monitoring the Response to Changing Mercury Deposition" published in the journal *Environmental Science & Technology*. The proposed program emerged from an EPA workshop in 2003 that brought together 32 scientists from across the United States to devise a national mercury monitoring program.

FIGURE 10: *Recent research shows elevated levels of mercury in some songbirds.*

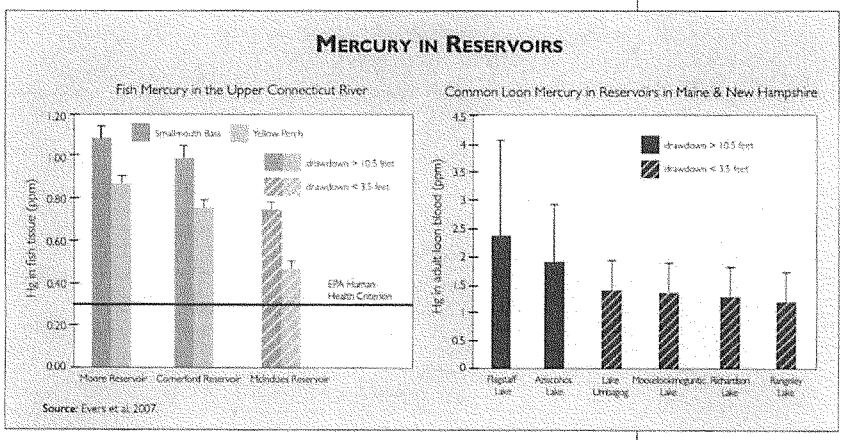


3. Reservoir Water Level Management

Several reservoirs in the Connecticut River in New Hampshire and the upper Androscoggin and Kennebec Rivers in Maine were identified as biological mercury hotspots. Mercury that is deposited to the landscape and transported to a reservoir can be readily converted to methyl mercury and mobilized under changing water levels. By exposing and then re-wetting large areas of shore land, fluctuating reservoirs provide prime conditions for the bacteria that produce methyl mercury. The methyl mercury formed in this shoreline environment can then be released to reservoirs during rain events or reservoir refilling.

A study of five reservoirs within a biological mercury hotspot in Maine shows that loon mercury concentrations increase with greater reservoir fluctuation. Mercury concentrations in loon blood are significantly higher in reservoirs that have summertime (June through September) drawdowns of 10.5 feet or more, than in reservoirs with drawdowns of 3.5 feet or less (Figure 11). Similar patterns in fish mercury concentrations were documented for smallmouth bass and yellow perch in three Connecticut River reservoirs within a biological mercury hotspot in New Hampshire. Researchers in Minnesota report that when reservoir fluctuations were dampened, fish mercury levels decreased (Sorensen et al. 2005). These findings suggest that fish mercury concentrations may be reduced by modifying water-level management regimes in certain reservoirs.

FIGURE 11:
Studies show that mercury concentrations in fish and loons are highest in reservoirs that have large water-level fluctuations, which provide prime conditions for bacteria that convert inorganic mercury to methyl mercury.



Conclusions

Mercury pollution is a complex problem involving different sources of mercury, diverse mercury deposition patterns, and wide-ranging ecological effects. While many questions remain regarding the science of mercury pollution, this much is clear:

- Mercury contamination is widespread in the United States, as evidenced by the fish consumption advisories that blanket the nation.
- Mercury emissions in the United States are the largest source of mercury deposition in many parts of the nation and in the Northeast, and domestic coal-fired power plants represent the single largest source of human-caused mercury emissions.
- Biological mercury hotspots exist across the northeastern United States and southeastern Canada, and represent areas where mercury levels in biota are high compared to the surrounding landscape; these hotspots pose serious risks to human and ecological health.
- Biological mercury hotspots are driven primarily by airborne mercury emissions and deposition that is amplified by large local mercury emission sources, high ecosystem sensitivity, and/or large water-level fluctuations in reservoirs.
- National and regional scale mercury models can underestimate mercury deposition near large emission sources, and fail to predict the relative contribution of emission sources such as coal-fired power plants.
- The case study in New Hampshire and Massachusetts demonstrates that emissions reductions from high-emitting sources near biological mercury hotspots in the United States will yield beneficial improvements in both mercury deposition and mercury levels in fish and wildlife.
- The case study further demonstrates that local coal-fired power plants are a significant contributor of some biological mercury hotspots, and reductions in mercury contamination may not be realized if a cap-and-trade policy allows emissions at these facilities to continue unabated.
- A national mercury monitoring network, coordinated with other international programs, should be established to better quantify total mercury deposition, identify potential additional biological mercury hotspots, and assess the environmental response to federal and state mercury emission policies.

Source Documents

The content of this report is based on three peer-reviewed scientific papers written by its authors with support from the Hubbard Brook Research Foundation. Unless otherwise as noted, all text, tables, and figures are adapted or reprinted from these papers:

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Biological Mercury Hotspots in the Northeastern United States and Southeastern Canada

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Biological mercury (Hg) hotspots were identified in the northeastern United States and southeastern Canada using a data set of biotic Hg concentrations. Eight layers representing three major taxa and more than 7300 observations were used to locate five biological Hg hotspots and nine areas of concern. The yellow perch and common loon were chosen as indicator species for the human and ecological effects of Hg, respectively. Biological Hg hotspots receive elevated atmospheric Hg deposition, have high landscape sensitivity, and/or experience large reservoir fluctuations. In the Merrimack River watershed, local Hg emissions are linked to elevated local deposition and high Hg concentrations in biota. Time series data for this region suggest that reductions in Hg emissions from local sources can lead to rapid reductions of Hg in biota. An enhanced Hg monitoring network is needed to further document areas of high deposition, biological hotspots, and the response to emissions reductions and other mitigation strategies.

Keywords: biological mercury hotspots, mercury sources, common loon, mercury monitoring, yellow perch

Mercury (Hg) is a local, regional, and global pollutant that affects fish, wildlife, and human health. Recently, 71 scientists from New England, New York, and eastern Canada compiled and analyzed more than 30,000 observations of Hg levels in biota, including 40 fish and 44 wildlife species (Evers and Clair 2005). The resulting database is a powerful tool to quantify spatial patterns of Hg in biota across the northeastern United States and southeastern Canada (referred to here collectively as the Northeast).

We focus on biological Hg hotspots in the Northeast because the spatial heterogeneity of Hg deposition and methylmercury (MeHg) in biota is an issue of international concern. For example, fish consumption advisories concerning Hg contamination exist in each of the eastern Canadian provinces and 44 states in the United States, including all states within our study area. This pattern of advisories demonstrates that Hg contamination is widespread.

Current state and national policies to control Hg emissions from point sources include the consideration of cap-and-trade options. Trading allows the providers of coal-fired electric utilities to purchase pollution credits in order to meet a national cap, rather than requiring reduced emissions for all facilities. Thus, trading has the potential to lead to static or increased emissions in some areas of the United States, which may produce changes in Hg deposition, cycling, and biological uptake. Increased deposition near areas that are highly sensitive to Hg or already affected by Hg deposition could increase Hg contamination in fish, and may increase the risk to people and wildlife that consume fish. An understanding of the mechanisms contributing to biological Hg hotspots is important when Hg trading policies are considered.

Given the growing scientific evidence of Hg contamination (Evers et al. 2005, Kamman et al. 2005) and the public policy interest in identifying specific geographic areas that are disproportionately elevated in Hg, it is important to develop a common definition for the term "biological mercury hotspot." We define a biological Hg hotspot as a location on

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the landscape that, compared to the surrounding landscape, is characterized by elevated concentrations of Hg in biota (e.g., fish, birds, mammals) that exceed established human or wildlife health criteria as determined by a statistically adequate sample size.

There are important considerations in defining and identifying biological Hg hotspots. The sources of Hg contamination are not easily differentiated in ecosystems. Therefore, the identification of biological Hg hotspots, based on the effects of Hg pollution, should not be constrained to those areas where high Hg concentrations can be attributed to a single source or sector. Rather, multiple sources from multiple sectors can contribute to a hotspot, and as a result we do not limit the definition of a hotspot to a single source or sector.

Biological Hg hotspots can occur in diverse locations across the landscape, and are not restricted to areas of high Hg deposition. Landscapes have critical characteristics that influence Hg transport to surface waters, the methylation of ionic Hg, and the bioaccumulation of MeHg in biota, thereby modifying sensitivity to Hg inputs (Driscoll et al. 2007). These characteristics include land cover, oxidation–reduction conditions, hydrologic flow paths, and nutrient loading. Modifications of the landscape, such as changes in land disturbance, can alter the supply of Hg to downstream aquatic ecosystems.

To further define and identify biological Hg hotspots in the Northeast, we analyzed the extensive existing database developed for Hg in fish and wildlife (Evers and Clair 2005). Although these summarized data are comprehensive, some areas within the Northeast remain poorly characterized for Hg, and additional biological Hg hotspots may exist. We also hypothesize mechanisms that contribute to the formation of the biological Hg hotspots. We use a case study of the lower and middle Merrimack River watershed, located in northeastern Massachusetts and southern New Hampshire, to estimate the impact of local emissions and assess the extent to which biota may respond to changes in local Hg emissions and deposition. Finally, we describe the need for increased long-term monitoring, process-level science, and improved Hg models to fill data gaps critical to locating hotspots, tracking changes in Hg levels, following emission controls, and assessing the impact of policy decisions.

Study area and methods

Regional databases of Hg in biota were gathered during a four-year effort by the Northeastern Ecosystem Research Cooperative (NERC) and published in a series of papers describing the distribution of Hg and MeHg in northeastern North America (Evers and Clair 2005). We used a subset of 7311 observations for seven species, in three major taxonomic groups that represent eight data layers, to quantify the spatial heterogeneity in tissue Hg concentrations (table 1, figure 1). Spatial data for Hg concentrations in biota were used to identify areas where the tissue burdens of Hg exceeded levels known to result in adverse effects.

The primary data layers for Hg concentrations in fillets of yellow perch (*Perca flavescens*) and in the blood and eggs of the common loon (*Gavia immer*) were used to locate biological Hg hotspots. Secondary data layers for whole-fish analysis of yellow perch and for Hg concentrations in largemouth bass (*Micropterus salmoides*), brook trout (*Salvelinus fontinalis*), bald eagle (*Haliaeetus leucocephalus*), river otter (*Lontra canadensis*), and mink (*Mustela vison*) were used to locate areas of concern. All data are presented in terms of wet weight (ww) unless otherwise described as fresh weight (fw), which includes biotic material such as feathers and fur. All means are arithmetic. We also used data on surface water chemistry and land cover to evaluate the factors contributing to the spatial heterogeneity of Hg in biota.

Data preparation. To develop a common measure across the data set, we calculated standardized conversions of Hg concentrations for different tissue types in yellow perch and common loons. We used the Hg concentrations of standard-length (20-cm) yellow perch (Kamman et al. 2005), relying on whole-fish concentrations as an indicator of ecological risk and on fillet concentrations as an indicator of human health risk. Where only whole-fish concentrations were available, we converted these values to fillet equivalents using a regression of average-age mean Hg concentrations for fillets against mean whole-fish Hg concentrations developed from a set of statistically randomized lakes (fillet Hg = [1.63 • whole-body Hg] + 0.06; $F_{41,1} = 46.6$, $p < 0.001$, $r^2 = 0.54$; Kamman et al. 2004). This regression is similar to one performed for Hg levels in fish analyzed from lakes in the western United States (Peterson et al. 2005). Similarly, Hg values for the eggs of the common loon were converted to equivalent values for the blood of the adult female loon (female loon blood Hg = [1.55 • loon egg Hg] + 0.22; $r^2 = 0.79$; Evers et al. 2003).

Impact thresholds. The effects of MeHg exposure are difficult to measure. The US Environmental Protection Agency (USEPA) bases human health criteria on consumption models. We used the USEPA suggested advisory level of 0.30 μg Hg per g (ww) in fish muscle tissue to identify biological Hg hotspots of human health concern (USEPA 2001). This level triggers advisories of one or fewer fish meals per month for sensitive groups, such as pregnant women, women of childbearing years, and children less than 12 years of age.

To identify biological Hg hotspots that pose risks to ecological health, we used accepted thresholds for adverse effects from Hg in several wildlife species, as derived from the literature. One of the more comprehensive data sets for assessing the adverse effects of Hg on wildlife is from studies on the common loon.

Blood and egg Hg concentrations have been linked to demonstrated adverse effects in the common loon. The level of 3.0 μg Hg per g ww, which was developed *in situ*, is based on (a) physiological effects, such as higher average corticosterone levels and increased developmental instability (Evers et al. 2004); (b) behavioral effects, such as lethargy in chicks

Table 1. Summary statistics of biological data layers for mercury (Hg) concentrations in fish and wildlife (μg per g) in the northeastern United States and southeastern Canada.

Category/species	Sample size	Data layer designation	Hg concentrations: Mean ± standard deviation	Hg concentrations: Range	Hg level of concern (tissue type)	Percentage of samples with concentrations > level of concern
Human health						
Yellow perch[a]	4089	Primary	0.39 ± 0.49	< 0.05–5.24	0.30 (fillet)	50
Largemouth bass[b]	934	Secondary	0.54 ± 0.35	< 0.05–2.66	0.30 (fillet)	75
Ecological health						
Brook trout	319	Secondary	0.31 ± 0.28	< 0.05–2.07	0.16 (whole fish)	75
Yellow perch[c]	(841)[d]	Secondary	0.23 ± 0.35	< 0.05–3.18	0.16 (whole fish)	48
Common loon[e]	1546	Primary	1.74 ± 1.20	0.11–14.20	3.0 (blood)	11
Bald eagle	217	Secondary	0.52 ± 0.20	0.08–1.27	1.0 (blood)	6
Mink	126	Secondary	19.50 ± 12.1	2.80–68.50	30.0 (fur)	11
River otter	80	Secondary	20.20 ± 9.30	1.14–37.80	30.0 (fur)	15

Note: All data are in wet weight except for fur, which is on a fresh-weight basis.

a. Fillet Hg in yellow perch is based on individuals with a standardized length of 20 cm.

b. Fillet Hg in largemouth bass is based on individuals with a standardized length of 36 cm.

c. Whole-fish Hg in yellow perch is based on individuals with a standardized length of 13 cm. Whole-fish Hg for yellow perch was converted to fillet Hg.

d. The sample population of 841 yellow perch examined for whole-fish Hg is included with the 4089 fillets (i.e., the total number of all biotic data layers does not double-count yellow perch).

e. Egg Hg for the common loon was converted to the adult blood equivalent.

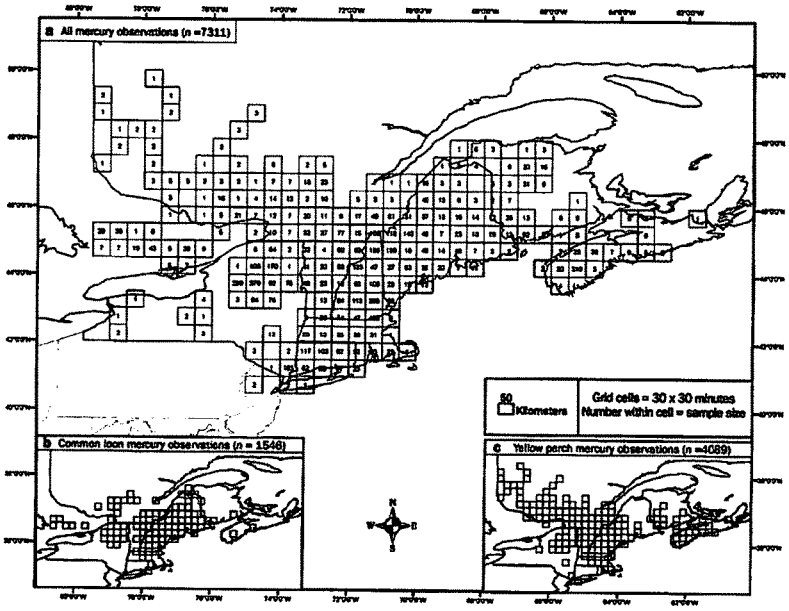

Figure 1. (a) Distribution of biotic mercury (Hg) observations across the northeastern United States and southeastern Canada, and specific distribution of Hg observations for (b) the common loon and (c) yellow perch.

(Nocera and Taylor 1998) and abnormal incubation patterns (Evers et al. 2004); and (c) reproductive effects, such as fewer fledged young from a territorial pair (Barr 1986, Burgess et al. 1998, Evers et al. 2004). Based on this level of concern and on estimates of nesting success, productivity levels can be modeled to determine population sinks and sources for loons (Evers et al. 2004, Nacci et al. 2005). Stage-based models indicate that when more than 25% of a loon population produces 40% fewer fledged young, a population sink occurs.

A second group of human health and ecological indicators was selected to identify areas of concern in the region. These secondary indicators are largemouth bass, brook trout, yellow perch (whole-fish concentrations), bald eagle, river otter, and mink. In this analysis, a whole-fish Hg concentration of 0.16 μg per g (ww) for yellow perch and brook trout was used as an adverse-effect level for piscivores, reflecting the documented risk to loons foraging on fish with whole-body concentrations above this level (Evers et al. 2004, Seiler et al. 2004). A blood Hg concentration of 1.0 μg per g (ww) in bald eaglets was selected as the adverse-effect level that is related to significant negative effects on reproductive success in Maine (DeSorbo and Evers 2006). Because of uncertainties in the accepted level of adverse effects for furbearers, a value of 30 μg per g (fw) in fur was used for river otter and mink, rather than the 20 μg per g (fw) used in some studies (Thompson 1996).

Spatial analysis. The biotic Hg data layers were plotted using a 30' × 30' polygon grid interval (or 0.5° × 0.5° grid) to summarize the data and provide a relevant geographic coverage using GIS (geographic information system) techniques. The grid size was selected on the basis of our understanding of the NERC data, reflecting the trade-offs between spatial detail and the number of sites with biotic Hg data within a cell. Grid interval size varied according to latitudinal and longitudinal position but averaged approximately 2200 to 2300 km^2. We employed power analyses to determine the minimum acceptable number of yellow perch and loon samples needed within any given grid cell to maintain a likelihood of detecting biological threshold limits ($p \pm 0.01$ and $\beta = 0.80$ for yellow perch; $p \pm 0.001$ and $\beta = 0.95$ for common loons). These analyses indicate that a minimum sample size of 10 independent sites per grid cell for yellow perch, and 14 for common loons, is needed to characterize Hg concentrations accurately.

The perch data were queried to display standardized Hg concentrations of at least 0.30 μg per g (ww), with each data point representing an independent sampling site. These data were joined to a 30' × 30' polygon grid, and the resulting grid was queried for a sample size of at least 10. We verified this analysis by converting the entire NERC fish Hg data set of more than 15,000 observations (Kamman et al. 2005) to a data set for standard-length yellow perch using the model created by Wente (2004). These data showed agreement with the spatial analysis, demonstrating that the yellow perch database was a robust indicator for biological Hg hotspots. The loon data were joined to a 30' × 30' polygon grid. These data were then queried to display (a) cells with a sample size of at least 14 and (b) cells with at least 25% of the data showing 3.0 or more μg Hg per g (ww).

For those grid cells that did not meet the sample size requirements for yellow perch and common loons, we examined Hg concentrations in the six secondary biotic data layers (table 1). Independent of sample size, those grid cells that had two or more biotic data layers with mean Hg concentrations that exceeded associated adverse-effect levels were identified as areas of concern. Locations of major historic and current Hg discharges at industrial sites (e.g., mercury-cell based chlor-alkali facilities, textile plants) were also identified (figure 2).

To help ascertain possible mechanisms responsible for biological Hg hotspots, we examined land-use and water-chemistry attributes of water bodies within each grid cell based on standardized data sets, such as those available through the USEPA Environmental Monitoring and Assessment Programs (both national and regional versions). Land-use percentages for forested, wetland, and agricultural areas were extracted from the US Geological Survey's National Land Cover Dataset, while total phosphorus (TP), dissolved organic carbon (DOC), pH, and acid neutralizing capacity (ANC) in surface waters were summarized in relation to sensitivity thresholds established by Driscoll and colleagues (2007) using NERC data (TP < 30 μg per L, DOC < 4 mg carbon [C] per L, pH < 6, and ANC < 100 microequivalents [μeq] per L).

Spatial analysis based on multiple data layers of mercury

Mercury concentrations within the two primary and six secondary data layers were available for 234 grid cells covering an area of 513,471 km^2. Five biological Hg hotspots were identified in the study region, based on the two primary data layers (yellow perch and common loon). A total of 663 sites, with 4089 measurements of yellow perch Hg concentrations, were analyzed for 147 grid cells representing an area of 336,723 km^2. A total of 101 grid cells (approximately 70% of the study region) had mean Hg concentrations for yellow perch that exceeded the USEPA human health criterion at one or more sites. Nine grid cells had mean Hg concentrations for yellow perch at 10 or more independent sites that exceeded the criterion, resulting in five biological Hg hotspots with a total area of 20,616 km^2 (figure 2).

In general, where standard-length yellow perch exhibited Hg concentrations in excess of 0.30 μg per g, other larger, more predatory, and more sought-after game fish, such as largemouth bass, also had elevated Hg concentrations. Mean perch Hg concentrations were highest in the western Adirondack Mountains of New York (H1a) and the middle part of the Merrimack River watershed in New Hampshire (H3a), followed by the lower part of the Merrimack River watershed

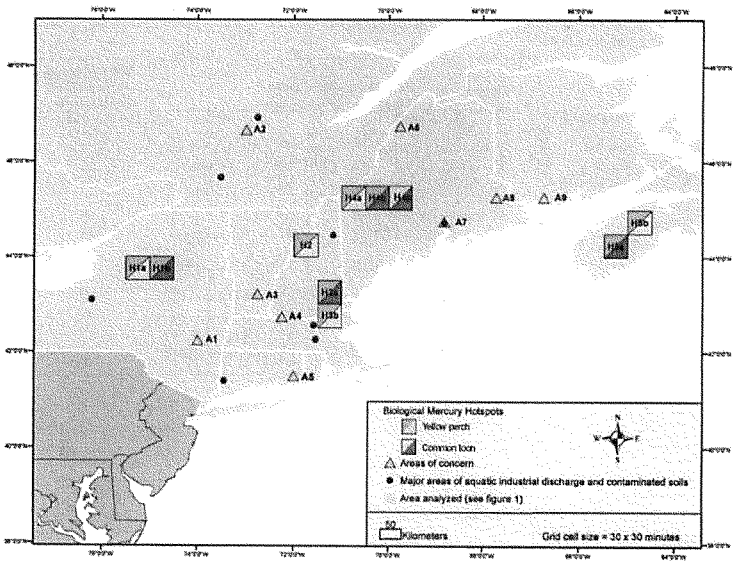

Figure 2. Distribution of biological mercury hotspots (H1a–H5b) and areas of concern (A1–A9). Areas of concern: A1, Catskill Mountains, New York; A2, LaMauricie region, Quebec, Canada; A3, Deerfield River, Vermont; A4, north-central Massachusetts; A5, lower Thames River, Connecticut; A6, upper St. John River, Maine; A7, lower Penobscot River, Maine; A8, Downeast region, Maine; A9, Lepreau region, New Brunswick, Canada. Hotspots: H1a, western Adirondack Mountains, New York; H1b, central Adirondack Mountains, New York; H2, upper Connecticut River, New Hampshire and Vermont; H3a, middle Merrimack River, New Hampshire; H3b, lower Merrimack River, Massachusetts and New Hampshire; H4a, upper Androscoggin River, Maine and New Hampshire; H4b, western upper Kennebec River, Maine; H4c, eastern upper Kennebec River, Maine; H5a, Kejimkujik National Park, Nova Scotia, Canada; H5b, central Nova Scotia.

in Massachusetts (H3b), the central Adirondack Mountains (H1b), and Nova Scotia, Canada (H5a and H5b).

Of the 1546 loons sampled in 102 grids, representing an area of 226,503 km^2, 33 grid cells met the minimum sample size requirement. Biological Hg hotspots associated with loons occur in five grid cells within four of the biological hotspots, covering an area of 11,027 km^2 (table 2, figure 2). In these grid cells, 25% to 93% of the sampled loon population had Hg concentrations above adverse-effect levels. In these biological Hg hotspots, common loons therefore are most likely to experience significant adverse effects at the population level. Mean loon blood Hg concentrations were highest in the upper Kennebec River region of Maine (H4b and H4c) and in Kejimkujik National Park in Nova Scotia (H5a).

Nine areas of concern were identified based on the six secondary data layers. These areas include the Catskill Mountains, New York (A1); the LaMauricie region, Quebec, Canada (A2); Deerfield River, Vermont (A3); north-central Massachusetts (A4); the lower Thames River, Connecticut (A5); the upper St. John River, Maine (A6); the lower Penobscot River, Maine (A7); the Downeast region, Maine (A8); and the Lepreau region, New Brunswick, Canada (A9; figure 2).

Identification and interpretation of biological mercury hotspots

To understand the mechanisms that may contribute to these biological Hg hotspots, it is necessary to consider Hg sources, atmospheric processes, landscape characteristics, and human disturbance to the landscape (figure 3). We hypothesize that three factors amplify the effects of regional and global atmospheric Hg emissions and deposition and are the likely major mechanisms contributing to the biological Hg hotspots identified here: (1) elevated atmospheric Hg deposition from local sources, (2) high landscape sensitivity, and (3) large

Table 2. Summary of data layers for mercury (Hg) concentrations (μg per g, wet weight) in yellow perch and common loons for each biological Hg hotspot in the Northeast.

Biological Hg hotspot	State/province	Hg concentrations: mean ± standard deviation (*n*, range)		Percentage of loons with Hg concentrations > level of concern
		Yellow perch	Common loon	
H1a: Adirondack Mountains (west)	New York	0.73 ± 0.15 (10, 0.57–0.96)	1.5 ± 0.3 (6, 1.1–2.1)	0
H1b: Adirondack Mountains (central)	New York	0.54 ± 0.15 (12, 0.39–0.80)	2.0 ± 1.2 (44, 0.3–4.1)	25
H2: Upper Connecticut River	New Hampshire, Vermont	0.35 ± 0.13 (17, 0.14–0.58)	1.1 ± 0.7 (45, 0.1–2.9)	0
H3a: Merrimack River (middle)	New Hampshire	0.78 ± 0.99 (38, 0.05–5.03)	2.6 ± 1.8 (39, 0.7–7.1)	28
H3b: Merrimack River (lower)[a]	Massachusetts, New Hampshire	0.65 ± 0.78 (17, 0.23–3.81)	NA (no loons sampled)	NA
H4a: Upper Androscoggin River	Maine, New Hampshire	0.44 ± 0.27 (12, 0.21–1.25)	1.9 ± 1.0 (92, 0.15–5.47)	14
H4b: Upper Kennebec River (west)	Maine	0.40 ± 0.09 (11, 0.24–0.52)	3.1 ± 2.1 (77, 0.6–14.2)	43
H4c: Upper Kennebec River (east)	Maine	0.38 ± 0.30 (3, 0.14–0.72)	2.2 ± 1.0 (31, 0.6–4.1)	26
H5a: Kejimkujik National Park	Nova Scotia	0.50 ± 0.18 (27, 0.14–0.85)	5.5 ± 1.4 (14, 2.9–7.8)	93
H5b: Central Nova Scotia	Nova Scotia	0.58 ± 0.86 (16, 0.14–3.79)	NA (no loons sampled)	NA

NA, not applicable.
a. *Source:* Hutcheson et al. 2003.

water-level manipulations (table 3). Atmospheric deposition is the major Hg input to the region (Fitzgerald et al. 1998), and both local sources and long-range transport of Hg are likely to be important in the formation of biological Hg hotspots. Although biological Hg hotspots may also originate from local sources of Hg-contaminated soils and waters, the impacts from these sources are less pervasive, and we therefore focus here on biological Hg hotspots originating from atmospheric deposition.

Mercury is emitted to the atmosphere from a variety of sources. The largest single source in the United States is coal-fired electric utilities. Mercury can be deposited locally or travel great distances, depending mostly on its oxidation state (i.e., 0, +2). Mercury is present in the atmosphere in several forms: elemental Hg, or Hg^0; gaseous divalent Hg, or Hg(II); and particulate Hg, or Hg(p). Elemental Hg has an approximately 0.5- to 2-year residence time in the atmosphere, so it constitutes the majority of airborne Hg. Gaseous divalent Hg and Hg(p) are generally deposited much more rapidly than

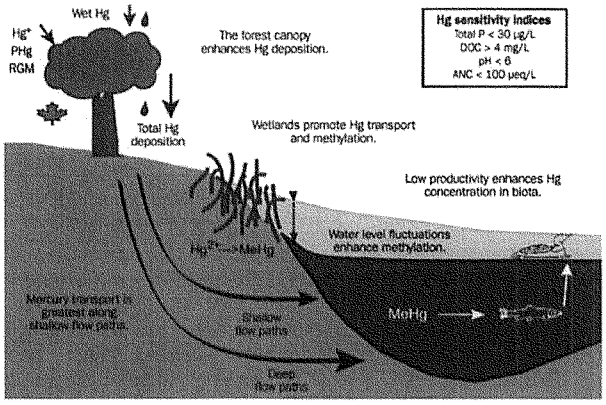

Figure 3. Conceptual figure illustrating important processes controlling the sensitivity of forest and linked aquatic ecosystems to atmospheric mercury (Hg) deposition and artificial water level regulation. The forest canopy enhances dry Hg deposition. Water transported along shallow flow paths supplies greater quantities of Hg than water in deep flow paths. Wetlands are important in the supply of dissolved organic carbon (DOC), which enhances the transport of ionic Hg and methylmercury (MeHg), and are important sites for the production of MeHg. The nutrient status and productivity of surface waters also control concentrations of MeHg in aquatic biota. Indicators of lakes sensitive to Hg inputs are shown in the insert (after Driscoll et al. 2007). Reservoir creation and water-level fluctuation will stimulate MeHg production in the littoral region. Abbreviations: ANC, acid neutralizing capacity; Hg^0, elemental Hg; P, phosphorus; PHg (i.e., Hg[p]), particulate Hg; RGM (i.e., Hg[II]), reactive gaseous Hg.

Table 3. Hypothesized mechanisms for presence of biological mercury (Hg) hotspots in the Northeast.

Biological Hg hotspot	State/ province	Hypothesized mechanisms of Hg contamination				
		Regional and global atmospheric deposition	Water-level management	Landscape sensitivity	Local air emissions	Local soil contamination
H1a: Adirondack Mountains (west)	New York	x	–	x	–	–
H1b: Adirondack Mountains (central)	New York	x	–	x	–	–
H2: Upper Connecticut River	New Hampshire, Vermont	x	x	–	–	–
H3a: Merrimack River (middle)	New Hampshire	x	–	–	x	–
H3b: Merrimack River (lower)	Massachusetts, New Hampshire	x	–	–	x	–
H4a: Upper Androscoggin River	Maine, New Hampshire	x	x	–	–	–
H4b: Upper Kennebec River (west)	Maine	x	x	–	–	x
H4c: Upper Kennebec River (east)	Maine	x	x	–	–	–
H5a: Kejimkujik National Park	Nova Scotia	x	–	x	–	–
H5b: Central Nova Scotia	Nova Scotia	x	–	x	–	–

Hg^0 and therefore have much shorter residence times. These oxidized species make up a small fraction of the total atmospheric Hg (less than 5% at remote sites) but can be responsible for a significant fraction of the total deposition. Gaseous divalent Hg and Hg(p) make up 50% to 90% of the Hg emitted from coal-fired electric utilities in the northeastern United States (NESCAUM 2005, NHDES 2005).

Although Hg^0 generally has a low deposition velocity, under some conditions Hg^0 can be rapidly converted to gaseous Hg(II) and deposited locally and regionally (Wang and Pehkonen 2004). Elemental Hg can also interact with the forest canopy, enhancing deposition rates (discussed below). Gaseous Hg(II) and Hg(p) have high deposition velocities; therefore, proximity to sources and the form of Hg emitted from sources play key roles in determining the amount of Hg deposited to a given area.

We hypothesize that once Hg has been emitted to the atmosphere and deposited to the landscape, the potential for biological Hg hotspots to develop depends on several factors, including the rate of deposition as well as site-specific characteristics such as landscape sensitivity, water-level management in reservoirs, and direct Hg input from water discharges and contaminated soils. Examples of how these factors affect organisms at higher trophic levels are provided below.

Landscape-driven biological mercury hotspots. Ecosystems vary in their sensitivity to Hg inputs; models predicting ecosystem sensitivity can be developed using environmental indicators (Roué-Legall et al. 2005). Mercury that is deposited from the atmosphere may be reemitted to the atmosphere, sequestered in soil or sediments, or transported with drainage waters to aquatic ecosystems, where it can potentially be methylated and bioaccumulate in aquatic organisms. Generally only a small fraction of atmospheric Hg deposition is transported to aquatic ecosystems (Grigal 2002). Nevertheless, the extent to which Hg is transmitted to surface waters varies greatly, and is controlled by multiple processes in the watersheds that connect atmospheric deposition to Hg fate in surface waters (figure 3). Ecosystems with enhanced Hg deposition, transport to surface waters, methylation, and bioaccumulation are considered Hg sensitive (Driscoll et al. 2007).

Forests enhance landscape sensitivity to atmospheric Hg deposition. Canopy trees scavenge atmospheric Hg (Rea et al. 1996). Atmospheric Hg(p), gaseous Hg(II), and oxidized Hg^0 may be adsorbed by foliage and subsequently leached in throughfall (Lindberg et al. 1995). Elemental Hg also enters foliage by the stomata and can ultimately be deposited to the forest floor via leaf litter. In northeastern North America, dry deposition associated with the canopy may provide 60% to 75% of total Hg inputs to forest ecosystems (Miller et al. 2005).

Landscape characteristics including shallow hydrologic flowpaths (Grigal 2002, Galloway and Branfireun 2004), the presence of wetlands (St. Louis et al. 1994), and unproductive surface waters (Chen et al. 2005) facilitate the transport, methylation, and bioconcentration of Hg in surface waters, thereby increasing an ecosystem's sensitivity to atmospheric Hg deposition (Driscoll et al. 2007). Moreover, acidic deposition has affected forested watersheds across eastern North America (Driscoll et al. 2001). It exacerbates ecosystem sensitivity to Hg because the addition of sulfate stimulates production of MeHg (Jeremiason et al. 2006) and the acidification of surface waters enhances concentrations of Hg in fish tissue (Hrabik and Watras 2002).

Two of the biological Hg hotspots in the Northeast, located within the Adirondack Mountains (H1a and H1b) and Nova Scotia (H5a and H5b), appear to be associated with watersheds that are highly sensitive to atmospheric Hg deposition (table 3); the H5a grid cell is of especially high concern because of demonstrated negative Hg impacts on common loon reproductive success (Burgess et al. 1998, 2005). The grid cells in these biological Hg hotspots have forested and wetland cover above the 80th percentile of all grid cells, and are in the lowest 10th percentile for agricultural land uses. These same

grid cells were characterized by water chemistry within the sensitive ranges for attributes associated with high fish Hg in the Northeast (Driscoll et al. 2007). The mean values for 28 water bodies contained in these grid cells are as follows: TP = 9.5 µg per L; DOC = 4.7 mg C per L; ANC = 75 µeq per L; pH = 6.1.

Biological mercury hotspots associated with water-level management. Mercury concentrations in biota are elevated in reservoirs of the Northeast relative to other aquatic environments (Evers et al. 2004, Kamman et al. 2005). We identified two biological Hg hotspots representing four grid cells that appear to be associated with water-level manipulations in reservoirs: the upper Connecticut River in New Hampshire and Vermont (H2) and the upper Androscoggin River watershed (H4a) and upper Kennebec River watershed of Maine (H4b, H4c).

Generally, elevated Hg levels can be attributed either to reservoir creation or to water-level manipulations within existing reservoirs. The initial saturation of soils resulting from the creation of a reservoir yields a large flux of Hg and other detrital material to overlying waters (Bodaly et al. 2004). The resultant decompositional environment of the soil–water interface favors bacterial methylation of recently deposited or legacy Hg adsorbed on soil and vegetative particles. The MeHg forms complexes with various DOC compounds, and several factors, including the composition of the DOC itself, mediate subsequent bioaccumulation (Bodaly et al. 2004, Driscoll et al. 2007). Methyl Hg concentrations have been shown to increase up to 30% above initial values within the first 13 years after reservoir creation (Schetagne and Verdon 1999).

Increases in fish Hg concentrations of 1.5 to 4 times natural lake background levels have been observed in new reservoirs, with concentrations peaking approximately 10 to 15 years postconstruction and declining thereafter (Schetagne and Verdon 1999). Where reservoirs are not further manipulated or managed, fish Hg concentrations typically decline to natural lake background levels 20 to 40 years after initial flooding (Anderson et al. 1995, Schetagne and Verdon 1999).

In addition to reservoir creation, water-level fluctuation influences fish Hg concentrations. Water-level fluctuation has been identified as a key variable in explaining elevated Hg concentrations in fish tissue (Verta et al. 1986). Shallow depth and variable hydroperiods are strongly associated with increased fish Hg concentrations in southeastern US ponds (Snodgrass et al. 2000). The sediments of dewatered and reinundated littoral zones are prime environments for methylation because of their transitioning reduction–oxidation conditions, which promote bacterial sulfate reduction. Methylmercury formed in the littoral zone can be transported to the remaining open-water portion of the reservoir either during rain events or when the reservoir is refilled. The availability of MeHg to reservoir biota is likely to vary in relation to the ratio of dewatered area to reservoir size. Steep-sided reservoirs with organic-poor substrates can be expected to display less efficient MeHg production, lower ambient MeHg concentrations, and less bioaccumulation than reservoirs with wide basins and large littoral areas with more organic matter.

Several reservoir systems in the Northeast illustrate the effects of water-level manipulations (figure 4). In one study in north-central Maine, the ratio of MeHg to Hg in samples from sediment cores was shown to increase considerably, and then remain elevated, after the onset of reservoir fluctuation (Haines and Smith 1998). In another Maine study of five interconnected reservoirs, Hg concentrations in loon tissue increased with greater reservoir fluctuation. In reservoirs that had large summertime (June through September) drawdowns (> 3 m), Hg concentrations in adult loon blood were significantly higher than in reservoirs with small drawdowns (< 1 m) (figure 4). Similar patterns in fish Hg concentrations were documented in an interconnected system of three Connecticut River reservoirs for smallmouth bass (*Micropterus dolomieu*) and yellow perch (figure 4). In Minnesota, dampening water-level fluctuations resulted in significantly improved fish Hg concentrations (Sorensen et al. 2005).

Biological mercury hotspots associated with direct water discharges and contaminated soils. In contrast to sources of Hg from air emissions, direct Hg discharges (e.g., industrial wastes, wastewater, stormwater overflow) and land-based contamination (e.g., landfills, former mining and industrial facilities) tend to affect discrete drainage areas. Eight well-known sites of Hg discharges into lakes and rivers were identified, though they are not considered biological Hg hotspots under our definition, since the data for Hg in biota are currently insufficient to make such determinations (figure 2). The influence of these sources on streams is well studied; generally, streams can rapidly transport and diffuse Hg from a site (Whyte and Kirchner 2000). However, some land-based Hg sources, such as those on rivers with extensive emergent, shrub, and forested floodplains, can have significant downstream biological impacts that may reach 30 km (Wiener and Shields 2000) to 130 km or more (Hildebrand et al. 1980) from the source, decades after termination of active Hg discharges. Mercury-cell chlor-alkali plants are well-known sources of Hg contamination (Hildebrand et al. 1980), and in some cases they may influence biotic Hg levels in lakes that are downwind (A7; figure 2). Other less-described sources include landfills with Hg-containing leachate (Niebla et al. 1976), historical mining activities (Seiler et al. 2004), and municipal wastewater treatment plants (Gilmour and Bloom 1995). Storm water discharges, particularly from areas associated with impervious cover in urban and suburban footprints, also can enhance Hg supply to surface waters (Rule et al. 2006). Estuaries and other wetlands are common end points of urban watersheds, and the potential exists for negative impacts to avian reproductive success from Hg runoff (Schwarzbach et al. 2006). To further assess potential ecological impacts, monitoring and remediation efforts need to be continued long after Hg discharges to surface water from

point sources or contaminated soils are terminated.

Biological mercury hotspots associated with local atmospheric emissions and deposition: A case study. Several studies have shown that the high ambient concentrations of gaseous Hg(II) typically observed in the vicinity of high-emission areas increase dry and wet Hg deposition (USEPA 1997, Bullock and Brehme 2002) and Hg concentrations in soils and sediments (Biester et al. 2002). Here we estimate emissions and deposition in southern New Hampshire and parts of northeastern Massachusetts in order to assess the linkages among local Hg emissions, deposition, and concentrations in biota.

The industrial source complex short-term air dispersion model, or ISCST3 (USEPA 1995), was used to examine the hypothesis that the biological Hg hotspot in the middle and lower Merrimack River watershed (H3a and H3b; figure 2) is associated with high deposition from local emissions sources.

The ISCST3 model is a steady-state Gaussian plume model, which is used to assess pollutant concentrations from sources at the local scale (within 50 km). It assumes that deposition of Hg^0 from anthropogenic emissions is balanced by the reemission of previously deposited Hg^0, because of its large vapor pressure and low solubility (Bullock and Brehme 2002, Cohen et al. 2004), so only deposition of Hg(II) and Hg(p) was simulated in this analysis (table 4). The Henry's law constant and molecular diffusivity used in the USEPA *Mercury Study Report to Congress* (USEPA 1997) were adopted for Hg(II). Following Landis and colleagues (2002), it was assumed that the fine fraction (0.68 μm) accounted for 70% and the coarse fraction (3.5 μm) 30% of the Hg mass.

The model was run using a 5-km grid based on the 1996 National Emissions Inventory (USEPA 1996) for Hg and the 2002 revised emissions inventory for the Northeast states (NESCAUM 2005). The input-modeling domain was defined as New Hampshire and several counties within the adjacent states of Maine, Massachusetts, and Vermont. The output-modeling domain was limited to New Hampshire and northeastern Massachusetts. Meteorological data from Concord, New Hampshire, and Portland, Maine, were used as the surface and upper air data for 2002, respectively.

The ISCST3 results indicate that a biological hotspot (H3a and H3b) exists within an area of elevated deposition that receives considerable Hg input from local and regional sources (figure 5). Model estimates show total Hg deposition associated with local and regional sources of 17 to 804 μg per m^2 per year in 1996 and 7 to 76 μg per m^2 per year in 2002. There are two possible reasons for this area of high Hg deposition: (1) The predominant wind direction has a westerly compo-

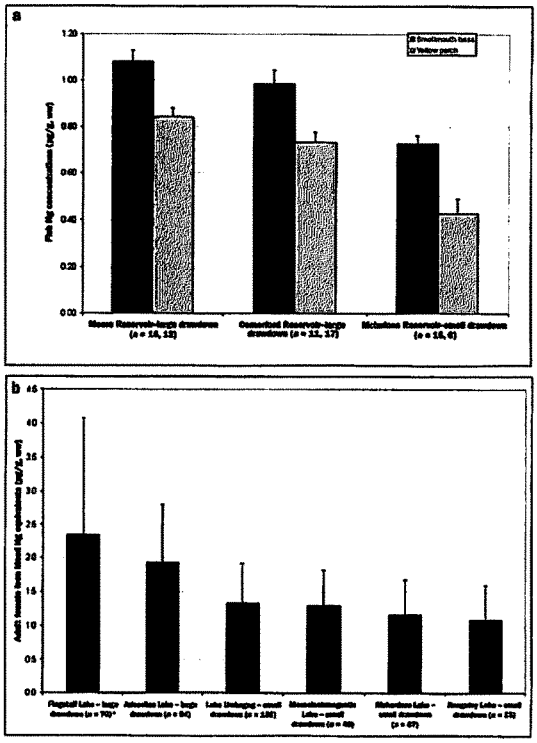

Figure 4. (a) Fillet mercury (Hg) concentrations for smallmouth bass and yellow perch (mean ± standard deviation [sd]) at three interconnected Connecticut River reservoirs in Vermont and New Hampshire and (b) blood Hg concentrations for the common loon (mean ± sd) at five interconnected Androscoggin River reservoirs in Maine and New Hampshire and one reservoir (Flagstaff Lake) in the upper Kennebec River watershed, Maine. (Although it is not hydrologically connected to the grid in the upper Androscoggin River watershed, Flagstaff Lake is illustrative of headwater reservoirs in that region that have large drawdowns.) Reservoir drawdowns from June through September that are less than 1 m are considered small, and those greater than 3 m are considered large. Kruskal-Wallis tests indicate significant differences between reservoirs with large and small drawdowns.

nent, and (2) major Hg sources are located in southern New Hampshire and Massachusetts. Of the total modeled deposition in 2002, Hg(II) deposition contributes the dominant fraction (90%) compared with Hg(p) (10%), primarily because the dry and wet deposition velocities for Hg(II) are higher than for Hg(p). In addition, the emissions of gaseous Hg(II) and Hg(p) from point sources contribute approximately 76% and 58% of the totals in the Hg(II) and Hg(p) categories, respectively (table 5). The ISCST3 results also show that dry deposition contributed more than wet deposition for Hg(II), while the opposite was true for Hg(p).

The USEPA estimated Hg deposition in the United States for 2001 using the community multiscale air quality (CMAQ) model. For the study area in northeastern Massachusetts and southern New Hampshire, they report a range in total deposition of 15 to 20 μg per m^2 per year (USEPA 2005). Miller and colleagues (2005) estimated regional Hg deposition for the study area using a "big-leaf" model and reported a range in total Hg deposition of 19 to 21 μg per m^2 per yr, with wet deposition of 5 to 6 μg per m^2 per year and dry deposition of 14 to 15 μg per m^2 per year. The values from the CMAQ model include local sources, but the emissions are averaged over a large grid cell, and therefore the model appears to underpredict total Hg deposition in the immediate vicinity of large emission sources. The big-leaf model represents regional and global deposition sources; the impact of large local emission sources was not directly accounted for. The local deposition estimates from the ISCST3 model represent an additional Hg input above the deposition estimated by the big-leaf model and therefore suggest that approximately 25% to 65% of total Hg deposition from all sources in the southern New Hampshire region is attributable to local emission sources.

Table 4. Deposition parameters of mercury (Hg) used for this study.

Form	Properties	Values used in this study
Divalent Hg	Molecular diffusivity[a]	0.045 cm^2 per s
	Solubility enhancement factor[a]	10^7
	Pollutant reactivity[a]	800
	Mesophyll resistance[a]	0
	Henry's law constant[a]	2.7×10^{-7}
	Liquid scavenging ratio[b]	2.5×10^{-4} (s·mm per hr) $^{-1}$
	Frozen scavenging ratio[b]	5.0×10^{-5} (s·mm per hr) $^{-1}$
Particulate Hg	Liquid scavenging coefficient (0.68 μm)[b]	7.0×10^{-5} (s·mm per hr) $^{-1}$
	Frozen scavenging coefficient (3.5 μm)[b]	2.8×10^{-4} (s·mm per hr) $^{-1}$

a. Adopted from USEPA 1997.
b. Adopted from Sullivan et al. 2004.

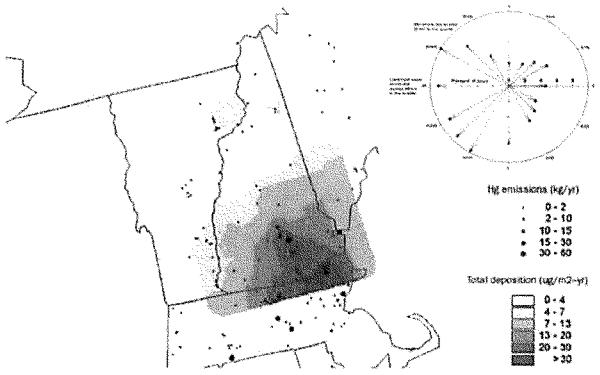

Figure 5. Left, map showing total mercury (Hg) deposition for 2002, estimated using the industrial source complex short-term model, or ISCST3; right, wind rose showing the direction of air flow for May through August 1999 to 2002 in southern New Hampshire, based on weekly wind roses from the NOAA (National Oceanic and Atmospheric Administration) Air Resources Laboratory's READY (Real-time Environmental Applications and Display System) analyses (NOAA 2006).

Table 5. Emission rates used in model domain in 2002.

Emission sources	Emission rates (kg per yr) Particulate mercury	Divalent mercury	Elemental mercury
Point sources	82.4	264.8	135.8
Area sources	60.4	90.6	245.0
Total emissions	142.8	355.4	380.8

Temporal patterns in biotic mercury. Historical data from the Merrimack River watershed biological hotspot (H3a and H3b) suggest that biotic Hg can change rapidly in response to changes in atmospheric emissions and deposition from local and regional sources. From 1997 to 2002, Hg emissions in southern New Hampshire declined 45 percent, largely as a result of restrictions on incinerators (table 6). Meteorological data from Concord were used to determine the dominant wind direction in the area of the Merrimack River watershed biological hotspot and to identify a group of study lakes downwind from major Hg sources. The average wind direction was calculated in grid cell H3a (latitude −43.08 N, longitude −71.16 W) for 1999 to 2002 using the months of May through August (a period of loon blood Hg measurements). The results show that airflow to grid cell

H3a had a westerly component during approximately two-thirds of this period (figure 5).

Based on the meteorological analysis, we selected 10 study lakes within grid cell H3a that were downwind of major Hg emission sources and, when pooled together, provided time series data for Hg in common loons. The study lakes are: Ayers, Canobie, Jenness, Massabesic, Mendums, Onway, Northwood, Pawtuckaway, Swains, and Tower Hill. Mean loon Hg concentrations in these lakes declined 64% from 1999 to 2002 (figure 6a), commensurate with the reduction in Hg emissions of 45% from upwind sources in southern New Hampshire (table 6). Recent data show no appreciable change in mean loon Hg concentrations from 2003 to 2005 (figure 6a). The grid cell immediately north of grid cell H3a, outside the area of highest Hg deposition within the middle Merrimack River watershed, provides a reference area for comparing the magnitude and temporal trends of loon Hg concentrations. This area has similar watershed cover and water chemistry to grid cell H3a. Here, mean loon Hg concentrations were 1.3 to 2.7 times lower than in grid cell H3a during the 1999 to 2002 time period, but still declined 30%. From 1999 to 2002, mean loon Hg concentrations in grid cell H3a exhibited a significant negative trend (using the Mann-Kendall test for normalized approximations; $s = -6$, $n = 4$, $z = -1.70$), and the grid cell immediately north of grid cell H3a did not exhibit a significant negative trend ($s = -4$, $n = 4$, $z = -1.02$).

Negative mercury trends in other taxa were observed within the lower Merrimack River watershed biological hotspot and demonstrated other lines of evidence during the same time period. In yellow perch, there was a significant decrease in fillet Hg concentrations between 1999 and 2004, based on individuals normalized to 24.3 cm in length within northeastern Massachusetts, which overlaps with grid cell H3b; comparatively, throughout the rest of Massachusetts, perch exhibited decreases approximately half as large as those in the Merrimack River watershed (C. Mark Smith and Michael Hutcheson, Massachusetts Department of Environmental Protection, Boston, personal communication, 7 July 2006). Mercury concentrations in zooplankton samples taken from three lakes in grid cell H3a declined between 1996 and 2002, compared with three study lakes outside grid cell H3a, in which the trend in total Hg in zooplankton did not decline (Chen et al. 2000; Carol Folt, Department of Biological Sciences, Dartmouth College, Hanover, New Hampshire, personal communication, 20 June 2006).

The consistency between the timing and magnitude of Hg emissions reductions and the declines in Hg concentrations in common loons, fish, and zooplankton could be related to several factors. A substantial amount of gaseous Hg(II) was removed from the

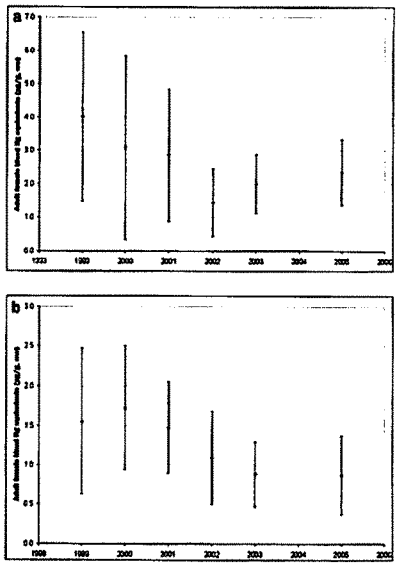

Figure 6. Temporal patterns for adult loon blood mercury (Hg) equivalents (µg per g, wet weight; mean ± standard deviation) in (a) the middle Merrimack River watershed (n = 53) and (b) the upper Merrimack River watershed (n = 43), New Hampshire. Note: The magnitude of the y axis, adult female blood Hg equivalents, differs between figure 6a and 6b.

Table 6. Values of mercury (Hg) emissions, deposition, and biotic concentrations in the middle Merrimack River watershed, New Hampshire, for 1996–1997, 1999, and 2002.

Measure	Year	
	1996–1997 and 1999	2002
Emissions in model domain	1515.3 kg	879.0 kg
Maximum annual deposition[a]	810 µg per m² per yr	76 µg per m² per yr
Area of elevated deposition	50 km²	20 km²
Average adult common loon blood equivalent[b]	4.02 µg per g	1.45 µg per g
Average zooplankton (45–202 µm)	5.14 ng per g	0.59 ng per g
Average zooplankton (> 202 µm)	1.72 ng per g	0.17 ng per g

a. Deposition estimates are based on monitoring data from the Mercury Deposition Network and ISCST3 (industrial source complex short-term) model analysis.

b. Common loon tissue Hg equivalents were determined from 10 lakes in southeastern New Hampshire from 1999 to 2005. The decline from 1999 to 2002 represents a statistically significant change ($t = 2.1$, $df = 16$, $p = 0.008$). Loon blood and egg Hg concentrations were collected starting in 1999.

Table 7. Emission reduction scenarios considered in this analysis.

Location of coal-fired electric utilities	Emissions (kg per yr)		
	Current	50% reduced	90% reduced
Merrimack Station	62.4	31.20	6.24
Schiller Station	5.00	2.50	0.50
Salem Harbor Station	8.80	4.40	0.88
Mount Tom Station	1.93	0.97	0.19

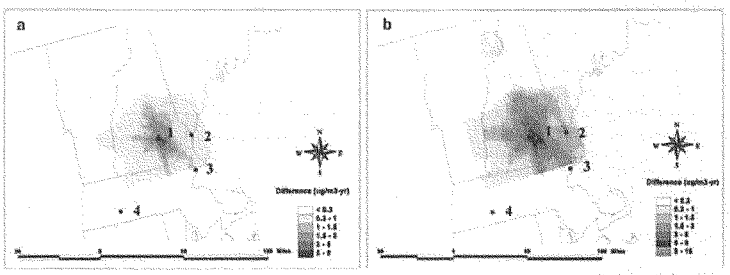

Figure 7. Total differences in mercury (Hg) deposition (μg per m² per year) statewide in New Hampshire (a) with 50% emission reduction and (b) with 90% emission reduction from four coal-fired utilities in New England. Power plant Hg emission sources: (1) Merrimack Station, (2) Schiller Station, (3) Salem Harbor Station, (4) Mount Tom Station.

local atmosphere and most likely reduced local Hg deposition, and this "new" Hg is generally thought to be more readily bioavailable than Hg that has been in the ecosystem for some time (Gilmour et al. 2003). Moreover, most of the study lakes have characteristics that are considered conducive to rapid response: They exist in close proximity to the emission sources, have small watershed-to-lake-area ratios (Grigal 2002), and have limited shoreline wetlands. Wetland areas less than 150 m from lake shoreline are predictive of loon blood Hg concentrations (Kramar et al. 2005), and therefore their extent influences the production of MeHg in the food web.

Links between local emission sources and birds have been measured elsewhere. In Britain, downward trends in piscivorous bird Hg levels were associated with reductions in local industrial air emissions (Newton et al. 1993). In the United States, recent downward trends in the Hg concentrations of Florida's wading birds were linked to reductions in Hg emissions and deposition from local sources (Frederick et al. 2004). Varying sulfate loads may also be a factor in the extent of MeHg production and availability in the Everglades (Bates et al. 2002).

Predicted future changes related to power plant emissions. The ISCST3 model was also used to evaluate two scenarios: a 50% and a 90% reduction in emissions from the four active coal-fired utilities located in the input modeling domain (table 7). The difference in deposition between the current and reduced emissions scenarios is evident in grid cells H3a and H3b (figure 7a, 7b). The average difference in deposition across all cells was 5% for the 50% reduction scenario and 9% for the 90% reduction scenario. However, the reduction in deposition was much greater in the areas of highest deposition; the model cells with the greatest percent decrease between current and projected deposition (23% for the 50% reduction and 41% for the 90% reduction) are located within 20 km of the Merrimack Station in New Hampshire, which is the largest coal utility in the modeling domain.

The scenario results indicate that a large portion of Hg(II) and Hg(p) is deposited within a short distance of these large sources, causing elevated deposition. Similarly, the results show that emissions from four coal-fired utilities in the area contribute approximately 40% of total Hg deposition attributed to local sources, and that decreased Hg emissions will result in substantial decreases in Hg deposition. The magnitude of the decreases in Hg deposition from local sources illustrated in these calculations (figure 7) should be viewed in the context of the additional Hg deposition from regional and global sources (19 to 21 μg per m² per year; Miller et al. 2005).

These results are based on the NESCAUM (Northeast States for Coordinated Air Use Management) inventory, which assumed that coal-fired utilities emit 70% of Hg as gaseous Hg(II) and Hg(p), on average. Recent stack-testing data for the Merrimack Station in New Hampshire suggest that gaseous Hg(II) emissions may constitute up to 92% of total Hg emissions at this facility (NHDES 2005). Under these conditions, we would expect baseline deposition to be higher than estimated here, and the decline in deposition associated with these emission reduction scenarios to be much greater.

Conclusions

Current levels of Hg deposition in the Northeast are 4 to 6 times higher than the levels recorded in 1900 (Perry et al. 2005). We identified five biological Hg hotspots in the region and hypothesized that these hotspots occur where the impacts of atmospheric Hg deposition are amplified by large reservoir fluctuations, highly sensitive landscapes, or elevated Hg deposition associated with large local emission sources.

Model estimates suggest that emissions from coal-fired power plants in the study region account for a large fraction of the total Hg deposited in the Merrimack River watershed hotspot, and that decreased emissions from these sources will result in decreased deposition. Significant and rapid improvements in Hg concentrations in common loons and other biota within this deposition-associated biological Hg hotspot (H3a, H3b) were documented for 1997–2002. Our analysis of the importance of local emission sources also emphasizes that emission trading rules must take local deposition and ecological conditions into account. Other management activities linked to potential reductions in biotic Hg concentrations include minimizing summertime water-level fluctuations on some reservoirs and creating suitable catchments for storm water runoff.

While existing data provide a strong basis for identifying biological Hg hotspots, large gaps in data and understanding continue to hamper our ability to quantitatively analyze sources and fully characterize the spatial and temporal patterns of deposition and biological availability across the United States and Canada. We suggest the development of comparable and linkable data sets for the primary and secondary data layers used here across North America; such data sets will further facilitate the identification of biological Hg hotspots. Developing novel indicator species, such as songbirds and bats, will enhance the ability to identify potential terrestrial biological Hg hotspots for invertivores that may or may not be directly associated with aquatic food webs.

At present, only 92 Hg wet deposition sites operate in the United States and Canada, and no coordinated national system exists to systematically collect and analyze Hg samples for dry deposition and biota in either country. A comprehensive Hg monitoring network has been developed (Mason et al. 2005) and, if employed, can be used to (a) better quantify wet and dry Hg deposition, particularly near high-emission sources; (b) detect additional deposition or biological Hg hotspots; (c) quantify the ecological and human health risks associated with existing biological Hg hotspots; and (d) track the resulting changes in management and policy actions. Ongoing process research and model development can be used to guide this monitoring network.

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Senator CARPER. Thank you for those kind words.

I would ask that Ms. Patton be granted an additional 5 minutes to continue.

[Laughter.]

Senator CARPER. No, thank you so much. There is an old saying, flattery won't hurt you if you don't inhale, so I am not breathing up here.

All right, let's go to questions. I think I get the first couple of questions, and then will yield to Senator Barrasso.

My first question is to our neighbor from Maryland, Secretary Summers. In your testimony, you discussed Maryland's experience with a similar State regulatory initiative, the Healthy Air Act. You mentioned that the implementation of the Healthy Air Act was happening at the same time that many power plants in the east were installing controls to achieve compliance with the EPA's Clean Air Interstate Rule. It sounds like Maryland's generators expressed similar concerns that we are hearing today; is that correct?

Mr. SUMMERS. Yes.

Senator CARPER. All right, thanks.

It sounds like the labor and materials were available and none of your companies needed a lot more time; is that correct?

Mr. SUMMERS. None of them needed more time.

Senator CARPER. All right, thank you.

Did Maryland experience blackouts as a result of this law? Did you have blackouts in Maryland because of this law?

Mr. SUMMERS. No.

Senator CARPER. Did Maryland experience electricity price spikes?

Mr. SUMMERS. No price spikes, either.

Senator CARPER. Why do you think that was the case?

Mr. SUMMERS. Well, I think that as the quote I read from Paul Allen indicated, that these things work very well and could be implemented in the proper timeframe. And it did not cause any of the impacts that had been predicted.

Senator CARPER. All right, thanks.

A question for Ms. Patton and for Dr. Lambert, if I could. Some of my colleagues have questioned the reasoning of cleaning up mercury. They have questioned why we would spend money in this country to clean up this neurotoxin when other countries are contributing to mercury in the atmosphere. Could each of you take maybe a minute apiece to discuss how cleaning up mercury from our largest source—that is coal-fired power plants—can have a beneficial impact on citizens' health? Do you believe that cleaning up mercury from our coal plants is worth the investment?

Ms. PATTON. Senator Carper, the American Academy of Pediatricians, the American Nurses Association, took the unusual step on Friday of filing a motion to intervene in defense of these standards. They are so important to human health. The National Academy of Sciences has issued an extensive report documenting the serious impacts of environmental exposure to mercury on our children's lives. Scientists estimate that over 400,000 children are born each year exposed to levels of mercury that impedes their ability to thrive and to grow.

ADA Environmental Solutions, this is a company in Littleton, Colorado, it has pioneered one of these mercury control technologies. It provides over a third of the bookings for mercury controls now in America. It announced its fourth quarter earnings were at 174 percent, dramatically up. It is hiring new people.

And guess where ADAES is headed to? It is headed to China. It is going to be delivering advanced, made in America mercury control technology to China. It is going to be growing jobs in my home State of Colorado. And who is one of its major investors? Arch Coal. And in 2002, when Arch Coal first joined up with ADAES, then-Secretary of Energy Spencer Abraham said, I commend Arch Coal, you are helping to show the way how we can deliver clean air, healthy air in America through lower emissions.

So there is just an enormous amount of work that people are doing to address these serious problems, and they are all quite serious. But with American innovation we can solve them, and in fact, we are. And we will be selling that technology to China.

Senator CARPER. Arch Coal?

Ms. PATTON. Yes, sir.

Senator CARPER. Now, that is a surprise.

Dr. Lambert, same questions, please.

Mr. LAMBERT. Thank you, Senator.

Mercury is a persistent compound in the environment. The continued addition of mercury to the environment will lead to accumulation. It has long half-life, and it will persist and become remobilized and create exposures up the food chain through fish to humans, and particularly affect children.

It is true that in the western United States long range transport across the Pacific from Asia does bring mercury to our coast, where it falls out, particularly in the Northwest, due to our wet climate. In the Northwest we don't have a lot of coal-fired plants. So the balance, or the budget there, looks different than other parts of the country. If you look in the Northeast, a large part of mercury pollution comes from outside States, and as the situation in Maryland, upwind transport is very important. So it is important to control from our local sources and additionally work toward global controls over time.

Senator CARPER. All right, thanks. My time has expired.

Dr. Barrasso.

Senator BARRASSO. Thank you very much, Mr. Chairman.

Mr. Alford, welcome back to the Committee. I want to hear your comments. I saw your written testimony, you said when electricity rates rise, so does the cost of doing business, putting investment, economic growth and jobs at risk. You further said that the rules are a cost increase, which crowds out other expenditures.

Earlier today, Ms. McCarthy was here, and she seemed to have an opposite view. She said that he updated standards are going to support thousands of good paying jobs for workers, hire to build and install and operate the equipment to reduce emissions. Does the EPA's new restrictions create a big boon for business, and should the Government be placing these restrictions on many of our industries, as she has stated? Can you explain why you believe she is wrong, her strategy is completely wrong?

Mr. ALFORD. Well, they are always wrong. EPA, any time they start analyzing cost and benefits, it is very far from reality. I think this is no exception. I think it is really insulting to say that we are going to put a bigger expense on you, and it is going to improve you economically.

I am looking at the economic crunch, the way they are going about it. Now, I am all for a good, clean environment. But let's do it in a good, logical fashion to where we don't have to take as much pain as they want to give us. If I have a sore elbow, don't cut my arm off. Let's sit down and work this thing out.

Senator BARRASSO. As an orthopedic surgeon, I would focus on the elbow.

[Laughter.]

Senator BARRASSO. You heard the testimony from Mr. James, kind of along the same line. So I would ask, are the members of your organization seeing what is happening in Avon Lake happening in other communities? Specifically, are those negative impacts that are happening in a town like Avon Lake happening nationwide, where school district budgets are going to be hurt, and children are going to be hurt, and emergency services for the sick and elderly are not going to be available because of the tax revenue that goes away and because of these regulations? I thought you might have an opinion on that.

Mr. ALFORD. Yes, a big ripple effect. It hurts. The saying goes with us, when the mainstream gets a cold, we get pneumonia. We are always the first to be fired and the last to be hired. It is always a struggle.

So they don't analyze it like they should. Where these coal plants are, these utility plants are right now, it is in about 55 percent of the African-American business population. We, the African-American businesses, are strongest in the Southeast and then again, upper Midwest. So if you take a string and a pin and stick it in Nashville, Tennessee, and then go about 4 inches on a map, 6 inches on a map with that pin, in that circular part, that is the Black business community of the United States. And that is exactly where these plants are located.

Senator BARRASSO. Thank you.

Mr. James, can I ask you a little bit, you stated that 80 people would be laid off at that coal-fired power plant at Avon Lake, and that their chances of easily finding work at the same pay and benefits—I am just curious what your thoughts would be on finding similar work at similar pay in the same community once the layoffs occur.

Mr. JAMES. Thank you, Senator Barrasso.

Very difficult. As you know, Ohio has had a difficult struggle in this economic recession, as a traditional manufacturing economy. Many of the jobs that the State of Ohio had in the 1970s and 1980s are gone, have been shipped away to other countries or moved away. So to replace those 80 direct jobs will be very difficult, finding work either in Lorraine or Cleveland.

If I may, it is more than just the 80 jobs. Certainly there has to be a multiplier effect of those 80 jobs, the people that shop and go out to dinner in Avon Lake. There is going to be additional secondary and tertiary loss of jobs because of those 80 jobs.

Senator BARRASSO. You also talk about emergency medical services, budget has to be cut because revenue is not coming in, there is a loss of income taxes and a loss in property taxes that fund paramedics, ambulances, training and education of paramedics. What are the impacts of that going to be in terms of the overall health availability and care for the people in that community?

Mr. JAMES. Certainly there will be some direct health impacts, if the facility were to close. Some of the property taxes that are collected from the facility is used to fund our paramedic and firefighters. Without those paramedics and firefighters, I think there is a risk that Avon Lake wouldn't be able to adequately service its 23,000 residents, send ambulances to them in enough time, take them to the hospital, tend to them on an emergency basis. That will certainly have a health impact.

Senator BARRASSO. Do you think that is happening in other communities that have the same impact?

Mr. JAMES. I am certain of that, Senator. There are at least 9 other communities, 10 other communities in Ohio that are facing the exact same problems.

Senator BARRASSO. And Mr. Alford, you are seeing this nationwide; is that correct?

Mr. ALFORD. Absolutely, sir. And another important point, in African-American communities, we are looking at 35 percent to 40 percent unemployment. The only way you are going to cure that unemployment is to create jobs and create businesses. So I think, No. 1, let's find a way to provide a paycheck. We will worry about the healthy after that paycheck starts coming.

Senator BARRASSO. Thank you.

Thank you, Mr. Chairman.

Senator CARPER. Thanks very much.

And I think, Senator Lautenberg, you are next.

Senator LAUTENBERG. I am not a doctor, but my father died when he was 43, working in the mills. His brother died when he was 52, and their father died at 56, when they were working in the mills in Patterson, New Jersey. The uncle who had a tavern lived to be 102, and I am not advocating more drinking.

[Laughter.]

Senator LAUTENBERG. But I am saying that that environment, those jobs that my dad had and my uncle, my grandfather, in the final analysis, helped kill them. And Mr. James, believe me, and Mr. Alford, I do sympathize with the condition that arises and displacement as changes are made. The question is, do you ever invest today for better results tomorrow?

According to the Clean Air Task Force, 2010, the Avon Lake plant was responsible for 29 premature deaths, 440 asthma attacks, 23 emergency visits as a result of asthma and 47 heart attacks, in the year 2010. It was no bed of roses before changes were made. And as a consequence, as we look around the country.

In 1986 I wrote a law to stop smoking in airplanes. It hurt the cigarette companies but it permitted people who couldn't fly before—work in the air cabins, attendants and so forth—to finally do it. And we reduced the level of smoking across the world. Forgive the vanity, but it made a difference in how people treated ciga-

rettes. It was a huge loss to the cigarette companies. They are still doing very well, unfortunately.

So what I say, or I raise the question, I ran a big company, very big. Three of us started—the company has 45,000 employees today. The company is ADP. They do the labor statistics, I was the founder of that, one of the three founders of that.

So when I had a CEO, I looked at whether we would invest here or invest there. And maybe at first there were some costs involved. But the benefits long run had to be considered. So I ask you, Mr. James, Mr. Alford, is there any time at all that you bury your head a little bit—and I don't like people out of work, particularly in the minority communities. I lived in those communities as a child. And to say OK, we have to make an investment here.

And what we hear from Ms. Patton and others, that the cost of change is grossly exaggerated by the proponents of status quo. Is there anything that we ought to do here, Mr. James? What do you think we ought to do about this?

Mr. JAMES. Thank you, Senator Lautenberg. I certainly understand and respect your point. As you may have heard, I spent a number of years as an assistant attorney general enforcing environmental laws. I certainly appreciate and respect their need. But at the same time, those laws need to be narrowly tailored to address specific issues, like mercury. It would be my understanding that the MATS rule goes beyond just narrowly tailored regulation to address mercury.

So my response to you is that if environmental regulation can be balanced, if power companies can be provided enough time and the regulations can be narrowly balanced, I think we can achieve both appropriate environmental regulation as well as protecting the jobs and support that these kinds of facilities can provide to local communities.

Senator LAUTENBERG. I think that it would, to me at least, would sound a little better balanced if you said we should continue to pursue cleaning mercury out of our system. We should pursue clean air altogether. We should try to reduce the number of cases of asthma, premature deaths. If the death is in your family, you don't look and say, what the hell are we spending all this money for.

Mr. ALFORD. I agree. I absolutely agree with you, and I agree with Mr. James, it should be narrowly tailored. But I think the pain shouldn't be disproportionately given without further looking or analyzing——

Senator LAUTENBERG. I am not a pain advocate.

Mr. ALFORD. A member of mine just sent me a picture from the Park Hyatt Hotel in Shanghai. He had a view of the window there, and he is standing by the window. He is up about 120 floors. You couldn't see beyond two blocks in downtown Shanghai.

There is a new coal mine opening in China every week.

Senator LAUTENBERG. Mr. Alford, I am pressured by the clock here. We have a mean Chairman. He will ring the bell.

Mr. ALFORD. Yes, sir. I will close by saying, we need to address those issues, true.

Senator LAUTENBERG. Yes, and I look at those issues, that is a major focus of mine. In the State of New Jersey, the most crowded State in the country, we have a section of the State that is very

well off, and we have five of America's poorest cities in our midst. When I see them in a HeadStart program or something, I really feel good.

I am a professional grandfather; you may have detected that.

Thank you very much, Mr. Chairman.

Senator CARPER. I think that brings us pretty close to the close here. I don't believe Senator Alexander is going to be able to come back and ask questions of this panel.

Sometimes when we conclude a hearing of this nature, I like to come back—we always ask our witnesses to give an opening statement, I am going to ask each one of you to take maybe 1 minute, or more than 1 minute, just to share with us some closing thoughts that may have been generated by virtue of this conversation, what others have said, the questions that have been asked.

Secretary Summers, why don't you take a minute, and we will conclude with Ms. Patton.

Mr. SUMMERS. Thank you, Senator Carper.

I guess I would just say, these systems work very effectively. We have direct experience in Maryland. We have upgraded six coal-fired power plants, 13 units in those plants. They are all doing very well today. We have other plants that are proposed to be built in Maryland today. So the implementation of this law, our Healthy Air Act, which is essentially the same as what we are discussing today, MATS, has been very successful in Maryland.

We have heard about all of the health effects, Maryland by virtue of being downwind from almost everyone except for Delaware, I guess, has some of the worst air quality remaining in the country. And we need these upwind sources to install the same kind of controls that we put into place. We believe that it is actually a boon for the economy. It has been in Maryland. Thank you very much.

Senator CARPER. Thank you, Secretary Summers.

Dr. Lambert.

Mr. LAMBERT. Thank you, Chairman Carper.

We are blessed in the United States with clean air in many ways. We have seen tremendous improvements in air quality. I grew up in Los Angeles, and I have seen what was described. I have been to Mexico City, I have been to other places where the pollution remains a challenge.

But our challenge here in the United States, even though you cannot see this pollutant, it is an insidious poison, it is in the air. And we have talked about how it affects children and pregnant women and fetuses. We get a wonderful co-benefit by scrubbing mercury out: all these other pollutants travel with it, which results in broad benefits for many Americans, particularly our seniors and those with pre-existing diseases like asthma.

The scientific evidence is not debated. There are big benefits to reducing cardio-respiratory diseases from these additional pollutants.

Senator CARPER. Thank you, Dr. Lambert.

Councilman James.

Mr. JAMES. Thank you, Senator Carper.

My understanding of the MATS rule, the USEPA has looked at mercury and then looked at a number of co-benefits from the reduction of mercury, whether it is the reduction of other kinds of pollut-

ants, such as PM, and other additional co-benefits, such as perhaps several thousand transient jobs, several thousand permanent jobs. I am not an expert; I am not sure if those statistics are true.

But what it does seem to me is that USEPA failed to take into account the co-costs of the mercury rule, the MATS rule, the costs that are associated with the loss of income tax and property tax, the loss that is associated with jobs and having vibrant communities.

So I would ask you, I would ask the USEPA, as you are exercising your authority, as you are exercising your discretion, that you consider the co-costs of your rulemaking, of your authority. Thank you.

Senator CARPER. Thank you.

Mr. Alford.

Mr. ALFORD. I want to encourage this Subcommittee to have more hearings and more discussions. We applaud your efforts so far and we encourage you to continue on.

I think like Maryland is suggesting to the upwind States to do a better job of environmental stewardship, the United States should do a better job of convincing other nations to do so, also. Do we trade with these culprits? Do we give financing or gifts to these culprits? I don't think we should. We should be a little harder.

Senator CARPER. All right, thank you, sir.

Ms. Patton.

Ms. PATTON. On February 29th, 2012, GenOn filed a 10K statement with the United States Securities and Exchange Commission in which it indicated it had not made a final decision about the closure of the Avon Lake facility.

Senator CARPER. When?

Ms. PATTON. On February 29th.

Senator CARPER. Really?

Ms. PATTON. It indicated that it was considering a number of factors, including factors entirely unrelated to the Mercury and Air Toxics Standards that would ultimately inform its final judgment about the future of that plant.

Senator Carper, we have models in our country of communities working together to meet these challenges. In my home State of Colorado, the State's leading power company worked together with Republican members of the general assembly, with Democratic members of the general assembly, with labor, with the American Lung Association, with concerned citizens. And it fashioned a plan that is exactly what Senator Lautenberg described. And that is the plan to deliver cleaner, healthier air for millions of people across the Colorado front range.

And some of those transitions involved closures, closures of aging, high emitting, inefficient coal plants that were commissioned well before the Denver Broncos became an official charter member of the American Football League. And we are transitioning to a 21st century, clean, modern energy infrastructure. And we are doing it working together as a community in a way that will deliver cleaner, healthier air, a steady flow of electricity cost effectively. There are lots of great models out there in America of people working together to meet these challenges.

Thank you, sir.

Senator CARPER. Thank you so much.

I really thank you all for being here and being part of this conversation with us. These are important issues, not just for States like Maryland and Virginia, New Jersey, New York, and all the way up the East Coast who live in what we call the end of America's tailpipe. We love living in Delaware; it is a great place to live. But 90 percent of our air pollution literally comes from places outside of our State that we are unable to control, which as you might imagine is a source of great frustration and why we have been anxious to see the level of emissions from other States to be reduced.

During one point in our hearing today I leaned over to Senator Barrasso, and I said, isn't the U.S. the Saudi Arabia of coal? And he said, yes. I said, isn't the U.S. on its way to becoming the Saudi Arabia of natural gas? And he said, yes, I think so. Then he told me that Wyoming is the Saudi Arabia of coal. I was born in West Virginia, and we are very proud of the fact that we produced a lot of coal there and provided a lot of electricity for folks around the country. Having said that, we also know now that burning coal, if we are not careful, if we are not smart about it, we can create enormous health problems for folks who happen to be downwind from us.

While we are making progress, I like to say, if it isn't perfect, make it better. And we can do better still.

I remember, Senator Lautenberg, about 7 or 8 years ago, after my first term here, I remember being visited by oh, gosh, 8 or 10 CEOs from different utilities around the country. One fellow was from one of the utilities in the southern part of our country, sort of a curmudgeonly old fellow. We had been meeting for about an hour, wrapping it up, and he said, OK, Senator, here is what you all need to do. He said, you need to tell us what the rules are going to be—this was with respect to air pollution—tell us what the rules are going to be, give us some flexibility, give us a reasonable amount of time, and get out of the way. That is what he said. I will never forget those words.

I thought that was pretty good advice for us then, on that issue, and it is good advice for us today.

Mr. Alford, you said in your response to one of our questions, I believe, maybe during your testimony, I think you said essentially, relieve us from this hammer on our head with respect to the regulation that EPA is promulgating. While I am concerned about a hammer on anybody's head, I am also even more concerned about the mercury in our bodies and in the bodies of child bearing women all over this country. I think we can be smart, to avert the hammer on our heads. And if we are smart, we can do that and reduce the fear and the reality of what happens when women of child bearing age with elevated levels of mercury give birth to babies.

We always learn things at these hearings. For me, one of the most interesting take-aways was the news that Southern Utility believes now, given the changes to modifications that EPA has made to their original proposed regulation, that they will be able to comply with this regulation as it has finally been promulgated. And they can do so for about one-third less cost than they had previously expected. I think as Ms. Patton said in her testimony, AP, big utility in the Midwestern part of our State, that they expect

they are going to be able to comply at about one-third the cost of what they originally anticipated. That is very encouraging news.

So here we are, we are coming to the end.

Senator Lautenberg, go ahead, please.

Senator LAUTENBERG. He is a generous man, also; he wasn't just mean, our Chairman.

A couple of questions. Secretary Summers, has Maryland experienced any electricity reliability problems as a result of the MACT pollution standards?

Mr. SUMMERS. None at all.

Senator LAUTENBERG. Dr. Lambert, the standards set pollution limits on mercury from power plants for the first time. Based on your research, can you explain how mercury and other toxic air pollution affects the health of children? Is there a general rule?

Mr. LAMBERT. The most sensitive system is the developing brain. So it is loss of memory, learning disabilities, attention deficits. These are permanent, life-long consequences for disturbance of early brain development.

Senator LAUTENBERG. And Ms. Patton, in 1990 Congress directed EPA to set mercury air toxic pollution standards by the year 2000. I am pleased that these standards are being implemented; Americans have waited far too long for clean air. Why were these important standards delayed for such a long time, in your judgment?

Ms. PATTON. Senator Lautenberg, there has been, it is a tragic delay, right, because the costs are imposed on our children's health. And the tragedy is that we have made in America solutions to meet these challenges. And the delay has been due to polarization, it has been due to agencies taking shortcuts that are inconsistent with the law and fly in the face of science. But today we now have, finally, long overdue, in place vital standards to protect our children's health, to protect our families' health. And we cannot afford for the delay, the costs are borne by our children.

Senator LAUTENBERG. And I close, Mr. Alford, I understand your frustration and why it is that as we see African-American development, business owners and professionals and so forth, that we ought not to make the load any heavier. But the question is, is a little bit heavier load right now worth the savings in life and health that we have in the future?

Mr. ALFORD. Savings of life, poverty brings far worse health than mercury coming out of a coal plant or a utility plant. Violence, crime, these kids that I see are far more likely to get a bullet in the head than asthma. And that is the reality of it. And that is because of the economic consequences of bad policy and practices, much of which comes from this Capitol Hill.

Senator LAUTENBERG. Yes, but we shouldn't, because of other problems, decide that we don't want to solve this problem. That is where I disagree with you.

Mr. ALFORD. Prioritize, is what I am saying.

Senator LAUTENBERG. Yes.

And Mr. James, you have had a barrel full of experiences in your career, and we can disagree on a particular subject. But I don't see you wanting to say, well, let's perpetuate the exposure to mercury and all those things.

So thank you. Thank you all for your testimony. And Ms. Patton, I have an active interest in the State of Colorado. I have two grandchildren, a son, and his wife who have made their lives living in Edwards, Colorado.

Thank you all. This was an excellent hearing, Mr. Chairman, and my compliments to you for getting the exposure that we wanted here.

Senator CARPER. Before we adjourn, I will just add one quick P.S. One of the previous administrators at EPA was the former Governor of our neighboring State, New Jersey. And that is Christy Whitman, good friend.

I hear Senator Lautenberg talking about his children and the love and affection he has for them. I am reminded of what Christy Whitman told me several years ago when she told me that she had become a grandmother for the first time. She said, grandchildren are one of the few things in life that are not overrated. Not overrated.

With that, the members of the Committee will have 2 weeks to submit any additional questions. We would ask that you respond promptly.

Again, we are grateful to all of you for being here today and for participating in what I think was quite a good hearing. Thanks so much.

This hearing is adjourned.

[Whereupon, at 12:03 p.m., the Committee was adjourned.]

[Additional statements submitted for the record follow]

STATEMENT OF HON. BENJAMIN L. CARDIN,
U.S. SENATOR FROM THE STATE OF MARYLAND

Thank you, Mr. Chairman, for holding this hearing. Thank you also to our witnesses for coming to testify this morning.

These standards are an important step for protecting public health and improving the Nation's economy.

We are all aware of the health impacts air pollution has on our most vulnerable populations: children, the elderly, and our poorer populations. Air pollution threatens those with asthma and respiratory problems and results each year in 12 million lost work days, 14 million lost school days, and 5,000 deaths.

Air pollution also leads to cancers and neurological, developmental, and reproductive problems.

Mercury, of which power plants are the single largest source of mercury emissions in the United States, causes serious developmental problems in children and infants.

The deposition of mercury into inland and coastal waters impacts our fisheries and introduces another pathway by which our kids, and anyone who fishes, can be exposed to mercury.

The Mercury and Air Toxics Standards can help us better protect our kids, our citizens, and our waters.

In 2006 Maryland responded to concerns about air pollution by enacting the Maryland Healthy Air Act. The Healthy Air Act sought to reduce Mercury, SO_x, and NO_x emissions by implementing the toughest power plant emissions law on the East Coast and setting an ambitious 3-year timeline.

Within 3 years Maryland saw reductions from a 2002 baseline of 90 percent in mercury, over 80 percent in sulfur dioxide, and over 70 percent in NO_x.

Maryland's ambitious approach did not harm the State's economy. In fact, energy companies reported substantial economic benefits from implementing the new standards.

For example, the Brandon Shores coal-fired power plant generated nearly 4 million man-hours of labor from Constellation's $1 billion investment. This included 26 months of work for 2,000 skilled construction workers.

Unrepresented in this figure are the additional jobs in manufacturing and distribution associated with the production of technologies and equipment purchased by the plant.

For these reason industry organizations like Ceres (pronounced Series) and the American Boiler Manufacturers Association as well companies like WL Gore, a major employer in Elkton, Maryland, that manufactures clean air technologies like baghouse hardware here in the United States, all support more clean air regulations that are more protective of public health.

Constellation's 12,000-megawatt Brandon Shores power plant, located near Glen Burnie, Maryland, is now one of the cleanest coal-burning power plants in the country and achieved this without substantial increases in utility rates.

The controls required by Maryland's Healthy Air Act are very similar to those required by EPA's Mercury and Air Toxics Standards.

Maryland's experience shows that an aggressive timeline is not only achievable but is also desirable. Plants are capable of meeting aggressive timelines, and the benefits are unparalleled.

Air pollution controls protect public health and save billions of dollars in associated medical costs. And contrary to rhetoric claiming that these controls are job killing, Maryland's experience demonstrates that implementing air pollution controls can create well paying jobs.

Maryland's experience also shows that we need a national standard to effectively address air pollution. Air pollution travels, and out of State impacts are felt no matter how much we control our in-State sources.

Despite our stringent State clean air law and one of the cleanest power generation fleets in the country, 12 of Maryland's 15 counties had 55 days or more last year during which ground-level ozone was at code orange or code red levels. Implementing national standards will help us better address pervasive air pollution threats.

EPA's Mercury and Air Toxics Standards are a necessary step toward protecting our citizens' health. The decision to promulgate these standards is not a political one, as our courts recognized when ordering EPA to issue these standards.

It is time to leave behind the disingenuous debates and instead recognize the public health and economic benefits that these standards can help us achieve.

STATEMENT OF HON. JAMES M. INHOFE, U.S. SENATOR FROM THE STATE OF OKLAHOMA

Chairman Carper, thank you for the hearing focusing on the new MATS, or Utility MACT, rule—the most costly rule in the history of the EPA and one that typifies President Obama's war on affordable energy. I would also like to thank the witnesses for being here today.

First, I'll say that Republicans are for clean air. In fact, I championed one of the first bills to reduce mercury—the Clear Skies Act. That legislation struck a balance between environmental protection and economic development. Unfortunately, Clear Skies was killed by radicals in the environmental movement because it didn't require reductions in carbon—in other words, it didn't cause enough economic pain. In 2005, when the Bush administration issued mercury regulations under the Clean Air Act, they also fell victim to environmental groups' court challenges. So today we would do well to remember that it is Republicans who first sought to reduce mercury, and it's the environmental establishment that has stopped progress for more than a decade.

We now debate EPA's replacement regulations. But this time no attempt has been made to balance environmental protection and economic development. In fact, the Utility MACT rule is at the heart of the Obama administration's war on affordable energy. Mirroring Obama's cap and trade agenda, this regulation isn't about saving lives or the environment. It's part of a calculated effort to kill traditional forms of energy, like coal, to benefit Obama's political allies. Backed by false claims and EPA propaganda, this regulation will fulfill Obama's campaign promise of skyrocketing electricity rates. [1]

Today we're going to hear about the benefits of this rule ad nauseam. These claims are disingenuous and misleading. The rule is ostensibly designed to reduce hazardous air pollutants (HAP), namely mercury. But over 99 percent of the bene-

[1] Picket, Kerry. "Obama: Energy prices will skyrocket under my cap and trade plan," News Busters. 3 November 2008 < http://newsbusters.org/blogs/kerry-picket/2008/11/02/obama-energy-prices-will-skyrocket> 19 March 2012.

fits claimed by EPA are from reducing fine particle matter (PM)[2] —not mercury—even though PM is strictly regulated under other CAA programs, including the National Ambient Air Quality Standard (NAAQS) for $PM_{2.5}$. Worse yet, nearly all of EPA's alleged benefits occur at levels well below the NAAQS.[3] This means EPA is justifying the rule by cleaning up what it simultaneously defines as clean air—duplicity at its best.

In fact, EPA's analysis shows us that mercury is the only HAP where any health benefits can be quantified. These benefits are estimated to be $6 million per year—at the most. At an estimated cost of nearly $10 billion, the benefits are exceeded by approximately 1,600 to 1.[4] You can see the gulf between benefits and costs in this chart, which I request be entered into the record.

This rule isn't about public health. It's about one thing—killing coal—as a gift to Obama's political allies: the environmental movement and crony capitalists who profit through Government intervention. The Obama administration could not pass cap and trade, so it is using EPA regulations to back-door its global warming agenda.

As we will hear from our witnesses today, working families will pay the price. Indeed, the plant being closed in Avon Lake, Ohio, is but one example of what is happening in cities and towns across the country as a result of EPA's rules. In fact, as of today nearly 22 gigawatts (that's the equivalent of approximately 50 medium-sized plants) operating in 20 States are slated to shut down, with more expected. These closures have been projected to increase electricity prices by as much as 20 percent, sending a ripple effect though the economy that could kill up to 1.64 million jobs.[5] You can see the impact on retail electricity prices in this poster. I ask that both this poster and the underlying study be added to the record.

EPA's environmental allies blame the plants' closing on natural gas prices and other market factors. But nearly every company closing plants has pointed directly at EPA's rules as the reason. Admitting as much, Administrator Lisa Jackson said in a recent interview, "EPA's role is . . . to level the playing field" so that coal-fired generation costs more relative to alternatives. This quote nicely captures EPA's global warming agenda—use the power of the Government to destroy one sector of the economy so that others may profit.

This regulation needs to be stopped. This is why I have introduced a resolution of disapproval which seeks to overturn Utility MACT. Contrary to claims, however, it doesn't amend the Clean Air Act or keep the agency from regulating mercury. Rather, it would send the rule back to EPA to be rewritten in a manner consistent with congressional direction—namely, in a way that reduces emissions but that doesn't unnecessarily kill jobs so that others may profit.[6]

[The referenced material follows:]

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[2] EPA, "National Emission Standards for Hazardous Air Pollutants from Coal- and Oil-fired Electric Utility Steam Generating Units and Standards of Performance for Fossil-Fuel-Fired Electric Utility, Industrial-Commercial-Institutional, and Small Industrial-Commercial-Institutional Steam Generating Units," page 683–4. http://www.epa.gov/mats/pdfs/20111216MATSfinal.pdf.

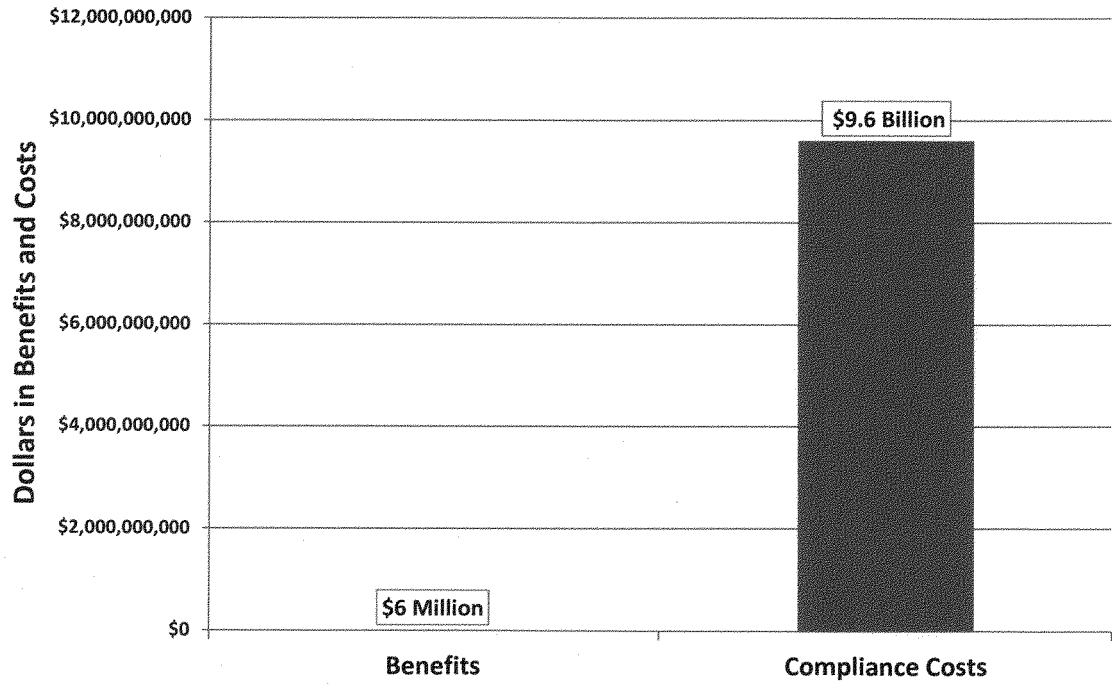
[3] EPA, "Regulatory Impact Analysis for the Final Mercury and Air Toxics Standards," page ES–4. http://www.epa.gov/ttn/ecas/regdata/RIAs/matsriafinal.pdf.

[4] EPA, "National Emission Standards for Hazardous Air Pollutants . . . ," page 664.

[5] "Potential Impacts of EPA Air, Coal Combustion Residuals, and Cooling Water Regulations," National Economic Research Associates for the American Coalition for Clean Coal Electricity, September 2011.

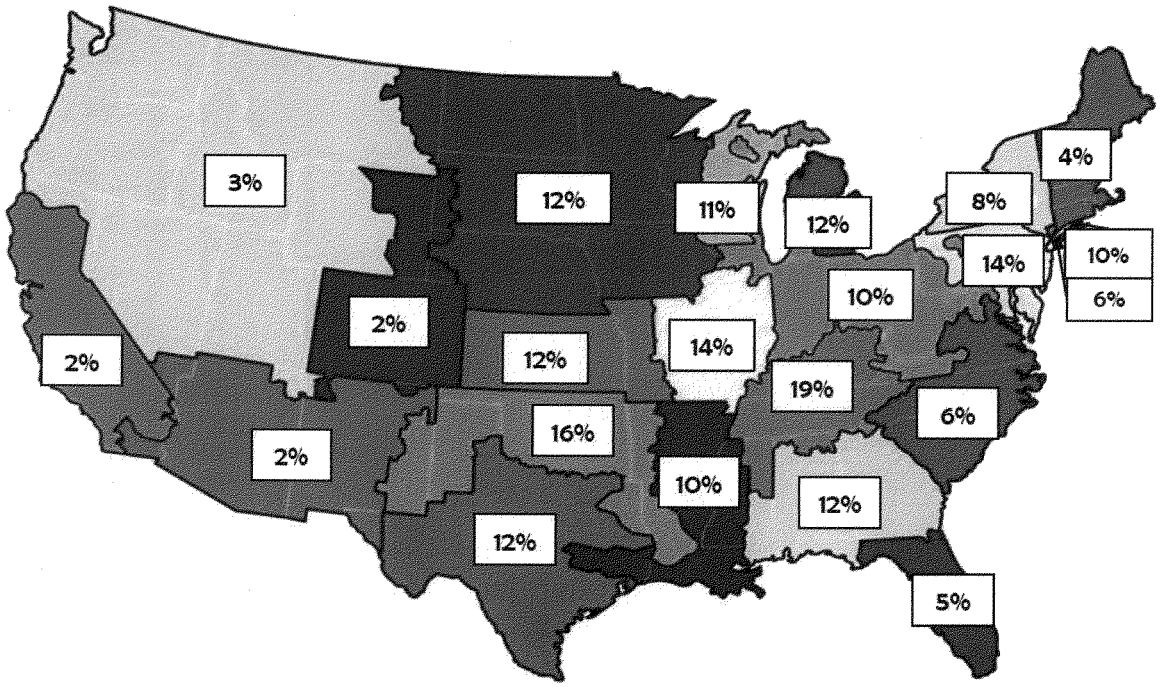
[6] "Impact of a Resolution of Disapproval Under the Congressional Review Act on an Agency's Authority to Issue Subsequent Regulations" February 8, 2012.

Utility MACT: Cost versus Benefits



Source: National Emission Standards for Hazardous Air Pollutants from Coal- and Oil-fired Electric Utility Steam Generating Units and Standards of Performance for Fossil-Fuel-Fired Electric Utility, Industrial-Commercial-Institutional, and Small Industrial-Commercial-Institutional Steam Generating Units, Final Rule. http://www.epa.gov/mats/pdfs/20111216MATSfinal.pdf, pages 664.

Retail Electricity Price Increases Due to New EPA Rules



Source: "Potential Impacts of EPA Air, Coal Combustion Residuals, and Cooling Water Regulations," National Economic Research Associates for the American Coalition for Clean Coal Electricity, September 2011.

[Additional material submitted for the record follows:]

Southern Company Services, Inc.
601 Pennsylvania Avenue, NW
Suite 800
Washington, D.C. 20004

Tel 202.261.5000

SOUTHERN COMPANY

March 21, 2012

The Honorable Thomas R. Carper
Hart Senate Building
Washington, DC 20510

The Honorable John Barrasso
Hart Senate Building
Washington, DC 20510

Dear Senator Carper and Senator Barrasso:

At a hearing of the Clean Air and Nuclear Safety Subcommittee held on March 20, 2012, titled, "Oversight: Review of the Environmental Protection Agency's Mercury and Air Toxic Standards (MATS) for Power Plants," EPA Assistant Administrator Gina McCarthy made a comment about Southern Company's compliance with the MATS rule. In her comments, McCarthy said that Southern had announced that we could comply with the rule by 2016.

Southern Company has not said that compliance with the Utility MACT rule will be achieved by 2016. In fact, Southern does not expect to have a compliance plan finalized until later in the summer of 2012. What Southern has said is that while the capital cost for compliance with the Utility MACT rule may be somewhat less than projected from the proposed rule because the final rule may require fewer baghouses, we have NOT said that compliance will be achieved by 2016. Time beyond the 3 year compliance period will still be needed due to the need for new scrubbers, baghouses, new gas pipelines, fuel conversions and transmission projects to comply with the rule's provisions plus address potential reliability problems. Southern remains concerned about the short time frame in the rule.

Thank you for letting us correct the record on this matter. Feel free to call if you have any questions or need further information.

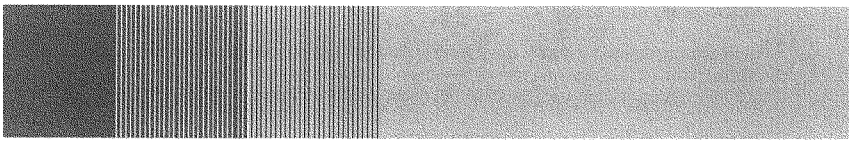
Sincerely,

L.Ray Harry
Director, Environmental Affairs

cc: Senator Barbara Boxer
Senator James M. Inhofe

September 2011

Potential Impacts of EPA Air, Coal Combustion Residuals, and Cooling Water Regulations



Prepared for:

American Coalition for Clean Coal Electricity

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Contents

Executive Summary

This report evaluates the potential energy and economic impacts of four major environmental regulations that would affect the electricity sector. The regulations include two major air emission policies—the Cross-State Air Pollution Rule (CSAPR) and regulation of mercury and other hazardous emissions (Utility MACT)—as well as policies to regulate coal combustion residuals (CCR) under the Resource Conservation and Recovery Act and to regulate cooling water intake under Section 316(b) of the Clean Water Act. We focus on the potential near- and medium-term (2012-2020) implications for electricity and other energy prices and for national economic impacts. This methodology is designed to complement analyses of individual regulations, including assessments of their social benefits and costs.

A. Background

Environmental legislation provides the mandate for the development of individual regulations. The U.S. Environmental Protection Agency (EPA)—sometimes in conjunction with state environmental agencies—develops regulations to implement these Congressional directives. EPA typically proposes a single regulation and provides information on its individual social costs and benefits (and other impacts), with previously-promulgated regulations being included in the baseline and the implications of other potential future regulations not considered.

In addition to analyses of individual regulations and their social costs and benefits, however, there are other impacts of environmental regulations that are of interest to policy makers but that are not necessarily included in regulatory analyses. Interest in "green jobs" has provided one additional focus. Some studies have noted that environmental mandates will increase employment in pollution control and clean technology sectors (see, e.g., Ceres 2010). Other commentators, however, have noted that these results ignore the jobs lost in the rest of the economy due to other impacts of the regulations, including increased electricity and other energy prices (see, e.g., Montgomery 2011).

There also has been a concern that focusing on individual regulations neglects the cumulative effects of multiple environmental regulations. Since these initiatives tend to increase future costs for coal-fired power plants, many studies have assessed the potential for regulations to lead to increases in coal unit retirements—since owners of some coal-fired power plants will choose to retire their units rather than install expensive control equipment—and some of these studies have assessed the possibility of impacts on electric system reliability.[1] Projections for a continuation of the recent trend of low electricity prices—driven by low natural gas prices—tend to increase pressures for coal unit retirements. Coal unit retirements and compliance costs for units that do not retire in turn can lead to increases in electricity and natural gas prices and decreases in coal prices. These changes in energy market conditions can lead to changes in output and employment.

[1] See Bipartisan Policy Center (2011), Brattle Group (2010), Charles River Associates (2010b), Edison Electric Institute (2011), ICF International (2010), M.J. Bradley & Associates and Analysis Group (2011), and North American Electric Reliability Corporation (2010).

B. Objectives and Methodology of This Study

This study develops a set of models to evaluate the potential effects of various environmental regulations on energy markets and economic activity. This methodology thus complements those that have been developed to estimate the costs and benefits—and other impacts—of individual regulations.

Specifically, this report develops estimates of the effects over the period from 2012 to 2020 of the four environmental regulations—the two air emission regulations as well as CCR and Section 316(b)—in three major areas:

1. *Coal unit retirements.* These are estimates of the effects of potential costs on future coal unit retirements. As noted, we develop a probability distribution based upon the range of uncertain parameters.

2. *Electricity and other energy market impacts.* These impacts include the potential effects on energy markets—including coal, natural gas, and electricity—as well as on overall compliance costs.

3. *Economic impacts.* These effects include impacts on the U.S. economy, including employment, gross domestic product (GDP), and disposable personal income (i.e., personal income after taxes).

The modeling framework begins with a set of detailed estimates of the likely compliance technologies—and their costs—associated with the individual regulations. These assessments are based upon the requirements of the individual regulations, including taking into account the potential flexibility provided under CSAPR.[2] For the CCR and Section 316(b) regulations, we use EPA estimates of compliance costs for the various affected units. The result is a set of estimates of the potential technologies and costs to individual electricity generating units under the four policies.

The next task is to estimate the effects of these projected costs on future retirements of coal-fired power plants. The retirement model we develop is a Monte Carlo uncertainty model designed to predict potential economic retirements based upon comparisons of the future costs of the coal-fired unit in comparison to the costs of the likely new generation that would be added in the future. The model incorporates uncertainties in key parameters affecting this comparison, including control costs and electricity and fuel (notably natural gas) prices; the model also takes account of the feedback effects of coal unit retirements on electricity and fuel prices.

The estimated coal unit retirements and the estimated compliance costs for non-retiring units are then input to the U.S. Department of Energy's National Energy Model System (NEMS) model, a well-established modeling framework used by the Energy Information Administration (EIA) to evaluate energy and environmental policies. To develop estimates of changes in employment and

[2] The implications of the emissions trading provisions of CSAPR for technology choices at individual units are developed through an initial run of the NEMS model (a model that is described in the text).

other economic impacts, the NEMS results are input to the Policy Insight Plus model developed by Regional Economic Models, Inc. (REMI PI+), a model used extensively by numerous government agencies and private groups to assess the economic impacts of public and private policies.

Although we have attempted to develop comprehensive assessments, the results should be viewed as subject to considerable uncertainties beyond those incorporated in the analyses. Projected coal unit retirements, for example, do not include the effects of other potential regulatory requirements—notably those related to greenhouse gases—and the impacts do not include potential effects of coal unit retirements on (or constraints related to) electricity system reliability. These omitted factors could lead to additional impacts beyond those estimated in this study.

C. Results of This Study

1. Coal Unit Retirements

The potential costs of the four policies are estimated to lead to 39 gigawatts (GW) of prematurely retired capacity by 2015 among the current coal-fired power plants. This estimate represents additional retirements above those in the reference case (i.e., retirements predicted without the four regulations in place) and accounts for about 12 percent of the 2010 U.S. coal-fired electricity generating capacity.[3] As noted, this estimate does not include the potential effects of other potential requirements—notably potential greenhouse gas emission regulations—or concerns related to detailed electricity system reliability.

2. Energy Market Effects

As noted, the energy market impacts of the various regulations were estimated using the National Energy Modeling System (NEMS) based on estimates of the coal units that retire and the compliance costs for units that do not retire. The NEMS output includes estimates of overall compliance costs for the electric sector as well as detailed impacts on energy markets.

Table ES-1 summarizes the potential costs for the electricity sector based on the level of coal retirements predicted in the retirement model. These costs include compliance costs for coal units that do not retire, capital costs for new capacity that would replace retiring coal units, and changes in fuel costs. Costs are projected to be approximately $21 billion (in 2010$) per year over the period from 2012 to 2020. The costs represent a total of $127 billion (present value in 2010$ as of January 1, 2011) over the period from 2012 to 2020. Capital costs for environmental controls and replacement capacity are about $104 billion.[4]

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[3] This level of retirements is estimated in the retirement model and is not influenced by utility retirement announcements.

[4] Capital costs exceed the total for environmental controls and replacement capacity because of net reductions in operating and maintenance costs.

Table ES-1. Electricity Sector Costs, 2012-2020 (billion 2010$)

	Annual Avg	PV
Environmental Controls	$15	$89
Replacement Capacity	$2	$11
Fuel	$5	$28
Total	$21	$127

Note: Compliance costs from 2012 through 2020 are discounted to January 1, 2011 using a real annual discount rate of 7 percent.
Annual average costs are based on the present values and discounting.
The cost of environmental controls includes net cost savings for operating and maintenance (O&M) expenses.
Source: NERA calculations as explained in text

The retirement of coal units and construction of replacement capacity affect electricity sector fuel consumption, fuel prices, and electricity prices. Table ES-2 summarizes the average potential energy market effects of the four regulations from 2012 to 2020. Appendix C provides information on the annual effects for 2012-2020, with effects that are both higher and lower than these average values.

Table ES-2. Average Annual Energy Market Impacts, 2012-2020

	Coal Retirements	Coal-Fired Generation	Coal Price at Minemouth	Gas-Fired Generation	Gas Price at Henry Hub	Avg Retail Elec Price
	(GW)	(million MWh)	(2010$/ton)	(million MWh)	(2010$/MMBtu)	(2010$/MWh)
	Average of 2012-2020 Projections					
Reference	3.1	1,911	$33.54	639	$4.48	$86.87
CSAPR+MACT+CCR+316(b)	42.2	1,699	$31.61	765	$4.95	$92.52
	Change from Average of 2012-2020 Reference Projections					
CSAPR+MACT+CCR+316(b)	+39.1	-212	-$1.93	+126	+$0.48	+$5.65
	% Change from Average of 2012-2020 Reference Projections					
CSAPR+MACT+CCR+316(b)	+1241%	-11.1%	-5.7%	+19.7%	+10.7%	+6.5%

Note: Coal retirements are cumulative from 2010 through 2020.
Source: NERA calculations as explained in text

Coal-fired generation is projected to decrease by an average of 11.1 percent over the period from 2012 to 2020. The reduction in coal demand is projected to decrease coal prices by 5.7 percent on average. In contrast, the regulations are predicted to increase natural gas-fired generation by 19.7 percent on average over the period and increase Henry Hub natural gas prices by 10.7 percent on average. The increases in natural gas prices would lead to an estimated average increase in costs of about $8 billion per year for residential, commercial and industrial natural gas consumers, which translates into an increase of $52 billion over the 2012-2020 period (present value in 2010$ as of 2011 discounted at 7 percent). Average U.S. retail electricity prices are projected to increase by an average of 6.5 percent over the period. Information on the annual energy market effects from 2012 to 2020 is provided in Appendix C.

3. Economic Impacts

The potential economic impacts of the four policies were estimated using the REMI PI+ model. Table ES-3 summarizes the potential economic impacts. The table shows both the average annual changes over the period from 2012 to 2020 as well as the cumulative effects over the same time period. These net figures take into account jobs that would be created in some sectors as a result of spending on pollution controls (i.e., "green jobs") as well as jobs lost due to higher electricity prices and other negative impacts.

Table ES-3. U.S. Economic Impacts, 2012-2020

	Annual Average	Cumulative
Employment	-183,000 jobs	-1.65 million job-years
Gross Domestic Product	-$29 billion	-$190 billion
Disposable Personal Income	-$34 billion	-$222 billion
Disposable Personal Income per Household	-$270	-$1,750

Note: All dollar values are in 2010$.
The cumulative employment impact is an undiscounted sum from 2012 to 2020; the cumulative GDP and disposable personal income impacts are present values as of January 1, 2011 using a real annual discount rate of 7 percent.
Disposable personal income impacts per capita from REMI were converted to disposable personal income impacts per household based on a current average U.S. household size of 2.58 people (Census 2011).
Source: NERA calculations as explained in text

Over the period from 2012 to 2020, about 183,000 jobs per year are predicted to be lost on net due to the effects of the four regulations. The cumulative effects mean that over the period from 2012 to 2020, about 1.65 million job-years of employment would be lost. As noted, these net employment losses reflect net gains in some sectors and net losses in others. Of the 70 sectors in the REMI PI+ model, sectors that would gain jobs account for about 55,000 added jobs per year on average, and sectors that would lose jobs account for about 238,000 fewer jobs per year on average. On a cumulative basis over the period from 2012 to 2020, the sectors that would gain jobs represent about 499,000 job-years, and the sectors that would lose jobs represent about 2,149,000 job-years.

Table ES-3 also shows the potential near- to medium-term impacts on GDP and disposable personal income. U.S. GDP would be reduced by $29 billion each year on average over the period, with a cumulative loss from 2012 to 2020 of $190 billion (2010$). U.S. disposable personal income would be reduced by $34 billion each year on average over the period, with a cumulative loss from 2012 to 2020 of $222 billion (2010$). The average annual loss in disposable personal income per household is $270, with a cumulative present value loss of about $1,750 (2010$) over the period from 2012 to 2020. Annual economic impacts from 2012 to 2020 are provided in Appendix D.

I. Introduction

This report examines various effects of environmental regulations being developed by the U.S. Environmental Protection Agency (EPA) that affect the electric utility sector. We focus on the cumulative effects of four major environmental regulations on the energy sector and on economic activity, including employment and other measures.

A. Background

EPA has proposed major air emissions and other regulations in recent years. The two air regulations that are likely to have the greatest effect on the electric utility sector are the Cross-State Air Pollution Rule (CSAPR) and the regulations of mercury and other hazardous air emissions under Section 112 of the Clean Air Act (Utility MACT). These two regulations are at different stages of development. CSAPR was promulgated as a final rule in August 2011 (although there are some outstanding issues that EPA continues to review). Utility MACT was proposed in May 2011 and is expected to be made final in November 2011.

In addition to these two major air emissions rules, electric utility plants face other potential environmental regulatory requirements that would require additional investments. EPA recently has proposed a regulation under Section 316(b) of the Clean Water Act that regulates cooling water intake structures from electric power plants (and other facilities) in order to reduce losses to fish and other aquatic organisms. In addition, EPA has proposed regulations under the Resource Conservation and Recovery Act that would change how some plants manage their solid waste streams (the ashes from the burned coal and the sludge from their flue gas desulfurization (FGD) systems). Our assessments focus on the two air emission regulations and the 316(b) and CCR regulations; electricity generating units face environmental costs for other potential regulatory requirements—notably including those related to greenhouse gases—that are not included in our estimated impacts.

The EPA has developed assessments of the potential impacts of these various regulations and proposed regulations in separate regulatory impact analyses (RIAs). These RIAs provide important information on the potential social costs and social benefits of the proposed regulations as well as their potential effects on the energy sector. The public comments provide other information on the potential effects of the individual rules. Information on individual regulations, however, is limited because it does not measure the cumulative effects of many potential regulatory requirements either on individual power plants or on energy markets.

In the face of the limited information provided by evaluating individual regulations, various studies have evaluated the combined effects of various EPA regulations. Most of the studies have evaluated impacts on potential retirements of coal-fired units and some studies have estimated potential implications for electricity system reliability.[5] These studies differ substantially in the

[5] See Bipartisan Policy Center (2011), Brattle Group (2010), Charles River Associates (2010b), Edison Electric Institute (2011), ICF International (2010), M.J. Bradley & Associates and Analysis Group (2011), and North American Electric Reliability Corporation (2010). Note that the ability of these national studies to evaluate

environmental regulations they evaluate and in the nature of their evaluations. The prospect of substantial expenditures for pollution controls results in additional projected coal unit retirements, as every prior study has found.

The potential economic impacts of these rules—including their potential effects on employment and other measures of economic activity—have been less studied than their impacts on potential coal unit retirements, although some studies have considered potential economic impacts of some aspects of the regulations. For example, Ceres (2010) has developed estimates of the potential positive effects of the regulations on employment related to expenditures for emission controls. As various commentators have noted, however, this study did not provide information on the potential negative effects of higher electricity prices and other means of financing the added costs (see, e.g., Montgomery 2011). To our knowledge, no other study has estimated the cumulative economic impacts that include both the positive and negative effects of these four major regulations.

B. Objectives of This Report

The overall objective of this report is to provide estimates of the cumulative energy and economic effects of these four environmental regulations over the period from 2012 to 2020. That is, we consider the potential effects of these regulations on energy markets as well as on employment and other measures of economic activity. We have developed a modeling framework to estimate these various effects. We emphasize, however, that we have not developed estimates of the potential social benefits and social costs of these regulations and do not evaluate whether the individual regulations—or possible regulatory alternatives—would be desirable from a societal perspective.

In particular, the assessments presented in this study include the following three major types of effects.

1. *Coal unit retirements.* We consider the potential effects of regulatory requirements on coal unit retirement decisions based upon various key uncertainties, including the level of future natural gas and coal prices as well as the level of compliance costs. We use the results from this modeling framework to develop potential ranges of total U.S. coal unit retirements.

2. *Energy market effects.* We use information on predicted coal unit retirements as well as information on control costs for units that are not expected to retire to develop estimates of the potential effects of the policies on electricity and other energy markets. The results include estimates of the total compliance costs for the electricity sector due to the regulations, including control costs (capital as well as operation and maintenance), changes in fuel costs, and the costs of additional capacity added.

3. *Economic impacts.* The economic impacts of the regulations—including effects on employment, gross domestic product (GDP), and disposable personal income (i.e., personal

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impacts on electricity system reliability is limited, since reliability impacts are likely to be sensitive to various system details (e.g., local transmission and voltage constraints) that are not included in the studies.

income after taxes)—are estimated by using the energy impacts in an economic impact model.

There are substantial uncertainties involved in developing these estimates. As discussed below, the model we use to develop estimates of coal unit retirements incorporates key uncertainties. It is important to emphasize, however, that other uncertainties are not modeled—including the possibility that coal and other units will face potential regulations related to greenhouse gases—and thus the projections presented in this report should be viewed as estimates of the likely impacts of only the four policies evaluated.

C. Outline of This Report

The remainder of this report is organized as follows. Chapter II provides an overview of the methodologies that are used and the policies that are evaluated in the study. Chapter III presents the results of the analyses. The appendices provide details on the models, compliance assumptions, methodologies, and results.

II. Overview of Methodologies and Policies

This chapter provides summary information on the methodologies used to estimate the potential economic impacts of the four policies. We also provide overviews of the four environmental policies that are modeled. Additional details of the models, policies, and data are provided in the appendices.

A. Modeling Framework

The methodology used in this study is based upon a set of linked models designed to assess the energy and economic impacts of environmental regulations affecting the electric utility sector. The empirical estimates of policy impacts are developed by comparing impacts under a baseline case (i.e., a case without the policies in place) and impacts under the policy case.

1. Overview of Modeling Framework

The modeling framework consists of three principal elements:

1. *Retirement Model*, which estimates whether coal units would be expected to retire based upon comparisons of the expected value of the future costs for the coal unit—including the likely potential costs of additional environmental controls—and the expected costs of an equivalent new natural gas combined cycle unit;

2. *National Energy Modeling System* (NEMS) model developed by the U.S. Energy Information Administration (EIA), which we use to assess the likely effects of compliance costs and coal unit retirements on the energy markets; and

3. *Policy Insight Plus model developed by Regional Economic Models, Inc. (REMI PI+),* which we use to develop estimates of the economic impacts of energy market effects.

The following sections provide summaries of these elements.

2. Coal Unit Retirement Model

Power companies face the choice of retrofitting existing coal units to meet regulations or retiring them if the future costs do not justify continued operation in light of the likely costs of alternative sources to meet future electricity demand. We developed a detailed model to evaluate whether existing coal units in the United States would be expected to retire taking into account the potential costs of retrofit (and other future costs) as well as uncertainties in energy prices and other factors.

The retirement model is designed to mirror the decision by power companies on whether to retrofit coal-fired units with environmental controls or retire them and replace them with new capacity. A Monte Carlo formulation takes into account major uncertainties involved in this decision.

The model begins with estimates of the potential additional costs related to environmental policies. The potential future costs for coal units are based upon EIA data on unit characteristics (including capacity, capacity factor, heat rate, O&M costs, coal type, and current environmental controls) and on EPA information on the potential costs of the various controls. The potential technologies and costs for each coal-fired unit also reflect the flexibility that CSAPR provides—due to the potential for emissions trading—as well as the fuel and electricity prices based upon a similar level of retirements.[6] The model thus takes account of the feedback effects of coal unit retirements on electricity and fuel prices.

The model uses statistical techniques and EPA data to simulate hourly electricity prices in each region—as a function of natural gas prices, time of day, season, peak/off-peak, and other factors—and generation decisions by coal units and potential replacement capacity, with generation a function of price and marginal cost. Uncertain parameters include the costs of controls, fuel prices and electricity prices, and the costs of the likely replacement alternative (a new natural gas combined cycle unit), with interactions among the uncertain parameters included in the Monte Carlo formulation.

Future coal unit costs are compared with the future costs of a new natural gas combined cycle unit by calculating the difference between the cost of the coal unit and the cost of the natural gas alternative in each of the 100 Monte Carlo draws. The unit is presumed to retire if the expected value of the cost difference is positive, i.e., on expectation, the coal unit would have greater future costs than a new natural gas combined cycle unit. Existing coal unit remaining lifetimes in these calculations are assumed to range between 10 and 20 years, depending upon unit age in 2015, to reflect the likelihood that owners of older units will have a shorter time horizon for recovering the cost of additional controls. The formulation accounts for the costs of using system energy during hours when coal units and the potential replacement capacity would not run.

3. NEMS Model

The National Energy Modeling System (NEMS) is a computer-based, energy-economy modeling system of the U.S. through 2030. NEMS projects the production, imports, conversion, consumption, and prices of energy, subject to assumptions on macroeconomic and financial factors, world energy markets, resource availability and costs, behavioral and technological choice criteria, cost and performance characteristics of energy technologies, and demographics. NEMS was designed and implemented by the Energy Information Administration (EIA) of the U.S. Department of Energy (DOE).

4. Regional Economic Models, Inc. Policy Insight Plus Model

The Regional Economic Models, Inc. (REMI) Policy Insight Plus (PI+) model produces estimates of the changes in employment, GDP, disposable personal income, and other macroeconomic variables due to changes in supply, demand, prices, and other types of inputs. Each version of the REMI PI+ model is custom-built for the regions of interest, which can range

[6] We develop the implications of emissions trading flexibility provided by CSAPR by running the NEMS model with the relevant caps. The technologies identified in this run for each unit are used in the retirement model.

from counties to entire countries. The REMI PI+ model incorporates detailed and up-to-date macroeconomic data from the U.S. Bureau of Economic Analysis, the U.S. Bureau of Labor Statistics, the U.S. Census Bureau, and other public sources. The REMI PI+ model is widely used by federal, state, and local agencies, as well as analysts in the private sector and academia, to estimate the effects of regulations, investments, closures, and other scenarios.

B. Overview of Policies Modeled

This section summarizes the four policies evaluated in this report, including the two air emission regulations (CSAPR and Utility MACT) as well as Section 316(b) and CCR. Appendix A provides details on how the reference case and the four policies are modeled, including information on the control cost assumptions that are used.

1. Reference Case

The version of NEMS used for the model represents current legislation and environmental regulations as of January 31, 2011. The policies included in the reference case include state requirements for reduction of mercury emissions but not the Clean Air Mercury Rule, which was vacated and remanded by the D.C. Circuit Court of the U.S. Court of Appeals on February 8, 2008. The reference case also includes the temporary reinstatement of the SO_2 and NOx cap-and-trade programs included in the Clean Air Interstate Rule (CAIR) as a result of the ruling issued by the United States Court of Appeals for the District of Columbia on December 23, 2008.[7] CAIR is included in the reference case through 2011. From 2012 onward, SO_2 and NOx caps revert to pre-CAIR levels.

Proposed federal and state legislation, regulations, or standards—and sections of legislation that have been enacted but require funds or implementing regulations that have not been provided or specified—are not reflected in the reference case. The excluded policies include the four policies evaluated in our study.[8]

2. Cross-State Air Pollution Rule

EPA promulgated CSAPR in August 2011, following a draft rule (Clean Air Transport Rule, or CATR) proposed in August 2010 as a replacement to CAIR. CSAPR requires 27 states to reduce power plant emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) from power plants in Eastern states in an effort to improve ozone and fine particulate air quality in other downwind states.[9] Under CSAPR, EPA set new limits on SO_2 and NO_x emissions for each state beginning in 2012. The limits tighten in some states in 2014.

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[7] EPA finalized CAIR in 2005 but the rule was remanded to EPA by the D.C. Circuit Court of Appeals in 2008. The court decision required EPA to develop a different regulatory approach but to implement CAIR in the meantime.

[8] Note that we include CSAPR in our assessments although EPA finalized CSAPR in August 2011 (EPA 2011a).

[9] In a separate but related regulatory action, EPA also issued a supplemental notice of proposed rulemaking to require six states to make summertime NOx reductions under the CSAPR ozone-season program. Finalizing this

3. Utility MACT

EPA proposed the Utility MACT rule in May 2011 to reduce emissions of mercury and other hazardous air pollutants (including other hazardous metals and acid gases) from coal- and oil-fired power plants across the country. The rule would set emission rate standards for different types of coal- and oil-fired units based on maximum achievable control technology. The emission rate standards would apply to mercury, other non-mercury metallic hazardous air pollutants (using particulate matter as a proxy), and acid gases (using hydrogen chloride as a proxy). Covered power plants would have up to three years to comply with the rule, but permitting authorities could grant one-year extensions to power plants if they required additional time.

4. Coal Combustion Residuals

EPA issued a proposed rule on June 21, 2010 related to the regulation of coal combustion residuals (also referred to as coal combustion waste) under the Resource Conservation and Recovery Act (RCRA). The regulations apply to the management of coal combustion residuals generated by steam electric power plants (i.e., electric utilities and independent power producers) that are disposed of in landfills and surface impoundments.

EPA co-proposed two approaches to the regulation of coal combustion waste. The first would regulate residuals under Subtitle C of RCRA as a "special waste." The second would regulate residuals under Subtitle D as a non-hazardous waste. Our assessments are based on the potential costs to individual units of regulating coal combustion residuals under Subtitle D.

5. Clean Water Act Section 316(b)

On April 20, 2011, EPA proposed cooling water intake requirements for existing power plants and other industrial facilities under Section 316(b) of the Clean Water Act. These facilities withdraw water and in the process, fish and other aquatic organisms are lost if they become trapped against intake screens ("impingement") or pulled into the cooling system ("entrainment"). Various technologies reduce impingement and entrainment losses, including the retrofit of plants with cooling towers to provide closed-cycle cooling.

EPA evaluated four alternatives for setting Section 316(b) standards, with Option 1 identified as its preferred option. Option 1 would require that existing plants withdrawing water above a proposed 2 million gallon per day threshold reduce the impingement mortality by meeting various national standards (EPA 2011b, pp. 22203-22204). In contrast, entrainment controls would be set on the basis of site-specific requirements. Under EPA's proposal, permit writers will be required to consider converting the condenser cooling system from once-through cooling to closed-cycle cooling through the use of cooling towers, which reduces net flow and thus entrainment losses (albeit at substantial cost and often undesirable environmental side-effects). EPA estimated the cost of installing cooling towers under Option 1 at the 46 fossil units with the

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supplemental program would bring the total number of covered states under the CSAPR to 28. EPA reports that it is proposing to finalize this proposal by late fall 2011.

largest cooling water withdrawals from tidal waters. Our assessments are based on the potential costs to individual units of the Option 1 alternative.

III. Study Results

This chapter summarizes the study results for our analyses of the cumulative energy and economic impacts of the four environmental policies. The results are grouped into three categories: (1) coal unit retirements; (2) energy market effects; and (3) economic impacts. Additional details are provided in the appendices.

A. Coal Unit Retirements

1. National Results

The potential costs of the four policies are estimated to lead to 39 gigawatts (GW) of prematurely retired capacity among the current coal-fired power plants. This figure represents additional retirements above those in the reference case (i.e., retirements predicted without the four regulations in place) and accounts for about 12 percent of the 2010 U.S. coal-fired electricity generating capacity. As noted, this estimate does not include the potential effects of other potential requirements—notably potential greenhouse gas emission regulations—or concerns related to detailed electricity system reliability.

We developed an assessment of the potential range of possible retirements using the information from the 100 individual draws from the retirement model. We calculated the retirements in each of the draws as a sensitivity analysis, assuming that a unit would retire if its future costs were greater that the future costs of the natural gas unit in those circumstances. The range of retirements was from 17 GW to 79 GW in these 100 cases. This range is roughly consistent with sensitivity results from other studies, although the other studies do not use the same assumptions and methodology.[10]

2. Uncertainties Regarding Estimated Retirements

The range of potential retirements provides an indication of the substantial uncertainty surrounding potential retirements due to uncertainties in future natural gas prices, control costs and other factors influencing individual retirement decisions. There are, however, some factors that are not included in the retirement model. The retirement model does not account for the possibility that adjustments could occur if the local effects of retirements were severe (e.g., likely to impair electricity system reliability). These adjustments would tend to reduce the actual level of retirements below those predicted by our model, which is based upon economic calculations, although the potential impacts on electricity prices could be greater than estimated assuming units are allowed to retire.

In addition, the model does not factor into the calculation of expected future costs the potential costs and other impacts associated with greenhouse gas regulations. Even without the prospect of

[10] EIA, for example, reports a range of retirements for the two air emissions regulations from 4.7 GW to 63.8 GW (net of reference case retirements) depending upon the level of future natural gas prices as well as the likely time horizon for amortizing compliance capital costs (EIA 2011, p. 50).

specific regulatory requirements, owners of coal-fired power plants are likely to reflect the prospect of potential greenhouse gas regulations in their decisions on whether to incur large compliance expenditures or retire their units. Our estimates do not take into account these effects, which would lead to greater coal unit retirements.

3. Regional Results

The expected coal unit retirements differ substantially among electricity regions. Table 1 shows the potential coal unit retirements by North American Electric Reliability Corporation (NERC) region.[11] The table also shows the percentage of 2010 coal capacity in each region that is predicted to retire by 2015 and each region's share of total U.S. retirements. Note that most retirements are in the Mid-Atlantic and Great Lakes and Southeast regions. These results are consistent with the results of other studies (e.g., Brattle Group 2010).

Table 1. Regional Retirement Estimates

		2010 Coal Capacity (GW)	Retirements (GW)	% of Regional 2010 Coal Cap	% of Total Retirements
	U.S. Total	318.1	39.1	12%	100%
NERC Regions					
NPCC	Northeast	5.7	1.3	22%	3%
RFC	Mid-Atlantic and Great Lakes	107.8	14.5	13%	37%
SERC	Southeast	98.5	18.0	18%	46%
FRCC	Florida	10.3	0.1	1%	0%
MRO	Upper Midwest	28.8	1.9	6%	5%
SPP	Oklahoma and Kansas	19.0	1.6	9%	4%
ERCOT	Texas	18.2	0.6	3%	1%
WECC	West	29.8	1.2	4%	3%

Source: NERA calculations as explained in text

B. Electricity and Energy Market Impacts

As described in the previous section, we used NEMS to estimate net changes in coal-fired generation, natural gas-fired generation, fuel prices, and electricity prices as a result of coal unit retirements and environmental controls due to the four policies.

1. National Results

Table 2 summarizes the potential costs for the electricity sector based on the level of coal retirements predicted in the retirement model. These costs include compliance costs for coal units that do not retire, capital costs for new capacity that would replace retiring coal units, and changes in fuel costs. Costs are projected to be approximately $21 billion (in 2010$) per year over the period from 2012 to 2020. The costs represent a total of $127 billion (present value in

[11] NEMS provides information for 22 regions; we have aggregated the results into the eight major NERC regions.

2010$ as of January 1, 2011) over the period from 2012 to 2020. Capital costs for environmental controls and replacement capacity are approximately $104 billion.[12]

Table 2. Electricity Sector Costs, 2012-2020 (billion 2010$)

	Annual Avg	PV
Environmental Controls	$15	$89
Replacement Capacity	$2	$11
Fuel	$5	$28
Total	$21	$127

Note: Compliance costs from 2012 through 2020 are discounted to January 1, 2011 using a real annual discount rate of 7 percent.
Annual average costs are based on the present values and discounting.
The cost of environmental controls includes cost savings for operating and maintenance (O&M) expenses.
Source: NERA calculations as explained in text

Table 3 summarizes the average effects of the four policies at the national level over the period from 2012 to 2020. (Detailed annual impacts are provided in Appendix C, with effects that are both higher and lower than these average values.)

Table 3. Average Annual Energy Market Impacts, 2012-2020

	Coal Retirements	Coal-Fired Generation	Coal Price at Minemouth	Gas-Fired Generation	Gas Price at Henry Hub	Avg Retail Elec Price
	(GW)	(million MWh)	(2010$/ton)	(million MWh)	(2010$/MMBtu)	(2010$/MWh)
	Average of 2012-2020 Projections					
Reference	3.1	1,911	$33.54	639	$4.48	$86.87
CSAPR+MACT+CCR+316(b)	42.2	1,699	$31.61	765	$4.95	$92.52
	Change from Average of 2012-2020 Reference Projections					
CSAPR+MACT+CCR+316(b)	+39.1	-212	-$1.93	+126	+$0.48	+$5.65
	% Change from Average of 2012-2020 Reference Projections					
CSAPR+MACT+CCR+316(b)	+1241%	-11.1%	-5.7%	+19.7%	+10.7%	+6.5%

Note: Coal retirements are cumulative from 2010 through 2020.
Source: NERA calculations as explained in text

The potential impacts of the four policies on energy markets are substantial.

- Coal-fired generation is predicted to decrease substantially, by an average of 11.1 percent relative to average reference case levels over the 2012-2020 period.
- In contrast, natural gas-fired generation is predicted to increase substantially, by an average of 19.7 percent relative to average reference case levels over the same period.

[12] Capital costs exceed the total for environmental controls and replacement capacity because of net reductions in operating and maintenance costs.

- Average coal prices are predicted to decline, reflecting the reduction in coal-fired generation. Coal prices decline an average of 5.7 percent relative to average reference case levels over the same period.

- Average natural gas prices are predicted to increase, reflecting the increased demand for gas-fired generation. Henry Hub natural gas prices increase an average of 10.7 percent relative to average reference case levels over the 2012-2020 period. These prices increases would increase costs by about $8 billion per year for residential, commercial, and industrial customers (and a total of about $52 billion as a present value as of January 1, 2011 over the period).

- Average retail electricity prices are predicted to increase an average of 6.5 percent over the same period.

It is useful to put these predicted impacts into perspective. For example, the predicted effect of the four policies on Henry Hub natural gas prices is $0.48/MMBtu. By way of context, the EIA reduced its forecast of future Henry Hub natural gas prices by approximately $2/MMBtu from AEO 2009 to AEO 2011.

2. Uncertainties Regarding Energy Market Impacts

The projected energy market impacts due to the four environmental policies are significant. The impacts arise both because of substantial compliance costs—that lead a substantial number of coal-fired units to retire and force other coal units to incur substantial retrofit costs in order to comply—and because of the market reactions to these initial impacts.

The impacts depend upon many factors, including the baseline conditions—including projected future natural gas prices—as well as the details of the market reactions to the policy changes that are embedded in the NEMS model. The baseline also includes assumptions on the nature of future regulatory requirements. As noted above, we modified the baseline in NEMS to evaluate the impacts of these air emission policies relative to the absence of similar SO_2 and NOx policies (no CAIR from 2012 onward); EPA made the same assumption in its recent analysis of CSAPR. We have included state mercury requirements in the baseline, which tend to decrease the impacts relative to a baseline without the state requirements.

The electricity market impacts also depend upon a host of specific elements of the electricity systems in various regions. Some of these elements are included in the assessments, such as the nature of the state regulatory regime. The NEMS results, however, do not include considerations related to highly location-specific factors such as transmission security and the time constraints on retiring units, particularly relatively large units (ICF 2011).

3. Regional Results

NEMS provides energy price results for various regions, including 22 electricity price regions. The electricity price impacts of the four policies differ by region depending upon many factors including the following:

- reliance on coal-fired generation under baseline conditions;
- coal unit retirements;
- need for replacement capacity;
- type of replacement capacity that NEMS builds;
- retrofits for coal units that continue to operate as well as the costs of those retrofits;
- capacity factors for coal units;
- regional fuel prices;
- interregional electricity trade; and
- regulatory regime.

Table 4 provides estimates of the percentage increases in retail electricity rates in the 22 NEMS electricity regions due to the four policies. As with the prior results, these figures are based upon the average percentage changes over the period from 2012 to 2020. (Detailed annual impacts are provided in Appendix C, with effects that are both higher and lower than these average values.)

Table 4. Average Electricity Price Impacts, 2012-2020

		2010$/MWh	%
	US Average	+$5.65	+6.5%
NEMS Regions			
NEWE	New England	+$2.93	+2.2%
NYCW	NYC	+$6.97	+4.2%
NYLI	NY Long Island	+$13.00	+8.0%
NYUP	NY Upstate	+$6.39	+5.6%
RFCE	Mid-Atlantic	+$10.38	+10.7%
SRVC	VA & Carolinas	+$4.05	+5.1%
SRSE	Southeast	+$6.94	+8.2%
FRCC	Florida	+$4.10	+3.9%
RFCM	Lower MI	+$7.63	+9.6%
RFCW	OH, IN, & WV	+$7.01	+8.6%
SRCE	KY & TN	+$8.36	+13.5%
MROE	WI & Upper MI	+$6.96	+9.2%
MROW	Upper Midwest	+$5.39	+7.8%
SRGW	South IL & East MO	+$6.73	+11.1%
SPNO	KS & West MO	+$6.42	+8.0%
SRDA	AR, LA, & West MS	+$5.16	+7.2%
SPSO	Oklahoma	+$8.75	+12.6%
ERCT	Texas	+$5.34	+6.9%
RMPA	CO & East WY	+$1.40	+1.5%
NWPP	Northwest	+$0.04	+0.1%
AZNM	AZ & NM	+$1.40	+1.6%
CAMX	California	+$2.25	+1.6%

Source: NERA calculations as explained in text

C. Economic Impacts

As noted, we used the REMI PI+ model to estimate the potential near- and medium-term economic impacts of the four policies based upon the energy market impacts estimated in NEMS.

1. Results

Table 5 summarizes the effects of the four policies on various economic impact measures, including impacts on employment, GDP, and disposable personal income. The table includes information on the average annual changes over the period from 2012 to 2020 as well as the cumulative effects over the period (detailed annual impacts are provided in the appendices).

Table 5. U.S. Economic Impacts, 2012-2020

	Annual Average	Cumulative
Employment	-183,000 jobs	-1.65 million job-years
Gross Domestic Product	-$29 billion	-$190 billion
Disposable Personal Income	-$34 billion	-$222 billion
Disposable Personal Income per Household	-$270	-$1,750

Note: All dollar values are in 2010$.
The cumulative employment impact is an undiscounted sum from 2012 to 2020; the cumulative GDP and disposable personal income impacts are present values as of January 1, 2011 using a real annual discount rate of 7 percent.
Disposable personal income impacts per capita from REMI were converted to disposable personal income impacts per households based on a current average U.S. household size of 2.58 people (Census 2011).
Source: NERA calculations as explained in text

Over the period from 2012 to 2020, about 183,000 jobs per year are predicted to be lost on net due to the effects of the four regulations. The cumulative effects mean that over the period from 2012 to 2020, about 1.65 million job-years of employment would be lost. U.S. GDP would be reduced by $29 billion each year on average over this period, with a cumulative loss from 2012 to 2020 of $190 billion (2010$). U.S. disposable personal income would be reduced by $34 billion each year on average over this period, with a cumulative loss from 2012 to 2020 of $222 billion (2010$). The average annual loss in disposable personal income per household is $270, with a cumulative loss of $1,750 (2010$).

The four policies would lead to different net employment impacts on different sectors. Of the 70 sectors in the REMI PI+ model, sectors that would gain jobs account for about 55,000 added jobs per year on average, and sectors that would lose jobs account for about 238,000 fewer jobs per year on average. On a cumulative basis over the period from 2012 to 2020, the sectors that would gain jobs represent about 499,000 job-years, and the sectors that would lose jobs represent about 2,149,000 job-years.

2. Uncertainties Regarding Economic Impacts

The estimated economic impacts of the four environmental policies over the period from 2012 to 2020 are substantial. These impacts include many factors, including: the positive impacts of expenditures on environmental controls and replacement electricity capacity; the negative effects of reduced coal sales and reduced coal production; the positive effects of increased natural gas sales; both the negative effects of higher natural gas prices on consumers and the positive effects on producers; and the negative effects of electricity price effects on consumers. In addition, the timing of impacts depends upon how the capital costs of pollution controls and increased replacement capacity are financed. The overall impacts are thus a complicated result of a large number of positive and negative factors.

These estimates are subject to various types of uncertainties, including uncertainties regarding the energy market and other inputs. As noted above, the coal unit retirements and energy market impacts are subject to various uncertainties, which translate into uncertainties regarding the economic impacts. There are additional uncertainties regarding the modeling of these economic

impacts. The macroeconomic modeling does not, for example, take into account the potential negative effect on the overall productivity and growth of the economy of reduced productive investment due to the financing of pollution control expenditures. The model also does not presume that environmental compliance expenditures use any unemployed or idle resources. In addition, the model assumes that consumers can shift away from more expensive energy and thus reduce the negative impacts of higher natural gas and electricity prices, an assumption that may understate the likely negative impacts of the price increases.

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Appendix A: Compliance Measures and Cost Estimates

This appendix provides information on the data and methodologies used to model potential compliance measures and compliance costs at coal units for relevant environmental policies in the reference case and the four potential EPA regulations (CSAPR, MACT, CCR, and 316(b)). We begin with information related to the reference case and then provide information related to each of the potential EPA regulations. We present our cost assumptions for air emission control technologies, which we used as inputs for both the reference case and policy case, at the end of this appendix.

A. Reference Case

As discussed in the report body, we modeled the energy market impacts of the potential EPA regulations using the National Energy Modeling System (NEMS), a comprehensive U.S. energy model developed and maintained by the U.S. Energy Information Administration (EIA). With the exception of the environmental policy inputs discussed in this appendix, we used the same inputs to NEMS as EIA used for its *Annual Energy Outlook (AEO) 2011* (EIA 2011a). Note that the inputs for *AEO 2011* which we did not modify include inputs related to various national, regional, and state environmental policies that are currently in place, such as state renewable portfolio standards and the Regional Greenhouse Gas Initiative.

The environmental policies in the reference case that are most relevant to the potential EPA regulations are the Clean Air Interstate Rule (CAIR) to reduce SO_2 and NO_x emissions from power plants and policies to reduce mercury emissions from power plants. EIA describes its inputs related to these policies for *AEO 2011* in EIA (2011b, pp. 104-107). Table A-1 summarizes our compliance assumptions related to these policies for our reference case.

Table A-1. Compliance Assumptions for Reference Case

Policy	Emission	Compliance Assumptions
CAIR	SO_2	Apply Phase 1 SO_2 cap (3.6 million tons) through 2011 and allow NEMS to determine which units would need to install SO_2 control technologies or switch to lower-sulfur coal in the interstate cap-and-trade program; from 2012 onward, allow SO_2 cap to revert to pre-CAIR level (based on Acid Rain Program)
	NO_x	Apply Phase 1 NO_x cap (1.5 million tons) through 2011 and allow NEMS to determine which units would need to install NO_x control technologies in the interstate cap-and-trade program; from 2012 onward, allow NO_x cap to revert to pre-CAIR level (based on NO_x Budget Trading Program)
State policies	Mercury	Include mercury reductions as required by state policies and allow NEMS to determine which units would need to install mercury control technologies

Source: NERA assumptions as explained in text

1. Clean Air Interstate Rule

EPA promulgated CAIR in 2005 to reduce SO_2 and NO_x emissions from power plants in 28 Eastern states (EPA 2005).[1] EPA established interstate cap-and-trade programs for both types of emissions. The caps for both types of emissions became tighter over two phases. The NO_x program consisted of Phase 1 (2009-2014) with a cap of 1.5 million tons and Phase 2 (2015 onward) with a cap of 1.2 million tons. The SO_2 program consisted of Phase 1 (2010-2014) with a cap of 3.6 million tons and Phase 2 (2015 onward) with a cap of 2.5 million tons. In December 2008, the U.S. Court of Appeals for the D.C. Circuit remanded CAIR to EPA but did not vacate it, thus allowing the first phases of the NO_x and SO_2 programs to take effect while EPA developed a replacement rule.

Our modeling for the reference case reflects that the CAIR Phase 1 programs have taken effect. We applied the CAIR Phase 1 caps for SO_2 and NO_x emissions (using EIA's inputs for *AEO 2011*) through 2011 and allowed NEMS to decide which units would need to install SO_2 control technologies or switch to lower-sulfur coal in the interstate cap-and-trade program. Our NEMS inputs for the reference case also include the SO_2 and NO_x control technologies that coal units have installed or have announced that they will install to comply with CAIR requirements (or any state or local policies requiring reductions in these emissions). EIA (2011, p. 106) summarizes the recent and planned retrofits for SO_2 and NO_x policies that are in NEMS.

As discussed in the report body and below, EPA has promulgated the Cross-State Air Pollution Rule (CSAPR) as a replacement for CAIR to take effect in 2012 (EPA 2011a). CSAPR would cover a somewhat different set of Eastern states than CAIR but would also involve interstate cap-and-trade programs and would set the caps at similar levels to CAIR. Thus, including CAIR in our reference case from 2012 onward would make it difficult to isolate the incremental impacts of CSAPR. We therefore terminated the CAIR Phase 1 caps after 2011 in our reference case and reverted SO_2 and NO_x caps to pre-CAIR levels (based on the Acid Rain Program and NO_x Budget Trading Program, respectively). Note that EPA also removed future CAIR caps from its reference case for modeling the incremental impacts of CSAPR (EPA 2011b, pp. 30-32).

2. State Mercury Policies

Seventeen states have enacted policies to limit mercury emissions from coal units (EPA 2011c, pp. 3-8). These state mercury policies vary significantly in their form, stringency, and schedule. Some policies took effect as early as 2008, while others will take effect as late as 2017.

EIA incorporated these state mercury policies into *AEO 2011*, and we used the same inputs for our reference case. To comply with these state mercury policies, some coal units install mercury control technologies such as activated carbon injection (ACI) and fabric filters in the reference case. We allowed NEMS to determine the compliance measures at coal units based on parameters built into NEMS on mercury emission rates for different types of coal and different

[1] SO_2 emissions from power plants in Western states are regulated under the Acid Rain Program (EPA 2010a). We did not modify the SO_2 caps for Western power plants in NEMS for our reference case or policy case.

configurations of environmental control technologies, including scrubbers and SCR (EIA 2011b, p. 105-106).

Note that when NEMS determines based on its compliance calculations that coal units will install scrubbers, the scrubbers are assumed to be wet scrubbers (EIA 2011a, p. 46). Thus, reductions in mercury emissions from scrubbers that NEMS builds to comply with state mercury requirements reflect parameters for wet scrubbers. When NEMS calculates mercury emissions from coal units with existing or planned dry scrubbers, however, the mercury emissions accurately reflect parameters for dry scrubbers. Modeling issues related to wet and dry scrubbers are discussed further in the context of MACT HCl compliance below.

B. Cross-State Air Pollution Rule

EPA promulgated CSAPR as a replacement for CAIR in August 2011 (EPA 2011a). As noted above, CSAPR would cover a somewhat different set of Eastern states (27 in total) than CAIR but would also involve interstate cap-and-trade programs and would set the caps at similar levels to CAIR. CSAPR would set caps on emissions in each state but would allow interstate trade of emission allowances provided that state emissions stay within so-called variability limits. Covered units would not be able to use allowances from the Acid Rain Program, NO_x Budget Trading Program, or CAIR for compliance with CSAPR. The caps for both SO_2 and NO_x would become tighter over two phases. The SO_2 program would consist of Phase 1 (2012-2013) with a cap of 3.4 million tons and Phase 2 (2014 onward) with a cap of 2.1 million tons. The annual NO_x program would consist of Phase 1 (2012-2013) with a cap of 1.2 million tons and Phase 2 (2014 onward) with a cap of 1.1 million tons.

Table A-2 summarizes our compliance assumptions for CSAPR.

Table A-2. Compliance Assumptions for CSAPR

Policy	Emission	Compliance Assumptions
CSAPR	SO_2	Apply SO_2 caps (3.4 million tons in 2012-2013 and 2.1 million tons from 2014 onward) and allow NEMS to determine which units would need to install SO_2 control technologies or switch to lower-sulfur coal in the interstate cap-and-trade program (within state variability limits); in order to discourage unrealistic fuel switching in the model in 2012-2013, do not allow banking of CSAPR SO_2 allowances in those years
	NO_x	Apply NO_x caps (1.2 million tons in 2012-2013 and 1.1 million tons from 2014 onward) and allow NEMS to determine which units would need to install NO_x control technologies in the interstate cap-and-trade program (within state variability limits); allow banking of CSAPR NO_x allowances

Source: NERA assumptions as explained in text

1. CSAPR SO_2 Compliance

We modeled the CSAPR SO_2 program in NEMS as an interstate cap-and-trade program with state variability limits and two phases. We allowed NEMS to determine which units would install SO_2 control technologies and which would switch to lower-sulfur coal.

CSAPR modeling by EPA indicates substantial switching among various coals in 2012 and 2013 based on their sulfur content (EPA 2011b and NERA analysis of underlying data). Although EPA's modeling results seem reasonable for the total amounts of low-sulfur and ultra-low-sulfur coal, it may not be feasible to achieve the extent of fuel switching implied in EPA's modeling due to the prevalence of long-term fuel contracts, rail networks, and other real-world practicalities for coal units to switch their coal types on such a large scale in the early years of the program. Coal units appear to switch fuels in the early years in EPA's analysis to build up a large bank of CSAPR SO_2 allowances. To avoid what seems to be potentially unrealistic fuel switching in our modeling, we include fuel switching to meet the 2012 and 2013 caps but not to build up a bank of CSAPR SO_2 allowances in the early years of the program.

2. CSAPR NO_x Compliance

We modeled the CSAPR NO_x program in NEMS as an interstate cap-and-trade program with state variability limits and two phases. We allowed NEMS to determine which units would install various NO_x control technologies. Since fuel switching is not an issue for NO_x programs, we allowed banking of CSAPR NO_x allowances in all years.

C. Utility MACT

EPA proposed the Utility Maximum Achievable Control Technology (MACT) rule in May 2011 to reduce emissions of mercury and other hazardous air pollutants (including mercury, other hazardous metals, and acid gases) from coal- and oil-fired power plants across the country. The rule would set emission rate standards for different types of coal and oil based on maximum achievable control technology. The emission rate standards would apply to mercury, particulate matter (PM) as a proxy for all non-mercury hazardous metals, and hydrogen chloride (HCl) as a proxy for all acid gases. Covered power plants would have up to three years to comply with the rule, but permitting authorities could grant one-year extensions to power plants if they required additional time. Table A-3 shows the proposed emission rate standards for mercury, particulate matter, and hydrogen chloride from existing coal units under the Utility MACT rule.

Table A-3. Proposed Utility MACT Emission Rate Standards for Existing Coal Units

Coal Rank	Mercury	Hydrogen Chloride	Particulate Matter
Bituminous and subbituminous	1.2 lb/TBtu	0.0020 lb/MMBtu	0.030 lb/MMBtu
Lignite	4.0 lb/TBtu	0.0020 lb/MMBtu	0.030 lb/MMBtu

Notes: TBtu: trillion British thermal units of fuel input
MMBtu: million British thermal units of fuel input
The mercury standard for lignite shown in the table is the "beyond-the-floor" limit; the MACT standard based on the top 12 percent of units would be 11.0 lb/TBtu.
The mercury standard for bituminous and subbituminous coal is the update from the original value of 1.0 lb/TBtu based on EPA's letter of May 18, 2011 (EPA 2011e).
Source: EPA (2011d), p. 25027

Table A-4 summarizes our assumptions for MACT.

Table A-4. Compliance Assumptions for MACT

Policy	Emission	Compliance Assumptions
MACT	Mercury	Apply mercury standards in 2015 at all units and allow NEMS to determine which units would need to install ACI, fabric filters, and/or scrubbers
	HCl	Assign costs for DSI in 2015 at unscrubbed units smaller than 300 MW that consume subbituminous coal (these units requiring DSI will also require fabric filters); require dry scrubbers at all non-DSI units that consume Western bituminous coal, subbituminous coal, or lignite (these units requiring dry scrubbers will also require fabric filters); require wet scrubbers at all units that consume Eastern bituminous coal (these units requiring wet scrubbers will not require fabric filters, but NEMS may retrofit them with fabric filters for mercury or they may require fabric filters for MACT PM compliance)
	PM	In addition to requiring fabric filters at all units with DSI or dry scrubbers, and in addition to requiring fabric filters (in combination with ACI) at some units for MACT mercury compliance, require fabric filters for MACT PM compliance at the necessary number of coal units so that the same percentage of total U.S. coal capacity has fabric filters in 2015 as in the EPA MACT RIA; use EPA's list of coal units installing fabric filters from the MACT RIA to identify the additional coal units that would require fabric filters

Source: NERA assumptions as explained in text

1. MACT Mercury Compliance

As noted above in the context of state mercury policies for the reference case, NEMS estimates mercury emissions from coal units and can determine which units would install ACI, fabric

filters, and/or scrubbers to comply with mercury reduction requirements. We required mercury reductions at all U.S. coal units based on the mercury standards in Table A-3. We assumed that compliance with the mercury standards would be required by 2015. Note that our inclusion of state mercury policies in the reference case dampens the impacts of the national MACT mercury standards in the policy case, because some coal units install ACI, fabric filters, and/or scrubbers anyway in the reference case to comply with the state mercury policies.

2. MACT HCl Compliance

NEMS does not model HCl emissions from coal units. Indeed, HCl emission rates from individual units can vary significantly over time as the unit burns coal from different mines and seams with different chlorine contents. Since NEMS does not model HCl emissions from coal units and thus cannot determine which controls would be required for compliance with HCl policies, we developed rules to assign HCl control technologies to individual units based on review of technology assumptions in EPA's regulatory impact analysis (RIA) for the MACT proposal (EPA 2011f) and other analyses, including comments on the MACT proposal submitted to EPA from various organizations (in Docket No. EPA-HQ-OAR-2009-0234). We assumed that compliance with the HCl standard would be required by 2015.

We assumed that every coal unit would require either dry sorbent injection (DSI), a dry scrubber, or a wet scrubber to comply with the HCl standard. Note that the variability in HCl emission rate at individual coal units over time would tend to cause owners to make relatively conservative assumptions about compliance measures so that they do not exceed the standard when the chlorine content of their coal happens to be high. DSI has significantly lower capital costs than a dry scrubber, which in turn has lower capital costs than a wet scrubber (EPA 2011c).[2] Since NEMS does not include DSI among its set of emission control technologies, we could not directly apply DSI to coal units in NEMS. Instead, we assigned costs to units requiring DSI to represent installation of DSI.

We assumed that DSI would be installed for HCl compliance at unscrubbed units smaller than 300 MW that consume subbituminous coal. The size limit for DSI is the same as the Bipartisan Policy Center's assumption for its analysis of potential EPA regulations (BPC 2011, p. 24); the Edison Electric Institute made a similar assumption for one of its modeling scenarios by limiting DSI to units smaller than 200 MW (EEI 2011, p. 4). We assumed that dry scrubbers would be installed for HCl compliance at all unscrubbed and non-DSI units that consume Western bituminous coal, subbituminous coal, or lignite. We further assumed wet scrubbers would be installed for HCl compliance at all unscrubbed units that consume Eastern bituminous coal. DSI and dry scrubber installations would also require fabric filters.

As noted above, NEMS assumes that all new scrubbers are wet scrubbers (EIA 2011a, p. 46). Scrubber cost inputs for the Retirement Model, however, accurately reflect whether the unit would need to install a wet scrubber or dry scrubber (or DSI). Moreover, we modified the unit-specific cost inputs in NEMS so that units needing to install wet scrubbers, dry scrubbers, or DSI had the appropriate costs.

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[2] Additional information on the costs of air emission control technologies appears at the end of this appendix.

3. MACT PM Compliance

NEMS does not model PM emissions from coal units and thus cannot determine which controls would be required for compliance with PM policies. The main control technologies for PM emissions are electrostatic precipitators (ESPs) and fabric filters (also called baghouses). NEMS includes fabric filters among its set of emission control technologies, but since NEMS does not model PM emissions, it only installs fabric filters on its own to reduce mercury emissions. We therefore developed rules to assign fabric filters to individual units based on reviews of technology assumptions in EPA's MACT RIA (EPA 2011f) and other analyses. We assumed that compliance with the PM standard would be required by 2015.

We assumed that most, but not all, coal units would require a fabric filter for PM compliance. Since NEMS installs fabric filters (in combination with ACI) on some coal units for compliance with state mercury policies and MACT mercury standards, these units would comply with the PM standard as well. We also required installation of fabric filters at units installing DSI or dry scrubbers for HCl compliance, and so these units too would comply with the PM standard. Thus, the only remaining coal units without fabric filters at this point are units with wet scrubbers (either existing wet scrubbers or new wet scrubbers for HCl compliance) and with sufficiently low mercury emission rates without fabric filters based on the NEMS parameters and determinations for mercury compliance. We reviewed EPA's MACT RIA data and assumed installation of fabric filters at the remaining coal units if they had fabric filters in the EPA data. The percentage of total U.S. coal capacity having fabric filters in our policy case is therefore approximately the same as the percentage in EPA's MACT RIA.[3]

Note that installing fabric filters at most U.S. coal units by 2015 is assumed to be feasible, despite the analysis by industry experts that such a large number of fabric filters could not be manufactured and installed in such a short period (UARG 2011).

D. Coal Combustion Residuals

EPA has considered several alternative forms of regulations in recent years for the disposal of coal combustion residuals (CCR), which include fly ash, bottom ash, boiler slag, and scrubber waste. The alternative forms of CCR regulations differ in their classification of CCR under Subtitles C or D of the Resource Conservation and Recovery Act (hazardous and non-hazardous, respectively) and compliance measures (for example, requiring liners at all surface impoundments or only at new surface impoundments). EPA proposed three alternative forms of CCR regulations in June 2010 (EPA 2010b). The unit-specific information in the RIA for this proposed rule, however, was based on a prior set of alternative forms that EPA developed in 2009 (EPA 2010c, p. 3).

Table A-5 summarizes our compliance assumptions for CCR regulations.

[3] EPA (2011f, pp. 8-18 and 8-14) gives the total U.S. coal capacity in 2015 in the MACT scenario as 299 GW, and 243 GW have fabric filters. Thus, 81 percent of total U.S. coal capacity in 2015 would have fabric filters in EPA's MACT scenario.

Table A-5. Compliance Assumptions for CCR Regulations

Policy	Compliance Assumptions
CCR	Assign costs to units in 2015 based on EPA Subtitle D in initial proposal

Source: NERA assumptions as explained in text

We modeled CCR compliance costs at coal units in 2015 based on EPA's unit-specific information for the initial form of CCR regulation under Subtitle D of the Resource Conservation and Recovery Act (EPA 2010c, Exhibit J3). As noted above, EPA only provided unit-specific information for the initial set of alternatives it developed in 2009; EPA did not provide unit-specific information for the final set of alternatives that it proposed in 2010. The initial form of CCR regulation under Subtitle D would lead to a cost of $30 billion (present value in 2009 dollars).[4] Note that this cost lies near the middle of the range of cost estimates for CCR regulation. For example, EPA (2010b, p. 10) gives the cost of the final form of Subtitle C regulation as $20 billion, and EPRI (2010, p. 4-3) gives the cost of Subtitle C regulation as between $55 billion and $77 billion.

We used this unit-specific cost information from EPA (2010c, Exhibit J3) as the basis for the potential costs of CCR regulation.

E. Section 316(b)

EPA proposed alternative forms of regulations for cooling water intake under Section 316(b) of the Clean Water Act in April 2011 (EPA 2011g). The regulations would affect the design of cooling water intake structures (to reduce impingement of aquatic organisms against intake structures) and the flow rates through cooling water systems (to reduce entrainment of aquatic organisms into cooling water systems) at power plants and other large facilities. The alternative forms of 316(b) regulations differ in their requirements for intake structures and flow rates, including possible use of best professional judgment for determining best technology available on a site-specific basis.

Table A-6 summarizes our compliance assumptions for 316(b) regulations.

Table A-6. Compliance Assumptions for 316(b) Regulations

Policy	Compliance Assumptions
316(b)	Assign costs to units in 2015 based on EPA Option 1 for impingement and 46 facilities installing cooling tower retrofits for entrainment

Source: NERA assumptions as explained in text

[4] EPA (2010b, Exhibit J3) gives the total annualized cost of the initial form of the Subtitle D alternative as $2.2 billion in 2009 dollars. EPA annualized these costs over 50 years. Using a real annual discount rate of 7 percent, this implies a present value of $30 billion.

We modeled 316(b) compliance costs for coal units in 2015 based on EPA information in the proposed rule related to Option 1, which includes a national requirement to reduce impingement, and an assumption that a total of 46 facilities would install cooling towers for entrainment under site-specific determinations. EPA (2011g, p. 22219) shows that Option 1 would lead to costs of $5 billion (present value in 2009 dollars) for electric generators to reduce impingement.[5] We estimated the apportionment of these costs across generation units, including coal units as well as natural gas, oil, and nuclear units, based on unit-specific cooling water intake data from EIA Form 860 (EIA 2011c).

EPA (2011g, p. 22211) noted that if the 46 fossil units with the largest cooling water withdrawals from tidal waters installed cooling towers to reduce entrainment, their total cost would be $7 billion.[6] Note that of the two hypothetical cooling tower scenarios for which EPA provided information, this scenario involved fewer facilities and lower total costs. We identified the 46 fossil units with the largest cooling water intake withdrawals from tidal waters using EIA Form 860 (EIA 2011c) and apportioned costs to individual units based on their intake data.

We used this unit-specific cost information based on EPA (2011g) as the basis for our modeling of the potential costs of 316(b) regulation.

F. Cost Assumptions for Air Emission Control Technologies

As discussed above, we relied on unit-specific inputs in NEMS for information about coal units for modeling retirements and energy market impacts. We modified the potential costs of air emission control technologies in NEMS to base them on EPA (2011c).

Table A-7 shows EPA and EIA assumptions for the costs of air emissions controls. These cost estimates include energy penalties for net capacity and heat rate due to some of the controls. Some types of costs show economies of scale (i.e., unit costs per kW are smaller for large units than small units), but other types of costs are uniform for all sizes of units. We used these cost assumptions from EPA in our modeling.

Note that the sudden large increase in demand for control technologies and skilled construction workers implied by our technology assumptions may not be feasible within the limited time assumed in our study and, in any event, the increased demand could drive up prices for control technologies. We did not develop any estimates of this "gold rush" effect. We assumed that the retrofits would be feasible on such a large scale and that there would be no price inflation due to the sudden increase in demand.

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[5] EPA (2011g, p. 22219) gives the total annualized cost of Option 1 for electric generators as $386 million in 2009 dollars. EPA annualized these costs over 50 years. Using a real annual discount rate of 7 percent, this implies a present value of $5 billion.

[6] EPA (2011g, p. 22211) gives the total annualized cost of the 46 facilities installing cooling towers as $480 million in 2009 dollars. EPA annualized these costs over 50 years. Using a real annual discount rate of 7 percent, this implies a present value of $7 billion.

Table A-7. Air Emission Control Costs

	100 MW		300 MW		500 MW	
	EPA	EIA	EPA	EIA	EPA	EIA
Wet Scrubber						
Capital (2010$/kW)	$850	$762	$622	$580	$538	$485
Fixed O&M (2010$/kW-year)	$24.40	$24.99	$11.20	$24.99	$8.35	$24.99
Variable O&M (2010$/MWh)	$2.11	$0.44	$2.11	$0.44	$2.11	$0.44
Capacity Penalty	-1.84%	-5.00%	-1.84%	-5.00%	-1.84%	-5.00%
Heat Rate Penalty	1.87%	5.26%	1.87%	5.26%	1.87%	5.26%
Dry Scrubber						
Capital (2010$/kW)	$727	-	$532	-	$460	-
Fixed O&M (2010$/kW-year)	$17.71	-	$8.86	-	$6.76	-
Variable O&M (2010$/MWh)	$2.70	-	$2.70	-	$2.70	-
Capacity Penalty	-1.45%	-	-1.45%	-	-1.45%	-
Heat Rate Penalty	1.47%	-	1.47%	-	1.47%	-
SCR						
Capital (2010$/kW)	$268	$225	$217	$184	$201	$165
Fixed O&M (2010$/kW-year)	$2.60	$2.25	$0.83	$1.88	$0.73	$1.66
Variable O&M (2010$/MWh)	$1.38	$0.34	$1.38	$0.34	$1.38	$0.34
Capacity Penalty	-0.58%	0.00%	-0.58%	0.00%	-0.58%	0.00%
Heat Rate Penalty	0.59%	0.00%	0.59%	0.00%	0.59%	0.00%
ACI						
Capital (2010$/kW)	$30	$6	$12	$6	$8	$6
Fixed O&M (2010$/kW-year)	$0.12	$1.71	$0.05	$1.71	$0.03	$1.71
Variable O&M (2010$/MWh)	$0.52	$0.26	$0.56	$0.26	$0.60	$0.26
Capacity Penalty	-0.06%	0.00%	-0.06%	0.00%	-0.06%	0.00%
Heat Rate Penalty	0.06%	0.00%	0.06%	0.00%	0.06%	0.00%
Fabric Filter						
Capital (2010$/kW)	$230	$78	$187	$78	$170	$78
Fixed O&M (2010$/kW-year)	$0.94	$5.97	$0.83	$5.97	$0.73	$5.97
Variable O&M (2010$/MWh)	$0.16	$0.00	$0.16	$0.00	$0.16	$0.00
Capacity Penalty	-0.60%	0.00%	-0.60%	0.00%	-0.60%	0.00%
Heat Rate Penalty	0.60%	0.00%	0.60%	0.00%	0.60%	0.00%
DSI						
Capital (2010$/kW)	$134	-	$61	-	$43	-
Fixed O&M (2010$/kW-year)	$2.39	-	$0.94	-	$0.61	-
Variable O&M (2010$/MWh)	$7.70	-	$7.70	-	$7.70	-
Capacity Penalty	-0.79%	-	-0.79%	-	-0.79%	-
Heat Rate Penalty	0.79%	-	0.79%	-	0.79%	-

Note: "-" denotes that NEMS does not model the control technology.
Source: EPA (2011c) and NEMS inputs

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Appendix B: Coal Unit Retirement Model

NERA has developed a retirement model to estimate the possible coal unit retirements due to the potential costs of EPA regulations. The model uses Monte Carlo uncertainty analysis to simulate the decision facing coal unit owners on whether to incur the costs to comply with additional future environmental requirements (and other future costs) or to retire the unit.

The sections below are organized as follows: Section A describes the main decision module, and Section B describes the sub-modules that generate the specific estimates used to run the Monte Carlo simulations in the main decision module.

A. Retirement Decision Module

The owner of each coal unit is presumed to base its decision on whether or not to retire the unit by comparing the future costs for the unit—taking into account potential additional environmental compliance costs as well as other costs—to the future costs of the likely alternative generation. The retirement decision module calculates the expected net present value (NPV) of costs for existing coal units as well as the NPV of costs for the likely alternative. Based upon likely future fuel market conditions, the alternative unit for comparison is assumed to be a combined cycle gas turbine (CCGT) unit. The cost calculations for coal and gas are done separately, but correlations in variables subject to uncertainty are taken into account. All retrofit costs are assumed to be incurred in 2015.

1. Net Present Value of Costs for Existing Coal Units

The NPV of costs for existing coal unit i is given by the following expression:

Equation 1. NPV of existing coal costs

$$d_{ir}R_i + \sum_{t=1}^{T_i} d_{it}(C_{it} + O_{it} + E_{it})$$

Where:

- R_i is the capital cost of retrofits. The total cost of retrofits for a given plant depends on the plant's current configuration, the randomly drawn retrofit costs for that plant from the retrofit/construction cost module, and what regulatory requirements the plant has in the regulatory scenario of interest. The cost of retrofits is then just the sum of the costs for each individual retrofit technology required at the plant.

- d_{ir} is the discount rate for unit i in year r, where r is the year in which retrofits take place. It is given by:

$$\left(\frac{1}{1+r}\right)^{t-1}$$

where t indicates time in years, where the first year in the model is t=1. The discount rate for a given unit depends on whether the utility that owns the unit is private or public. Following the NEMS model, we take the mean of the (real) discount rate to be 7 percent for units owned by public power organizations (e.g., the Tennessee Valley Authority and rural electric cooperatives) and 11.8 percent for units owned by private (investor-owned) companies, including units owned by regulated utilities with private (investor-owned) parent companies.

- d_{it} is the discount rate for unit i in year t, defined as above for d_{ir}.

- T_i is the remaining lifetime of unit i in years.

- C_{it} is the cost of coal for unit i in year t. The cost of coal is calculated by the hourly operation module when run decisions are calculated. It is essentially the average cost of coal across all operating hours weighted by the capacity factor at each hour. These plant-specific costs are developed as described in the coal cost module section. For the small number of plants with missing coal costs, average regional costs are used. If a retrofit increases the plant heat rate it will increase coal costs.

- O_{it} is the operating and maintenance (O&M) cost for unit i in year t. This is calculated as the sum of variable O&M and fixed O&M. Some retrofits result in additional O&M costs; where this is the case, variable O&M and/or fixed O&M are increased accordingly. We use EPA's O&M cost assumptions from the MACT analysis. Variable O&M costs for a year are calculated as the sum of hourly variable O&M costs. If we take V_{ih} to be the variable O&M costs for unit i in hour h (in dollars per megawatt-hour), then V_{it}, the variable O&M costs for unit i in year t, are given by:
  $$\sum_{h=1}^{8760} TC_i (L_{ih} \cdot V_{ih})$$
  where TC_i is the total capacity for plant i and L_{ih} is the capacity factor for plant i in hour h.

- E_{it} is the cost of system energy for unit i in year t necessary to compensate for capacity factors less than one at any hour. In order to make an appropriate comparison between existing coal and new gas, the costs of both gas and coal in our model are calculated as the costs to generate TC_i times 8760 energy per year. This assures that the retirement decision accounts for differences in the capacity factors of new and existing units. Thus, included in the calculation of the costs of existing coal is the cost of system energy necessary to compensate for capacity factors less than one at any hour. E_{it} is calculated as:
  $$PM_{it} \cdot PE_{it} \cdot G_{it}$$
  Here, G_{it} is the generation by unit i in year t, PM_{it} is the ratio of the weighted average system energy cost to the overall average electricity price across all simulation draws at the power hub to which plant i is assigned ($WASC_{ij}/ASEC_{it}$), and PE_{it} is the average marginal cost of energy in the NERC region to which i belongs in year t (from the NEMS model outputs). The value of G_{it} is an output of the hourly operation module and is calculated as:
  $$G_{it} = \sum_{h=1}^{8760} TC_i (L_{ih})$$
  The weighted average system energy cost is calculated as:

$$WASC_{ijt} = \frac{\sum_{h=1}^{8760}(1 - L_{ijh})P_{ijh}}{\sum_{h=1}^{8760}L_{ijh}}$$

whereas the overall average system energy cost is:

$$ASEC_{it} = \frac{1}{8760} \cdot \frac{1}{100} \cdot \sum_{j=1}^{100} \sum_{h=1}^{8760} P_{ijh}$$

where P_h is the marginal cost of energy at hour h from the electricity price module. Thus, the factor of $PM_{it} \cdot PE_{it}$ in the calculation of E_{it} serves to calibrate the outputs of the electricity price and hourly operation modules to NEMS electricity prices and map the five power hubs to the twenty-two NERC regions.

2. Net Present Value of Costs for Potential Alternative Unit (New CCGT)

The NPV of costs for replacing existing coal unit i with new CCGT of equal capacity is calculated as:

Equation 2. NPV of replacement CCGT costs

$$\sum_{t=1}^{T_i} d_{it}(CG_{it} + OG_{it} + EG_{it} + ON_{it})$$

Where d_{it} and T_i are identical to that for existing coal, and:

- CG_{it} is the average delivered cost of gas for the region in which unit i is located in year t using the appropriate capacity factor and heat rate.
- OG_{it} is the total O&M costs in year t for a CCGT constructed to replace unit i. This incorporates both fixed and variable O&M costs. The variable O&M costs are a function of the hourly capacity factors for a new CCGT in year t. These capacity factors are modeled based on the predicted operation of a sample of recently constructed CCGTs in each region and are an output of the hourly operation module. Thus, there are actually several calculations of replacement CCGT costs to compare to each coal plant, one for each CCGT in the sample of recently constructed CCGTs in each region.
- EG_{it} is the cost of grid energy to bring total generation to TC_i times 8760. This is calculated in the same way as the cost of grid energy for coal plants.
- ON_{it} is the equivalent annual overnight capital cost payment in year t for a CCGT replacement for plant i. The overnight costs are always annualized over the entire lifetime of the gas plant (30 years, consistent with the NEMS model), and are based on the sampled CCGT overnight costs drawn in the retrofit/construction cost module. However, since T_i may be less than 30 (and the modeling horizon only encompasses 25 years), the entire capital cost of the plant is not reflected in this calculation. This avoids inappropriately overstating the equivalent annual cost of a CCGT plant built to replace an existing coal plant.

3. Monte Carlo Retirement Decision Calculation

The NPV of costs for existing coal and for replacement CCGT are compared in each of the 100 simulation draws used in the Monte Carlo formulation. The costs for CCGT are based on the minimum of costs calculated using the sampled recently constructed CCGTs in each region as the basis for hourly operation of a new CCGT. Since a new CCGT would be at least as efficient as any existing CCGTs, this calculation is conservative (in the sense that it might overstate the future costs of a future CCGT and thus understate the likelihood of retirement).

The owner is presumed to retire the coal unit based upon a comparison of the NPV of the costs of the coal unit and the costs of the replacement CCGT plant. In particular, the retirement decision sub-module calculates the difference in costs for each of the 100 equally-likely Monte Carlo draws. The coal unit is presumed to retire if the expected value of this cost difference is positive, i.e., the coal unit is expected to be more expensive than the replacement natural gas unit.

B. Individual Cost Component Sub-Modules.

The Retirement Model includes separate sub-modules to model the various elements that influence the cost of continuing to operate an existing coal unit and the cost of replacing the exiting coal unit with a new combined cycle gas turbine (CCGT) unit. The methodology in each sub-module for energy prices results in mean values based upon the NEMS model using AEO 2011, with the sub-modules focusing on developing estimates of the potential alternative price paths. These sub-modules are summarized and described below.

1. *Natural gas price simulation sub-module*. This sub-module simulates possible future natural gas price paths. The formulation assumes that future natural gas prices can be modeled as an autoregressive process.

2. *Coal price sub-module*. This sub-module models regional coal prices. The formulation assumes that future coal prices can be modeled as a vector autoregression (VAR) process. Coal prices in several regions are modeled as dependent time series.

3. *Electricity price sub-module*. This sub-module models hourly electricity prices. The empirical formulations are based upon data from five major trading hubs across the United States.

4. *Hourly power plant operation sub-module*. This sub-module models the hourly operation of existing coal plants greater than 25 megawatts (MW) capacity. The sub-module also models operation of CCGT units in each region on the basis of recently constructed units.

5. *Retrofit and construction costs sub-module*. This sub-module models retrofit costs for emission control technologies and construction costs for new CCGT units as random variables, with the construction parameters assumed to be correlated. (Costs for the same type of control at different plants are assumed to be more highly correlated than costs for different controls and for controls and new construction costs.) The parameters for the model are taken from EPA cost assumptions for the MACT analysis and recent engineering reports.

The following sections provide additional information on these sub-modules.

1. Natural Gas Price Simulation Sub-Module

The natural gas price module models natural gas prices as an autoregressive process of order one (AR-1 process). The model for price at time t is:

Equation 3. Natural gas price model

$$\log(p_t) = \alpha + \gamma \log(p_{t-1}) + \varepsilon_t, \quad \varepsilon_t \sim N(0, \sigma^2)$$

The parameters of the model are a constant term (α), an autoregressive term (γ), and a random error term (ε_t), which is assumed to be normally distributed with zero mean and unknown variance (σ^2). The parameters are estimated from daily Henry Hub price data for the years 2005-2010. The estimated value of the autoregressive term is less than one, and therefore the model for gas price is mean-reverting.

Using the estimated parameter values, we then simulate 100 future daily natural gas price paths from 2011-2035 for use in the model. Simulation is relatively simple: starting from the last day's price in the historical data, simulate the first day of the forecast series by taking the log of the previous day's price, multiplying by the estimated value of γ, adding the estimated value of α, and adding a value drawn from $N(0, \sigma^2)$. This is repeated for the second day of the forecast using the simulated value from the first day, and so on until prices have been simulated through the end of 2035. This entire process is then repeated 100 times to give 100 daily price paths through 2035.

As noted above, we adjust the simulated natural gas price paths such that the expected gas price in each year matched the EIA forecast. The expression for the price at time t in our model is given by:

Equation 4. Expression for price in the natural gas model

$$p_t = \exp(\alpha + \varepsilon_t) p_{t-1}^{\gamma}$$

From this we have that the expression for the expected price at time t, given the price in the previous period, is:

Equation 5. Expression for expected value of price in period *t* given price in period *t-1*.

$$E(p_t \mid p_{t-1}) = \exp\left(\alpha + \sigma^2 / 2\right) p_{t-1}^{\gamma}$$

From this expression it is clear that any constant C added to the right hand side of the original log-log form of the model will result in the conditional expectation of p_t being multiplied by $\exp(C)$. Thus, we simulate many price paths and take the mean price in each year (which is a consistent estimator of the expectation of price in any year). We then add a constant C_y to the right hand side of Equation 3 for every day in year y such that the expected price in year y

matches the NEMS price in year y. We then simulate 100 price paths from this calibrated form of the model.

2. Coal Price Sub-Module

The variability in coal prices is modeled using information for the two main coal contracts for bituminous and sub-bituminous coal (Central Appalachian/Big Sandy and Powder River Basin (PRB), respectively) using a vector autoregression (VAR). (Lignite coal variability is assumed to be the same as sub-bituminous.) The model assumes that coal prices are a stochastic process and that prices in the two regions are related. The mathematical form of the model is:

Equation 6. Coal price model

$$Y_t = c + AY_{t-1} + \varepsilon_t, \quad \varepsilon_t \sim N_2(0, \Sigma)$$

Where Y_t is a 2x1 vector of prices (the Appalachian and PRB prices at time t), A is a linear transformation of the lagged price Y_{t-1}, c is a 2x1 vector of constants, and ε_t is a bivariate normal random variable with a 2x1 mean vector of zeroes and covariance matrix Σ. We use historical weekly coal price data from 2005-2010 to estimate the parameters of the model (c, A, and Σ).

We then simulate from this model 100 weekly price paths for 2011-2035 for PRB and Appalachian coal. As noted, the modeling assures that the mean prices are equal to those predicted in NEMS; we calculate the ratio of the average price in each year for each of the two coal contracts in our forecast to the average price from 2005-2010. We then add constants to the expression in equation 4 to make the ratios of the annual average price to the 2005-2010 average the same as the ratio of the annual mine mouth prices for bituminous and subbituminous coal in NEMS to the average prices for those coals from 2005-2010. Thus, the VAR model gives us the dependence structure and uncertainty in coal prices, whereas NEMS provides the means.

We then take a two-year moving average of the simulated coal prices in each of the 100 simulations and then take the ratio of this moving average to the overall average coal price for each year (across all simulations). We use the plant-specific average fuel costs from EIA 423 for 2005-2010 and multiply them by the ratio of the moving average from each of the 100 simulations to the overall moving average to get plant-specific coal prices for each week in the model. We use a long-term moving average to reflect that most coal prices for electric utilities are set by long-term contracts and an analysis of historical market prices compared to historical coal costs for electric utilities showed that a two-year moving average was a good predictor of relative coal price movements.

A small number of plants are missing cost data for delivered coal in EIA 423. We impute costs for delivered coal based on the quantity and type of coal delivered to each plant using an inverse-distance weighted average of the costs of the same type of coal delivered to nearby plants. We verified that the historical average delivered prices for the 22 NERC regions in the NEMS model calculated from EIA 423 (and using the above methodology to fill in missing prices) were very similar to NEMS average prices for the years 2005-2010 for those regions. The EIA data provides monthly coal costs; for consistency with the run decision model, we linearly interpolate between the monthly costs to obtain daily coal costs.

3. Electricity Price Sub-Module

The variability in hourly electricity prices is modeled using data for five hubs throughout the United States (ERCOT, PJM, Cinergy, SP15, and NYISO). Electricity prices are taken to be a function of the previous hour's electricity price, natural gas prices (with the magnitude of the effect varying with the hour), hour of day, season, whether the day is a weekend day or a weekday, and an innovation (error) term. The innovations are normal with zero mean and stochastic, time-varying variance. The mathematical specification is an exponential GARCH (EGARCH) model and is given by the following set of equations:

Equation 7. Electricity price model

$$\log(p_t) = X_t\beta + \alpha\log(p_{t-1}) + \varepsilon_t$$
$$\varepsilon_t = \sigma_t z_t \quad z_t \sim N(0,1)$$
$$\log(\sigma_t^2) = \omega + \gamma_g g(Z_{t-1}) + \gamma_s \log(\sigma_{t-1}^2)$$
$$g(Z_t) = \theta Z_t + \lambda\left(|Z_t| - E\left(|Z_t|\right)\right)$$

Where p_t is the price at time t, and X is a matrix of covariates. The structure of the model allows the sign and magnitude of the standard normal random variable Z_t to affect volatility (σ^2) separately. The model also allows for heteroskedasticity (through the dependence of σ_t^2 on σ_{t-1}^2) and volatility clustering (periods of large price swings and periods of relative calm).

The covariates in the mean regression (the matrix X_t) include dummy variables for hour of day, hour of day dummies interacted with natural gas prices, seasonal dummies, and weekday/weekend dummies. The model parameters are estimated on historical electricity price data for the five electricity price hubs for 2005-2010. We then simulate electricity price series for each of the five hubs from the model, using as inputs the simulated natural gas prices from the natural gas price model. We simulate 100 realizations of hourly prices for 2011-2015.

4. Hourly Power Plant Operation Sub-Module

The hourly power plant operation module models power plant hourly run decisions and output as a function of price and marginal costs. The relevant price variability in the model is determined by matching each power plant to one of the five regional hubs. As noted, the mean electricity prices are based upon NEMS AEO 2011.

The decision of whether to operate is modeled as a logistic regression:

Equation 8. Run decision model

$$r_t \sim bernoulli(p_t)$$
$$p_t = \Pr(r_t = 1) = \frac{e^{X_t\beta}}{1 + e^{X_t\beta}}$$

Where $r_t = 1$ indicates that the plant decides to run at time t. Here X_t is a vector of covariates, which in this case are constant, the hourly electricity price, and negative one times the sum of fuel costs and allowance costs per MWh for the plant at each hour. In the case of CCGT plants, the implied heat rate (ratio of the electricity price to the gas price) is used in place of the electricity price less costs.

Conditional on operating, we then model the capacity factor (output divided by capacity) as a mixture of linear regression models. In this model, each unit can operate in up to five distinct "modes," and the choice of "mode" is a function of the electricity price less costs (or, in the case of CCGT, the implied heat rate) and a constant specific to each mode. Conditional on choosing a "mode," the capacity factor is modeled as normally distributed with mean and variance estimated from the data. The mathematical representation of the model is:

Equation 9. Capacity factor model

$$m_t \mid r_t = 1 \sim multinomial(1, s_t)$$

$$s_{jt} = \Pr(m_t = j \mid r_t = 1) = \frac{e^{X_t \beta_j}}{\sum_{i \neq j} e^{X_t \beta_i}} \quad \beta_1 = \vec{0}$$

$$L_t \mid m_t = j, r_t = 1 \sim N(\mu, \sigma^2)$$

Where m_t is the operating mode at time t (m_t=1,...,5), s_t is a simplex vector (vector whose components add to one, making them plausible as probabilities for different alternatives), X_t is a matrix of covariates (here covariates are the electricity price less costs for coal plants or implied heat rate for CCGT and a dummy for the operating "mode" alternative), L_t is the capacity factor at time t and μ and σ^2 are the mean and variance of a normal distribution. The choice of this form for the model was based on the observation that power plant capacity factors exhibit multimodality, whereas electricity prices, the main factor in power plant operation decisions, do not. Thus, some type of model allowing for flexible multimodality was necessary, and the mixture of normal models is one such model that has well-established estimation techniques available.

We estimate the model on historical hourly power plant operation data for coal plants and a sample of recently constructed CCGTs for the years 2005-2010. The model predicts the historical capacity factors very accurately, with virtually all of the variance in the historical data explained by the model. We then simulate power plant operation for coal plants and sampled CCGTs using the simulated electricity, coal, and gas prices from the electricity and gas price modules for the years 2011-2035, as well as estimates of incremental variable cost of new controls, expected allowance prices, and heat rate penalties of new controls as factors affecting coal plant marginal costs. The result is 100 sets of hourly plant operation patterns for every plant in the dataset.

5. Retrofit Costs and Construction Costs Sub-Module

This sub-module develops information on the variability in technology retrofit costs as well as CCGT construction costs, which are assumed to be correlated in our model. We model the

variability in costs for the relevant control technologies (wet and dry scrubbers, dry sorbent injection, fabric filters, activated carbon injection, closed cycle cooling, and coal combustion residual compliance costs) and for new CCGTs. The correlations include those for different technologies and the same plant, for the same technology across plants, and for retrofit costs and new construction costs. The vector of all control costs is modeled as multivariate lognormal, mathematically represented as:

Equation 10. Retrofit/control costs model

$$r \sim N(\mu, \Sigma)$$

$$c = e^{r}$$

Where r is a multivariate normal random variable with mean vector μ and covariance matrix Σ, and c is the control/construction cost vector (a vector containing all control/construction costs for all plants). There exists a closed-form expression for the expected value of c as a function of μ. We take the EPA's control costs estimates for different control types and EIA's overnight costs for CCGT as the expected value of c, and back solve for the mean vector μ. No suitable data exists to estimate the covariance matrix Σ. Thus, we create a covariance matrix from a correlation matrix with the following assumed structure. We assume that the correlation between costs for the same control at different plants is 0.6 and the correlation between costs for different controls at different plants is 0.4. We assume that the correlation between costs for all environmental controls and the capital cost of a new CCGT is 0.4. Thus, we assume that costs for the same type of control will be more highly correlated than costs for different types of controls.

In order to create a covariance matrix from this correlation matrix, we also must define a variance vector for the control/construction costs (a vector containing the variances for each control type/plant combination and for CCGT retrofit costs). As described previously for the mean vector, there is a closed-form expression for the variance vector of the normal distribution in terms of the variance vector of the lognormal distribution. Variances are based on the uncertainty ranges given in the Raytheon Coal Unit Environmental Cost Model documentation (which is used by EIA to estimate plant retrofit costs in the NEMS model). In the Raytheon documentation, retrofit costs estimates are given with an uncertainty of ±30%. We assume that standard deviations of the lognormal cost distributions are 15% of the cost, or half of the uncertainty range given by the Raytheon report.

The model takes 100 separate draws of retrofit/construction costs from the multivariate lognormal distribution defined above. The joint variability in costs for retrofits and for new CCGT construction is then used in the retirement decision sub-module, as discussed above.

Appendix C: Energy Market Modeling

This appendix provides details on the National Energy Modeling System (NEMS) as well as our data and methodology for using NEMS to model the potential energy market impacts of the four EPA regulations. This appendix also shows key energy market impact results from NEMS for each year between 2012 and 2020.

A. National Energy Modeling System

This section provides an overview of NEMS and its input categories related to emission controls.

1. Overview

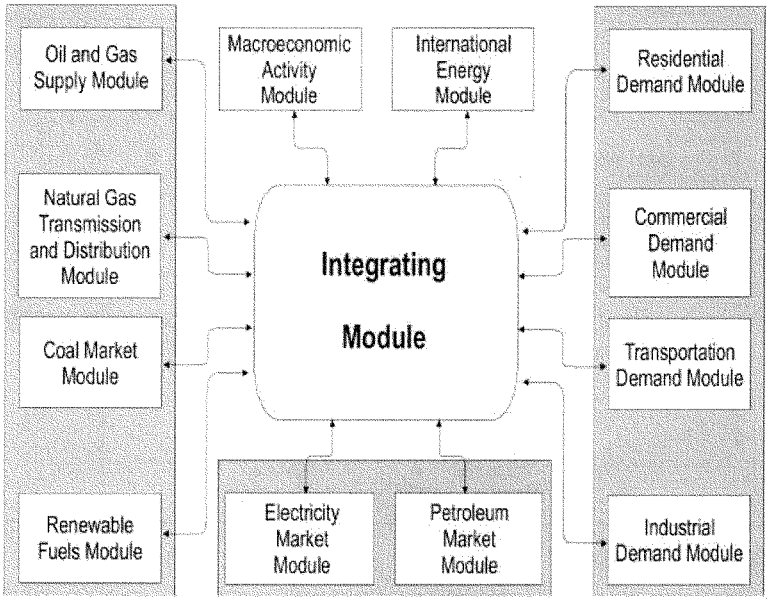
The U.S. Energy Information Administration (EIA) developed and maintains NEMS to produce projections of energy prices and quantities in the long term. EIA also uses NEMS to perform policy analyses in response to requests from Congress, the White House, the Department of Energy, and other government agencies. EIA prepares an *Annual Energy Outlook* (*AEO*) with long-term projections of energy prices and quantities based on current policies and various assumptions. As discussed in Appendix A, our modeling of the potential energy market impacts of the four EPA regulations with NEMS is based on inputs for *AEO 2011* (EIA 2011a); its assumptions are summarized in EIA (2011b).

Figure C-1 shows the thirteen modules in NEMS and their linkages. All modules interact via the Integrating Module at the center of the figure. The four modules to the left in the figure (Oil and Gas Supply, Natural Gas Transmission and Distribution, Coal Market, and Renewable Fuels) relate to the supply of primary energy sources. The four modules to the right in the figure (Residential Demand, Commercial Demand, Transportation Demand, and Industrial Demand) relate to the demand for energy. The two modules to the bottom of the figure (Electricity Market and Petroleum Market) convert primary energy sources into electricity and petroleum products. Finally, the two modules to the top of the figure (Macroeconomic Activity and International Energy) provide information from outside U.S. energy systems.

NEMS uses the thirteen modules shown in Figure C-1 to balance energy supply and demand in each region of the United States. In particular, the model calculates the least-cost way to satisfy demand in each region based on the costs of alternative forms of energy and various constraints, including resource availability and energy transportation infrastructure. The level of regional detail in NEMS varies for different forms of energy. For example, NEMS divides the United States into 22 electricity markets, 13 coal production regions, and nine natural gas production regions. Regional detail for energy demand is based on the nine Census divisions.

Additional detail on energy market modeling and NEMS can be found in EIA (2009) and EIA (2011b).

Figure C-1. Overview of NEMS



Source: EIA (2011b, p. 4)

2. Input Categories Related to Emission Controls

NEMS input files include a database of all generation units in the United States as well as parameters that apply uniformly to all units within certain categories. The database includes current and planned scrubber, SCR, and particulate controls for each coal unit in the United States. The database also includes information on some types of environmental control costs for each coal unit. Other types of environmental control costs enter NEMS as parameters that apply uniformly to the relevant coal units.

Table C-1 summarizes unit-specific and uniform inputs related to emission controls. Note that direct sorbent injection (DSI) is not included as an emission control in NEMS, as discussed in Appendix A.

Table C-1. NEMS Inputs Related to Emission Controls

	Miscellaneous	Scrubbers	SCR	ACI	FF	DSI
Unit-specific inputs	- Construction date - Retirement date - Capacity - Capacity factor (historical) - Heat rate - Baseline fixed O&M cost (excluding controls) - Baseline variable O&M cost (excluding controls) - Baseline annual capital cost (excluding controls)	- Current or planned configuration - Capital cost ($/kW) - Emission reduction percentage	- Current or planned configuration - Capital cost ($/kW) - Additional fixed O&M cost - Additional variable O&M cost - Emission reduction percentage	- Current or planned configuration - Emission reduction percentage (based on other controls and coal type)	- Current or planned configuration - Emission reduction percentage (based on other controls and coal type)	- Not in NEMS
Uniform inputs for all coal units		- Capacity penalty - Heat rate penalty - Additional fixed O&M cost - Additional variable O&M cost		- Capital cost ($/kW) - Additional fixed O&M cost - Additional variable O&M cost	- Capital cost ($/kW) - Additional fixed O&M cost	- Not in NEMS

Source: NERA review of NEMS inputs

3. Input Categories Related to CCR and 316(b)

NEMS does not model compliance with CCR or 316(b) policies. As discussed further below, we modeled these policies in NEMS by adding their costs to the unit-specific inputs for general capital costs.

B. Methodology

This section describes NEMS inputs and outputs for modeling the potential energy market impacts of the four EPA regulations.

1. NEMS Inputs

We entered three types of modeling inputs into NEMS: (1) potential emission control costs; (2) coal unit retirements; and (3) compliance measures. This section describes each of these types of inputs.

a. Emission Control Costs

As described in Appendix A, we used EPA estimates for potential emission control costs rather than the EIA assumptions built into NEMS. As summarized above in Table C-1, NEMS incorporates data on the potential costs of environmental controls in case installation of such controls is required. We modified these emission control costs in NEMS for both the reference case and policy case so that costs would consistently reflect EPA cost estimates in both cases. For example, the reference case includes state mercury regulations that would cause some coal units to install ACI and fabric filters. The costs of these ACI and fabric filter retrofits in the reference case reflect EPA cost assumptions, just as they do in the policy case.

To achieve the maximum level of unit-level detail on costs and compliance measures, we used the unit-specific inputs shown in Table C-1 to the maximum extent possible. For emission control costs without unit-specific inputs in NEMS, we used uniform inputs for all units. As shown above in Table C-1, NEMS has unit-specific inputs for scrubber capital costs and SCR capital and O&M costs, so we modified these unit-specific inputs to reflect EPA cost assumptions. Since NEMS only has uniform inputs for scrubber O&M costs and ACI and FF costs, we modified those uniform inputs to reflect EPA cost assumptions. Since NEMS does not model DSI, the variable O&M cost of FF, or the heat rate and capacity penalties of any emissions controls other than scrubbers, we adjusted the relevant unit parameters manually in the unit database. Our modifications for emission control costs are shown below in Table C-2.

Table C-2. Modification of NEMS Emission Control Costs

	Scrubbers	SCR	ACI	FF	DSI
Capital	Assign by unit using NEMS scrubber capital cost input variable	Assign by unit using NEMS SCR capital cost input variable	Assign uniform cost to all units	Assign uniform cost to all units	Assign by unit using NEMS general capital cost input variable
Fixed O&M	Assign uniform cost to all units	Assign by unit using NEMS SCR fixed O&M cost input variable	Assign uniform cost to all units	Assign uniform cost to all units	Assign by unit using NEMS general fixed O&M cost input variable
Variable O&M	Assign uniform cost to all units	Assign by unit using NEMS SCR variable O&M cost input variable	Assign uniform cost to all units	Assign by unit using NEMS general variable O&M cost input variable	Assign by unit using NEMS general variable O&M cost input variable
Heat Rate Penalty	Assign uniform penalty to all units	Assign by unit using NEMS heat rate input variable	Assign by unit using NEMS heat rate input variable	Assign by unit using NEMS heat rate input variable	Assign by unit using NEMS heat rate input variable
Capacity Penalty	Assign uniform penalty to all units	Assign by unit using NEMS capacity input variable	Assign by unit using NEMS capacity input variable	Assign by unit using NEMS capacity input variable	Assign by unit using NEMS capacity input variable

Source: NERA

b. Coal Unit Retirements

As described in Appendix B, we used the Retirement Model to determine which coal units would likely retire rather than incur costs for the four EPA regulations. We also used the Retirement Model for the reference case to determine which coal units would likely retire even in the absence of the four EPA regulations. We entered these retirements into the NEMS database of generation units for the end of 2014 (immediately before compliance with MACT, CCR, and 316(b) is assumed to be required in 2015). We did not allow NEMS to retire coal units based on its own economic evaluations in either the reference case or the policy case.[1]

c. Compliance Measures

The compliance measures that we modeled for CSAPR, MACT, CCR, and 316(b) for the policy case are described in Appendix A. That appendix also describes our modeling of compliance measures for the two most relevant environmental policies in the reference case: CAIR and state mercury regulations. Our methodology and assumptions are summarized briefly here.

We modeled CAIR in the reference case by setting regional emission caps through 2011 in NEMS and allowing NEMS to determine which coal units would need to install environmental controls or fuel switch to lower their SO_2 and NO_x emissions. We modeled state mercury regulations in the reference case by requiring mercury reductions in specific regions in NEMS based on the locations of states with mercury regulations and allowed NEMS to determine which coal units would need to install ACI, fabric filters, and/or scrubbers to comply.

For the policy case, we modeled CSAPR by setting regional caps in NEMS and allowing NEMS to determine which additional coal units would need to install environmental controls or fuel switch to lower their SO_2 and NO_x emissions beyond reductions for CAIR (or for caps without CAIR from 2012 onward). We modeled the MACT mercury standards by requiring mercury reductions based on the standards shown in Appendix A and allowing NEMS to determine which coal units would need to install ACI, fabric filters, and/or scrubbers to comply. We modeled the MACT HCl and PM standards by requiring scrubbers, DSI, and/or fabric filters at particular units, as discussed in detail in Appendix A. Finally, we modeled the CCR and 316(b) regulations in NEMS by applying their unit-specific costs in the NEMS database of generation units using the input variable for general capital costs, since NEMS does not model compliance with non-air emission regulations such as the CCR and 316(b) regulations.

[1] The NEMS model provides less detailed modeling of coal unit retirements than provided for in the retirement model we used. With regard to dispatch, NEMS provides for 216 distinct periods (summer, winter, spring and fall by peak, off-peak and weekend). As with other retirement models (see, e.g., Brattle Group 2010), our retirement model models the full 8,760 hours per year of electricity prices and thus allows for more precise dispatch modeling and forecasts of costs for existing and potential new units. Our model also incorporates uncertainties in key energy price and cost variables and allows the retirement decision to depend upon these uncertainties.

2. NEMS Outputs

Based on the coal unit retirements and the costs of the compliance measures, NEMS calculated the cost-minimizing set of energy prices and quantities. NEMS also endogenously determined the new generation capacity necessary in each electricity region to replace the coal units that would retire. The electricity price results from NEMS include the costs of compliance measures as well as the costs for new generation capacity, among other electricity price components.

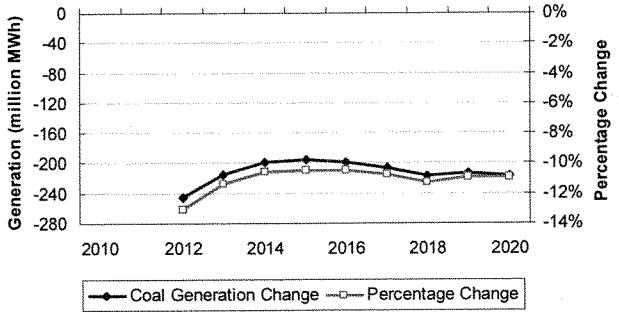
C. Results

This section shows key energy market impact results from NEMS due to the four EPA regulations for each year between 2012 and 2020.

1. Coal-Fired Generation

Figure C-2 shows the change in coal-fired generation between 2012 and 2020 due to the four EPA regulations relative to reference case projections. Coal-fired generation decreases because of the coal unit retirements and the additional costs borne by coal units that do not retire (which make the units less competitive in electricity markets and thus lower their capacity factors). Note that coal units incur costs for their SO_2 and NO_x emissions in the policy case beginning in 2012 due to the introduction of the trading program for CSAPR, with CAIR assumed not to be in place after 2011. In 2015, when many coal units install scrubbers and DSI for MACT HCl compliance, their SO_2 emissions decrease and allowance prices decrease to zero. As a result, coal units have lower costs for SO_2 emissions from 2015 onward than they had from 2012 to 2014. This tends to raise their capacity factors relative to their levels from 2012 to 2014. Coal unit retirements contribute to lower coal-fired generation from 2015 onward.

Figure C-2. Change in Coal-Fired Generation Relative to Reference Case

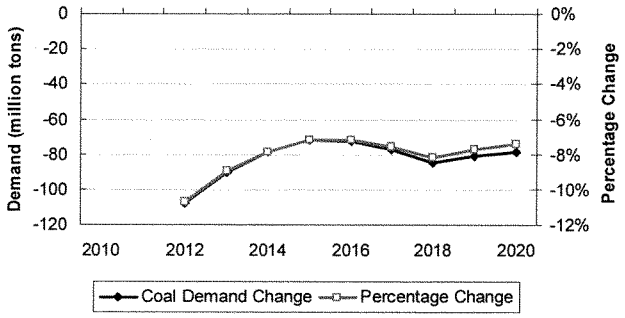


Note: Coal-fired generation in 2010 was 1800 million MWh (EIA 2011a).
Source: NERA calculations as explained in text

2. Electricity Sector Coal Demand

Figure C-3 shows the change in electricity sector coal demand between 2012 and 2020 due to the four EPA regulations relative to reference case projections. Just as for coal-fired generation, electricity sector coal demand decreases because of the coal unit retirements and the additional costs borne by coal units that do not retire (which make the units less competitive in electricity markets and thus lower their capacity factors). The percentage change in electricity sector coal demand is similar to the percentage change in coal-fired generation; the small difference between the percentage changes reflects shifts in the average heat content of coal consumed by units.

Figure C-3. Change in Electricity Sector Coal Demand Relative to Reference Case

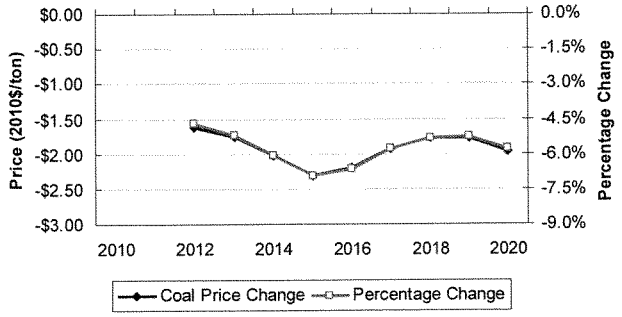


Note: Electricity sector coal demand in 2010 was 1000 million tons (EIA 2011a).
Source: NERA calculations as explained in text

3. Coal Price

Figure C-4 shows the change in average coal minemouth (i.e., wholesale) price between 2012 and 2020 due to the four EPA regulations relative to reference case projections. The price of coal would decrease because of reduced demand for coal by the electricity sector.

Figure C-4. Change in Average Coal Minemouth Price Relative to Reference Case

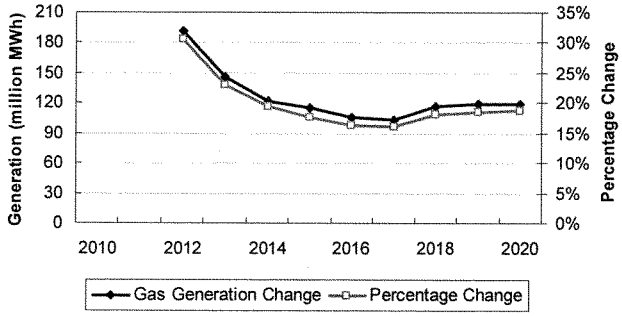


Note: Average coal minemouth price in 2010 was $37/ton (2010$) (EIA 2011a).
Source: NERA calculations as explained in text

4. Natural Gas-Fired Generation

Figure C-5 shows the change in natural gas-fired generation between 2012 and 2020 due to the four EPA regulations relative to reference case projections. When coal units retire and capacity factors for the remaining coal units decrease (due to the costs of environmental controls), the electricity sector shifts toward natural gas. The increase in natural-gas fired generation reflects both new gas units and higher capacity factors for existing gas units. The increase in natural gas-fired generation in each year is somewhat smaller than the decrease in coal-fired generation shown above in Figure C-2 because other energy sources also substitute for coal and total electricity consumption decreases somewhat in response to higher electricity prices (shown below in Figure C-8).

Figure C-5. Change in Natural Gas-Fired Generation Relative to Reference Case

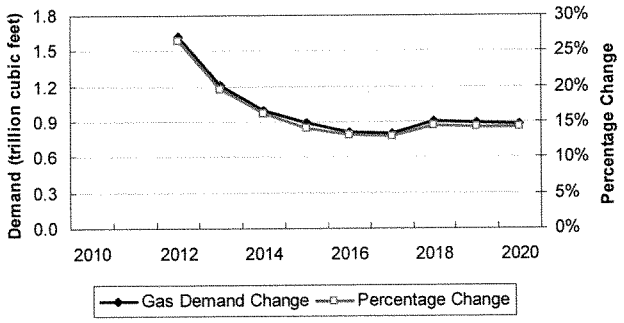


Note: Natural gas-fired generation in 2010 was 750 million MWh (EIA 2011a).
Source: NERA calculations as explained in text

5. Electricity Sector Natural Gas Demand

Figure C-6 shows the change in electricity sector natural gas demand between 2012 and 2020 due to the four EPA regulations relative to reference case projections. Just as for natural gas-fired generation, the increase in electricity sector natural gas demand reflects both new gas units and higher capacity factors for existing gas units. The percentage change in electricity sector natural gas demand in each year is similar to the percentage change in natural gas-fired generation.

Figure C-6. Change in Electricity Sector Natural Gas Demand Relative to Reference Case

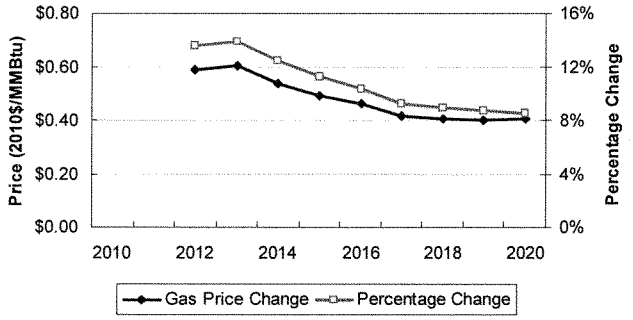


Note: Electricity sector natural gas demand in 2010 was 7.2 trillion cubic feet (EIA 2011a).
Source: NERA calculations as explained in text

6. Natural Gas Price

Figure C-7 shows the change in natural gas price at Henry Hub between 2012 and 2020 due to the four EPA regulations relative to reference case projections. The price of natural gas would increase because of the substantial increase in demand for natural gas by the electricity sector (taking into account the reduction in natural gas demand in other sectors as prices rise).

Figure C-7. Change in Natural Gas Price at Henry Hub Relative to Reference Case



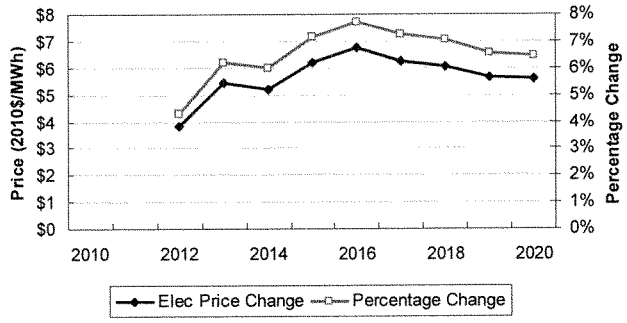
Note: Average natural gas price at Henry Hub in 2010 was $4.50/MMBtu (2010$) (EIA 2011a).
Source: NERA calculations as explained in text

7. Electricity Price

a. U.S. Electricity Price

Figure C-8 shows the change in average U.S. electricity retail price between 2012 and 2020 due to the four EPA regulations relative to reference case projections. The increase in electricity price reflects environmental control costs at coal units that do not retire, SO_2 and NO_x emission costs for CSAPR, construction of new gas units and increased capacity factors for existing gas units, and higher natural gas price.

Figure C-8. Change in Average U.S. Electricity Retail Price Relative to Reference Case

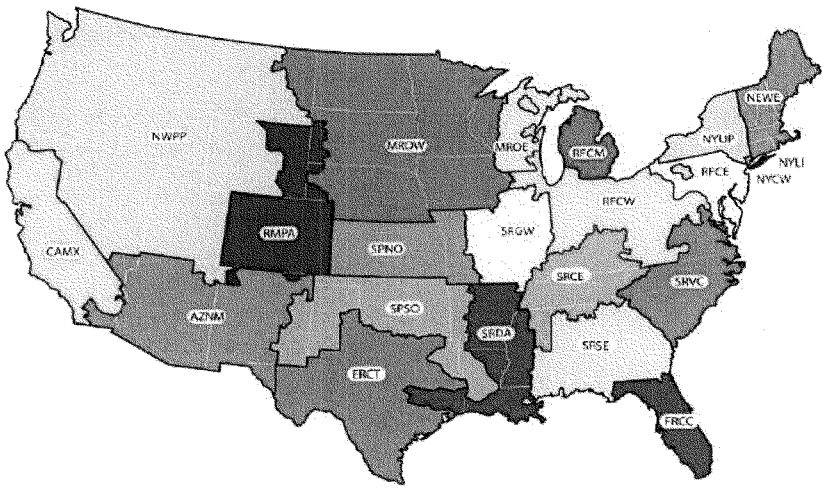


Note: Average U.S. electricity retail price in 2010 was $97/MWh (2010$) (EIA 2011a).
Source: NERA calculations as explained in text

b. Regional Electricity Price

Figure C-9 provides a map of the 22 electricity regions modeled in NEMS.

Figure C-9. NEMS Electricity Regions



Source: EIA (2011b, p. 95)

Table C-3 provides estimates of the electricity retail price impacts in the 22 NEMS electricity regions between 2012 and 2020 due to the four EPA regulations. The impacts reflect different extents to which natural gas prices, coal prices, emission allowance costs, coal unit retirements, and retrofits affect electricity prices in each year in different regions. For example, regions that rely much more on natural gas-fired generation than coal-fired generation (e.g., New England) have larger impacts during 2012-2014 than 2015-2020, because the increase in natural gas prices tapers off over time (see Figure C-7). On the other hand, regions that rely much more on coal-fired generation than natural gas-fired generation (e.g., Kentucky and Tennessee) have smaller impacts during 2012-2014 than 2015-2020, because coal unit retirements and most retrofits occur in 2015.

Table C-3. Regional Electricity Retail Price Impacts, 2012-2020 (2010$/MWh)

		2012	2013	2014	2015	2016	2017	2018	2019	2020	Avg
	US Average	+$3.80	+$5.45	+$5.21	+$6.18	+$6.73	+$6.25	+$6.06	+$5.62	+$5.56	+$5.65
NEMS Regions											
NEWE	New England	+$4.01	+$5.81	+$4.98	+$4.89	+$2.99	+$1.61	+$0.99	+$1.30	-$0.24	+$2.93
NYCW	NYC	+$6.63	+$10.35	+$8.90	+$8.12	+$6.91	+$5.95	+$5.47	+$5.21	+$5.23	+$6.97
NYLI	NY Long Island	+$10.77	+$17.39	+$15.45	+$14.09	+$12.48	+$12.22	+$11.65	+$11.40	+$11.53	+$13.00
NYUP	NY Upstate	+$6.14	+$9.37	+$8.04	+$6.65	+$5.45	+$5.33	+$5.32	+$5.59	+$5.62	+$6.39
RFCE	Mid-Atlantic	+$8.29	+$13.26	+$11.41	+$12.57	+$10.81	+$11.26	+$10.69	+$7.24	+$7.88	+$10.38
SRVC	VA & Carolinas	+$2.63	+$3.71	+$3.71	+$4.13	+$4.91	+$4.72	+$4.41	+$4.13	+$4.06	+$4.05
SRSE	Southeast	+$3.19	+$4.29	+$5.15	+$7.17	+$9.63	+$8.97	+$8.51	+$8.02	+$7.53	+$6.94
FRCC	Florida	+$3.60	+$4.81	+$4.22	+$4.22	+$4.42	+$4.20	+$3.96	+$3.64	+$3.82	+$4.10
RFCM	Lower MI	+$3.70	+$5.41	+$7.10	+$7.31	+$10.00	+$9.51	+$8.83	+$8.46	+$8.35	+$7.63
RFCW	OH, IN, & WV	+$5.42	+$8.65	+$8.08	+$7.18	+$7.12	+$6.85	+$6.59	+$6.48	+$6.70	+$7.01
SRCE	KY & TN	+$4.68	+$4.38	+$5.30	+$9.11	+$11.36	+$10.88	+$10.25	+$9.93	+$9.37	+$8.36
MROE	WI & Upper MI	+$5.63	+$7.78	+$8.12	+$6.57	+$7.37	+$7.14	+$6.79	+$6.54	+$6.66	+$6.96
MROW	Upper Midwest	+$1.41	+$1.11	+$1.23	+$4.90	+$8.36	+$8.20	+$7.94	+$7.85	+$7.54	+$5.39
SRGW	South IL & East MO	+$3.98	+$5.83	+$6.20	+$6.69	+$8.59	+$8.11	+$7.49	+$6.93	+$6.72	+$6.73
SPNO	KS & West MO	+$5.46	+$2.35	+$3.13	+$4.84	+$8.10	+$7.98	+$8.17	+$8.61	+$9.13	+$6.42
SRDA	AR, LA, & West MS	+$2.03	+$3.40	+$4.27	+$5.14	+$6.96	+$6.56	+$6.29	+$5.98	+$5.80	+$5.16
SPSO	Oklahoma	+$3.33	+$7.65	+$8.27	+$8.89	+$11.13	+$10.61	+$9.75	+$9.43	+$9.68	+$8.75
ERCT	Texas	+$4.85	+$7.01	+$6.14	+$9.15	+$6.27	+$3.51	+$4.34	+$3.60	+$3.16	+$5.34
RMPA	CO & East WY	+$0.60	+$0.40	+$0.70	+$1.54	+$2.16	+$1.99	+$1.86	+$1.72	+$1.65	+$1.40
NWPP	Northwest	-$0.14	-$0.30	-$2.27	-$1.22	-$0.07	+$0.38	+$1.20	+$1.40	+$1.36	+$0.04
AZNM	AZ & NM	+$0.82	+$0.70	+$1.04	+$1.39	+$1.71	+$1.69	+$1.56	+$1.86	+$1.85	+$1.40
CAMX	California	+$1.34	+$2.05	+$2.19	+$2.26	+$2.28	+$2.59	+$2.59	+$2.45	+$2.45	+$2.25

Source: NERA calculations as explained in text

Table C-4 shows the percentage changes in electricity retail prices in the 22 NEMS electricity regions relative to reference case projections.

Table C-4. Regional Electricity Retail Price Impacts, 2012-2020 (Percentage Changes)

		2012	2013	2014	2015	2016	2017	2018	2019	2020	Avg
	US Average	+4.3%	+6.2%	+6.0%	+7.1%	+7.7%	+7.2%	+7.0%	+6.5%	+6.5%	+6.5%
NEMS Regions											
NEWE	New England	+2.9%	+4.3%	+3.7%	+3.7%	+2.3%	+1.2%	+0.7%	+1.0%	-0.2%	+2.2%
NYCW	NYC	+3.8%	+6.1%	+5.3%	+4.9%	+4.2%	+3.6%	+3.4%	+3.2%	+3.2%	+4.2%
NYLI	NY Long Island	+6.3%	+10.4%	+9.4%	+8.7%	+7.7%	+7.6%	+7.3%	+7.1%	+7.2%	+8.0%
NYUP	NY Upstate	+5.0%	+7.9%	+6.9%	+5.8%	+4.8%	+4.7%	+4.8%	+5.0%	+5.0%	+5.6%
RFCE	Mid-Atlantic	+8.4%	+13.7%	+11.9%	+13.1%	+11.3%	+11.7%	+11.0%	+7.4%	+7.8%	+10.7%
SRVC	VA & Carolinas	+3.3%	+4.6%	+4.7%	+5.2%	+6.3%	+6.1%	+5.6%	+5.2%	+5.0%	+5.1%
SRSE	Southeast	+3.8%	+5.3%	+6.5%	+9.1%	+11.9%	+10.4%	+9.6%	+8.9%	+8.3%	+8.2%
FRCC	Florida	+3.4%	+4.5%	+4.0%	+4.0%	+4.2%	+4.0%	+3.8%	+3.5%	+3.7%	+3.9%
RFCM	Lower MI	+4.7%	+6.9%	+9.1%	+9.2%	+12.4%	+11.7%	+10.9%	+10.5%	+10.4%	+9.5%
RFCW	OH, IN, & WV	+6.2%	+10.2%	+9.7%	+8.7%	+8.7%	+8.5%	+8.3%	+8.3%	+8.6%	+8.6%
SRCE	KY & TN	+7.2%	+6.9%	+8.5%	+14.7%	+18.6%	+17.9%	+17.0%	+16.5%	+15.5%	+13.6%
MROE	WI & Upper MI	+7.6%	+10.5%	+10.7%	+8.7%	+9.4%	+9.3%	+8.9%	+8.7%	+8.8%	+9.2%
MROW	Upper Midwest	+2.0%	+1.6%	+1.7%	+7.0%	+12.1%	+11.9%	+11.6%	+11.6%	+11.3%	+7.9%
SRGW	South IL & East MO	+6.5%	+9.6%	+10.3%	+11.0%	+14.1%	+13.3%	+12.4%	+11.5%	+11.2%	+11.1%
SPNO	KS & West MO	+6.9%	+2.8%	+3.7%	+5.8%	+9.9%	+9.9%	+10.4%	+11.1%	+12.0%	+8.1%
SRDA	AR, LA, & West MS	+2.7%	+4.6%	+5.9%	+7.1%	+9.9%	+9.4%	+9.0%	+8.7%	+8.4%	+7.3%
SPSO	Oklahoma	+4.7%	+11.1%	+12.0%	+12.8%	+16.0%	+15.3%	+14.1%	+13.6%	+14.0%	+12.6%
ERCT	Texas	+6.4%	+9.4%	+8.3%	+12.2%	+8.1%	+4.4%	+5.5%	+4.5%	+3.9%	+7.0%
RMPA	CO & East WY	+0.7%	+0.4%	+0.8%	+1.7%	+2.4%	+2.2%	+2.1%	+1.9%	+1.9%	+1.6%
NWPP	Northwest	-0.2%	-0.5%	-3.7%	-2.0%	-0.1%	+0.6%	+2.1%	+2.5%	+2.5%	+0.1%
AZNM	AZ & NM	+1.0%	+0.8%	+1.2%	+1.6%	+1.9%	+1.9%	+1.8%	+2.1%	+2.1%	+1.6%
CAMX	California	+0.9%	+1.4%	+1.5%	+1.6%	+1.6%	+1.9%	+1.9%	+1.8%	+1.8%	+1.6%

Source: NERA calculations as explained in text

D. References

Brattle Group. 2010. *Potential Coal Plant Retirements Under Emerging Environmental Regulation.* Cambridge, MA: Brattle Group, December 8.

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Appendix D: Macroeconomic Modeling

This appendix provides details on the Policy Insight Plus (PI+) macroeconomic model developed and licensed by Regional Economic Models, Inc. (REMI) as well as our data and methodology for using this model to estimate the potential macroeconomic impacts of the EPA regulations.

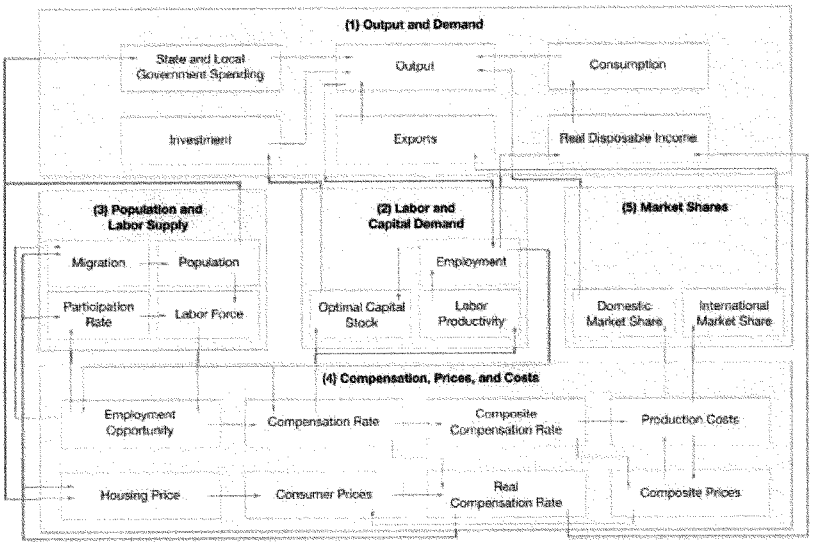
A. Overview of REMI Model[1]

The REMI PI+ model produces estimates of the changes in employment, gross domestic product (GDP), disposable personal income (i.e., personal income after taxes), and other macroeconomic variables due to changes in supply, demand, prices, and other types of inputs. Each version of the REMI PI+ model is custom-built for the regions of interest, which can range from counties to entire countries. The REMI PI+ model incorporates detailed and up-to-date macroeconomic data from the U.S. Bureau of Economic Analysis, the U.S. Bureau of Labor Statistics, the U.S. Census Bureau, and other public sources. The REMI PI+ model is widely used by federal, state, and local agencies, as well as analysts in the private sector and academia, to estimate the effects of regulations, investments, closures, and other scenarios.

Figure D-1 shows the five blocks in the REMI PI+ model and their linkages. The Output and Demand block balances supply and demand for all major sectors of the economy, including both domestic and international sources of supply and demand. The Labor and Capital Demand block models employment and capital stock based on output, wage rates, and capital costs. The Population and Labor Supply block models labor participation rate and population based on wage rates in the various regions and the size of the various sectors. The Compensation, Prices, and Costs block models each sector's production cost, including labor cost based on wage rates. Finally, the Market Shares block uses production cost to model each sector's domestic market share and international market share, which are passed back up to the Output and Demand block.

[1] This section draws on model documentation from Regional Economic Models, Inc. (REMI 2011).

Figure D-1. Key Blocks and Linkages in the REMI Model



Source: REMI (2011)

B. Overview of Methodology

We modeled the potential macroeconomic impacts of the EPA regulations using a 70-sector REMI PI+ model covering the entire United States. The model has regional detail based on Census divisions.

We developed inputs to the REMI model using the energy market modeling results from NEMS for the four EPA regulations.[2] Inputs to the REMI model can take the form of either dollar amounts or percentage changes from the built-in forecasts in the model. We entered all our inputs for this study as dollar amounts measured in constant dollars.

The types of REMI inputs developed from NEMS and other sources are summarized below.

1. *Environmental control costs.* We developed inputs for the positive effects of the capital and operations and maintenance (O&M) costs of environmental controls at the coal units that do not retire. These inputs include the costs of all the projected scrubbers, SCR, ACI, fabric filters, DSI, and compliance measures for the CCR and 316(b) regulations, broken out to the specific model regions in which they are projected to occur. We used the same cost

[2] Details on the energy market modeling results from NEMS are provided in Appendix C.

assumptions as those used in modeling potential coal unit retirements. These capital and O&M costs enter the REMI model as increased demand for machinery manufacturing and construction.

2. *Replacement capacity costs.* We developed REMI inputs for the positive effects of capital costs of new generation capacity to replace the coal units that are projected to retire. Most of the replacement capacity is combined-cycle gas technology. We developed estimates of the capital costs of replacement capacity using energy market modeling results and capital cost assumptions from NEMS. These capital costs enter the REMI model as increased demand for machinery manufacturing and construction.[3] The costs are apportioned to model regions based upon the regions where NEMS has projected the construction of new units will occur.

3. *Coal sales decreases.* We developed REMI inputs reflecting the negative effects of reductions in coal sales. These reductions arise both from coal unit retirements and from the lower capacity factors for coal units that continue to operate but are utilized less because their generation costs are greater due to controls. We developed estimates of reductions in coal sales using regional coal production and mine mouth (i.e., wholesale) price results from NEMS. The NEMS results reflect estimates of changes in coal demand not only in the electricity sector but also in the residential, commercial, and industrial sectors; the changes in these other sectors are small because these other sectors consume very little coal relative to the electricity sector. The values enter the REMI model as decreased sales for the mining sector in the relevant regions.

4. *Coal price decreases.* We developed REMI inputs for the negative impacts of decreases in coal prices on producers due to the decreased demand for coal in the electricity sector. The gains to electricity consumers from the lower coal prices are included below in the estimated effects of changes in electricity prices (which reflect the net effect of compliance costs and changes in fuel costs). In principle, the reductions in coal prices would lead to gains to consumers in non-electric sectors. NEMS does not provide information on coal prices and costs for these sectors that would allow us to assess these potential effects but they would be small because non-electric coal use is a small fraction of utility coal use.[4] We developed estimates of the decreases in coal prices using regional coal production and mine mouth (i.e., wholesale) price results from NEMS. The negative impacts on producers enter the REMI model as decreases in dividend income and government transfer payments (due to the decrease in government tax receipts from lower dividend income taxes).

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[3] The O&M costs of replacement capacity are assumed to be approximately equal to the avoided O&M costs of the coal units that retire. Thus, neither the O&M costs of replacement capacity nor the avoided O&M costs of the coal units that retire are entered into the REMI model, as they would cancel each other out. Since O&M costs of the generating units themselves are small relative to the other inputs to the REMI model, omission of the O&M costs of replacement capacity and coal units that retire does not significantly affect the results of the macroeconomic modeling. In contrast, we do include inputs to reflect the O&M costs of new retrofits as noted above.

[4] The residential, commercial, and industrial sectors collectively accounted for less than 7 percent of total U.S. coal consumption in 2010 (EIA 2011a). Coal price effects for these sectors are considerably smaller than any other effect included in this macroeconomic impact analysis.

5. *Natural gas sales increases.* We developed REMI inputs for the positive impacts of increases in natural gas sales due to the increase in demand from the electricity sector (from new natural gas units replacing the coal units that retire and higher capacity factors for existing gas units). The net increase in natural gas sales, however, is smaller than the increase in electricity demand because the increases in natural gas prices lead to reduced demand from residential, commercial and industrial sectors.[5] We developed estimates of the net increase in natural gas sales using regional natural gas production and wellhead (i.e., wholesale) price results from NEMS. The values enter the REMI model as increased sales for the oil and gas extraction sector.

6. *Natural gas price increases.* We developed REMI inputs for both the positive impacts on natural gas producers of higher natural gas prices (relative to cost increases) and the negative effects of higher natural gas prices on non-utility consumers. (As with coal prices, the negative effects on electric company customers are included in the electricity price impacts.) We developed regional estimates of the increase in natural gas prices using regional natural gas consumption and retail price results for the residential, commercial, and industrial sectors from NEMS. The impacts on consumers enter the REMI model for households as decreases in purchasing power due to increases in natural gas prices and for commercial and industrial sectors as increases in natural gas costs. The impacts on producers enter the REMI model as increases in dividend income and government transfer payments (due to the increase in government tax receipts associated with dividend income taxes).

7. *Electricity price increases.* We developed REMI inputs for the negative impacts of increases in electricity prices on consumers (residential, commercial, and industrial). Because changes in electricity sector costs—for pollution control equipment and fuel price changes—are reflected in electricity prices, electricity producers as a group are not expected to be affected. We developed regional estimates of the increase in electricity prices for consumer groups using regional electricity consumption and retail price results for the residential, commercial, and industrial sectors from NEMS. These values enter the REMI model as increases in electricity price (change in purchasing power) for households and electricity costs for commercial and industrial sectors in the various regions.

8. *Financing of capital costs.* This component arises because the capital costs for pollution control and new capacity are not reflected fully in electricity rates in the years in which they are incurred, although these costs are ultimately reflected in higher electricity rates (as noted above). We developed information on the financing of pollution control and replacement capacity expenditures, in particular the extent to which these capital expenditures would lead to reduced investment or reduced consumption in the years in which the capital expenditures are made, and then increased investment or increased consumption in the years in which

[5] We used the version of REMI that allows for complete fuel substitution for other factor inputs, which assumes that consumers can shift away from more expensive energy and thus reduce the negative impacts of higher natural gas and electricity prices. This assumption may understate the negative imacts of the price increases. We also entered the costs of substitution away from energy into the REMI model as increased demand for energy-efficient appliances. Including this effect may overstate the positive impacts if the REMI model already incorporates these positive adjustments related to substitution away from energy.

electricity price increases reflect these capital costs but the capital expenditures have already been made.

C. Information on Modeling Components

This section provides additional information on the inputs to the REMI modeling. [6]

1. Environmental Control Costs

Environmental control costs consist of the capital and O&M costs for compliance measures at the coal units that do not retire. As discussed in the report body, we assumed that CSAPR would take effect in 2012 and MACT, CCR, and 316(b) would take effect in 2015. The NEMS results reflect compliance in these years, but that model does not incorporate leadtimes for controls. NEMS builds some scrubbers for compliance with the CSAPR SO_2 policy in 2012, and it builds other controls by 2015. We entered the capital costs of controls installed in 2012 into the REMI model as costs in 2012, and we entered the capital costs of controls installed in 2015 into the REMI model as costs spread evenly in 2013, 2014, and 2015 to reflect their leadtime. Costs from 2016 onward primarily reflect the O&M cost of environmental controls. The costs are net of pollution control costs in the reference scenario (which primarily reflect currently planned retrofits by 2012 and mercury controls for state policies in the reference case).

The environmental control costs represent increased demand for manufacturers and construction companies. We reviewed detailed budgets for several retrofit projects in the electricity sector (e.g., PSNH 2010, DOE 2003) and determined that approximately 70 percent of the costs were for equipment and 30 percent for construction. Thus, we modeled 70 percent of the environmental control costs in each year in REMI as increased demand for the machinery manufacturing sector and the remaining 30 percent as increased demand for the construction sector. These environmental control costs are allocated to regions in REMI based on the locations of the coal units incurring the costs.

2. Replacement Electricity Capacity Costs

Replacement capacity costs consist of the capital costs for new electricity capacity (primarily combined-cycle gas units) that NEMS projects will be built, based on its evaluation of supply and demand in regional electricity markets, to replace the coal units that retire.[7] Most of the

[6] We considered using the optional NEMS macroeconomic activity module to develop the macroeconomic impact estimates but concluded that it would be less appropriate than REMI for this study. The NEMS macroeconomic module uses only changes in energy prices and quantities from NEMS to assess macroeconomic impacts. Thus, the module does not account for the increase in demand for machinery manufacturing and construction or the need to finance the capital expenditures. REMI allows us to incorporate both effects. Moreover, the NEMS macroeconomic module aggregates all energy price changes (including electricity, coal, and natural gas) into a single energy price index for purposes of evaluating macroeconomic impacts. REMI allows us to input separate estimates for the different energy types.

[7] As noted above, neither the O&M costs for replacement capacity nor the avoided O&M costs for coal units that retire are included in the macroeconomic modeling, because they are assumed to be approximately equal in size and therefore would cancel each other out.

replacement capacity is built shortly before 2015 in anticipation of the many coal unit retirements in that year, but some replacement capacity is built later in the modeling period. The assumed capital costs for new capacity are based upon EIA estimates (2011b, p. 97). The replacement capacity costs are net of new capacity costs in the reference scenario. (The four policies pull forward some new capacity that would be built later in the reference scenario.)

The replacement capacity costs represent increased demand for manufacturers and construction companies. Based on our review of electricity sector project budgets (described above), we assumed that 70 percent of the capital costs were for equipment and 30 percent for construction. Thus, we modeled 70 percent of the replacement capacity costs in each year in REMI as increased demand for the machinery manufacturing sector and the remaining 30 percent as increased demand for the construction sector.

NEMS generates estimates of replacement capacity costs for each of its 22 electricity regions, which are based on electric reliability regions defined by the North American Electric Reliability Corporation (NERC). We allocated these values to the regions in the REMI model based upon the shares of baseline generation capacity.

3. Coal Sales Reduction

The coal unit retirements and reduction in capacity factors for non-retiring coal units projected due to the four regulations would lead to decreased demand for coal in the electricity sector. We modeled the reduction in coal sales using regional NEMS results on coal production and minemouth (i.e., wholesale) price. In particular, we calculated the change in coal production in each region and multiplied it by the average of the minemouth prices in the reference case and policy case in each region to capture the quantity effect of the four regulations for coal.[8] We allocated these values to the regions in the REMI model based on the regional data from NEMS. The values enter the REMI model as decreased sales for the mining sector.

4. Coal Price Decreases

This section considers the effects of coal price decreases on producer surplus. As noted above, we did not model coal price effects on consumers because the price effect for the electricity sector is included in the electricity price effects and the price effects for residential, commercial, and industrial sectors are negligible because of their low coal consumption.

The reduction in coal prices due to reduced demand by the electricity sector would reduce producer surplus in the coal sector.[9] We developed REMI inputs for this reduction in producer surplus in the coal sector based on NEMS results by multiplying the change in coal minemouth price (a negative value) by the average of coal productions in the reference and policy cases. We entered the reduction in producer surplus into the REMI model as reductions in dividend income and allocated it across regions based on their share of the U.S. population. Since dividends are

[8] The price effects on consumer and producers surplus are modeled below.

[9] Producer surplus is the amount by which price exceeds marginal cost (or the minimum amount that producers would accept to produce the good), summed over all production. It relates to total profit in a sector.

distributed by companies after paying income taxes, we first multiplied the producer surplus by an estimated effective corporate income tax rate and modeled this change in government corporate income tax receipts as a change in transfer payments. We used an estimated effective corporate income tax rate of 40 percent based on a review of tax rates for energy companies (API 2010, p. 7) and allocated the change in transfer payments across regions based on their share of the U.S. population. We then modeled the remainder of producer surplus as dividend payments.

5. Natural Gas Sales Increase

The new gas units and higher capacity factors for existing gas units due to the four regulations would lead to increased demand for natural gas in the electricity sector. Since higher natural gas prices in the REMI model lead to lower natural gas sales, but the regulations would lead to both higher natural gas prices and higher natural gas sales due to the outward shift of the demand curve for natural gas in the electricity sector, we needed to calibrate the natural gas sales inputs to ensure that the REMI results would be consistent with the NEMS results for natural gas sales. We did this by running the REMI model first with the inputs shown above except the change in natural gas sales, examining the natural gas sales results from the REMI model, and calibrating the natural gas sales inputs to correspond with the values from NEMS. We modeled the increase in natural gas sales using regional NEMS results on natural gas production and wellhead (i.e., wholesale) price. In particular, we calculated the change in natural gas production in each region and multiplied it by the average of the wellhead prices in the reference case and policy case in each region to capture the quantity effect of the four regulations for natural gas. We allocated these values to the regions in the REMI model based on the regional data from NEMS. The values enter the REMI model as increased sales for the oil and gas extraction sector.

6. Natural Gas Price Increases

This section considers the impacts of increases in natural gas prices—due to increased electricity sector demand—on consumers and producers.

a. Impacts on Natural Gas Consumers

The increase in natural gas demand in the electricity sector would increase the price of natural gas for all sectors of the economy. We used regional NEMS results on natural gas consumption and retail prices for the residential, commercial, and industrial sectors to develop REMI inputs for these adverse consumer impacts. NEMS produces these results for the nine Census divisions. We calculated the change in retail natural gas price in each region and multiplied it by the average consumption in the reference and policy cases in each region to capture the price effect of the four regulations for natural gas. We allocated these values to the regions in the REMI model based on their historical shares of natural gas expenditures in their Census divisions. We entered the values for the residential sector in the REMI model as decreased household purchasing power (reflecting the increased natural gas prices), and we entered the values for the commercial and industrial sectors as increased natural gas costs for these sectors.

b. Impacts on Natural Gas Producers

The increase in natural gas prices due to expanded demand by the electricity sector would increase producer surplus in the natural gas sector. As with producer surplus in the coal sector, we modeled the increase in natural gas as increases in dividend payments and government transfer payments, using an effective corporate income tax rate of 40 percent. The change in producer surplus is calculated as the change in wellhead price multiplied by the average production in the reference and policy cases.

7. Electricity Price Increases

The four regulations would lead to increases electricity prices for the residential, commercial, and industrial sectors. We used regional NEMS results on electricity consumption and retail prices for the residential, commercial, and industrial sectors to develop REMI inputs for this type of impact.[10] NEMS produces these results for the nine Census divisions. We calculated the change in retail electricity price in each region and multiplied it by baseline consumption in each region to capture the price effect of the four regulations for electricity. We allocated these values to the regions in the REMI model based on their historical shares of electricity expenditures in their Census divisions. We entered the values for the residential sector in the REMI model as increased electricity price (change in purchasing power) for households, and we entered the values for the commercial and industrial sectors as increased electricity costs for these sectors.

8. Financing of Capital Costs

We presume that electricity companies would finance the net capital cost requirements (capital costs for environmental controls and new capacity minus contemporaneous electricity rate increase due to financing) in each year through debt financing. The impacts on the economy in each year would depend in part upon the extent to which the increased utility demand for capital—primarily from 2012 to 2015, with much smaller investment required from 2016 onward for replacement capacity–would lead to reductions in investment elsewhere in the economy, i.e., crowd out other investment. Since the REMI model does not reflect changes in the overall productivity of the economy due to changes in investment, however, the distinction between changes in investment and changes in consumption as the source of financing is less important.[11]

The extent of crowding out of other investment depends upon the short-run demand and supply elasticities for investment capital as well as on the detailed general equilibrium effects in the overall economy. If the short-run capital supply elasticity is zero, as many researchers have found (see Bernheim 2002), 100 percent of the increased demand by the electricity companies would be reflected in reduced investment elsewhere.

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[10] Note that the changes in retail electricity prices from NEMS reflect the annualized costs of environmental controls and replacement capacity, not the actual expenditures by the electricity sector in each year. This issue is discussed below in the context of financing.

[11] Studies suggest that the general equilibrium economic effects of crowding out productive investment could be substantial. See Schmalensee (1994).

Various studies have considered the specific crowding out of pollution control expenditures. Gray and Shadbegian (2001) find that pollution control expenditures in the pulp and paper sector actually lead to more than a 100 percent reduction in other capital expenditures in the sector when account is taken of reductions at individual plants (188 percent decline) and approximately 100 percent decline considering only capital expenditures at other facilities. Jorgenson and Wilcoxen (1990) in their study of the effects of pollution control expenditures on the U.S. economy use a short-run elasticity for the supply of capital of zero (i.e., perfectly inelastic), implying 100 percent crowding out of investment in the short-term.

One plausible alternative is to assume 100 percent crowding out of private investment, based upon estimates of a zero short-term elasticity of supply of capital and some of the empirical estimates for compliance costs. Since the elasticity of supply may be greater than zero, we assumed crowding out of 50 percent for the net investment years.[12] We presumed that that the other 50 percent of net utility investment would come from additional savings and thus reduced consumption.[13] We presumed that the bondholders would receive additional income in the later years.

The reduced private investment is entered into REMI as reduced investment in residential structures, nonresidential structures, and nonresidential equipment based on their shares of baseline U.S. investment. The change in income for bondholders is entered into the REMI model as changes in consumption.[14]

D. Modeling Results for the Four Environmental Policies

We modeled the potential net macroeconomic impacts of the four regulations by entering all the inputs categories described above into the REMI model. We also calibrated the REMI model to ensure that the net changes in sales for the coal, natural gas, and electricity sectors with all the inputs were consistent with their net changes in sales from NEMS.[15]

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[12] If the modeling included the negative effects of crowding out productive investment on economic growth, it would be more important to be precise about the specific amount of crowding out of private investment.

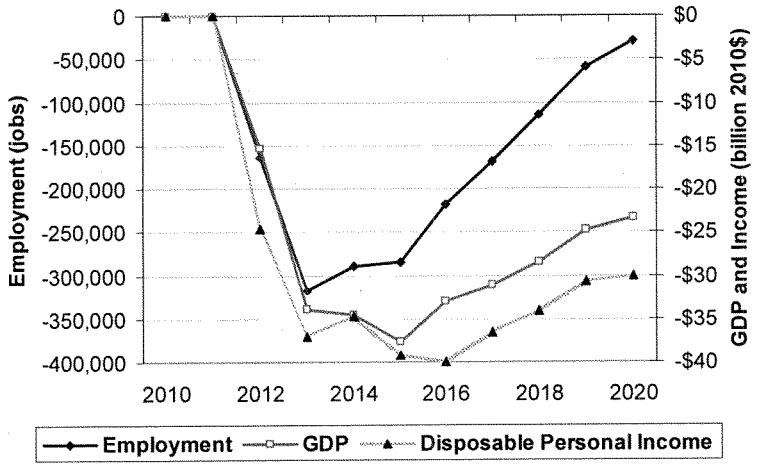
[13] These calculations presume that environmental compliance expenditures do not use unemployed or idle resources. As Schmalensee (1994) points out, there is no reason why tightening environmental regulation would weaken economy-wide forces that produce unemployment and, indeed, that the net short-term impact of tightening environmental standards is likely to increase overall unemployment in the near term in the process of shifting jobs within the economy (with monetary and fiscal policies, changes in exchange rates, changes in foreign economic policies and economic conditions and firm and household expectations being the major factors determining overall macroeconomic conditions).

[14] Entering the change in income alternatively as a change in dividends, interest, and rent would yield very similar results (because REMI indicates that dividends, interest, and rent in any year are mostly used for consumption in that same year).

[15] We performed this calibration by (1) running REMI once with all inputs except changes in sales; (2) calculating the difference between changes in sales from REMI for the coal, natural gas, and electricity sectors and their changes in sales from NEMS; and (3) running REMI again with the difference in sales (in addition to other inputs) so that the sales results from REMI would be consistent with the sales results from NEMS.

Figure D-2 shows the annual impacts of the four environmental policies on U.S. employment, GDP, and disposable personal income from 2012 to 2020 predicted by the REMI model.

Figure D-2. Macroeconomic Modeling Results



Source: NERA calculations as explained in text

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