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Quicksilver Politics: Mercury Narratives and Environmental Governance

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QUICKSILVER POLITICS: MERCURY NARRATIVES AND ENVIRONMENTAL GOVERNANCE

By

Andrew Pearce Carter

A DISSERTATION

Submitted to the Faculty of the University of Miami in partial fulfillment of the requirements for the degree of Doctor of Philosophy

Coral Gables, Florida

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A dissertation submitted in partial fulfillment of
the requirements for the degree of
Doctor of Philosophy

QUICKSILVER POLITICS: MERCURY NARRATIVES AND
ENVIRONMENTAL GOVERNANCE

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Environmental mercury poses a potentially serious health threat to human populations, particularly through bioaccumulation and biomagnification processes which can concentrate ambient mercury to dangerous levels in fish, a food source for a significant percentage of the earth’s population. Emitted from both natural and anthropogenic sources, mass industrialization over the past few decades has significantly increased the amount of mercury in the environment, increasing health risks for humans and other organisms. A pollutant of both local and global concern, regulating environmental mercury risk has proven exceedingly difficult due to scientific uncertainty and numerous cultural, psychological, economic, and political factors.

This dissertation consists of a series of self-contained yet thematically related research projects that explore mercury and the human relationship with it, with a focus on environmental governance in the face of scientific uncertainty and conflicting values. Collectively it is simultaneously a cultural history of mercury and the human relation with it, a critical policy analysis of the failures and successes of environmental governance as it relates to it, and a philosophical and sociological exploration of the difficulties in regulating complex problems like it.
Chapter 2 critically reviews the current status of mercury-related science, including its biogeochemical cycling, control technologies, and health impacts, identifying uncertainties and research gaps that hinder effective policymaking. Chapter 3 explores the philosophical dimensions of environmental policy analysis, critically reviewing its dominant epistemological research paradigms of neopositivism and interpretivism, and offering an alternative, critical realism. Chapter 4 presents an environmental history of mercury, and uses cultural models theory to link the modern American anti-vaccine movement with mercury poisoning events in the past, most notably the Minamata Bay poisoning in Japan. Chapter 5 examines the decades-long debate over whether to regulate mercury emissions from coal-fired power plants in the United States under the Clean Air Act, and how that debate fit into larger environmental discourses in the country. Chapter 6 examines the development of the Minamata Convention, a global treaty designed to reduce mercury risk, and analyzes why it succeeded and what challenges face its implementation. Finally, Chapter 7 discusses common threads that emerge out of the dissertation as a whole, discusses what lessons it holds for future environmental policy development.
DEDICATION

To my friends and family who have been there for me through this whole thing.

To my parents Virginia and Andy, who have remained supportive no matter how many times I end up back in school, and to Bahareh for her continued love and support.
ACKNOWLEDGMENTS

I would like to thank the numerous people who have made this research possible. First, of course, I would like to thank my advisor Kenneth Broad who has provided invaluable mentorship and encouragement whenever needed, while at the same time giving me an amazing gift in the freedom to go wherever my research interests were taking me. The members of my committee have without exception been tremendously helpful and friendly in guiding me in my research: Thank you to Tony Hynes, Richard Williamson, and Dan Sarewitz for that.

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life. I would also like to thank my fellow members of Research Intersections, and William Prado and Tatiana Perrino at the Graduate School for their support.

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<td>AAP</td>
<td>American Academy of Pediatrics</td>
</tr>
<tr>
<td>AHJWG</td>
<td>Ad Hoc Joint Working Group</td>
</tr>
<tr>
<td>AMAP</td>
<td>Arctic Monitoring and Assessment Programme</td>
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<tr>
<td>AMDE</td>
<td>Atmospheric mercury depletion event</td>
</tr>
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<td>AMNet</td>
<td>Atmospheric Mercury Network</td>
</tr>
<tr>
<td>APA</td>
<td>Administrative Procedures Act</td>
</tr>
<tr>
<td>ASGM</td>
<td>Artisanal small-scale gold mining</td>
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<tr>
<td>BACT</td>
<td>Best available control technology</td>
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<tr>
<td>BAT</td>
<td>Best available technology</td>
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<tr>
<td>BEP</td>
<td>Best environmental practices</td>
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<td>CAA</td>
<td>Clean Air Act</td>
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<td>CAMR</td>
<td>Clean Air Mercury Rule</td>
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<tr>
<td>CBDR</td>
<td>Common but differentiated responsibilities</td>
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<tr>
<td>CEC</td>
<td>Commission for Environmental Cooperation (NAFTA)</td>
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<tr>
<td>CEQ</td>
<td>Council on Environmental Quality</td>
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<tr>
<td>CWA</td>
<td>Clean Water Act</td>
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<tr>
<td>DTP</td>
<td>Diptheria-Tetanus-Pertussis</td>
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<tr>
<td>EDF</td>
<td>Environmental Defense Fund</td>
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<tr>
<td>EGU</td>
<td>Electric generating unit</td>
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<td>EIA</td>
<td>Energy Information Administration</td>
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<tr>
<td>EJ</td>
<td>Environmental Justice</td>
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<tr>
<td>EMEP</td>
<td>European Monitoring and Evaluation Programme</td>
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<td>EPA</td>
<td>Environmental Protection Agency</td>
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<tr>
<td>EPRI</td>
<td>Electric Power Research Institute</td>
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<tr>
<td>ESM</td>
<td>Environmentally sound management</td>
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<td>EU</td>
<td>European Union</td>
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<td>FDA</td>
<td>Food and Drug Administration</td>
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<td>FIFRA</td>
<td>Federal Insecticide, Fungicide and Rodenticide Act</td>
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<tr>
<td>GAO</td>
<td>Government Accountability Office</td>
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<td>GEF</td>
<td>Global Environment Facility</td>
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<td>GMOS</td>
<td>Global Mercury Observation System</td>
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<td>GOM</td>
<td>Gaseous Oxidized Mercury</td>
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<tr>
<td>GwH</td>
<td>Gigawatt hour</td>
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<tr>
<td>HAP</td>
<td>Hazardous Air Pollutant</td>
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<tr>
<td>Hg</td>
<td>Mercury</td>
</tr>
<tr>
<td>HHS</td>
<td>Secretary of the Department of Health and Human Services</td>
</tr>
<tr>
<td>IAQR</td>
<td>Interstate Air Quality Rule</td>
</tr>
<tr>
<td>ICPM</td>
<td>Inductively coupled plasma mass spectrometry</td>
</tr>
<tr>
<td>IISD</td>
<td>International Institute for Sustainable Development</td>
</tr>
<tr>
<td>IOMC</td>
<td>Inter-Organization Programme for the Sound Management of Chemicals</td>
</tr>
<tr>
<td>JUSCANCE</td>
<td>Japan/U.S./Canada/New Zealand regional organization</td>
</tr>
<tr>
<td>LCV</td>
<td>League of Conservation Voters</td>
</tr>
<tr>
<td>Acronym</td>
<td>Full Form</td>
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<tr>
<td>LRTAP</td>
<td>Convention for Long-range Transport of Atmospheric Pollutants</td>
</tr>
<tr>
<td>MACT</td>
<td>Maximum Achievable Control Technology</td>
</tr>
<tr>
<td>MATS</td>
<td>Mercury and Air Toxics Standards</td>
</tr>
<tr>
<td>MDN</td>
<td>Mercury Deposition Network</td>
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<tr>
<td>MEA</td>
<td>Multilateral environmental agreement</td>
</tr>
<tr>
<td>MEBA</td>
<td>Mercury Export Ban Act</td>
</tr>
<tr>
<td>MMR</td>
<td>Mumps-Measles-Rubella</td>
</tr>
<tr>
<td>NAAQS</td>
<td>National Ambient Air Quality Standards</td>
</tr>
<tr>
<td>NAAQS</td>
<td>National Ambient Air Quality Standards</td>
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<tr>
<td>NADP</td>
<td>National Atmospheric Deposition Network</td>
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<tr>
<td>NAFTA</td>
<td>North American Free Trade Agreement</td>
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<tr>
<td>NAS</td>
<td>National Academy of Science</td>
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<tr>
<td>NESHAP</td>
<td>National Emission Standards for Hazardous Air Pollutants</td>
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<tr>
<td>ng</td>
<td>nanogram</td>
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<tr>
<td>NGO</td>
<td>Non-Governmental Organization</td>
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<tr>
<td>NIEHS</td>
<td>National Institute of Environmental Health Sciences</td>
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<tr>
<td>NOAA</td>
<td>National Oceanographic and Atmospheric Administration</td>
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<tr>
<td>NODA</td>
<td>Notice of Data Availability</td>
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<tr>
<td>NOx</td>
<td>Nitrous oxides</td>
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<tr>
<td>NRC</td>
<td>National Research Council</td>
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<tr>
<td>NRDC</td>
<td>National Resources Defence Council</td>
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<tr>
<td>NSPS</td>
<td>New Source Performance Standards</td>
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<tr>
<td>NSPS</td>
<td>New Source Performance Standards</td>
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<tr>
<td>OEWG</td>
<td>Open-Ended Working Group</td>
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<tr>
<td>OIG</td>
<td>Office of the Inspector General [EPA]</td>
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<tr>
<td>OMB</td>
<td>Office of Management and Budget</td>
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<tr>
<td>pg</td>
<td>picogram</td>
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<tr>
<td>PM</td>
<td>Particulate matter</td>
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<tr>
<td>pmol</td>
<td>picomole</td>
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<tr>
<td>POP</td>
<td>Persistent organic pollutant</td>
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<tr>
<td>ppm</td>
<td>Parts per million</td>
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<tr>
<td>PUFA</td>
<td>Polyunsaturated fatty acid</td>
</tr>
<tr>
<td>RfD</td>
<td>Reference dose</td>
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<td>RGM</td>
<td>Reactive gaseous mercury</td>
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<td>S</td>
<td>Sulfur</td>
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<td>SAB</td>
<td>Science Advisory Board</td>
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<td>SAICM</td>
<td>Strategic Approach to International Chemicals Management</td>
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<td>SDWA</td>
<td>Safe Drinking Water Act</td>
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<tr>
<td>STS</td>
<td>Science and Technology Studies</td>
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<td>tpy</td>
<td>Tons per year</td>
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<tr>
<td>UN</td>
<td>United Nations</td>
</tr>
<tr>
<td>UNEA</td>
<td>United Nations Environment Assembly (formerly the UNEP GC)</td>
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<tr>
<td>UNECE</td>
<td>United Nations Economic Commission for Europe</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>UNEP</td>
<td>United Nations Environment Programme</td>
</tr>
<tr>
<td>UNEP GC</td>
<td>UNEP Governing Council (pre-2013)</td>
</tr>
<tr>
<td>UNFCCC</td>
<td>United Nations Framework on Climate Change</td>
</tr>
<tr>
<td>USPHS</td>
<td>United States Public Health Service</td>
</tr>
<tr>
<td>VCM</td>
<td>Vinyl chloride monomer</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
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<tr>
<td>ZMWG</td>
<td>Zero Mercury Working Group</td>
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Chapter 1
Introduction
1.1 Overview

Environmental mercury poses a potentially serious health threat to human populations, particularly through bioaccumulation and biomagnification processes which can concentrate ambient mercury to dangerous levels in fish, a food source for a significant percentage of the earth’s population. While mercury’s neurotoxic effects have been known for thousands of years (Bachour, 2015), it was not until the second half of the 20th century that scientists became aware that mercury could pose a danger to human populations even at low environmental levels through such bioaccumulation and biomagnification processes (Jensen & Jernelöv, 1969). This realization was driven not only by emerging scientific research but also by a number of widely-publicized mass mercury poisoning events, the most well-known occurring in Minamata, Japan, where for more than a decade waste methylmercury from a chlor-alkali production plant poisoned fish and through them the local community.

Accordingly, over the past several decades numerous regulatory and legal initiatives at the local, national, and international level have been instituted to mitigate the human health dangers of environmental mercury. However, the environmental mercury issue thus serves as a particularly salient example of what Rittel and Webber (1973, p. 160) famously referred to as “wicked” problems: hard-to-define problems existing in open systems, with no easy answers, and where “pluralities of politics make it impossible to pursue unitary aims.” Environmental policy decisions like what to do with mercury are constrained not just by significant uncertainties in the relevant science, but also by competing stakeholder values and ideologies, cognitive limitations and biases,
oftentimes convoluted legal and political processes, and economic and other societal factors.

Untangling complex environmental problems has frequently proven incompatible with the traditional approach to policy analysis and development, which sees environmental problems as primarily technical ones that can be solved through rigorous scientific methodologies, and presumes the environmental policy is best solved, at least ideally, by an orderly progression through various stages of problem identification, analysis, policy development, and implementation, with factual scientific and technical decisions (for example, how to quantify the health risks from a specific pollutant) made by putatively dispassionate and neutral experts like scientists, and value judgments (for example, the level of risk from that pollutant that requires policy intervention) made by policymakers, presumably installed in their position through some form of democratic means, and representing the moral consensus of the community. Such an approach tends to take a philosophically neopositivist approach that sees the solution of social problems – or mixed social-ecological problems – as amenable to the same sort of problem-solving approaches found in science and engineering. ¹ The neopositivist approach to policy analysis often assumes rationality not just in the analyst but also in the social objects of analysis; stakeholders in an environmental debate are assumed to act rationally on the information given them, and to know their preferences and act to maximize them.

While few people working in policy studies or analysis would dispute that real-world policy development almost inevitably falls short of the “policy cycle” ideal, that ideal is not a strawman; it is still taught in environmental policy classes, is often reified in

¹ I will define the neopositivist approach to which I am referring in more detail in Chapter 2.
the laws and regulations by which governmental environmental policy analysts operate, and its DNA can often be seen in the numerous environmental management frameworks offered in academic journals which seek to prescribe a generalizable method to approaching environmental issues. The failure of the “policy cycle” approach can be seen clearly in the highly contested, legislated, and litigated mercury policy debates of the past several decades – or the highly contested, legislated, and litigated debates over climate change, acid rain, ozone depletion, fisheries management, etc. Rationalist analyses of environmental policy domains tend to quickly collapse in the face of just about every complex environmental problem scientists, policymakers, and the public have attempted to deal with. A number of policy theorists have offered various postpositivist approaches that seek to replace the positivist, technocratic approach to solving environmental problems with more participatory processes that seek to incorporate increased democratic control of policy decisions and account for the inevitable politicization of science in policy disputes (e.g., Ascher, Steelman & Healy, 2010; Fischer, 2003). However, these approaches have their own limitations and drawbacks, and while environmental policy processes have grown increasingly collaborative over the past few decades, much of the ground-level environmental policy analysis done, at least in the United States, follows the natural science paradigm.

The stakes involved in environmental policy debates can be high, with quite possibly the most obvious example the potentially existential threat of climate change. But while it has not received quite the attention that climate change debates have, policy debates over mercury also can have a global impact on the lives of a significant percentage of the population. More than three billion people, many in the developed
world, rely on fish as a major protein source, and much of that fish may contain unsafe levels of mercury. The damage caused by mercury can be hard to detect but potentially profound, impacting the developing brains in ways that can have lifelong costs (Grandjean, 2013).

There are no easy solutions to the mercury problem. As with many environmental policy areas, policy decisions about mercury face tradeoffs between costs (both economic and non-economic) and benefits. For example, mercury control laws or regulations that are too lax risk serious harm to human populations, while those that are overly stringent may cause significant economic costs to, among others, those same populations, while not reducing risk to any significant extent. Too much fish consumption of high-mercury species may cause neurodevelopmental or other health effects, while too little fish consumption generally is correlated with worse population-level health outcomes – and refraining from eating fish is often not feasible in impoverished areas where fish may be the only readily available protein source. Artisanal gold miners often face significant inhalation risks from mercury use, but rely on such mining to support themselves and their families. Finding the balance between these sets of competing interests, especially under conditions of uncertainty as to the scope of those costs and benefits is extremely difficult, requires consideration of not only the physical and biomedical sciences but also cognitive psychology, ethics, and the structure of the law, suggesting a critical need for an interdisciplinary approach to identifying and resolving problems in the environmental policy process.

My original research plan for this project started out as a general investigation of how ‘mercury’ stakeholders understood and acted upon mercury risk, with the goal of
analyzing those beliefs and decisions in the context of what the science said, focused on discrete stakeholder groups. Applied and problem-focused, the idea was to try and pull out what was working with mercury policy and what was not, and use the former to fix the latter – or at least to propose concrete, albeit modest goals to improve reasoning and decision-making about mercury.

That is not the dissertation you are reading. Just as positivist approaches to environmental policy have largely foundered on the shores of actual experience, my attempt to distill stakeholder perceptions of mercury into some parsimonious comparative framework has gone down under the metaphorical weight of mercury science and policy. While the goal of this dissertation has not changed – I still seek to examine how “wicked” problems like environmental mercury have been managed, perceived, understood, and acted upon by individuals, including policymakers, scientists, and the general public, and propose possible avenues to improving how we deal with them – the way I try to reach that goal has changed. Instead of trying to reduce the scientific, cultural, and political histories related to mercury, I instead try to detail and interpret them in all (or most of) their complexity.

The dissertation is structured as a series of stand-alone chapters that examine different related aspects of the overarching policy challenge associated with wicked environmental problems, organized by theoretical, epistemological, and substantive issues relating to environmental policy, using the environmental mercury problem as an overall case study. Though made up of self-contained works the dissertation can be seen simultaneously as an analysis – and illustration – of the difficulties inherent in dealing with wicked environmental problems generally, a historical account of mercury and our
relationship to it, and an exploration of possible ways to deal with the complexity underlying these kinds of environmental issues. It is interdisciplinary in that I draw on the natural sciences, social sciences, and humanities to explore the nature of complex environmental problems and how we deal with them.

### 1.2 Dissertation Structure

The dissertation is structured in a building block format and is summarized in Table 1. The first two chapters critically review the bodies of social theory and mercury science respectively, establishing a foundation for subsequent chapters. The next three analyze specific mercury-related historical case studies.

Table 1.1. Dissertation structure.

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<td>5</td>
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<td>Mercury as a Global Pollutant: Negotiating the Minamata Convention</td>
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A more detailed description follows:
In Chapter 2 I critically review the scientific and technical literature on environmental mercury, both in terms of its biogeochemical cycling, its public health impacts, and control technology. I focus especially on uncertainties that may impact policy decision-making, and unresolved debates on different aspects of how mercury moves and transforms through the environment, and how it impacts organism health. Engaging with the mercury science is important not only in understanding the historical development of mercury policy and the current constraints placed on policy development by scientific uncertainty, but also in developing proposals to improve the policy process. Mindful of the fact that policymakers often rely on consensus reports that often gloss over, ignore, or minimize points of disagreement (Sarewitz, 2011), I go beyond consensus and review reports to examine key original research literature across multiple technical and scientific fields, creating both a stand-alone critical and multidisciplinary review of mercury science, and a scientific and technical foundation for the subsequent chapters.

In Chapter 3 I explore the philosophical foundations of environmental policy analysis as a field, particularly epistemological issues about how we can understand environmental problems that implicate both natural and social systems. Though this chapter does not limit itself to mercury specifically, the approach I advocate forms an epistemological foundation for the later, mercury-specific chapters. I first examine the major competing social science paradigms of the 20th and 21st centuries, positivism and interpretivism, in the context of the field of policy analysis. While acknowledging the strengths of both approaches, I argue they each tend towards certain fundamental flaws rendering them insufficient, on their own, for effective analysis of complex social-
ecological problems. Instead, I propose that critical realism offers a useful epistemology to approaching environmental policy analysis that may be a way to bridge positivist and interpretivist approaches while maintaining the utility of both. Critical realism is a philosophical metatheory developed by the philosopher Roy Bhaskar and extended by a number of predominately English philosophers and social scientists that seeks to chart a middle ground between the naturalistic positivism that has historically dominated both natural and social scientific inquiry, and the interpretivist turn among social scientists towards understanding how people understand, construct, and communicate the world around them. A critical realist policy analysis remains interpretivist in methodology, but remains constantly engaged with the ontological reality of both the natural and social phenomena that must be understood to address an environmental problem.

In Chapter 4 I present a historical case study of environmental mercury, examining the history of human experience with it, particularly through the second half of the 20th century as awareness of its toxic nature grew. Relying on historical records, legal records, medical and scientific literature, media reports, and social media, I focus particularly on two historical mercury-related phenomena: the Minamata Bay poisoning event of the 1950s, and the American anti-vaccine movement of the 2000s, which saw public anxiety over the mercury-based vaccine preservative thimerasol. I argue that the contemporary mental models of mercury risk that may have driven anti-vaccine advocates’ anxiety over mercury may be at least partially driven by the well-publicized media accounts in the United States of the Minamata Bay and other poisoning events in the United States in the early 1970s. I make this connection through a cultural or mental models theory, which hold that human beings reason through consulting internal
representations of the real world, a theory developed by cognitive psychologists and anthropologists that has become widely used as a theoretical framework for understanding human reasoning and decision-making about environmental problems. This chapter functions not only as an independent work of interdisciplinary historical scholarship but by examining Minamata and environmental poisoning events in its first part helps place the other case studies in their historical context, in the same way that the preceding chapter places all three case studies in their scientific context.

In Chapter 5 I present my second case study, the multi-decade debate in the United States over regulating mercury emissions from utility plants under the Clean Air Act of 1970. The Clean Air Act debates over utility-sourced mercury emissions have hinged, at least nominally, on scientific uncertainty, with regulations delayed or weakened on the putative grounds that the science was not settled enough to impose what could be extremely costly control measures on utilities. The debate over utility-sourced mercury emissions cannot be adequately examined on its own; from the Clean Air Act’s creation until the present, a strengthening anti-regulatory movement has emerged and environmental issues have become increasingly polarized, with an executive branch frequently controlled by politicians either unable or unwilling to fully implement Clean Air Act provisions, particularly regarding hazardous air pollutants. As overt attempts to weaken or delay Clean Air Act provisions proved less effective, politicians and policymakers interested in reducing environmental regulations’ burdens on business have turned to discursive practices to discursively frame the debate and manipulate the machineries of regulation to accomplish their goal rather than through direct legislation. Relying on regulatory records, legislative records, relevant case law, and media reports, I
analyze the legal and regulatory evolution of mercury emissions from electric utilities, relating it to wider political debates in the United States that have impacted environmental laws and regulations since the 1970s. Throughout I focus not only on the overt legal and regulatory debates over mercury regulation under CAA, but also examine the “subterranean political processes that shape ground-level policy effects,’ as well as the ways that powerful actors shape and restrict the political agenda” (Layzer, 2012 at 11).

In **Chapter 6**, I present the third and final case study of the dissertation by examining the environmental mercury problem on a global dimension. At the same time that the Clean Air Act mercury battles described in the preceding chapter were working their way through the regulatory process and the courts, mercury regulation debates were also being played out on an international level with the development and passage of the Minamata Convention, a multilateral environmental agreement designed to mitigate the dangers of environmental mercury at a global scale. Signed in Kumamoto, Japan, in 2013, the Convention was the first major global environmental treaty in approximately a decade. Relying on governmental records, independent reports, and semi-structured interviews of key United States negotiators, domestic regulators, and other attendees, I examine the Convention negotiations through an American lens, examining not only the social, cultural, and discursive elements that structured the Convention and led to its successful (at least to most observers) conclusion, but the ground-level practices that shaped the Convention’s creation, and how its course was influenced by American domestic politics.
Finally, in Chapter 7, I summarize the preceding chapters and describe common threads, themes, and connections between each, discuss the difficulties and conflicts inherent in modern environmental governance, and evaluate the utility of the critical realist framework described in Chapter 2. Drawing on these lessons I discuss and compare possible approaches to environmental governance that may draw on these lessons to improve the policymaking process. Throughout the dissertation I tend towards skepticism but not cynicism; while “wicked” problems like mercury are intractable, they are not insoluble, and understanding the complex causal relationships that have driven mercury policy creation may provide help in improving the environmental policy process.

1.3 Research Contributions

While numerous studies have been conducted about various facets of mercury policy by both governmental entities and academics – the subject is fairly well-traveled ground – through these chapters I hope to make several original theoretical and substantive contributions to mercury policy studies specifically, and environmental policy studies generally, namely the following:

(1) By critically examining the philosophical foundations of policy analysis options, I hope to explore epistemological questions that have long been debated in other social sciences but have frequently gone unaddressed in environmental policy analysis, particularly the positivist–interpretivist divide and the possibility of a critical realist synthesis of both approaches. While there is a large body of work on environmental theory on how best to analyze environmental problems – and human behavior related to environmental problems – environmental policy theorists often do not engage with more basic epistemological questions as to the limits of scientific (or social scientific)
understanding of a problem and the methodological impacts of those limits. These issues will be discussed in more detail in Chapter 3 below.

(2) To provide a holistic history of human experience with mercury, tracing the evolving relationship between human beings and the element through history, and examining common threads and themes that arise between the three case studies (Chapters 4 through 6), and discussing what those connections can tell us about environmental governance strategies generally.

(3) By engaging with the legal and regulatory structures surrounding mercury regulation in the United States, I hope to provide a more nuanced view of the constraints on environmental policy creation that exist beyond scientific and social limitations. This includes not only the limitations of the political process, but also how the structure of American laws and regulations can significantly narrow what can be done through federal and state environmental governance, even in the face of wide stakeholder support, and oftentimes in ways the legislators and policymakers never intended. These issues will be discussed primarily in the Clean Air Act case study (Chapter 5), and to a lesser extent in the Minamata Convention chapter (Chapter 6).

(4) By attempting to holistically present the history of mercury use throughout human history, with a focus on the Minamata Bay poisoning and similar environmental poisoning events, and link those events to contemporary cultural conceptions of risk in Chapter 4, I hope to transform cultural or mental models theories into an interpretive tool that can be used to explain social phenomena.
Chapter 2
Mercury Science: A Critical Interdisciplinary Review
2.1 Overview

Mercury is a heavy metal found globally and ubiquitously in the atmosphere, lithosphere, and hydrosphere, though usually in trace amounts. Toxic in most forms, mercury can negatively impact the health of human and non-human populations, most commonly through bioaccumulation and biomagnification processes that concentrate organic mercury compounds into unsafe levels in organisms, including in many fish consumed by human populations. While in recent decades public awareness of the dangers of environmental mercury has led to numerous national and transnational attempts to reduce the amount of mercury that is released into the environment, as well as warn vulnerable populations of its dangers, such actions are significantly hindered by substantial uncertainties in the science of mercury both in terms of how it moves through the environment as well as the levels at which it is likely to negatively impact the health of human populations.

This review examines the current state of the science of mercury, primarily in its biogeochemical cycling and in its attendant health impacts on human and non-human populations, and focuses on those uncertainties that can potentially impact policy and regulation decisions. It is intended to provide a condensed, overhead view of the relevant fields with a focus on breadth rather than depth. This chapter relies on review articles to provide a consensus of what is known and not known about the science of environmental mercury, though original research articles are cited where appropriate to demonstrate specific examples of the topic at issue, to identify important fundamental papers in the mercury science discourse, or to illustrate a point not discussed (or in some cases glossed over or simplified) in the review literature. This review is divided into two parts: the first
examines the mercury biogeochemical cycle, including fate, transport, and control technology, while the second examines the adverse impacts of mercury on human populations and, to a lesser extent, non-human biota.

### 2.2 Basic Characteristics of Mercury

As an element mercury has several unusual chemical properties which impact its movement through the environment. It is one of only two elements, and the only metal, which is liquid at room temperature, allowing it to evaporate relatively easily across temperature ranges found over most of the earth. It is also able to amalgamate gold and silver, meaning that mercury can in effect “dissolve” the gold or silver in ore, leaving most other minerals unaffected. When the liquid amalgam is heated, the mercury will evaporate leaving the gold or silver in a more purified form. As will be discussed later, the use of mercury in gold mining by small-scale artisanal gold miners has become one of the most significant sources of human-sourced mercury in the environment. Mercury exists in seven stable isotopes (or forms with differing numbers of neutrons) and 17 synthetic and radioactive isotopes, with mass numbers ranging from 185 through 206; recent advances in isotopic measurement techniques may provide new tools in measuring environmental mercury and better understanding its movement through the environment.

Mercury’s movement and transformation through the environment as well as its toxicological effects rely primarily on its chemical structure, namely its valence. An atom’s valence represents the number of electrons which can be used to form bonds, and in turn determines a mercury atom’s possible oxidation states, or how many of the valence electrons have been gained (“oxidized”) or lost (“reduced”) from a neutral elemental state. Mercury is found in its fairly unreactive elemental (Hg\(^0\)) form in nature,
as well as in more reactive oxidized monovalent (Hg\textsuperscript{I}) and divalent (Hg\textsuperscript{II}) forms, meaning an individual mercury atom may have lost either one or two of its valence electrons respectively allowing it to form bonds with other atoms (including other mercury ions).\textsuperscript{2} Hg\textsuperscript{II} is the most common stable form found in nature and can be further converted into organic forms, particularly methylmercury, which makes up the primary health risk to human populations; thus, the processes by which mercury is oxidized to Hg\textsuperscript{II} and by which Hg\textsuperscript{II} is reduced back to elemental Hg\textsuperscript{0} or converted to toxic organomercury compounds are areas of significant importance to both researchers and policymakers. As used in this chapter, “oxidized mercury” will refer to the inorganic Hg\textsuperscript{I} or Hg\textsuperscript{II} species, either in ionic form (e.g., Hg\textsuperscript{2+}) or as mercury compounds (e.g., HgCl\textsubscript{2}, or mercuric chloride); some literature refers to this as inorganic mercury or reactive gaseous mercury (RGM), or more commonly in the recent literature gaseous oxidized mercury (GOM). Both oxidized and to a lesser extent elemental forms may attach to particulates in the atmosphere, which are characterized in the literature as particulate mercury, or Hg\textsuperscript{P}.

2.3 Biogeochemical Cycling of Mercury in the Environment

The biogeochemical cycle of mercury – how it is moves through the air, water, land, and through organisms – is a complex process, the understanding of which is currently subject to significant scientific uncertainty. This section first examines the basic chemical characteristics of mercury, its natural and anthropogenic sources, and global distribution patterns, before moving on to two important chemical reaction processes:

\textsuperscript{2} A quadrivalent form (Hg\textsuperscript{IV}) has been synthesized under laboratory conditions under extreme low temperature (Wang, Andrews, Riedel & Kaupp, 2007) and a trivalent form (Hg\textsuperscript{III}) was reported synthesized (Deming et al., 1976) but such synthesis has not been replicated and the original report is considered doubtful (Barysz & Ishikawa, 2010 at 71).
redox reactions and methylation. It then addresses current technological limitations of, and possible means of improving, environmental mercury measuring and monitoring.

2.3.1 Mercury Abundance and Distribution

Mercury is a comparatively rare element, with an abundance of in the earth’s crust of approximately .05 mg/kg or 50 parts per billion (“ppb”), with most of this in the form of mercuric sulfide (HgS), commonly known as the reddish mineral cinnabar (Schroeder & Munthe, 1998). Mercury has a natural biogeochemical cycle, where mercury in the earth is released into air and water, moves through the atmosphere, hydrosphere, and biosphere, and is ultimately deposited into terrestrial or deep-sea sinks, removing it from that cycle (Selin et al., 2008). Because atmospheric mercury can travel long distances, atmospheric transport and transformation of mercury is of special focus in current environmental research.

Mercury is found in the atmosphere predominantly in gaseous elemental mercury (“GEM”) form, or the evaporated form of the familiar silvery liquid, though small amounts of particulate mercury and oxidized forms are also found. GEM is well-mixed in the atmosphere and typically found in atmospheric concentrations of about 1.6 nanograms per meter cubed (ng m$^{-3}$) (Selin, 2009).\(^3\) As oxidized and particulate forms are more likely to be deposited quickly through both wet (precipitation) and dry deposition (settling in gas or particle form), they are found in far smaller, and spatially more variable concentrations than GEM, generally on the order of 1-200 picograms (pg) m$^{-3}$ (typically on the lower end of that range) though there are significant measurement difficulties with GOM that make estimates potentially unreliable (Cheng & Zhang, 2017; Deeds et al.,

\(^3\) A nanogram (ng) is one billionth of a gram; a picogram (pg) is a trillionth of a gram, or having a thousandth of the mass of a nanogram.
Natural emissions to the atmosphere from terrestrial and aquatic surfaces are exclusively in elemental form, while industrial sources such as coal-fired power plants can emit oxidized species directly, though the ratio of elemental, oxidized, and particulate mercury released from such sources is a matter of significant debate in the atmospheric science community (Ariya et al., 2015; Kos et al., 2013).

Concentrations of all species tend to be slightly higher in the northern hemisphere than the southern, and total gaseous mercury levels likely peaked in the late 1980’s before decreasing in the 1990’s (Slemr et al., 2003; Sprovieri, Pirrone, Ebinghaus, Kock & Dommergue, 2010). The chemical species in which mercury is found in the atmosphere may differ substantially between rural and urban areas, with the former tending to have a higher percentage of GEM than the latter (Schroeder et al., 1995).

Trends in mercury emissions inventories are uncertain. While the past few decades have seen a general decline in global mercury emissions due to improved technology and decreased mercury use in industry, increased power plant construction in developing countries, particularly in China and India, as well as the increasing use of mercury in artisanal small-scale gold mining (ASGM), are a cause of concern and may indicate that overall global emissions are rising again, though such determinations are difficult to make in light of significant uncertainty in global estimates and different methodologies used to calculate those estimates (Pirrone et al., 2010; Sprovieri et al., 2010; UNEP, 2013c). While reducing direct anthropogenic mercury emissions may help reduce health risks in the long-term, there is still a large pool of anthropogenic mercury in water and sediments that is continuously being re-emitted to the atmosphere. If mercury emissions are, in fact, increasing, those increased levels are not reflected in measurements in North
America and European monitoring stations at least, possibly due to increased oxidation and thus relatively rapid subsequent deposition (Sprovieri et al., 2010).

Mercury levels in the ocean have been measured at between 0.1 and 2 picomoles per kilogram of seawater (pmol kg$^{-1}$) with most of that consisting of Hg$^{II}$ species, with concentrations varying depending on ocean basin and depth sampled (Lamborg et al., 2014a; 2014b). Converted to units of mass, this would represent between approximately 20 and 410 nanograms of mercury per cubic meter of seawater, representing a generally higher concentration than found in the atmosphere. The oxidized form is readily reduced to elemental Hg$^{0}$, leading to surface waters being supersaturated with that form, with significant evasion of elemental mercury to the atmosphere (Lamborg et al., 2014a). Lamborg et al. (2014a) estimate that anthropogenic input of mercury into the oceans have led to an approximately 150% increase in the amount of mercury in waters above the thermocline, and a 300% increase in the mercury content of surface waters. Most mercury input to the open ocean comes from wet and dry atmospheric deposition (Mason et al., 2012).

2.3.2 **Natural and Anthropogenic Sources of Environmental Mercury**

Mercury emissions to the atmosphere come from both anthropogenic and natural sources. Natural sources of mercury include outgassing from oceans and terrestrial surfaces, volcanoes, and biomass burning, with ocean re-emission being the largest single natural source. Anthropogenic sources include various types of industrial combustion, chlor-alkali plants, medical devices, dental amalgams, cement production, and gold and silver mining. Currently, the largest single anthropogenic source of environmental
mercury is artisanal small-scale gold mining (ASGM), though significant questions remain as to the global, as opposed to local, impact of ASGM-sourced mercury.

Accurately evaluating the relative importance of anthropogenic sources of mercury is difficult, and mercury emissions estimates for various sectors tend to have significant uncertainty which can often range from 25% up to a factor of five depending on the source (Pacyna, Pacyna, Steenuisen & Wilson, 2006; Pirrone et al., 2010). Emission flux estimates from anthropogenic and natural sources have varied, sometimes widely, between contemporary studies (Mason & Sheu, 2002). In 2008 an estimated 2,682 Mg of mercury was released from oceans, out of a total natural emission estimate of 5,207 Mg (Pirrone et al., 2010). Pirrone et al. (2010) concluded that mercury emissions make up an estimated 70% of the global mercury emissions budget at 2,320 Mg yr⁻¹, with the rest coming from man-made sources. These numbers are consistent with the 2,000 Mg yr⁻¹ of anthropogenic mercury emissions estimated by Streets et al. (2011) in 2008, and the 1,930 yr⁻¹ estimated by Pacyna et al. (2010) for 2005. An earlier inventory of anthropogenic sources for 2000 calculated total anthropogenic mercury emissions of 2,190 tons per year, equivalent to 1,987 Mg (Pacyna et al., 2006). Earlier calculations tended to estimate natural mercury emissions at significantly lower levels than more recent figures (Pacyna, Pacyna, Steenhuisen & Wilson, 2006). Despite the wide variability in mercury estimates, recent calculations tend to conform far more closely with each other than early research in environmental mercury levels, where flux estimates varied widely: at one point, estimates of total flux of mercury to the atmosphere were estimated at anywhere from 2,300 up to 190,000 Mg yr⁻¹ (!) (Slemr, Schuster & Seiler,
1985). Anthropogenic mercury emissions to the atmosphere tend to be spatially concentrated, as shown on Figure 2.1.

Figure 2.1. Geospatial distribution of anthropogenic mercury emissions in g/km² (not including emissions from contaminated sites). Figure from UNEP/AMAP (2013, p. 29).

Distinguishing natural and man-made sources can be difficult due to knowledge gaps in terms of biogeochemical cycling. Indeed, a panel convened at the 8th International Conference on Mercury as Global Pollutant advised against using the term “mercury re-emission” because “in most cases” it was impossible to determine whether a source is emitting natural or anthropogenic mercury to the atmosphere (Lindberg et al., 2007, p. 19). Rate of emission can differ even at the same source depending on environmental or geological factors. Mercury emissions from volcanoes, for example, are dependent on whether the volcanoes are in a degassing phase or an eruption phase; volcanoes and other geothermal activities are estimated to release about 90 Mg yr⁻¹ of mercury to the atmosphere (Pirrone et al., 2010).
Mercury’s solubility – or the amount of it that can be dissolved into a solvent like water – varies widely based on its chemical composition and oxidation state, and is a primary driver of transport mechanisms in the atmosphere. Solubility is typically measured in terms of how many moles of a substance will dissolve in a kilogram of the solvent; elemental mercury is fairly insoluble in water, at approximately $3.03 \times 10^{-7}$ mol kg$^{-1}$ at standard ambient temperature and pressure, but oxidized forms have significantly higher solubility (Clever, Johnson & Derrick, 1985). For example, the potentially important atmospheric form of mercury (II) chloride (HgCl$_2$), has a solubility of approximately $2.69 \times 10^{-1}$ mol kg$^{-1}$, (meaning more than 800,000 times as much HgCl$_2$ can dissolve in water as elemental mercury), while mercury (II) bromide (HgBr$_2$), another potentially important oxidized form in the atmosphere (von Glasow, von Kuhlmann, Lawrence, Platt & Crutzen, 2004), has a solubility of approximately $1.70 \times 10^{-2}$ mol kg$^{-1}$, also several orders of magnitude higher than that of elemental mercury (Clever et al., 1985).

Gaseous elemental mercury therefore tends to remain in the atmosphere for long periods of time, but when it loses one or more electrons through oxidation – which occurs in the atmosphere primary through a reaction with another chemical functioning as an oxidant – the more soluble oxidized form will quickly and readily be absorbed into precipitation or onto particles and be transported to the ground and surface waters. The residence time of elemental mercury in the atmosphere, or the average time a mercury atom or molecule will remain before being removed, is estimated to be from 6 months to a year, while the more soluble oxidized and particulate forms are quickly scavenged by
precipitation and removed from the atmosphere, typically in a few weeks (Schroeder & Munthe, 1998).

The two most significant anthropogenic sources of environmental mercury at a global level are stationary combustion (primarily of coal, such as in coal-fired power plants) and artisanal gold mining (Pirrone et al., 2010). Those sources have been particularly prominent in the contemporary global mercury debate, and will be addressed in more detail below.

2.3.3 Mercury from Combustion: Sources and Emissions Inventories

Mercury emissions from stationary combustion sources, largely but not exclusively from coal-fired power plants, make up the largest single anthropogenic mercury atmospheric emission source at an estimated 880 tonnes emitted in 2005 (Pirrone et al, 2010). Mercury emissions from coal combustion vary depending on the mercury content of the coal and the type of pollution control technology available; over the past several decades improvements in emissions controls, principally of particulate matter, sulfur dioxide, and nitrogen oxides, have also reduced mercury emissions in plants that use those controls as a co-benefit (EPA, 2005a; Senior, 2015). China has become the largest mercury emitting nation in the world, largely due to increased energy consumption (Fu et al., 2012). Due to increased energy use, Pacyna et al. (2010) project that absent improvements in emission control, total mercury emissions could increase by 25% in 2020 compared with 2005 inventories in Asia, representing a significant increase in terms of global emissions; however, it is important to note those estimates were made before China both committed to mercury emissions controls in the Minamata Convention, as well as before a massive increase in solar power use (e.g. Giang, Stokes, Streets,
The mercury content of coal is generally high enough that measurement does not entail the difficulties found in measuring ambient environmental levels (Kolker & Quick, 2015). Correspondingly, emissions estimates for stationary combustion of coal make up the most accurate emissions estimates (Pacyna et al., 2010). In-stack flue gas concentrations of mercury are generally 1-30 micrograms per meter cubed (µg/m$^3$) (Galbreath & Zygarlicke, 2000).

Mercury in coal is associated primarily with iron disulfide (FeS$_2$, commonly known as pyrite) and mercuric sulfide (HgS, or cinnabar) components, which evolve to elemental mercury during combustion (Ariya, 2015b; Galbreath & Zygarlicke, 2000; Senior, 2015; UNEP, 2015). As the gas cools, a percentage of this elemental mercury is oxidized through reaction with other substances in plant stacks, most likely chlorine and/or bromine, or attaches to particles created during combustion, primarily fly ash, to form particulate mercury (Galbreath & Zygarlicke, 2000; Senior, 2015; UNEP, 2015). The rate of oxidation in the stack is therefore influenced by the presence of substances such as chlorine and bromine, which is in turn driven by coal composition. Significant uncertainty is associated with the ratio of elemental, oxidized, and particulate forms to each other in most emissions, which is of particular importance to modelling deposition patterns near combustion sources. Laboratory experiments have found that oxidized species at the stack can range from nearly negligible amounts to over 95% (Senior, 2015).

While atmospheric models have typically assumed oxidized forms make up a significant percentage of the mercury found in combustion emissions, recent measurements from the AMNet mercury monitoring network have suggested, at least in the eastern United States and Canada, that elemental mercury makes up 90% of the form
found in emissions (Kos et al., 2013). Reduction of oxidized mercury after it leaves the flue or stack may explain the discrepancy between speciation in the stack and models predicted, possibly through reaction with sulfur dioxide (SO$_2$), but experimental studies of possible in-plume reactions have been inconclusive (Kos et al., 2013). Mercury emissions depends heavily on the mercury content of the coal used, which varies significantly based on geological origin. The estimated worldwide average mercury content of coal is (3±1) X 10$^2$ ppb, though the measured content ranges from 1 ppb to 330 ppm (Ariya et al., 2015b). There is no statistical difference in mercury content between most types of coal, except for anthracite versus sub-bituminous (Ariya et al., 2015b). However, increasing levels of halogens like chlorine or bromine in coal can lead to increased mercury oxidation during combustion practices and easier capture (Kolker, Quick, Senior & Belkin, 2012).

The efficiency of mercury removal varies significantly between plants and is dependent on the type of control technology used and the form of mercury found in the stack before it reaches the pollution control technology. Emissions technologies that impact mercury tend to fall into two categories: combustion controls, which minimize the formation of nitrous oxides through changes to the combustion environment, and post-combustion controls, which remove particulate matter, sulfur dioxide, and nitrous oxides through physical filtering or chemical processes before waste gas is released to the atmosphere (Senior, 2015). An EPA study of U.S. plants found fabric filters typically had the highest removal efficiency, capturing 90+% of post-combustion mercury emissions, reaching an average of 98% when coupled with a spray dryer absorber system or wet flue gas desulfurization systems (EPA, 2005a; UNEP, 2015). Electrostatic precipitators,
which use an electrostatic charge to remove small particles from gas flow without 
impeding that flow, tend to have the lowest removal efficiency by themselves, 
particularly when used with higher temperature gases, though frequently multiple stages 
of pollution control are utilized (EPA, 2005a). Mercury emissions can also be reduced 
prior to combustion through washing mercury-containing non-combustible minerals from 
coal, or through selecting lower-mercury coal, though mercury contained in the organic 
combustible matrix cannot be removed through washing (Kolker & Quick, 2014; UNEP, 
2015).

2.3.4 Artisanal Gold Mining: Sources and Emissions Inventories

In recent years mercury releases to the environment from ASGM have become 
more significant as rising gold prices have led to a global gold rush and a corresponding 
rise in overall use of mercury for gold amalgamation. Pirrone et al. (2010) characterize 
ASGM as the largest single anthropogenic source of global mercury emissions, at 
approximately 1,000 tonnes, and the second largest anthropogenic source of atmospheric 
emissions, at approximately 400 tonnes. Gold is soluble in mercury at room temperature, 
and for thousands of years miners and refiners have added elemental mercury to gold-
containing ore to create an amalgam. Waste materials are removed from the amalgam, 
after which point the mercury-gold amalgam is heated to evaporate the mercury, leaving 
the gold. The amount of mercury used to refine gold varies widely depending on whether 
it is used on whole, unprocessed ore, or whether it is used on a gravity concentrate, where 
higher-density materials such as gold have been mechanically separated to some extent 
from waste materials (Telmer & Veiga, 2009). Whole ore amalgamation uses an average 
of around 5 units of mercury to produce 1 unit of gold, though this number can range up
to 50 units; concentrate amalgamation uses significantly less, typically 1 to 2 units of mercury per unit of gold produced (Telmer & Veiga, 2009). Emissions from individual amalgamation operations vary dramatically depending on how the process is carried out, but unless mercury is captured for re-use or disposal during the process it is inevitably emitted to the environment in some form, whether through evaporation or discharge into terrestrial or aquatic environments.

Understanding the amount of mercury releases from ASGM on a global level is extremely difficult due to extreme uncertainty as to the scope and scale of mercury-using ASGM operations. Attempts to inventory such releases on a global scale have resulted in a range of possible amounts. Telmer and Veiga (2009) estimated that ASGM releases between 640 and 1350 Mg yr\(^{-1}\), with an average of 1,000 Mg yr\(^{-1}\), using various data sources including direct measurements, trade data, and interviews with miners and gold merchants. Of that 1,000 Mg yr\(^{-1}\) 350 Mg yr\(^{-1}\) are directly emitted to the atmosphere while 650 Mg yr\(^{-1}\) are released into terrestrial and aquatic media (Telmer & Veiga, 2009). They estimated another 50 Mg yr\(^{-1}\) of terrestrial and aquatic emissions volatilizes, resulting in a total ASGM-sourced mercury emissions to the atmosphere of 400 Mg yr\(^{-1}\). However, there are significant data gaps rolled into those total source numbers.

For example, faced with uncertain, yet likely high, ASGM emissions in Indonesia, Telmer and Veiga (2009) estimate total emissions at 100 to 140 Mg yr\(^{-1}\), arriving at that number by taking previous estimates for two separate regions in Indonesia, and then doubling those estimates to account approximately for increases in gold prices (and thus presumably increased mining), and additional regions involving mining mentioned by Aspinall (2002) as having ASGM – while at the same time rejecting Aspinall’s estimate
of total ASGM-sourced mercury releases in Indonesia at 1,400 Mg yr\(^{-1}\) as too high. Despite significant uncertainties in their methodology and the substantial amount of guesswork, subsequent reviews of global emissions sources have tended to rely on Telmer and Veiga’s work as the most reliable (Pirrone et al., 2010; Rafaj, Bertok, Cofala & Schopp, 2013).

2.3.5 **Biogeochemical Transformations, Fate, and Transport**

The two most important biogeochemical transformations of mercury are oxidation and reduction (collectively “redox”) reactions, and methylation/demethylation reactions. Significant experimental and theoretical work has been done on both kinds of reactions, with mixed and sometimes ambiguous results.

2.3.5.1 **Redox Reactions**

Redox reactions of mercury species take place both in air and water, with atmospheric processes playing an especially significant part in global fate and transport of mercury. The principal oxidizing and reducing agents of mercury in the atmosphere are yet unknown and this uncertainty in turn makes it difficult to accurately model mercury movement and deposition patterns. Because global movement of mercury is driven in large part by redox reactions, they are a subject of significant study in the atmospheric science community.

The rate at which elemental mercury is oxidized by a potential oxidant is driven both by the reactivity of mercury in relation to that oxidant, which is in turn driven by the kinetic and thermodynamic characteristics of the reactants, as well as the concentration of both mercury and oxidant in the atmosphere (Ariya et al., 2015; Hynes, Donohue, Goodsite & Hedgecock, 2009). Determining what oxidizes mercury in the atmosphere –
and how quickly it is oxidized – is complicated not only by uncertainties in the rate at which different chemicals react with mercury, but also by how the complex mix of chemicals in the atmosphere interfere with or facilitate those reactions (Hynes et al., 2009). Reduction processes are similarly uncertain, though atmospheric reduction is thought to occur primarily heterogeneously in water droplets (Ariya et al., 2015).

One of the most important factors that determine both the relative importance of an oxidant and the rate at which mercury can be oxidized in the atmosphere is the rate coefficient of the reaction. The rate coefficient is a temperature- (and sometimes pressure-) dependent value that determines the rate of reaction between any two specific reactants; given the concentration of those reactants, the rate coefficient allows the determination of the speed at which they will react. Determining the rate coefficient can be extremely complex, particularly in laboratory settings where mercury atoms are in proximity to numerous other trace atmospheric gases, and where reactions might be multi-step, may occur through the collision of mercury and oxidant both in gaseous form, or may occur in or at the border of precipitation or particulate matter (Hynes et al., 2009). Experimental and theoretical determinations of rate coefficients frequently differ significantly both among and between each other, sometimes by many orders of magnitude (Hynes et al., 2009).

Research into oxidation and reduction pathways is typically done through field experiments, laboratory experiments, and theoretical calculations; much of the current debate over redox reactions deals with harmonizing inconsistent results derived from these three methods (Hynes et al., 2009; Subir et al., 2011). Both field and laboratory experiments are hindered by measurement issues (discussed in more detail below) and
uncertainties in the sequence of reactions. Computational methods are complicated by mercury’s high atomic number and corresponding large number of orbiting electrons, which causes its inner shell electrons to move close to the speed of light, creating relativistic effects that increase the mass of those electrons and interact with the valence electrons involved in chemical reactions (Subir et al., 2011). Ab-Initio thermochemistry calculations, based on principles of quantum mechanics, provide tools for calculating, or at least approximating, rate coefficients, but such tools are difficult to use and have not yet been suitably developed to deal with heterogenous reactions (Ariya et al., 2015; Subir et al., 2011).

Early researchers suggested ozone (O$_3$) as the principal atmospheric oxidizing agent, with oxidation occurring primarily in precipitation (Iverfeldt & Lindqvist, 1985; Slemr et al., 1985). Mercury chemistry models have historically followed suit, tending to use ozone as the principle oxidant, with oxidation occurring primarily in water droplets (Hynes et al., 2009; Ryaboshapko et al., 2002). The hydroxyl radical (OH·), a highly reactive molecule that functions as the primary oxidant for many trace gases has also been heavily used in models (Hynes et al., 2009; Subir et al., 2011). Research over the past two decades has cast doubt on the importance of these reactions however: the discovery of atmospheric mercury depletion events (“AMDEs”) in the north polar region has led to a reassessment of mercury chemistry, including the relative importance of homogenous gas phase transformations (where both mercury and the oxidant are in gas phase), as well as the importance of ozone and the hydroxyl radical as oxidants (Hynes et al., 2009).
Reactive bromine and other halogen species such as chlorine and iodine have become increasingly recognized as significant drivers of atmospheric reactions in the troposphere (Saiz-Lopez & von Glasow, 2012). Atmospheric ozone depletion events – where ozone is rapidly depleted through reacting with oxidants in the presence of sunlight – have been observed for decades, and are generally thought to be halogen-driven processes, possibly driven by the halogen bromine as the primary oxidant (Hynes et al., 2009). Schroeder et al. (1998) first discovered mercury depletion events occurring frequently during the spring of 1995 that strongly resembled ozone depletion events. Lindberg et al. (2002) collected similar data, proposing that these events were likely driven by the same chemical mechanisms as ozone depletion events, largely by halogen chemistry. Similar AMDEs have been measured in the mid-latitude atmosphere near the Dead Sea correlated with increases in bromine levels (Obrist et al., 2011). There is significant debate over the fate of mercury removed from the atmosphere by polar AMDEs, including the extent to which mercury scavenged onto snow surface remains there, is emitted, or is transported to surface waters (Poissant et al., 2008). As mercury is readily reduced at surfaces, net oxidation rates are important factors influencing contributions to environmental toxicity through mercury-bromine reactions (Saiz-Lopez & von Glasow, 2012).

While experimental work on AMDEs have provided strong evidence that bromine is a primary oxidant of elemental mercury in regions that can have high level of bromine, like polar regions and the Dead Sea area, studies of bromine-mercury reactions since the discovery of polar AMDEs have also provided evidence that such reactions in the middle and upper troposphere may be a significant oxidation pathway (Coburn et al., 2016;
Hynes et al., 2009; Lindberg et al., 2007). Concurrently with the discovery of AMDEs and the possible bromine-mercury reaction, more recent thermodynamic analyses of the mercury-ozone and mercury-hydroxyl radical reactions have suggested that the latter may not occur under atmospheric conditions to any significant extent (Hynes et al., 2009; Selin et al., 2009). The significance of mercury oxidation by ozone is, however, a matter of intense debate and controversy (Ariya et al., 2015). There is slightly less uncertainty regarding oxidation reactions in atmospheric aqueous chemistry, where ozone probably is the primary oxidant (Hynes et al., 2009).

Photochemical oxidation and reduction both may occur in surface waters (Mason et al., 2012), and oxidation reactions on surfaces or interfaces such as aerosols, lake and snow surfaces may be important generally but there is a significant lack of understanding as to these reactions; however, improved understanding of surface reactions may explain current gaps in atmospheric redox reactions (Hynes et al., 2009; Subir, Ariya & Dastoor, 2011, 2012).

Dry deposition, which occurs when elemental, oxidized, and/or particulate mercury settles to the ground through gravity or diffusion, may drive the largest portion of global mercury deposition, but there is a significantly higher uncertainty inherent in dry deposition estimates than wet, and the relative importance of wet and dry deposition varies regionally (Selin et al., 2008; Zhang & Wong, 2007). Wet deposition of oxidized mercury species has been of greater focus by researchers because those processes are subject to high variability in mercury deposition, such as between high- and low-precipitation regions, and because wet deposition is overwhelmingly in the form of
oxidized species which can be converted to highly toxic organomercury species, particularly methylmercury.

Reduction of oxidized forms to elemental mercury is assumed to occur primarily in the aqueous phase in the atmosphere, but only a limited number of potential reduction pathways have been identified, including decomposition of HgSO₃ or reduction by HO₂, aqueous phase reduction by dicarboxylic acid under sunlight, and all proposed reduction pathways in the atmosphere have significant limitations (Ariya et al., 2015; Subir et al., 2011).

Redox reactions in the ocean are similarly uncertain, and the distribution of mercury species in the ocean is, however, poorly documented (Batrakova et al., 2014; Cossa et al., 2011). Both oxidation and reduction occur simultaneously, at the same order of magnitude, and both may be photochemically mediated (Batrakova, Travnikov & Rozovskaya, 2014; Whalin, Kim & Mason, 2007). As with atmospheric redox reactions, there is evidence that bromine may serve as the primary oxidant of elemental mercury in the ocean, particularly in the mixed boundary layer (“MBL”) (Hynes et al., 2009; Lindberg et al., 2007). The hydroxyl radical may also be a significant oxidant in natural waters, and may also react with halogens like bromine or chlorine to create aqueous radicals like OBr⁻ which then react with elemental mercury or alternately reduce the rate of reduction (Whalin et al., 2007). Recent research has also suggested that some sulfur-reducing bacteria may oxidize elemental mercury directly (Hu et al., 2013). Reduction may be photochemically mediated, and correlated with photosensitive dissolved organic matter (Batrakova et al., 2014; Whalin et al., 2007). Photochemical processes are dependent on the intensity and type of radiation (Batrakova et al., 2014).
2.3.5.2 Methylation and Trophic Pathways

Mercury can be converted into organic form through various natural processes; the most common process is methylation, where oxidized mercury species are converted to methylmercury, a highly toxic organic form of the element that makes up the primary mercury health risk to human populations. Methylation occurs when one or two methyl groups (CH₃) are added via ionic bonding to oxidized mercury; monomethylmercury is the form found primarily in fish, and consists of a mercury compound with a single methyl group added. Methylmercury is efficiently transferred up the food chain through biomagnification processes; predators therefore tend to have higher methylmercury levels than their prey.

Methylation occurs primarily through natural processes in aquatic environments, though mercury can also be artificially methylated, either intentionally to create fungicides, or as a byproduct of industrial processes like chlor-alkali production. As with oxidation/reduction reactions, methylmercury can also be demethylated in the environment through natural processes. Because natural methylation typically requires oxidized forms, the rate of methylmercury creation in the environment is therefore heavily dependent on the interplay of oxidation, reduction, methylation, and demethylation processes, as well as other environmental variables. While there is a great deal of uncertainty about the specific mechanisms that drive natural methylation and demethylation processes, the end results of these processes can be seen in the detectable levels of organic mercury concentrations in fish tissue. Mercury both bioaccumulates and biomagnifies across food webs; bioaccumulation means that organisms can collect and retain mercury over time, while biomagnification means that organisms that
bioaccumulate mercury will pass much of that mercury to other organisms that consume them.

Most methylation of mercury in fresh water and coastal habitats occurs through anaerobic respiration by sulfate-reducing bacteria in sediment (Lamborg et al., 2014; Parks et al., 2013). The exact microbial methylation process remains unknown, though Parks et al. (2013) have identified the genes responsible for it in two sulfur-reducing bacteria. Furthermore, a physiologically diverse group of bacteria and fungi have been observed creating methylmercury in laboratory situations, though the extent to which this happens in the environment has not been extensively investigated (Poissant, 2008). Parks et al. (2013) propose that methylation by sulfur-reducing bacteria occurs through active transport of inorganic mercury through cell walls, followed by methylation in the cytoplasm. Recent research has suggested that anaerobic bacteria can oxidize and methylate elemental mercury themselves, though at a slower rate than already oxidized mercury (Hu et al., 2013). Methylation may be associated with detoxification processes (Batrakova et al., 2014).

Methylation pathways in the deep ocean are less understood, as methylation is observed in the water column where those bacteria are absent (Lamborg et al., 2014). The primary form of methylmercury in the deep ocean is dimethylmercury (Ariya et al., 2009; Conaway et al., 2009; Hynes et al., 2009). Like monomethylmercury, it is probably driven by microbial processes and associated with sinking particulate organic matter (Conaway et al., 2009). Rates of methylation depend on also on physical parameters like pH (Batrakova et al., 2014). Dimethylmercury appears to be quickly converted to monomethylmercury, and may be a significant source of that contaminant in marine
ecosystems. However, dimethylmercury itself does not bioaccumulate (Conaway et al., 2009).

Some researchers have also proposed that non-biological methylation may occur when oxidized mercury forms react with certain organic molecules in fresh and saltwater (Celo, Leach & Scott, 2006). Aerobic respiration, including in coastal and marine surface waters, may also be responsible for methylation of mercury in the ocean, and may also be responsible for significant demethylation (Monperrus et al., 2007).

Bioaccumulation and biomagnification processes are thought to be driven because both inorganic and organic mercury species are lipophilic, meaning they attach to lipids or fats. Methylmercury is transported far more efficiently through food webs, however. Mason, Reinfelder & Morel (1995) propose that inorganic species are sequestered in microbial membranes which tend to be excreted by zooplankton, while methylmercury is far more likely to remain in the cytoplasm and subsequently digested. The methylmercury content of fish and other aquatic or marine organisms depends on multiple factors, with one major one being its trophic level – organisms higher on the food chain tend to have higher mercury content. Methylmercury concentrations in phytoplankton vary but would typically be $10^{5.5}$ times higher than in the surrounding water and constitutes the major trophic biomagnification relationship, while methylmercury concentrations in fish tend towards $10^{6.5}$ times higher than in the surrounding waters (Mason et al., 1995).

The biomagnification of methylmercury through food webs can be reported through trophic magnification factors (“TMFs”), which vary between habitat and trophic community structure, and are reported as the antilog of the slope of the regression line.
comparing chemical concentration with the trophic level of organisms in a food web (Lavoie et al., 2013). Mercury contamination is determined by log\(^{10}\)-transformed concentrations of mercury in nanograms per gram of dry weight, while trophic level is determined by using stable isotope analysis of nitrogen (Lavoie, Jardine, Chumchal, Kidd & Campbell, 2013; Ruus et al., 2015). Typical TMFs for methylmercury can vary widely between food webs, with mean TMFs of 4.3 for freshwater and 6.2 for marine sites, though with high standard deviations representing significant variance between food webs (Lavoie et al., 2013). Higher values represent steeper regression lines and thus more significant biomagnification. A summary figure showing the mercury biogeochemical cycle is shown below as Figure 2.2.

Figure 2.2. A summary of the biogeochemical cycle. Emissions estimate numbers are from Mason et al. (2012).
2.3.6 Measuring and Modeling Mercury in the Environment

As discussed above, the science of mercury biogeochemical cycling is constrained by significant gaps in the understanding of mercury fate and transport. This section discusses the current state of mercury measurement and modeling technology, with a focus on its limitations and possible opportunities to expand technological tools to overcome some of the gaps discussed. It examines current measurement technologies and the limitations therein, current monitoring networks, global and regional models, and stable isotope analysis, a new and potentially useful method of examining mercury transport in the environment.

2.3.6.1 Mercury Measurement Technology - Atmospheric

Due to the low concentrations in which mercury is typically found in the environment, accurate measurement of ambient mercury levels is difficult and subject to uncertainty due to technological limitations and human error. Sampling methodology and detection methods vary depending on the phase and media of the sample tested, but significant time, care, and expertise is required to measure mercury species accurately. Environmental mercury species collected are typically operationally defined – or as the total mercury captured by a specific collection method – rather than by precise chemical species, as there is currently no way to determine the precise mercury compounds found in environmental samples. Elemental, oxidized, and particulate form of mercury exist in the atmosphere; the latter two forms are believed to consist primarily of Hg$^{II}$, though there is no consensus as to what actual Hg$^{II}$ species are being measured in environmental samples (Jaffe et al., 2014).
Measurement and speciation of atmospheric mercury typically involves the capture of air samples from which mercury is collected and pre-concentrated on gold-coated surfaces before being analyzed through atomic fluorescence spectroscopy or atomic absorption spectroscopy (Gustin et al., 2015). Measurement of atmospheric mercury tends to be more standardized than mercury in other matrices, with the most commonly used devices manufactured by Tekran®, including by all major long-term atmospheric monitoring projects, though these may be used in conjunction with other analyzers (Gustin et al., 2015). The primary Tekran® unit pulls air samples in through a heated elutriator, or separation tube, which removes larger particles, and different operationally defined mercury species are collected on various surfaces before the oxidized forms are reduced to elemental mercury and total gaseous mercury is measured (Gustin et al., 2015). Optional speciation units can be integrated to the primary unit to allow separation and measurement of oxidized and organic forms. However, Gustin et al. (2013, 2015) have argued that the Tekran® devices may undermeasure oxidized forms by potentially significant amounts, up to a factor of three, hypothesizing that reactive species might be deposited in-device before reaching the point of measurement, though this position was heavily contested in the atmospheric mercury community (Jaffe et al., 2014; Zhang, 2015). More recent work has supported the contention that there are significant limitations in measuring gaseous oxidized mercury (Cheng & Zhang, 2017; Hynes et al., 2017). The general consensus among atmospheric mercury researchers is that significant uncertainty exists in the accuracy of measuring GOM and PBM due to lack of knowledge as to the chemical species involved, possibility of interference in the measurement devices themselves, and a lack of an accepted calibration method (Jaffe et al., 2014).
Total mercury measurements of which elemental forms make the majority are generally accepted as more accurate than measurement of oxidized forms (Jaffe et al., 2014; Pirrone et al., 2013). GEM may also be measured over large spatial areas through ground-based lidar systems, which provides a 3-dimensional profile of elemental mercury. Lidar works through illuminating a target area with a laser and analyzing the light reflected. Lidar sensing of mercury has a theoretical resolution of about 1 m, with a detection limit of approximately 2 ng; the technique requires advanced equipment and processing, as well as wind speed and direction information (Ferrara et al., 1992; Grönlund et al., 2005). Due to its detection limit, which exceeds average ambient levels, lidar’s effectiveness seems limited to areas with particularly high levels of atmospheric mercury due to mining, industrial, or volcanic activity.

Speciation analysis of solid or liquid samples like sediments, soils, water, and biological materials typically takes several steps: (1) extraction of mercury from the substance measured; (2) concentration/purification/clean-up processes; (3) separation of different mercury species; and (4) detection (Jagtap & Maher, 2015). Separation is typically done through gas chromatography or high-performance liquid chromatography for environmental or biological matrices such as water, sediment, fish tissue, and blood (Jagtap & Maher, 2015). For substances with extremely low concentrations of mercury, such as uncontaminated water, the mercury must be pre-concentrated. Detection limits for these types of environmental samples vary substantially depending on mercury species, sample type, method, and equipment used, but detection limits as low as approximately 25 femtograms (or quadrillionths of a gram) were achieved analyzing reference sediments for methylmercury with inductively coupled plasma mass
spectrometry (ICPMS), though most reported detection limits are significantly higher, even with ICPMS systems (Jagtap & Maher, 2015). The U.S. Environmental Protection Agency has promulgated measuring protocols for ensuring continuing compliance with federal environmental regulations, with detection limits of about 2 ng/L for total mercury in water (EPA, 2002b) and about .01 ng for solids and solutions (EPA, 2007), though methods used for research purposes are generally more precise.

2.3.6.2 Environmental Mercury Monitoring Networks

There is little disagreement that measuring mercury species in the environment is an exceedingly difficult enterprise, with significant room for technological improvement. The expense incurred and expertise required to measure atmospheric mercury at ambient levels has meant that measurements of mercury concentration and deposition are globally limited; while in addition to research project-specific measurements, most long-term monitoring projects cover predominately developed nations in the northern hemisphere, and even in those regions coverage is often sparse (UNEP, 2016). Africa appears to have only two permanent monitoring stations, neither of them in the interior (UNEP, 2016). The European Union created the Global Mercury Observation System (GMOS) in 2010 to combine measurements from ground-based stations, over-water observations, and aircraft, in both hemispheres, including 35 ground-based monitoring stations (GMOS, 2017). The current regional networks do provide valuable long-term data, though spatial and temporal coverage tends to be extremely limited. In the United States, the National Atmospheric Deposition Program (NADP) operates the Mercury Deposition Network (MDN), which provides the only long-term record of total mercury concentration and deposition in precipitation in the United States and Canada, with measurements dating
back to 1996 (NADP, 2017a). In 2009 NADP created a new, more intensive subset of
MDN called the Atmospheric Mercury Network (AMNet) to measure weekly total
mercury in precipitation as well as fractions of mercury in air including oxidized,
particulate, and elemental forms at some locations (NADP, 2017b). The monitoring and
evaluation provisions of the Minamata Convention is likely to provide impetus going
forward for increased monitoring networks and data sharing (UNEP, 2016, pp. 7-8). In
the face of widespread data gaps, numerous deposition models have been created to fill
them, though as discussed below, numerous uncertainties, particularly in chemical
reaction assumptions, limit the utility of such models.

2.3.6.3 Mercury Fate and Transport Models

Numerous atmospheric mercury models have been created to predict transport and
fate of environmental mercury, though the accuracy of those models tends to be limited
due to fundamental uncertainties, particularly in mercury chemistry. Models tend to
incorporate multiple variables, including emission inventories, transport mechanisms,
chemical reactions, cloud processes, and deposition, as well as mercury policy measures
that may impact emissions (Lin et al., 2007). Because of the uncertainties discussed
above, assumptions must be made to fill in the knowledge gaps as to mercury
biogeochemical processes and current and potential future emissions inventories,
particularly regarding atmospheric fate and transport, which drives most of the
transglobal movement of mercury.

Seigneur, Vijayaraghavan, and Lohman (2006), Lin et al. (2006), and Lin et al.
(2007) conducted sensitivity analyses of global and regional atmospheric mercury
models, and found that redox reactions constitute the major source of uncertainty in
models both at a global and regional level. Models can also be impacted by the rapidly changing mercury science literature, particularly concerning redox reactions and redox-driven transport mechanisms. For example, models have frequently assumed ozone to be the primary oxidant both in gas and liquid phase reactions (Bergan & Rodhe, 2001). Ryaboshapko et al. (2002) reviewed five separate mercury chemistry models, showing a significant difference between redox reaction assumptions, with one model (created by the EPA) not incorporating any gas phase oxidation, while the others assumed gas phase oxidation by ozone, two of them exclusively by that reaction, and using the rate coefficient determined by Hall (1995). However, Pal and Ariya (2004) calculated a rate coefficient an order of magnitude faster than Hall’s, and using subsequent experimental thermochemical data, Hynes et al. (2009) showed that it was unlikely that ozone comprises a significant gas phase oxidant of mercury at all. Measuring this oxidation rate is difficult because the reaction is so slow that it is difficult to separate heterogenous chemistry from gas phase reactions. Seigneur et al. (2006) found that using the Pal and Ariya rate coefficient as opposed to the Hall rate coefficient resulted in unrealistically low predicted mercury concentration; they speculated that unidentified reduction processes or higher-than-assumed global mercury emissions could compensate for the faster oxidation rate.

Variables can be constrained by known values (or known ranges of values); for example, rates of oxidation and reduction must be consistent with actual measured concentrations and deposition patterns (Seigneur et al., 2007). However, at present the unknowns across multiple variables are significant enough to weakly constrain several of the more important variables, even within those known constraints. For example, model
rate coefficients of an atmospheric oxidation path might be inconsistent with measured concentrations, but that might be a function of an incorrect oxidant chosen, an incorrect rate coefficient of that reaction, over- or under-estimating the rate of reduction, or incorrect emissions estimates (Hynes et al., 2009; Lin et al., 2007; Seigneur et al., 2007). Unsurprisingly, model predictions are frequently inconsistent with actual measurements, particularly of oxidized and particulate forms. Zhang et al. (2011) tested the dry deposition rates predicted by three models by comparing those rates with field measurements, finding all three models significantly overpredicted surface-layer GOM and PBM concentrations by factors of 2-10 at most of the monitoring locations tested, though GEM measurements were generally within 30% of predictions. The models also differed from each other by up to a factor of 2 regionally, and greater than that locally (Zhang et al., 2012). Kos et al. (2013) suggest model-related overestimation may be related to overestimation of oxidized forms in emissions. Travnikov et al. (2017) also found model-to-measurement comparisons showed significant disparities between predicted and measured reactive mercury. Model-to-measurement comparisons are also made more difficult by the difficulties in measuring oxidized species in the atmosphere described in Section 3.5.1 above (Travnikov et al., 2017). Aquatic and marine transport models have also been created, though they have tended to focus less on global or large-scale regional transport and more on local water bodies such as rivers, lakes, and coastal environments (Massoudieh et al., 2010). As with atmospheric models, uncertainties in redox pathways, emissions inventories, and redox reactions reduce the predictive power of such models (Mason & Sheu, 2002; Massoudieh et al., 2010). In terms of global transport mechanisms, ocean models can inform global atmospheric transport models
through improved estimates of air-sea transport, for example estimates of evasion of elemental mercury from water surfaces. Using a coupled ocean-atmosphere model Horowitz et al. (2017) have recently argued that atomic bromine sourced from marine organobromine sources is the primary atmospheric oxidant.

The significant uncertainties inherent in modeling mercury result in a high level of variation between transport and deposition models. Figure 2.3, for example, shows the different results obtained by three of the major global transport models (GLEMOS, GEOS-Chem, and GMHG). Each model assumes 1875 tonnes per year global anthropogenic emissions, though each assumes different natural and legacy emissions (GLEMOS: 3995; GEOS-Chem: 5070; GMHG: 3660), and assume different oxidants (AMAP/UNEP 2015).

Figure 2.3. Spatial distribution of GEM (first column) and total mercury deposition (second column) according to different model (taken from AMAP & UNEP 2015, p. 16).

2.3.6.4 Stable isotope analysis

In recent years a significant amount of research has been conducted on the mercury biogeochemical cycle through stable isotope analysis, which may offer an
important new tool in tracking mercury’s transformation and movement through the environment. Stable isotope analysis allows researchers to potentially differentiate between pools of mercury in the environment based on the isotopic composition of that pool. While the first experimental differentiation of mercury isotopes through evaporation was done nearly 100 years ago (Brönstead & Hevesy, 1920), it was not until the past decade that technological advances in spectroscopy has allowed the measurement of mercury isotopes at the trace levels found in nature (Blum & Berquist, 2007).

Mercury undergoes both mass-dependent fractionation and mass independent fractionation. Mass-dependent fractionation occurs during certain transformations that favor heavier or lighter isotopes. For example, lighter isotopes of mercury tend to evaporate more preferentially than heavier; evaporating exactly half of a sufficiently large sample of mercury and condensing the evaporated mercury into a separate container would result in two samples that have the same number of mercury atoms but different isotopic compositions and thus different masses. Almost all chemical reactions leave a residual pool with a higher percentage of heavier isotopes (Blum, Sherman & Johnson, 2014; Chen, Hintelmann, Feng & Dimock, 2012). Mass-independent fractionation has also been observed in natural mercury isotopes, and may be based on structural differences between isotopes that impact certain reactions. Mass-independent fractionation has been observed with mercury isotopes undergoing photochemical reactions (Blum & Berquist, 2007; Chen et al., 2012). Mass-dependent fractionation is typically reported as the difference in isotopic ratios between the sample measured and a known reference sample. Mass dependent fractionation is typically reported as the
difference between the measured mass independent fractionation and the same value as predicted by transition state theory (Blum & Berquist, 2007; Blum et al., 2014).

Numerous studies have found that different kinds of anthropogenic and natural mercury reservoirs exhibit different isotopic compositions, making isotope analysis a useful tool for sourcing and tracing the path of mercury through the environment. For example, Sherman et al. (2014) examined precipitation samples in the area surrounding a coal-fired utility boiler in Florida, and concluded that mercury samples near the boiler were isotopically distinct from other sites in the state. Similarly, Foucher, Hintelmann, Al, and MacQuarrie (2013) investigated a watershed in New Brunswick, Canada, that was impacted by mining activities, finding that isotopic compositions between the mercury in leachings and the mercury in groundwater near the mine were similar, suggesting contamination of the latter by mining activities. They also found isotopic characteristics of mercury in surface water changed with distance from the mine, and speculated that this could be a result of reduction and volatilization processes that preferentially reduced and evaporated oxidized forms as the mercury moved further from the mine (Foucher et al., 2013).

Stable isotope analysis of mercury has also been used to examine mercury pathways through food webs in aquatic and terrestrial environments. Tsui et al. (2014) found that isotopic composition of mercury in benthic and terrestrial invertebrates varied significantly, allowing measurement of biomagnification pathways. Day et al. (2012) found isotopic variation in seabird eggs related to distance from shore, suggesting that seabird food from terrestrial/geogenic and oceanic reservoirs could be isotopically distinguished.
While stable isotope analysis has the potential to be a useful tool in examining biogeochemical transport and transformations of environmental mercury, it is likely too early to accurately gauge its usefulness in resolving the current major uncertainties in the mercury biogeochemical cycle, and significant limitations with the method exist. Measuring environmental mercury is difficult enough at ambient environmental levels, and distinguishing the extremely small difference in masses between isotopes adds another layer of measurement difficulties. Still, some researchers have claimed to be able to source mercury based on isotopic signature from centennial to millennial time scales (Enrico et al., 2017; Sun et al., 2016).

2.4 Mercury Health Impacts

Mercury policy at the local, national, and international level is driven primarily by health concerns; however, like the environmental science the health science of mercury has significant gaps in understanding. While mercury has been well-established as a potent neurotoxin at high levels, the health impacts of low levels of exposures is more uncertain. Despite this, numerous governments have implemented regulations that attempt to limit the amount of mercury being discharged into the environment, as well as provide consumption guidelines that attempt to balance the need to prevent adverse health impacts from mercury while retaining the health benefits of eating seafood.

2.4.1 Basic Mechanisms and Clinical Manifestations

The potential adverse health impacts of direct mercury exposure have been known since antiquity, though it was not until the middle of the 20th century that scientists became aware that environmental exposure outside of mining or industrial activities could be dangerous. Awareness of the dangers of environmental mercury was driven
largely by the Minamata poisoning event, when large numbers of residents of a city in
Kumamoto, Japan, suffered from mercury poisoning. The source of the mercury was
traced to a chlor-alkali plant that had been dumping methylmercury-contaminated
effluent into Minamata Bay, where it contaminated fish. Major poisoning events also
primarily due to the consumption of seed grain treated with methylmercury-based
fungicide (Amin-Zaki et al., 1976). While concerns over environmental mercury were
driven originally by poisoning events, the discovery of methylation and biomagnification/
 bioaccumulation pathways in the 1960s led to public health concerns over ambient
mercury levels unrelated to such events. Similar bioaccumulation mechanisms occur
across a wide range of toxics, though evaluating (and regulating) bioaccumulation risks is
difficult (e.g. Williamson, Burton, Clarke & Fleming, 1993).

Detecting methylmercury-induced adverse health impacts can be extremely
difficult due in part to the same difficulties in tracking its movement and transformation
through the environment: mercury levels in the body, even at dangerous levels, are
extremely difficult to detect and there are significant gaps in understanding movement
and chemical transformations in the body. It is quite possible that many incidents of low-
level mercury poisonings have gone undiagnosed, particularly in populations that show
high yet unexplained rates of neurodevelopmental abnormalities (NRC, 2000; Ceccatelli,
Bose, Edoff, Onischenko & Spulber, 2013). Furthermore, in vitro and in vivo studies have
suggested that exposure to methylmercury may have epigenetic effects, changing how
DNA is expressed without changing the underlying code itself and leading to
neurological abnormalities later in life, even where symptoms were not observed in
childhood and even well after exposure to unsafe levels has ceased (Carvan et al., 2017; Ceccatelli et al., 2013).

Toxicity of mercury is heavily dependent on chemical species; for example, consumption of the liquid mercury in a thermometer would likely not cause acute poisoning, while the form dimethylmercury is so toxic that in one reported case a researcher who spilled a single drop of it on her gloved hand suffered severe poisoning resulting in death within a year despite prompt and aggressive medical treatment (Nierenberg et al., 1998).

The residence time and action of mercury in the body depends on route of exposure and chemical species. Elemental mercury in vapor form is well-absorbed in the lungs (75%-85%), while elemental mercury in liquid or vapor form is not well-absorbed in the gastrointestinal tract (<.01%); inorganic mercury is somewhat better-absorbed in the gastrointestinal tract, with 7-15% of mercuric chloride absorbed, with absorption of mercuric salts proportional to their solubility in water (NRC, 2000). Methylmercury is readily absorbed through the gastrointestinal tract, with 95% absorption, as well as through the skin and lungs (NRC, 2000).

The overall half-life of mercury in the body depends on its species and where it is located, with overall half-life of methylmercury approximately 70-80 days, elemental mercury 58 days, and inorganic divalent mercury 1-2 months, though varying estimation methods have resulted in differing results among researchers over time (NRC, 2000; Jo et al., 2015). Half-life can vary significantly, however, depending on how the mercury entered the body and where it is located (NAS, 2000; Jo et al., 2015).
Clinical symptoms of mercury also depend upon route of exposure and chemical species. Mercury has a strong affinity for sulfur – one of the reasons the most common environmental form is mercury sulfide – and tends to bond to the sulfur found in sulphydryl groups, molecular structures that perform important roles in biological function. Methylmercury molecules in the body will therefore frequently bond with biologically important amino acids such as L-cysteine, interfering with metabolic function and forming toxic compounds. Methylmercury readily crosses the blood-brain barrier, possibly using such an amino acid carrier (Wolfe et al., 1998).

Inhalation of mercury vapor has been shown to cause bronchial irritation and peripheral neuropathy, while high levels of methylmercury can result in paresthesia, ataxia, and vision and hearing loss (Clarkson et al., 2003). Perhaps the most serious clinical manifestation of elevated mercury levels can be seen in unborn babies and small children, and pathological studies of mercury poisoning victims have indicated that it affects different areas of the brain depending on age (Myers et al., 2009). Ceccatelli et al. (2013) have also suggested that neural stem cells may be more susceptible to neurotoxic effects from mercury than differentiated neural cells, and exposure levels that have no effect on adults can cause severe developmental abnormalities to children and the unborn, some permanent (Ceccatelli et al., 2013). Most fish advisories are targeted at pregnant women and parents of small children, but determining the exact health impacts of long-term exposure to low levels of methylmercury is difficult and constitutes a major source of scientific uncertainty when regulating mercury. Chronic low-level exposure to mercury through sources such as fish consumption have been linked to
neurodevelopmental delays, increased leukemia and liver cancer risk, reproduction difficulties, and higher cardiovascular death rates (NRC, 2000).

2.4.2 Epidemiological Studies and the Role of Other Nutrients in Mercury Toxicology

The health impacts of acute mercury poisoning are well-known due in large part to studies of poisoning event victims. Of greater uncertainty, however, are the effects of lower levels of exposure that do not necessarily invoke symptoms of mercury toxicity that are less easy to detect. In light of increasing public concern over environmental mercury and its possible impact on human populations that consume seafood, several major longitudinal studies have been conducted on the impacts of methylmercury through fish consumption on child development with varying results. The two most significant were prospective studies initiated in the 1980’s which followed large cohorts of children from birth.

The first large-scale study took place in the Faroe Islands, an area of Denmark with high amounts of seafood consumption, including significant consumption of pilot whale meat typically high in mercury. The Faroese study recruited 1,022 singleton births from 1986-1987; maternal hair and cord blood concentrations of methylmercury were taken and a battery of cognitive tests were given at ages seven, 14, and 22 (Debes, Budtz-Jørgensen, Weihe, White & Grandjean, 2006; Debes, Weihe & Grandjean, 2016; Grandjean et al., 1997). Prenatal mercury exposure (as measured by maternal levels) was associated with decreased performance on numerous cognitive tasks across each examination, though at age 22 years the deficits appeared to be less serious, though still present, and likely permanent (Debes et al., 2016).
A similar longitudinal study in the Seychelles, however, found conflicting neurodevelopmental results even while finding similar levels of prenatal mercury exposure. The Seychelles Child Development study recruited a cohort of 779 children in 1989 to determine the effects of prenatal and postnatal mercury exposure on neurodevelopmental outcomes, with exposure determined by measuring methylmercury hair content, either the mother’s (to determine prenatal exposure) or the subject’s (for postnatal exposure). Neurodevelopmental outcomes were measured through different tests applied at specified endpoints over a period of approximately 24 years (Davidson et al., 2010; Myers et al., 2003; van Wijngaarden et al., 2013; van Wijngaarden, 2017). No consistent patterns were found in the relationship between pre- and post-natal mercury exposure and neurodevelopmental factors or scholastic achievement; small statistically significant associations were noticed for certain cohort demographics on a limited number of tests, but considering the small size of the associations and the fact that some showed a beneficial relationship between mercury exposure and achievement, these were likely statistical artifacts arising by chance.

A third, smaller longitudinal study had been conducted earlier in New Zealand, finding a consistent association between high prenatal methylmercury exposure and lower performance on psychological and scholastic texts (Crump et al., 1998; NRC, 2000). While the study was performed before the Seychelles and Faroe Islands studies, the results were not published in peer-reviewed form until after the two larger studies had begun publishing; while the seafood consumed by the New Zealand cohort and the testing methodologies used were like those found in the Seychelles study, the results were more consistent with the Faroe Islands studies (NRC, 2000).
In the United States, a Congressionally-mandated report by the National Academies of Science’s National Research Council (2000), commissioned to evaluate an acceptable reference dose (RfD) for mercury exposure comprehensively evaluated existing research on the toxicological effects of methylmercury, including the differing results then extant from the Seychelles, Faroe Islands, and New Zealand studies. The report characterized each as “well-designed,” ultimately finding no clear answer as to why the results differed. The report suggested a number of potentially confounding variables may have resulted in different developmental outcomes for the studies, including media (hair versus cord blood) and period of time (third trimester mercury exposure versus total mercury exposure throughout the pregnancy) measured, as well as differences in seafood consumption type and frequency (NRC, 2000). The NRC Report also suggested that certain nutrients, particularly those found in fish like omega-3 fatty acids and selenium could offer protection from methylmercury (NRC, 2000). A subsequent epidemiological studies of a new Seychellois cohort did in fact suggest that prenatal mercury exposure may be confounded by the positive neurodevelopmental impact of nutrients such as iodine and long-chain polyunsaturated fatty acids (“PUFAs”) (Davidson et al., 2008; Strain et al., 2008). While acknowledging the “conflicting results present a vexing choice” for the development of a revised RfD,” the NRC Report ultimately recommended the results of one of the cognitive tests in the Faroe Islands study as the critical study for setting a reference dose, which was consistent with the benchmark dose created by the EPA.

Consistent with the Seychelles and Faroe Islands discrepancy, subsequent longitudinal studies have found mixed results, with some studies showing
neurodevelopmental deficits, with others showing no relation (Gribble et al., 2015). A Polish study found that higher maternal hair or cord blood mercury levels were correlated with a greater probability of delayed psychomotor or mental performance (Jedrychowski et al., 2006). One Italian study found a non-significant association between prenatal mercury exposure and neurodevelopmental factors, but large-scale studies in Italy and Japan found no significant correlations (Gribble, 2015).

The role of different nutrients in human health and development and their relationship with mercury, particularly because some nutrients common in fish (such as selenium, iodine and PUFAs) are likely correlated with improved mental and developmental performance and therefore might explain the discrepancies between studies. Of special importance are PUFAs; seafood has the highest concentration of those nutrients of any food source, and PUFAs have been associated with positive health effects including cardiovascular health and neurological development (Gribble et al., 2015). These effects may explain why mercury levels are not always associated with adverse health effects; for example, Oken et al. (2008) found that increased maternal fish consumption during pregnancy was associated with improved cognition at 3 years, though within the high fish consumption cohort higher mercury level was associated with lower developmental test scores. While the NAS Report offered selenium as one possible protectant against the adverse neurodevelopmental effects of mercury, an epidemiological comparison of the Seychelles and Faroe cohorts found no statistically significant interaction between selenium and mercury (Choi et al., 2008).

If these or other nutrients are responsible for explaining the relationship between neurodevelopmental scores and mercury across studies, the next question to be asked
would be whether such nutrients interfere with or inhibit mercury’s toxicological effects, or whether they simply separately increase neurodevelopmental performance sufficiently to make up for (or more than make up for) mercury’s separate adverse impact. Research into nutrients like PUFAs and selenium that may serve as possible mediating, moderating, and confounding variables in mercury toxicity is hampered by the fact that nutrient levels and mercury levels are rarely measured from the same fish tissue (Gribble et al., 2015).

2.4.3 The Effects of Mercury on Non-Human Organisms

While the biological literature on mercury has focused primarily on human health, mercury levels can significantly impact non-human organisms as well. The impact of heavy metal toxicity on organisms generally varies widely; many organisms, ranging from unicellular bacteria to plants to animals have evolved to neutralize, detoxify, or remove such metals through physiological and biochemical adaptations (Bjerregaard, Andersen & Andersen, 2007 at 258). For example, while selenium’s potentially protective effects in humans is debated, in some other organisms has been found to react with it to form mercuric selenide, a relatively nontoxic species. Nigro and Leonzio (1996) found granules of mercuric selenide in the livers of toothed whales and dolphins, sea lions and cormorants, corresponding with a reduced percentage of the more toxic methylmercury form in those organisms. They note that mercuric selenide granules are not found in baleen whales (Nigro & Leonzio, 1996), suggesting that they are biosynthesized rather than created through non-biological chemical reaction.

Some organisms may be particularly vulnerable to mercury’s effects; for example, birds are particularly susceptible to organic mercury poisoning, and seabirds and other
species which feed at estuaries tend to be among the most contaminated (Boening, 2000). Symptoms of mercury poisoning in birds include reduced feeding, difficulty flying or walking, and impaired muscular coordination, and even where acute symptoms are not present reproduction can be negatively impacted (Scheuhammer, 1987). For mammals, the primary symptom of mercury poisoning is, as in humans, neurological damage, including sensory deficits and behavioral impairment, with smaller carnivores like minks and ferrets more susceptible than larger species (Wolfe, Schwarzbach & Sulaiman, 1998). Through biomagnification and bioaccumulation species, higher-trophic-level species tend to have higher mercury levels. For example, mercury poisoning is thought to be a driving factor in the high incidence of health issues found in the critically endangered Florida panther population, causing the death of at least one and possibly other individuals (Facemire, Gross & Guilette, 1995). However, mercury bioaccumulation and biomagnification processes differ widely by species, habitat, season, and trophic structure (Ruus et al., 2015).

2.5 Conclusion

The ubiquity and potentially serious impacts of environmental mercury on human and non-human populations requires policy decisions to be made at the local, national, and international level. Such policy decisions are hindered by the significant uncertainty as to the entire mercury biogeochemical cycle, as well as in its physiological effects. Both environmental and biological systems are immensely complex and operate in open systems with a multiplicity of causal mechanisms that can interfere with each other. However, certain uncertainties appear more important to resolve in the context of current
policy, regulatory, and legal needs. Resources therefore may be better prioritized for research programs that address these gaps, namely:

1. Significantly increased global monitoring of mercury concentration and deposition rates, particularly in the developing world where mercury emissions from power plant usage and ASGM are increasing;

2. Additional resources dedicated to understanding atmospheric redox reactions, the chemical processes that impact how mercury moves and transforms around the world. Coupled with the results of more comprehensive monitoring, this would improve regional and global mercury models, helping identify regions (and populations) at particular risk from environmental mercury and informing policy decision-making as to regulating mercury emissions; and

3. Interdisciplinary research into the relationship between methylmercury and micronutrients in fish such as PUFAs that may inhibit or compensate for mercury’s potentially toxic impacts, incorporating the work of marine scientists, epidemiologists, and toxicologists. This could facilitate interventions in the form of better localized consumption guidelines that more adequately balance the need to protect human health from mercury’s toxic effects while allowing the health benefits of fish consumption.
Chapter 3
Philosophical Foundations of Environmental Policy Analysis: Can Critical Realism Bridge the Neopositivist/Interpretivist Divide?
3.1 Overview

Environmental policy analysis, whether prescriptive or descriptive, remains plagued with significant failures; we are, generally, poor at prescribing human interventions that can significantly mitigate environmental problems, particularly those “wicked” problems (Rittel & Webber 1973) that defy easy analysis or solution. Environmental policy typically relates to two different types of goals: pollution control and natural resource management. Both implicate complex and interconnecting social and ecological systems that defy easy analysis or solution, and cut across multiple levels of organization both physically and socially – local, regional, national, and international. Designing and implementing (or even analyzing after-the-fact) a given environmental policy effectively often requires not only an in-depth understanding of human behavior and institutions, but also a similarly complex understanding of physical phenomena. Layered upon these uncertainties are the multitude of political and ideological lenses which have seen debates over environmental policy become some of the most contentious political debates on the public stage.

While environmental policy analysts do carry out some their work in the natural sciences, the unified discipline is fundamentally a social science in practice because its primary aims are to describe and prescribe institutions that govern how societies engage with their natural surroundings. As such, environmental policy analysis as a practice also necessarily becomes caught up in recurring debates over social science epistemology, including the fundamental question of whether the researcher’s understanding of the social behavior studied can best be captured through the methodological templates of the natural sciences, i.e., hypothetico-deductive reasoning and empirical verification (or
falsification) of theories, or through more interpretivist methods that focus on the social
construction of reality and meaning, and how problems are defined and communicated by
the stakeholders encountering them. Traditionally, environmental policy analysts have
largely followed the former approach. Under this paradigm, and as implemented in the
modern policy analysis field as practiced by most government and many academic
analysts, the practitioner’s job is to serve as a “neutral” expert who can analyze policy
options and select or help select the optimal choice given the policy goals. Such methods
tend to be focused on quantitative data and statistical analyses, with the presumption that
such methods can be generalized across different times and places to analyze similar
issues. In the policy analysis context, this has been approach has been referred to
alternately (though typically by its critics) as “traditional policy analysis” (Shulock,
1999), the rationality project (Stone, 2002 at 7), or the technocratic approach (Jasanoff,

Though neopositivist approaches to policy analysis are still widely used, they
have been caught up in the same crisis as the social sciences have in general: an
overarching failure to create a predictive science of society or to consistently provide
effective solutions to social problems (e.g. Boguslaw, 1979; Fischer, 1998; Rittel &
Webber, 1973). Analysts can describe but rarely accurately predict, and attempts to do so
through public policy prescriptions frequently fail, either through their own inherent
flaws or because they are either ignored or changed by political actors in ways that
reduce their effectiveness, often intentionally.

In the face of this failure, and objecting to the neopositivist approach as not only
methodologically flawed but also morally suspect, a number of policy researchers have
instead aligned themselves with the interpretivist turn in the social sciences and humanities. Drawing on work done over the last several decades of the 20th century in fields such as Science and Technology Studies (STS) and cultural anthropology, proponents of interpretivism not only see social phenomena as fundamentally different from physical phenomena – and thus requiring a different way of examining it – but also inextricably linked with questions of value that cannot be captured adequately by neopositivist investigation. Extreme versions of this often see neopositivism as unsuitable for both science and social science.4“Interpretivism” covers a significant variety of research theories and methods, ranging from the hermeneutical to critical, but it shares a common set of themes: A focus on the construction and communication of meanings, qualitative research methodologies, a suspicion of naturalistic inquiry, and a greater willingness for the social scientist to explicitly engage with normative questions.

This chapter attempts to do three things: (1) Describe the two major competing philosophical approaches to environmental policy analysis, neopositivism and interpretivism, situating each in their philosophical and historical context; (2) Propose an alternate philosophical foundation to environmental policy analyses, critical realism, a meta-theory that seeks to engage with a naturalist reality while recognizing the epistemological limitations of knowing that reality; and (3) Conclude with some examples of what a critical realist approach to environmental policy analysis might look like, and how such an approach would differ from primarily neopositivist or interpretivist

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4 Such beliefs are common in postmodernist/post-structuralist and critical research programs. These paradigms are sometimes distinguished from interpretivism, though the boundaries between them and more “traditional” interpretivist approaches are often blurred or amorphous, particularly in applied social science fields like policy analysis. For the purposes of this paper, I group postmodern and critical approaches to policy under the interpretivist umbrella; to the extent that extreme relativist versions of those paradigms do not qualify as “interpretivist,” they are not particularly relevant to environmental policy analysis.
approaches. Some of the examples set forth here to illustrate different approaches are
taken primarily from environmental policy in the United States, particularly at the federal
level, though the philosophical debates discussed are global in scale and not restricted to
a specific political or cultural milieu. A significant amount of work has already been
written on the debate between neopositivist and interpretivist approaches to policy
analysis, as well as on the critical realist alternative to those approaches. Here I attempt to
offer an original contribution to the literature by collecting, condensing, and analyzing
both subjects in the specific context of environmental policy analysis as a field.

3.2 Neopositivism and the Birth of the “Policy Scientist”

The 20th century saw the convergence of unprecedented changes to the physical
and social environment. Two centuries of industrial growth and scientific development
had both fundamentally reshaped the physical environment at the same time it provided
resources for rapid population growth across the world. Improving transportation
networks led to increased economic ties between often far-flung areas of the earth.
Concomitant with the rapid spread of industrialization has been growth in the size and
responsibility of national and local governments as increasingly complex and spatially
expanding economic and transportation infrastructures, including the massive
mobilization of both human beings and industrial capacity needed for the two world wars.

The growing success and prestige of the natural sciences and cognate engineering
fields inspired social thinkers to mimic their methods when attempting to derive scientific
“laws” regarding social behavior that could be applied to an increasingly more complex
social sphere. While a-deductive approaches to problem-solving in the natural sciences
had largely driven the scientific revolution, prior to the late 19th century approaches to
analyzing social institutions had remained largely the province of philosophers. However, by the late 1900s a founding generation of social scientists, inspired by the synergetic success of the rapidly developing science and technology of the time, proposed a new course for those studying the social. The founder of this “scientific” approach to social science, Auguste Comte (1865/1848), proposed that both the natural sciences and the “human” sciences shared a positivist epistemological framework, an assumption that was seized upon by many in the rapidly expanding social sciences. As Rabinow and Sullivan put it (1979, p. 1), “[a]s long as there has been a social science, the expectation has been that it would turn from its humanistic infancy to the maturity of hard science, thereby leaving behind its dependence on value, judgment, and individual insight.”

Fischer (1998, pp. 143-144) provides a useful definition of the neopositivist approach as it became expressed in the policy analysis field as “the modern-day embellishments of ‘positivism,’” incorporating two main prongs: (1) it assumes knowledge of social phenomena can only be reliably gained through following traditional natural or formal “scientific” methods of “empirical falsification [or verification] through objective hypothesis testing,” with the goal of generating empirical explanations of human behavior that can be applied across cultural and historical contexts; and (2) it enforces a “rigorous separation of facts and values,” where the investigator sees her job solely as establishing those empirically derived facts without any “normative context or implications.” Normative aims, to the traditional neopositivist policy analysis, are to be decided by political actors such as elected officials. In terms of environmental health risks, for example, the neopositivist policy analysts’ job is to quantify those risks, then create or select the most effective means to ameliorate that risk based on the normative
instructions given by the normatively empowered policymaker or politician – whether it is to reduce the chance of harm to a specific probability, or to compare the costs and benefits associated with harm reduction strategies.

Both prongs of the neopositivist approach are heavily influenced by the work of the philosopher David Hume. Hume argued that to establish that one event caused another, the observer could only infer such a causal relationship from observation of “constant conjunction” between the possible cause and the possible effect (1748, p. 148). Even then, according to Hume, there is no way to conclusively demonstrate matters of fact because at some point that constant conjunction must fail. Philosophers of science would refine the Humean proposal, most famously Karl Popper who extended and formalized the thesis by arguing that scientific discovery could in fact only be carried out through falsification of hypotheses, with the ones that survive such falsification accepted as provisionally but never conclusively true (Popper, 1959). Hume was also influential in establishing that scientific (or any other kind) of factual inquiry could not discover moral truths, or that you could not go from “is” to “ought” (1738/2007, p. 302).

In the United States, the positivist European sociology was adapted along with a burgeoning field of “scientific management” theories as well as parallel movements developed in the private sector to increase industrial efficiency (Waldo, 2006, pp. 40, 47; Stone, 2002, p. 7). In the political sphere, Progressive Era thinkers and politicians sought to bring about good (and efficient) government by shifting policymaking authority from frequently corrupt elected bodies to putatively neutral professional experts (Waldo, 2006, p. 40; Stone, 2002 at p. 7).
As the regulatory state grew through the 20th century, the quantitative social sciences and “scientific management” practices of industry and governments converged into a syncretic, specialized field of “policy science.” Its early theorists, most prominently the political scientist Harold Lasswell, articulated a “policy science” paradigm that saw the policy analyst’s job as establishing the “empirical validity” of policy options (Lasswell, 1971, p. 24) through a process modeled on the positivist assumptions underlying the natural sciences.

There are two central assumptions of most neopositivist policy analysts that fundamentally direct how they practice. The first is that policy is – or at least should be – follow a “policy cycle,” where policy development is done through a series of discrete stages that separate factual determinations (to be made by the “policy scientist”) from value determinations (to be made by political actors, presumably democratically elected ones). The “policy cycle” idea is based on both the neopositivist search for “covering laws” that can be employed universally, as well as its separation of factual determination from value judgment. The second is the rationalist belief that individual actions take actions consistent with maximizing their own gains; adopted largely from economics, this “rational-actor” model drives a significant amount of policy decision-making, and is frequently expressed through another policy tool out of economics, cost-benefit analysis.

The primacy of neopositivism in governmental policymaking is not particularly surprising; politicians tend to want a definitive answer to policy questions defensible with quantitative data. In the United States especially, another factor driving the neopositivst dominance may be the fact that many non-positivist theoretical approaches draw from social science traditions that are politically fraught in that country, where relativist forms
of inquiry have historically been viewed with suspicion, at least until recently, by those on the political right. Furthermore, incorporating diverse stakeholder meanings into environmental policy discussions can also be counterproductive for regulated industries that oftentimes wield outsized influence in policy debates, and are often able to leverage significant technical expertise to prepare putatively “objective” analyses of policy options that benefit those industries – particularly when rulemaking authority is held by politicians skeptical of environmental regulations to begin with (Layzer, 2012; Mintz, 2012). Disciplinary factors also play a large role; environmental policy analysis is frequently conducted by engineers, natural scientists, and economists who are more comfortable with using quantitative data to probe naturalistic causal mechanisms than they are with deconstructing stakeholder meanings and interests, and who tend to see their factual inquiries as free (ideally) from political concerns that may impact those findings. Furthermore, and particularly important for environmental policy analysts, the neopositivist approach can in some cases be built into law and policy (Ascher et al., 2011). In United States federal courts, for example, the admissibility of scientific evidence is determined by the Court. In Daubert v. Merrell the United States Supreme Court held that in determining admissibility a “key question to be answered . . . will be whether it can be (and has been) tested,” and explicitly quoted Karl Popper for the proposition that “[t]he criterion of the scientific status of a theory is its falsifiability, or refutability, or testability.” (Daubert v. Merrell Dow Pharmaceuticals, 1993).

3.3 The Interpretivist Turn

While it remained the dominant approach in the social sciences generally up until the second half of the twentieth century, neopositivist approaches to examining human
phenomena and prescribing human actions failed in large part to fulfill Comte’s vision of precision and reliability. Though the positivist approaches to policy analysis are still widely used as an evaluation tool, particularly in governmental agencies, and taught to undergraduate public policy students, such an approach has been caught up in the same crisis as other social sciences: an overarching failure to create a predictive science of society or consistently provide effective solutions to social problems (Boguslaw, 1979; Fischer, 1998; Rittel & Webber, 1973).

Furthermore, the sociological critiques of science developed after Kuhn’s groundbreaking 1962 *Structure of Scientific Revolutions* also called into doubt many of the epistemological assumptions of the natural sciences themselves, further weakening the argument that the natural sciences should serve as a normative ideal for the social ones (Kuhn, 2012; Sismondo, 2008). Science and cognate technical fields held a privileged position since the Enlightenment; Comte saw natural science as the ideal template for the social sciences precisely because of that apparent success. For Kuhn and his successors, rather than be an objective and continuous refinement of empirically-based models that are tested objectively against the natural world, science is a social process in which the scientist is caught up in the scientific paradigm in which she works; in the Kuhnian view, scientists debating opposing theories arguing for different theories “see different things when they look from the same point in the same direction.” (Kuhn, 2012, p. 150).

Kuhn’s work inspired a revolution in the sociological and historical study of science and contributed to the formation of the field of Science and Technology Studies
which explores, among other things, the social construction of science and scientific practice. That field in turn helped create a skeptical attitude towards traditional scientific methods across a wide swathe of other social science practitioners, including public policy researchers: If neopositivism did not even produce what its proponents claimed it did for the natural sciences, how could it do so for the social ones? For the environmental policy analyst called on to investigate both natural and social systems, the STS project complicates both analyses.

In addition to the perceived epistemological shortcomings in the traditional social sciences in general, critics have attacked it for divorcing ethical judgments from “policy science” and privileging expert decision-making, questions of value can be recharacterized as scientific or technical questions and thus removed from democratic control (Amy, 1984; Durning, 1999; Hawkesworth, 1988 at 6; Jasanoff, 2009, p. 229). Indeed, not only can those questions of value be redefined, but even hidden – as Daniel Sarewitz notes, the “risk for society . . . comes from pushing the political into the black box of the technical, thus making it invisible to democratic actors.” (Sarewitz, 2016, p. vi). This is especially true for what the physicist Alvin Weinberg (1974, p. 209) famously referred to as “trans-scientific questions,” or questions of fact that be asked of, but not answered by, science due to factors such as logistical impossibility or because they cannot be separated from questions of value.

Extensive historic accounts support such arguments; the perceived strength of natural science methodology also increased its value in policy debates as a rhetorical weapon: “Because science is highly valued as a source of reliable information, disputants

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5 Also referred to as Science, Technology and Society by some practitioners.
look to science to help legitimate their interests” (Sarewitz, 2000, p. 83). The historical record is replete with examples: Sheila Jasanoff, for example, has detailed how environmental policy participants often try to gain control of debate by characterizing key issues as either policy or science when they are at the boundary at both (Jasanoff, 1990). Similarly, examining the historical development of United States federal environmental regulatory apparatus since, Judith Layzer found much of putatively “scientific” debate existed instead as “struggles to define problems and characterize solutions within a rhetorical and institutional context” (Layzer, 2012, p. 11).

The perceived shortcomings of the neopositivist project in the social sciences generally has led to an explosion of theories and methods to explore human behavior that reject positivism, mostly under a postpositivist umbrella focused not on quantitative analysis or the derivation of universal social laws, and more on the “interpretation” of the subjective human meanings of those involved in, or impacted by, policy (or proposed policy). Applied to policy analysis, this interpretivist approach engages more explicitly with stakeholder values and systems of meaning, with its “central question . . . How is the policy issue being framed by the various parties to the debate?” (Yanow, 2000, p. 11). The interpretive turn in social science necessarily repudiates both prongs of the neopositivist project. Rather than conceive of social phenomena as amenable to the same investigative methods as physical phenomena, the interpretivists see such phenomena as driven largely by – and existing in – human meaning, values, desires, and discourses, or the “web of language, symbol, and institutions that constitut[e] signification.” (Rabinow & Sullivan, 1979, p. 4).
3.4 The State of the Environmental Policy Field

This neopositivist-interpretivist divide in environmental policy approaches leaves two overall approaches that offer insight into policy descriptions and prescriptions that exist in tension. The neopositivist framework provides, on its surface, quantitative rigor of the natural sciences, which may become more useful in light of computational advances, the increasing availability of large datasets, and insights from recent – and fruitful – experimental research into judgment and decision-making (e.g., Kahneman, 2011). At least in theory, this approach is more scalable and amenable to comparative analyses. However, it also tends to reduce complex social and natural phenomena to simple models or equations that are parsimonious but unreflective of social-ecological complexities, and susceptible to politicization. And when faced with environmental policy failures, neopositivist approaches therefore tend to focus on improving either the tools of environmental policy analysis (e.g., models, monitoring methods, or statistical methods) or improving the policy process itself in a way that increases incorporation of scientific and technical expertise (e.g., increased reliance on the “best available science”). Those utilizing this approach “have not abandoned the hope that the instruments of perfectibility can be perfected” (Rittel & Webber, 1973, p. 158).6

The interpretivist framework gives the environmental policy analyst improved tools to both examine how individuals involved in or impacted by policy decisions, and

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6 For example, when Peter House and Roger Shull, two government scientists with collective decades of experience in policy analysis at the EPA, attempted to summarize the field in their 1991 book, *The Practice of Policy Analysis: Forty Year of Art & Technology*, they divide the history of Federal “policy analysis” into eras based on the types of quantitative models used – and propose that past limitations in the value of those models may be remedied by increasing computing power. Reflecting the neopositivist discomfort with questions of values, they suggest issues “dominated by moral perspectives” are often not amenable to policy analysis (p. 25).
to cast a more critical eye on the political and ideological interests and strategies used to
direct the policy process. This has allowed interpretivist-minded analysts to draw out
value judgments from putatively “value-neutral” policy choices and show how they
influence policy decisions. However, as too often practiced, the moral dimensions of
policy choices remain caught in the center of the interpretivist project, defined by Yanow
(2000, p. 5) as the “presupposition that we live in a social world characterized by the
possibilities of multiple interpretations.” As a result, interpretivists frequently articulate
stakeholder values without evaluating their rationales. Furthermore, an overly
interpretivist, critical focus on the meaning has often led to ignoring the extradiscursive
reality of the physical world, with scientific research often cast as a mostly – or even
completely – social activity that displaces alternate and equally valid forms of
knowledge. An environmental policy to reduce public health risks of a contaminant is
only successful if it in fact reduces that health risk, and the measures taken to do so do
not cause greater damage elsewhere, and not simply if the policy has wide approval or
public acclaim.

However, mirroring neopositivists, many interpretivists see policy failures as
tending to arise from a failure to be interpretivist enough – in other words, properly
understand and incorporate stakeholder understandings into policy development. They
therefore urge increased focus on understanding and incorporating impacted stakeholders
in environmental policy decisions, often calling for an “argumentative,” “deliberative,” or
“discursive” approach to policy analysis and development (Fischer & Gottweis, 2012;
Hajer & Wagenaar, 2003; Fischer, 2003). By embracing rather than trying to exclude
rhetorical and discursive contention, these theorists seek to create procedures that would
make such debates transparent and subject to democratic control and procedural equity. Such approaches take different forms, but are often modeled on the idea of argumentation undertaken by legal arguments in the courtroom, incorporating analogues of rules of evidence, and seeking to “move the policy evaluation process towards a judicious mix of pragmatism and rigour” (Fischer, 2003, p. 187). Is embracing an adversarial process of democratic engagement by stakeholders, constrained by fair and transparent inclusion, as a model for environmental policy a way forward? Historical evidence suggests that in many cases, no. Certainly anyone who has practiced law knows that the outcomes of court cases frequently lack either pragmatism or rigor, evidentiary rules are often subject to abuse or manipulation, and economic disparities between litigants are too often dispositive of cases. Jasanoff (1990, p. 246) objects to submitting such policy disputes to adversarial processes, arguing that they “promote[] an unproductive deconstruction of science and fosters the appearance of capture.” An “argumentative” development process also appears to suffer the same problem as the focus of interpretivist approaches generally: it tends to measure success in terms of collective stakeholder satisfaction; a defensible goal when satisfaction is the main or only goal, as in Yanow’s interpretive analysis of public satisfaction with a local community center (2000, p. 33), but not when the protection of health or safety is dependent on physical phenomena that cannot be adjudicated away.

The two paradigms exist in tension. Generalizable theories based on sociological, economic, and psychological phenomena arise out of the neopositivist project before frequently falling by the wayside as they prove inadequate at predicting human behavior or adequately addressing environmental problems (e.g. Rittel & Webber, 1972; Shulock,
Interpretivists can dismantle neopositivist assumptions that social and natural phenomena can be objectively understood and predicted by a neutral researcher, but a focus on meaning and discourse frequently leaves little room to predict or prescribe policy.

So given these two dominant paradigms, and operating under the almost inescapable conclusion that environmental policy has been less than successful, how should a policy analyst proceed? Addressing the “ongoing quarrel” between positivists and interpretivists, Gorski (2013, p. 660-61) cautions that it “did not prevent social scientists from producing valuable research . . . [and] [w]e have learned to glide through social reality with some skill.” But according to Gorski, this is only because social researchers “have unlearned” what they were taught and passed the “tacit knowledge of good research practice on to others” (2013, p. 661). Similarly, environmental policy analysts on both sides of the divide have done important, and occasionally successful work – in the sense that they accomplish many or all of their objectives – through a pragmatic engagement with environmental problems in their particular social, scientific, and geographical contexts. In recent decades government-based environmental policy analysts have become more accepting of approaches that accomplish this, such as improved stakeholder involvement, collaboration, and adaptive management.

Academic policy analysts and theorists have often been on the forward edge of these developments, developing elaborate methods that go beyond the policy cycle concept and seek to more effectively navigate the tensions between technocracy and democracy, developing critiques and proposing solutions to retain scientific rigor while increasing transparency and public involvement in policy (e.g., Ascher et al., 2011;
Guston, 2013). Such approaches are, of course, easier said than done. Ascher et al. (2011, p. 190) propose that reforming environmental policy institutions requires a “hybrid of formal science, local knowledge, and public preferences,” but figuring out exactly how to arrange that hybrid is difficult. Local knowledge may be valuable for policy decision-making, but contra some extreme relativist versions of interpretivist research, it seems unwise to incorporate its factual conclusions into policymaking simply because it is local knowledge (and thus stakeholder meaning). Harry Collins and Robert Evans refer to this as the “Problem of Extension” (2002): Even accepting STS critiques of scientific claims to objective truth, and the need to incorporate democracy into policy science discussions, policymakers are still left with the question “How far should participation in technical decision-making extend?”

The greater the level of hybridity – the more an environmental problem implicates a complex mixture of natural and social phenomena as well as questions of value – the greater the chance that policy analyses and prescriptions fall within the neopositivist-interpretivist gap. While there are, of course, no easy answers, a different epistemological approach may help in bridging this divide.

3.5 Critical Realism as an Alternate Philosophical Framework

Just as “neopositivism” and “interpretivism” as used here encompass broad groupings of theoretical and methodological approaches to policy analysis, “critical realism” has various different forms and practices, though the modern intellectual movement whose founder is generally considered to be the British philosopher Roy
Bhaskar. A full philosophical treatment of critical realism is well beyond the scope of this paper, though I will briefly summarize some of the primary principles that Bhaskar initially developed. These initial principles and their implication for practice have been largely (though not universally) retained by other critical realist scholars as the core components of the metatheory, and which may have special import for environmental policy analysis. Bhaskar’s later work has generally not had the same impact as his earlier work, and as a result modern critical realism in the social sciences tends to follow that earlier work, as augmented and extended by other theorists (e.g. Gorski, 2013; Sayer, 2000, p. 170).

3.5.1 Roy Bhaskar and the Development of Critical Realism

The beginning of critical realism dates largely from 1974, when Bhaskar published *A Realist Theory of Science*, in which he proposed a “comprehensive alternative to the positivism that has usurped the title of science” (Bhaskar, 2008, p. 1). Like many of his contemporaries, Bhaskar was skeptical of the positivist epistemological tradition in science, but he also did not see any of the alternative theories of the time as an adequate replacement epistemology for the sciences. While it was clear to him that the positivist principles were unsustainable, interpretivist approaches (he referred to them as hermeneutic) were also problematic; he thought both approaches suffered from what he

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7 This should be distinguished from the identically-named philosophical movement of the early 20th century, epitomized by such thinkers as Roy Wood Sellars, Maurice Mandelbaum and George Santayana, though there are some common threads between both movements (Verstegen, 2010).
8 For a more comprehensive introduction to critical realism, see Archer, Bhaskar, Collier, Lawson and Norrie (1998), Collier (1994), and Sayer (2000).
9 A number of other thinkers have developed similar realist alternatives (e.g., Hacking, 1983; Putnam, 1981).
10 Natural scientists have generally paid little attention to Bhaskar or most philosophers of science, though many have engaged critically to some extent with Popper and Kuhn. (e.g., Sokal & Bricmont, 1997).
referred to as the “epistemic fallacy” – the reduction to or analysis of the world and the things in it to statements about knowledge (Bhaskar, 2008, p. 26).

To avoid this epistemic fallacy, Bhaskar argued for a re-engagement with ontology, or the study of what exists in reality, unmediated by the human perception or conception of it. Traditional epistemological questions such as “How can we trust our senses?” or “How accurately does our knowledge represent actual reality?” have been a subject of debate for thousands of years. Bhaskar inverted that question, approaching it from an ontological perspective, asking: “What must the world be like for knowledge of the world to be possible?” Focusing on the practice of science in the real world rather than as abstract “observation,” Bhaskar reasoned that scientific experimentation presupposed both the existence of an actual reality with structures and causal mechanisms that existed whether we perceived them or not. Rejecting the Humean position that causation could only be explained in terms of “constant conjunctions of events,” Bhaskar reasoned that such causal reasoning could only hold true in closed systems (like scientific experiments). In other words, that a meteorologist found that at a specific time a sudden decrease in air temperature did not result in rain does not mean that decreasing temperatures cannot cause rain, but simply that some other causal mechanisms (whether detected or not) counteracted that tendency.

Rather than a “flat” reality populated by phenomena and our observations of them, Bhaskar proposed instead a stratified reality, one that had to be distinguished from our knowledge of it. He did this by first dividing “objects of knowledge” into the intransitive and the transitive. Transitive objects of knowledge are, according to Bhaskar, “the artificial objects fashioned into items of knowledge by the science of the day”
These are the products of scientific inquiry, things like facts, theories, models, and methods. Intransitive objects of knowledge, on the other hand, are the unchanging characteristics of the real world, unaffected by our interpretation or understanding of it. Bhaskar then created a further layer of differentiation between “three overlapping domains of reality”: the real, the actual, and the empirical (Bhaskar, 2008, p. 46). The real consisted of everything that exists, whether social or natural, and including mechanisms, powers, and relations, whether they have been expressed or not (or observed or not). The actual consists of those things in the real that have been expressed. The empirical makes up a narrowed subset of the actual, consisting of expressions that have been observed. From these starting points, he established the concept of emergence: Strata of reality are dependent on a lower level, but irreducible to it (2008, pp. 160-161). Causal mechanisms in one strata cannot explain a more advanced one; the common example is knowing the structure and dynamics of hydrogen and oxygen atoms cannot allow one to adequately explain the emergent properties of water (e.g. fluid mechanics).

It was in Bhaskar’s second work, The Possibility of Naturalism, in which he placed the social sciences into the same realist framework, work that would ultimately spark a cohesive realist movement among philosophers and social scientists. Bhaskar did this by asking a question similar to the one on which he premised his realist theory of science: “What properties do societies possess that might make them possible objects of knowledge of us?” (Bhaskar, 1979, p. 31). He answered the question similarly, but not identically, to the analogous question he asked about how we could understand the natural world; as with his epistemological approach to scientific inquiry, Bhaskar saw the social scientist’s job as seeking to articulate the causative mechanisms of social
phenomena rather than simply follow a neopositivist search for constant conjunctions, with the understanding that like many natural systems, social systems were open. Social phenomena, like natural phenomena, were ontologically stratified and marked by emergent levels that were dependent on more basic levels, but irreducible to them. Just like the behavior of water could not be explained in terms of the structures of hydrogen and oxygen atoms, societies could not be explained in terms of the behavior of individual actors.

For Bhaskar, however, the social world had a large caveat: Social structures, unlike natural ones, could not exist outside the actions of human actors. That did not mean, however, that such social structures and mechanisms did not have an independent existence; Bhaskar explicitly rejects Karl Popper’s maxim that “all social phenomena, and especially the functioning of social institutions, should be understood as resulting from the decisions etc. of human individuals.” (as cited in Bhaskar, 1998, p. 208). But he also rejects the opposing view represented by structuralists like Emile Durkheim (and taken up in the past couple of decades by numerous post-structuralists and postmodernists) that individual human behavior was largely driven by the social structures of which they were a part. Proposing what he called a “transformational mode of social action,” Bhaskar theorizes that the existence of social institutions prior to human interaction with them rendered their study possible; just as with natural scientific inquiry, critical realist social scientists could examine social behavior in terms of causal mechanisms involved in an intransitive social system that could be explained in terms of causal mechanisms and emergent properties. Critiquing the second neopositivist prong of the fact-value dichotomy, Bhaskar suggested that factual investigation could have a
normative effect in the form of an “emancipatory potential . . . contingent upon, and entirely a consequence of, its contextual explanatory power” (Bhaskar, 1979, p. 32). Better explanations of causal mechanisms can free the members of society from illusions that can hinder wellbeing.

Bhaskar’s influence on practicing natural scientists was minimal, but with philosophers and social scientists his theories received far more attention. Though much of the postmodernist/poststructuralist turn in social science came after, Bhaskar’s work generated powerful critiques of that turn (e.g., Sayer, 2000).

3.5.2 Critical Realism: Implications for the Environmental Policy Analyst

The critical realist approach combines for both the natural and social sciences what Bhaskar referred to as the “‘holy trinity’ of critical realism” (Bhaskar, 2010, p. 1; see also Archer et al., 2016):

1. **Ontological realism**: much of reality exists outside our awareness, observation, or knowledge of it;
2. **Epistemological relativism**: any understanding of that reality we gain is fallible and always conditioned by our historical, social, and cultural context; and
3. **Judgmental rationality**: despite this fallibility, there are logical criteria for distinguishing between better and worse accounts of that reality.

For the environmental policy analyst analyzing natural, social, and hybrid phenomena, these three foundations offer if not a well-specified theoretical or methodological framework, a general guideline both to choose such frameworks, and a mandate to focus her research on understanding causal mechanisms and the emergence of phenomena from a multiplicity of those mechanisms.
While this may seem uncontroversial, particularly to the policy analyst, the critical realist position goes against centuries of neopositivist assumptions and methods in both the social and natural sciences that are used in policy analysis. The Humean search for constant conjunctions is perhaps most strongly reified in correlational statistical methods like regression models, methods which lie at the core at both natural and social scientific fields heavily invested in the environmental policy domain, as well as hypothesis testing. As Gorski (2013, p. 663) states it, “[t]he ghost of logical positivism still haunts contemporary discussions of methodology.” Furthermore, given the multiplicity of potential causal mechanisms in open systems (like most social-ecological systems), analysis often requires “a diachronic explanatory reduction’, that is, a reconstruction of the historical processes of their formation out of ‘simpler’ things.” (Bhaskar, 2015, p. 39). For the environmental researcher, a static analysis of a situation without understanding how that situation arose limits understanding.

3.5.3 What Does a Critical Realist Environmental Policy Analysis Look Like?

Even accepting critical realism would serve as the philosophical foundation for a theory of an environmental policy analysis, two questions arise: First, why should analysts openly engage with philosophy when developing or applying their work if it does? Second, assuming the answer to the first question is yes, what would a critical realist environmental policy analysis actually look like?

There have been numerous arguments made for the importance of theory in policy analysis, both theoretical and applied (e.g. Cairney, 2013; Colebatch, 2005). Indeed, drawing too sharp a distinction between theory and method seems untenable; as Sayer (2000) notes, “observation is not theory-neutral but theory-laden, and . . . theory does not
merely ‘order facts’ but makes claims about the nature of its object” (Sayer, 2000). Thomas Kuhn formulates it as “[p]aradigms determine large areas of experience at the same time” (Kuhn, 2012, p. 128). The study of policy is no exception to this maxim: The analyst cannot do her job without some preconceived epistemological stance as to the validity of the processes she is using to obtain knowledge of the object of her study whether that object be social, biophysical, or a “hybrid” (Latour, 1993, p. 1) of both. Ignoring theory simply risks moving it to the researcher’s unconscious, where it can unreflexively impact her work while preventing self-examination.

This does not mean the analyst need actively reconstruct explicit epistemological grounds for each analysis from the ground up: an initial engagement and agreement with a philosophical framework like critical realism can allow the analyst to devise relatively straightforward guiding principles to be a foundation for the analyst’s subsequence work – even if the exact steps which she took to come to that foundation later escape her memory. Both prongs of critical realism, addressing both the natural sciences and social sciences, offer that comprehensive metatheoretical foundation for environmental policy analysis. Indeed, where the environmental policy analyst must frequently move between natural scientific questions (e.g., how does a certain contaminant move through the environment) and social scientific questions (e.g., what social institutions would be effective means of reducing the risk of that contaminant), critical realism offers a comprehensive metatheory: an epistemological base upon which appropriate theoretical and methodological approaches can be built.

Accepting, at least going forward, that engagement with critical realism will enhance the environmental policy analysis process, what would that process look like?
Critical realism has often been criticized for its lack of specificity, but it intentionally does not mandate a specific theoretical or methodological approach, instead urging that the nature of a stratified, differentiated reality requires pluralist modes of inquiry. While critical realism does not tell us which types we must use, it does to some extent tell us what not to use. Purely neopositivist theories or methods that expressly disavow inquiry into the unobservable – like the behaviorist school that dominated American experimental psychology for most of the 20th Century – should not be used, at least in isolation. If such methods are used their limitations should be openly acknowledged and supplemented by an interdisciplinary mixture of methods better able to collectively elucidate causal structures. For example, a general linear model that associates a specific adverse environmental health impact with certain demographic factors should not be the sole driver of which policy intervention is appropriate. The critically engaged analyst should examine why members of that community are disparately impacted by an environmental hazard.

On the other end of the spectrum, some postmodernist approaches that seek to delegitimize any statements about reality are incompatible with a critical realist approach; while postmodern critical methods, such as deconstruction, can assist the policy theorist in re-appraising previously unconscious assumptions and biases, they cannot be taken to the ultimate postmodernist conclusion of purely relativist, fractured modes of knowing. Deconstruction without construction can ultimately results in what Andrew Sayer has referred to as “defeatist postmodernism,” or the erasure of the distinction between true and false.
Archer et al. (2016) propose that critical realism can “provide a warrant for a historical sociology that uses small-N case comparative analysis to reconstruct the complex, contingent, and conjunctural nature of causality” – such a research program for environmental policy analysis would exist in direct contradiction of the “policy cycle,” and be far closer to the interpretivist policy analysis program set forth by Yanow (2000) and others. Environmental policy under this warrant would seek to place environmental problems in their unique historical context. However, such a case study-focused analysis in a critical realist frame would always keep in mind the biophysical existence of environmental problems and how social institutions interact with them, and have interacted with them historically.

From the policy researcher’s perspective, critical realism is neither revolutionary nor a panacea for the central problems of the environmental policy field. Not all critical realist insights may prove useful to environmental policy analysis, and those that do would likely result in evolutionary as opposed to revolutionary change to the analysis and prescription of human institutions to climate change. Furthermore, analyses of real-world public policy are often constrained in ways that other natural and social scientific analyses are not, in that often the policy analyst’s directive from her employer is to follow a narrowly prescribed method using designated datasets and analytical methods. When the analyst has the freedom to use it, critical realism has provided value to environmental policy-related research. Forsyth (2008, p. 2), for example, proposes that “[critical] realist political ecology . . . seek[s] to reconstruct new and more effective science for environmental policy that is both biophysically more accurate than existing conceptions, and socially more just.”
In order to extend a critical realist epistemology and ontology to actual *methodology*, I discuss possible critical realist approaches to specific aspects of environmental policy research, including both how substantive policy analysis might be done, as well as the procedural process of environmental policy evaluation, development, and intervention. Below I explore three areas in which critical realism can impact how environmental policy analysis is performed, specifically: (1) interdisciplinarity; (2) defining environmental problems; and (3) environmental justice. The first two involve methodological approaches to environmental policy analysis, while the third examines a substantive approach amenable to a critical realist approach. This is not meant to be exhaustive but rather a limited articulation of the form in which a critical realist environmental policy analysis might be expressed, and offer concrete examples of how the admittedly vague philosophical tenets discussed above may impact the analyst’s work.

### 3.5.3.1 Interdisciplinarity

One of the few concrete mandates to critical realist social science practitioners is to embrace interdisciplinary approaches to their work. The interdisciplinarity urged by critical realism is premised largely on its core principal of emergence; since phenomena emerge from a multiplicity of causal mechanisms across different strata of reality, understanding how these mechanisms interact requires cross-disciplinary understanding. The critical realist theorist Andrew Sayer (2000, p. 7) sees “[d]isciplinary parochialism . . . a recipe for reductionism, blinkered interpretations, and misattributions of causality.”

Under this tenet, neither physical and natural phenomena should be considered, or studied, as ontologically “flat” phenomena: just as the properties of water cannot be
derived from the structure of hydrogen and oxygen atoms, the functioning of a banking system cannot be derived solely from the psychology of the bankers. Bank system functioning emerges out of a complex multiplicity of social and natural mechanisms, including banking laws, the workings of other parts of the economy, physical and infrastructure design, etc. Describing why that system functions the way it does may require analysis carried out through a number of disciplinary analyses, including economics, law, psychology, and engineering.

While calls for interdisciplinarity have become more frequent across both natural and social science fields, the environmental policy field in some ways has been long ahead of the game: the nature of environmental problems tends to require collaborative work between experts on various aspects of natural scientists such as chemists, toxicologists, and biologists. On the social science side, economists have also frequently collaborated on policy analyses, particularly when rule development requires economic evaluation, such as in cost-benefit analyses or economic feasibility determinations. From a critical realist perspective, interdisciplinarity has a deeper importance than simply collaboration. The "purely additive pooling of the results of the knowledge of the distinct mechanisms" (Bhaskar, 1998, p. 4) does not provide adequate tools to analyze emergent phenomena in open systems because of the complex interdependence of causal mechanisms. A cognitive understanding of how these mechanisms work together is required.

This is especially true for many of the complex systems environmental policy analysts study. For example, climate change implicates numerous disciplines and causal mechanisms, both natural, social, and hybrid. In examining the challenges posed by
anthropogenic climate change, Bhaskar himself argues that the “interdisciplinary research worker [must have] a judicious combination of disciplinarity and interdisciplinarity in their education” to deal with things like climate change (2010, p. 20). Citing C.P. Snow’s “two cultures” argument, Bhaskar further suggests that the research worker aiming for interdisciplinary understanding should pick her subsidiary discipline from the other side of the natural or social science fields. As to the extent of training in that subsidiary field, Bhaskar cautions at the very least that members of interdisciplinarity teams must be able to "communicate effectively in cross-disciplinary understanding [which] will necessitate a form of education and continuing socialization of the interdisciplinary research worker, very different from that involved in orthodox multidisciplinarity." (Bhaskar, 1998, p. 5).

The level of understanding of that subsidiary field, of course, remains a question. Collins and Evans (2002, p. 254) usefully distinguish between "interactional experience" and “contributory experience.” The former represents "enough expertise to interact interestingly with participants," while the latter represents "enough expertise to contribute to the science of the field being analysed." (Collins & Evans, 2002, p. 254). This may offer a suitable goal for the interdisciplinary critical realist analyst as well; indeed, an intermediate level between "interactional" and "contributory" expertise may be a better target for analysts who must incorporate the work of specialists into their own decision-making.11

A related advantage offered by intense interdisciplinarity is that it can give the analyst a more accurate view of the current transitive state of the environmental science

11 Of course, this depends on the field; a low level of interactional experience may be the best a non-specialist policy analyst may hope for when looking at a field like say, quantum mechanics, but for most of the fields in which an environmental policy analyst encounters -- say epidemiology or ecology -- a high level of interactional expertise is possible.
under dispute. As Sarewitz (2011) notes, scientific research prepared for policy-making is often done through consensus reports, with “[t]he commitment to consensus . . . com[ing] at a high price: the elimination of proposals and alternatives that might be valuable for decision-makers dealing with complex problems.” The problem is not limited to policymakers but also extends to natural scientists working in different fields. Collins and Evans (2002, p. 246) argue that scientists outside the “core” of practicing specialists in one field tend to see the “core’s” field as operating with more certainty than the “core” recognizes, because like policymakers and the general public they tend to learn about that field from sources that “[i]nevitably . . . condense and simplify.” An interactional understanding not just of the abstract principles of such a field but also its practices, including how its practitioners evaluate and debate points of uncertainty or contention, which often have policy implications.

3.5.3.2 Problem Definition and Ontological Engagement

With critical realism’s focus on understanding a structured, differentiated reality, when using it to analyze environmental policy issues proper ontological categorization becomes more of a concern. For example, a recurring debate in environmental research is the extent to which “natural” domains can – and should – be distinguished from artificial ones. Philosophical approaches to examining nature and culture often fall between two diametrically opposite poles, holding either (1) a dualist “categorical opposition between Nature (body, animals, biological and physical conditions and contexts of life and so on) and Culture (meaning, subjectivity, identity, the human)” (Benton, 2005); or (2) a monist dissolution of the boundaries into “hybrid, chimeric, complex, and entangled” wholes (Castree & MacMillan, 2001, p. 210).
A great deal of environmental social science over the past several years has focused on distinguishing (or breaking down distinctions between) “nature” and “culture,” or more specifically the natural and built environments. Unsurprisingly, considering its focus on ontology, much critical realist discussions of environmental issues have therefore focused on the nature/society dichotomy (Forsyth, 2001). How environmental researchers approach that debate can have real-world policy implications. For example, from an environmental history perspective, conceptions of a strong nature-culture divide led to the preservation movement and the creation of nominally “pristine” parks and wilderness areas. More recent policy approaches that break down those sharp distinctions may be reflected in the use of ecosystem-based management approach to environmental management that examines the interaction between both human and non-human elements in an ecosystem.

Definitions of environmental degradation seem to be particularly problematic as a category. Fairhead and Leach (1998), for example, critique the orthodox definition of environmental degradation in the context of West African deforestation, showing that purported forest loss attributed to population growth and the breakdown of organized natural resource management actually misrepresented the landscape, which had actually seen forest growth over the relevant time. Examining that work and similar critiques of environmental degradation definitions, Forsyth (2001) offers an expressly critical realist approach to conceptions of degradation, arguing against “environmental orthodoxies” which he links to “historic scientific practice based on the search for positivist and universal laws” (Forsyth, 2001, p. 3). He argues that understanding degradation cannot be defined simply biophysically but also must explore how purportedly scientific laws
relating to the environment reflect historic political and social relations (Forsyth, 2001). Going beyond an interpretivist deconstruction of such meanings, he argues for “reconstruct[ing] new and more effective science for environmental policy that is both biophysically more accurate than existing conceptions, and socially more just” (Forsyth, 2001, p. 2).

Similar definitional problems may arise in defining and acting on invasive species. Traditional scientific views of invasive species see them as a significant threat to “natural” landscapes, and seek to control that threat through measures such as border control of plant and animal species, ranging from requiring ships to discharge ballast water far from their destination ports, to tightly regulating which plants and animals can be transported through networks. Over the years, however, some researchers working in an interpretivist frame have criticized the concept of “invasive species” as largely a linguistic construction rooted in xenophobic fear of the other (Peretti, 1998; Raffles, 2011; Subramaniam, 2001).

Such conceptions of “invasive species,” they argue, both feed on and feed into oppressive xenophobic views of immigration. Does this provide a good ontological base for policy prescriptions? To the discourse-focused academic, divorced from the extradiscursive reality of the invasive species’ impact – at worst, they may see a slight increase in produce prices at the grocery for crops impacted by such species – such interpretation is easy. To the rural farmer who sees her crop destroyed and her livelihood threatened or destroyed by these species, such deconstruction does little; for example, in sub-Saharan Africa maize makes up the staple food for approximately half the population, a region where approximately 200 million people are chronically
undernourished. Despite the critical importance of maize to some of the poorest communities in Africa, the region has significantly depressed maize yields largely due to invasive species like witchweed and the larger grain borer insect (e.g. Gressel et al., 2004). Critics of invasiveness as a discursive construct typically do not, of course, deny that individual species, including invasive ones, may require management. Their call for a more contextualized understanding that avoids general “covering laws” is convincing – but not necessarily to the extent that they wish to take it. It minimizes the fact that invasive species do have a tendency to disrupt ecosystems specifically because they are from outside, i.e. they did not co-evolve with native species and the latter are thus less likely to have developed defensive or offensive capacities which would protect them. Discursive purity may therefore come at the price of biophysical damage. As Margaret Archer puts it that “[t]he post-modern experience is not on globally for those needing bread not circuses and seeking freedom of expression not expressive freedom” (Archer, 1998, p. 193). Along similar lines, Benton (2005, p. 142) criticizes the “comforting invention” of socially constructed nature, extrapolating such construction to an absurdist conclusion: “[f]ortunately for the indigenous peoples of the tropical moist forests, their ‘nature’ is a different one from that of the loggers and dam-builders: both can happily coexist in their incommensurable cultural universes (I don’t think!).”

3.5.3.3 Investigating Environmental Justice

The third example I present involves the analysis of environmental inequity through an environmental justice paradigm. Traditional neopositivist approaches to

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12 In a later work Raffles later did “[c]oncede[] a limited, strategic version of . . . relatively autonomous in their biophysicality . . . nature,” which he characterizes as existing “somewhere in the region of a critical realist approach to the non-human.” (Raffles, 2002, p. 172).
environmental policy and governance tended to come from a utilitarian perspective, assuming environmental policy decisions were to be made in such a way so as to maximize overall benefits while reducing overall costs, without paying specific attention to who exactly enjoys those benefits and pays those costs – cost-benefit analysis is one manifestation of this. Over the past couple of decades, however, a number of activists, academics, and policymakers have argued that this approach can be discriminatory towards communities that already suffer from the effects of other forms of social, geographical, and procedural inequities, particularly poor communities and communities of color.

In the United States this movement began in the early 1980s in response to a decision by the state of Georgia to situate a PCB disposal site in a predominately low-income, predominately African-American community (Brown, 1995). Though the resulting protests were unsuccessful in stopping the disposal site, they did set off what quickly became known as the environmental justice movement, a social movement seeking to ensure “the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies” (EPA, 2013). Though it started as an activist movement, environmental researchers subsequently created an academic field investigating environmental justice issues; most notably, the United Church of Christ’s Commission for Racial Justice (which had held a leading role in the original Warren County demonstrations) commissioned a landmark report that found black, Hispanic, and Indian communities were more likely to live in the vicinity of toxic waste sites (CRJ, 1987).
Subsequent research in the United States has followed this template, focusing primarily on investigating spatial and temporal correlations between environmental hazards – often toxic waste sites – and demographic characteristics, typically race and ethnicity. However, this neopositivist, correlationist approach has proven problematic in establishing incidents of environmental discrimination. First, the results of spatial proximity analyses cannot show in themselves the causal mechanisms that led to the correlation between environmental hazards and specific ethnic or socioeconomic groups. This can have real-world impacts; for example, the United States Supreme Court has held that plaintiffs can only successfully prosecute a federal claim for racial discrimination against the government if they can show that the discrimination was intentional (Alexander v. Sandoval, 2001). In such a situation, merely showing that a toxic waste site had a disparate impact on African-Americans, for example, would not be sufficient to find relief under American civil rights laws.

Second, while spatial analyses can offer a snapshot – or a series of snapshots – of distributions of social and environmental phenomena, they are heavily dependent on the assumptions built into geographical information models, particularly scale. One common manifestation of this is what geographers refer to the Modifiable Areal Unit Problem, which occurs when point data like toxic sites are aggregated into values that apply to a certain areal unit (e.g., toxic waste sites per county) (Openshaw, 1984). Spatial correlations that exist when the areal unit used is the county may weaken, strengthen, or vanish when a larger or smaller areal unit is used. Thus, when Anderton et al. (2014) examined the demographics of toxic waste sites in the United States but using smaller census tract areal units instead of the zip code areal units used by the United Church of
Christ study, they found “almost no support for the general claim of environmental inequity.” A critical realist approach to environmental justice, therefore, might focus less on establishing conjunction of environmental hazards and the proximity of poor communities and communities of color through correlation studies, and focus instead on the causal mechanisms and the unique historical characteristics of potential sites of inequity.

One possible template for this kind of critical realist environmental justice research could be the Michigan Civil Rights Commission’s report on the Flint, Michigan water crisis of 2014-2016. Lack of proper oversight and financial problems in the city of Flint led to a horrific lead poisoning epidemic when municipal authorities attempted to switch the city’s water supply to a cheaper source. During the change, the city used the local Flint River as a temporary supply of water, but the high acidity of the water leached lead from water pipes, leading to widespread lead poisoning. In the aftermath of the crisis, the Michigan Civil Rights Commission, an independent government agency tasked with investigating discrimination in the state, conducted a lengthy study of what caused the crisis. Though the Commission examined the immediate proximate cause of the crisis, and who it affected, they also examined the complex history of Flint and the United States. The Commission concluded that the underlying issue behind the water crisis was a historical and systemic racial segregation and discrimination of the African-American community over more than a hundred years (MCRC, 2017, p. 2). Though the Commission did not take an expressly critical realist approach, the language they use shows a similar acceptance of complex causal mechanisms: “Today’s disparities . . . are often the result of the complicated relationship between numerous factors, policies and
causes that interconnect to produce and reproduce . . . racial disparities and unjust harms” (MCRC, 2017, p. 19).

3.6 Conclusion

How do we make decisions when creating policy interventions to regulate human interactions with the environment? And how should we? Any attempt to examine environmental problems and prescribe social institutions to address them requires some epistemological assumptions as to how we can obtain knowledge of our objects of study and the intrinsic constraints on humans’ ability to obtain that knowledge. Analyzing those assumptions requires taking a step back from methodology to look at the philosophical foundations of what those methods can tell us, a step that policy analysts often do not take.

Modern environmental policy analysis and development has moved towards a deeper and more critical approach to understanding environmental problems that implicate both natural and social systems. Critical realism may offer analysts a philosophically coherent and potentially useful epistemological foundation in support of this goal. Accepting ontological realism but epistemological fallibilistic – that there is a real world out there independent of our conception of it, but that our explanations of it will always be provisional and subject to revision – critical realism mandates an interdisciplinary approach, a skepticism of “covering laws,” and an openness to the complexity and interdependence of social-ecological systems.
Chapter 4
Evolving Cultural Models of Mercury: From Minamata to the Anti-Vaccine Movement
4.1 Overview

The element mercury has played a unique role in human life from before recorded history to the present. A critical component of some industrial processes and an unwanted byproduct of others, mercury and its risks have been debated in one form or another for more than 2,000 years. Early alchemists saw mercury as a fundamental reagent of the cosmos, a spiritually imbued representation of the creative energy of the universe, and a medicinal agent both potent and dangerous. From alchemy to medicine to science, and back to alchemy again, mercury has held a unique place in the cultural imagination, as a sign of power and peril, a symbol of both industrial optimism – clean, fluid, and silvery, it visually reified the space age aesthetic – and later a darker symbol of the costs of industry as an environmental pollutant which could damage human brains, particularly those of the young and vulnerable.

This chapter first discusses of mercury’s historic use by human societies from prehistory into the twentieth century before providing a detailed historical account of the Minamata Bay poisoning in Japan in the 1950s, the most prominent mercury poisoning event, and its aftermath both in that country and in the United States, placing that account in the context of wider environmental concerns and anxieties through the second half of the twentieth century. The chapter then examines the anti-vaccine movement in the United States during its resurgence of the late 1990s through the present, particularly as it relates to the mercury-based vaccine preservative, thimerasol, arguing that conceptions of mercury risk among anti-vaccine activists and authors was influenced by not only environmental poisoning events but also the governmental and industry responses to those events, with the Minamata poisoning the most prominent such event.
4.2 Theoretical and Methodological Approach

In making that argument, I rely on the critical realist metatheory originated by the philosopher Roy Bhaskar and his intellectual antecedents, particularly on two core aspects of critical realist thought, particularly when making my analysis: The distinction between the intransitive and transitive objects of knowledge; the former represents the extradiscursive “thing” that exists whether we observe it or not, while the latter represents our understanding of that real “thing,” subject to mistake and revision. The intransitive mercury is the silvery metal element, chemically defined by its 80 protons and its bonding affinities, toxic in its mechanisms but technologically useful. The transitive mercury is the shifting human understanding and belief as to what mercury is and what it can do, a conception that, like the element itself, has metamorphosed over time, transited from one state to another, then back again.

The second critical realist base for this chapter is a focus on causal mechanisms rather than simple description or observation of correlations between events. In proposing a causal relationship between environmental poisoning events, particularly Minamata, and the anti-vaccine movement, I rely on the cultural models concept developed by cognitive anthropologists and psychologists examining reasoning about physical or natural systems. Cultural models, also known as mental models, or when applied to the lay public, folk, or naïve models, are how human beings reason and make decisions about the world around them (Atran, Medin & Ross, 2005).

They are constructed through individual experience but influenced by cultural consensus and shared understandings. Mental models are notoriously difficult to decipher, interpret and articulate, as such models are unobservable and subject to multiple
layers of subjective interpretation not just by the researcher but also by the subject who acts upon or articulates such models. Thus, while the cultural model explanations below are only speculative, the position that human beings truly reason and make decisions through model-based reasoning processes has been supported by converging lines of both experimental and theoretical research across different fields such as cognitive psychology (Johnson-Laird, 2010, 2013), cognitive anthropology (Kempton, 1986; Kempton & Falk, 2000), organizational studies (Forester, 1971; Rook, 2013), and human factors (Wilson & Rutherford, 1989). Therefore, in any given period and culture understanding of mercury must by necessity involve the use of mental models that are historically situated and culturally constituted and communicated, and can provide, if not a rigid naturalistic methodology by which to explain them, an interpretive standpoint from which to explore the transitivity of objects of knowledge.

Thus, the medieval alchemical promises of mercury may be echoed in the quack medicine of the nineteenth and twentieth centuries in the United States, promises which still manifest in grey market mercurial medicines found in the botanicas of American cities. A young boy who saw the tragic photographs of the Minamata mercury poisoning victims would years later spearhead laws and regulations to limit mercury risk in this country, first as a Senator and later as President of the United States (Obama, 2007, p. 29).13 Awareness of Minamata and growing media attention to the mercury in fish through the 1970s onwards created a sense of dread that may be a contributing factor in the rise of the movement to reject vaccines containing the mercury compound thimerasol,
causing a health crisis in the United States and other countries where that movement took hold.

4.3 Mercury Use from Pre-History Until the Twentieth Century

The most common compound of mercury on Earth is mercuric sulfide, known as the red mineral cinnabar. Early modern humans encountered cinnabar in areas of volcanic activity, where the bright red mineral would have shown clearly against the darker rocks surrounding it. This deep, rich red made it appealing to early artists, and cinnabar-based pigments were used as early as 8,000 BC for painting, including on the walls of the world’s oldest urban settlement, Çatal Hüyük, in modern-day Turkey. In addition to its vivid color, cinnabar has another unusual property: globules of liquid mercury can form on the surface of high-mercury deposits, sometimes naturally if the mercury concentration is high enough, but also through intense heat applied to the mineral. A number of ancient cultures developed ways to extract mercury from cinnabar, typically involving evaporating elemental mercury, then capturing and cooling it so it would precipitate in its pure form. The secret of mercury production was discovered (or rediscovered) throughout the ancient world, including by the ancient Chinese, Persians, Assyrians, and Mayans (Lins & Oddy, 1975; Pendergast, 1982; Rapp, 2009, p. 242), and cultures often worked mercury into complex systems of spirituality and mysticism (Cheak, 2013, pp. 207-8; Principe, 2013, pp. 35-7; Sivin, 1976; Wright, 2011, p. 49). In addition to its (usually fictitious) alchemical or health characteristics, early metalworkers found elemental mercury could amalgamate both silver and gold, seeming to dissolve them; heating the amalgam would evaporate the mercury, leaving the silver or gold in a

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14 For a full treatment of mercury science, see Chapter 2.
purer and more recoverable form, a method that is still used in the present to extract gold from gold ore, particularly in the developing world, a phenomenon that has grown in recent years due to increases in the price of gold.

Even while alchemists and mystics worked mercury into elaborate cosmological theories, and ancient metalworkers used it in their trade, there was a widespread awareness of the dangers that mercury could pose. Galen of Pergamon, a Greek physician of the second century A.D., considered by some second only to Hippocrates in his influence on the history of medicine, considered mercury poisonous (Swiderski, 2008, p. 13). These debates were still raging in Renaissance Europe; when Paracelsus, the founder of the field of toxicology, set forth his maxim that “[s]olely the dose determines that a thing is not a poison” he then used mercury as an example of such a substance that was poisonous at higher doses, though he himself prescribed it therapeutically (Deichmann, Henschler, Holmstedt & Keil, 1986).

European enthusiasm for mercury waned as alchemy gave way to chemistry, and the frequently confused and quasi-mystical medicine of the Medieval and Renaissance gave way to the more scientifically rigorous (and generally less deadly) medical practice of the nineteenth century, though mercury remained a popular tool in the clinician’s toolbox during that period, with one critic and medical practitioner complaining that “our text-books recommend mercury in almost every disease” (Habershon, 1860). By the turn of the century, however, clinical evidence of the dangers of mercury, the lack of evidence of significant health benefits for its use, and the availability of alternative antibiotics had driven it largely outside mainstream medicine. This process was likely helped by the professionalization of the medical profession in the United States and abroad around that
time period, which weakened the market for the kind of medication promoted by the amateur, mercury-loving quack pharmacist. The second half of the nineteenth century especially had seen an attempt by state governments to prevent or at least more tightly regulate the sale of poisons, and by the beginning of the next century numerous had started regulating mercury (and many other dangerous medicinal chemicals) as a poison, making it unlawful to sell or deliver without significant warning label or notice requirements (Wilber, 1912).

This did not, of course, stop mercury poisoning: mercury bichloride tablets were still often used as a germicide prior to the advent of modern antibiotics, and the early 1910s saw a well-publicized epidemic of deaths from such tablets, with a reported seventy-eight cases occurring in New York in a single eight-month period in 1914 (“Anti-bichloride fight on,” 2014). Many of the newspaper accounts reported many victims had taken the tablet accidentally, mistaking them for “headache tablets,” though at least some of those reports may have been phrased as such to preserve the reputation of the deceased, as mercury bichloride was still commonly used at the time to treat syphilis, despite the availability of the more effective Salvarsan.

4.4 Toxic Landscapes: Minamata and the Hidden Costs of the Industrial Age

By the middle of the twentieth century mercury had been displaced in most medicine, though its unique chemical properties made it increasingly useful to the chemical industry, particularly for things like the chlor-alkali industry, in pesticides, and to the creation of explosives for use in construction or war. The physicality of liquid mercury matched the optimism of the post-war years: clean and fluid, reflective and symbolic of change. Sculptor Alexander Calder created a modernist mercury fountain for
the Spanish pavilion at the 1937 World Exposition in Paris (Daniel, 2016, pp. 50-51). But technological optimism over the rapid development of technology and industry following the war would soon give way to more public pessimism as the costs of that development began to be incurred. Like many other useful industrial chemicals, mercury would show a frightening dark side.

4.4.1 The Minamata Bay Poisoning: 1953-1968

Minamata remains the dominant and defining event in the historical narrative over the perils caused by environmental mercury. Located in Kumamoto Prefecture, on the coast of the island of Kyushu, the city of Minamata was the site of Chisso Corporation, a large, politically powerful petrochemical manufacturer. In 1953 residents of the small fishing communities surrounding Minamata Bay started noticed something strange: local birds appeared to be having problems with coordination, frequently falling from perches or flying into buildings, while local cats suffered similar problems with tremors and other unusual movements, leading to some observers to refer to “dancing cat disease” (Kaplan & Dubro 2012 p. 164; Huddle & Reich 1972 p. 107).

The mysterious condition did not stay limited to birds and cats, as local fishers and their families soon began to suffer similar symptoms. Minamata fisher Sohachi Hamamoto, for example, woke up one morning hard of hearing and having difficulty with movement and balance; his condition worsened every day until he had to be hospitalized, and continued to deteriorate in the hospital until he died. Even more heartbreaking was the impact on the child victims. One 5-year old girl was brought in suffering symptoms of extreme brain damage, including an inability to walk and
incoherent speech; her two-year-old sister joined her in the hospital several days later with the same symptoms (Smith & Smith, 1975, pp. 28, 79-80).

Physicians and researchers initially examining the victims offered various explanations to the sufferers (and their parents), including cerebral palsy, malnutrition, and infectious disease, but by 1956 the number of victims had reached the point where medical authorities realized that they were suffering from a common malady, almost certainly some sort of environmental contaminant. The presence of the Chisso plant, of course, suggested pollution as a possible culprit; locals fishing in the Bay had long been aware of the environmental damage caused by the plant effluent; the plant’s drainage channel emanated a rotting stench, and the natural biota clinging to boat hulls would be stripped away if they moored their boats near it. Indeed, the plant had been paying local fishers token payments to compensate them for the damage caused to fishing areas since 1925, but the new poisoning was starkly different from the environmental degradation with which the fishers were familiar (Brett & Cronon, 2011, p. 147).

The impact of this sudden “Minamata Disease” was horrific. Forty percent of the victims died, and autopsies showed brains that had in some cases been eaten away until they looked like sponges. The illness overwhelmed the abilities of the local health authorities, and a committee of medical researchers from Kumamoto University were called in to investigate the issue. They quickly developed numerous theories as to Minamata Disease’s cause, including that some infectious disease caused it, or an environmental or food contaminant. However, by early 1959 the scientific consensus had developed that the symptoms most closely resembled the effects of heavy metal poisoning as the culprit, and after researchers considered and rejected manganese,
thallium, and selenium as possible contaminants, they settled on organic mercury as the most likely cause of the disease by the middle of the year (Sugiyama, 2015, pp. 125-126).

The Chisso Corporation, aided by other industry actors, launched an effective – and occasionally violent – counteroffensive to deflect blame and introduce doubt in the researchers’ findings that mercury-laden effluent from its factory was the cause of Minamata disease. They were supported, in part, by the local residents’ loyalty to the company; Chisso employed a substantial portion of them, and Japanese cultural norms demanded a loyalty to one’s company that turned many plant employees against their fisher neighbors. Company loyalty would also silence a Chisso company doctor, Hajime Hosokawa, who had been treating victims at the plant hospital, and in 1959 began conducting his own experiments to determine the source of the disease. He found that when he fed plant effluent to a cat, it developed the same symptoms as the victims, but when he reported the result to management he was ordered to stop. Loyalty to the company kept him quiet for a decade, until he finally testified, from his deathbed, about the results of his experiment – and the fact that he had informed the company of those results (Smith & Smith, 1975, pp. 122-3; Sugiyama, 2015, pp. 127-9).

Cultural attitudes towards both disease and fishers’ peripheral role in Japanese society also became barriers to the fishers’ quest for both explanation and compensation. In Japanese society fishers lived “outside mainstream political and economic power.” (Brett & Cronon, 2011, p. 141). One Minamata victim, Eiko Sugimoto, was almost killed when a man tried to push her off a cliff, and disputes broke out not only between the unafflicted and the afflicted, but also between victims who wished to negotiate directly
with the company for redress and those willing to mediate through government channels (Smith & Smith 1975, p. 122; Gill & Kazuko, 2014).\textsuperscript{15}

By 1958 increasingly frustrated victims and their families, often treated as pariahs by their neighbors, publicly demanded not only better pollution controls at the factory but also compensation, going so far to demonstrate at the factory. Eventually, in 1959, Chisso agreed to sign small indemnity contracts with victims, which appeared to quiet complaints for the next decade, and installed a “Cyclator” which the company (falsely) claimed would clean the effluent of mercury. They also diverted effluent to sedimentation pools, and through them into a river north of Minamata Bay, flushing much of the mercury into the larger Shiranui Sea of which Minamata Bay was one inlet. However, the victims continued to suffer, and the company continued to discharge methylmercury-laced effluent. However, the anger of the victims, their families, and supporters would be rekindled in 1966 when on the other side of Japan, in Niigata Prefecture, a similar poisoning event occurred when a chlor-alkali plant owned by a large chemical firm, Showa Denko, released methylmercury-containing effluent into the Agano River. The disease followed the same course as in Minamata, including the abnormal cat behavior, and ended up with human victims, who unlike Minamata fishers lived in a community far enough from the plant that they faced little local political or community opposition to their claims (Smith & Smith, 1975, pp. 117-120).\textsuperscript{16}

\textsuperscript{15} Increased willingness to challenge industrial and government institutions in Minamata also coincided with a growing environmental movement in Japan through 1960s and 1970s connected to transnational environmental movements of the time, see Avenell (2013).
\textsuperscript{16} The company would ultimately stop discharging methylmercury-laced effluent in 1966, when technological advances, particularly the introduction of an effluent processing circulation system, made it unnecessary (Amasawa, Teah, Khew, Ikeda & Onuki, 2016).
As community anger in Minamata once again grew in response to Niigata, likely aided by a growing environmental movement in Japan, Chisso Corporation not only ignored or denied the accusations, but fought back with hired “security” companies that had ties to the Japanese underworld. Violence instigated by those security companies as well as by allied ultranationalist groups, broke out on numerous occasions, including at one shareholder meeting where a prominent Associated Press photojournalist, W. Eugene Smith, was severely beaten, leading to partial blindness and damage to several vertebrae. Eventually, however, a Japanese federal judge found the Chisso Corporation guilty of gross negligence, ordering compensation be paid (Kaplan & Dubro, 2003, pp. 164-8; Smith & Smith, 1975, p. 95; Avenell, 2013). In 2012 there were still 2,273 recognized patients suffering from the effects of the poisoning, though many more residents have sought to be recognized by the government as victims (Aoyama & Hudson, 2013).

While the events at Minamata were covered extensively in the Japanese press (Sugiyama, 2015, pp. 125-128), isolated reports were slow to appear in the Western press through the 1950s and 1960s, including in academic journals. A special article on “Minamata Disease” appeared in the September 20, 1958 issue of The Lancet, describing the outbreak, and suggesting possible contaminants that may have caused it, including methylmercury (McAlpine & Araki, 1958). A later 1959 issue of the journal Nutrition Reviews by the same authors summarized Japanese-language reports of the symptoms suffered by Minamata villagers, but also identified mercury poisoning as just one possible explanation for the symptoms observed (McAlpine & Araki, 1959). Other than sporadic reports in the academic health literature, however, the poisoning event went largely unnoticed in the Western English-language press. Though the researchers at
Kumamoto University had concluded that organic mercury poisoning caused Minamata Disease by 1959, and their accounts reached the English-language medical literature as early as 1962, it was not until 1970 when the risks of environmental mercury would reach the public stage in force (Takeuchi, Morikawa, Matsumoto & Shiraishi, 1962).

4.4.2 The Ecotoxicological Turn in Environmental Science

At around the same time that Japanese residents of Kumamoto were coming to grips with Minamata Disease, the effects of mercury were being observed half a world away, in Sweden. There, the victims of mercury in the landscape were less noticeable than in Minamata. Beginning in the mid-1950s Swedish authorities had begun to discover numerous animals, primarily birds, in the countryside, lying dead with signs of poisoning; subsequent chemical analyses showed high levels of mercury. Swedish scientists therefore spearheaded a research program into environmental mercury. In 1969 Jensen and Jernelöv established via a laboratory study that oxidized mercury could be methylated in sediments. Subsequently, other researchers determined that methylmercury could then accumulate through the food chain, noting that “hazards rapidly increase towards the top of the chain” (Borg, Erne, Hanko & Wanntorp, 1970; Jensen & Jernelöv, 1969). As noted in Chapter 2 poisoning events also occurred in a number of other countries in the 1950s through 1970s, most notably in Iraq, due to consumption of mercurial fungicide-laced grain (Amin-Zaki et al., 1976).

By this time period both scientists and the general public had become aware not only of the fact that environmental contaminants could cycle through nature and ultimately harm human beings, but also that this transfer could be mediated through

17 The ecotoxicology of mercury is addressed in more detail in Chapter 2.
biological and ecological processes, largely though not completely through the work of Rachel Carson, as well as pioneering French scientist Rene Truhaut who coined the study “ecotoxicology.” While human beings had long connected health hazards with poor environments, such connections tended to be made only when the environment exhibited something visible or olfactory, for example with the “miasma” theory of disease which saw sickness transmitted by the noxious gases of swamplands. Carson, Truhaut, and other scientists of the era had managed to translate to the public the fact that harmful contaminants could impact them unseen, and inspired a burst of research into the ecological dynamics of such contaminants. While early concerns focused on DDT and other pesticides, mercury would also soon loom large in the public imagination in the United States (Carson, 1962; Truhaut, 1977).

4.4.3 Mercury and the American Consciousness: 1970 Onwards

Though a few reports of Minamata made it to specialized outlets in the United States, the mainstream media paid little attention until 1970. However, before the news of Minamata had reached the United States public consciousness, the country had its own mercury poisoning outbreak, though on a smaller scale than had been seen in Japan or Iraq (See Chapter 2). In October of 1969 Ernest Huckleby, a 47-year-old father of seven who worked as a school custodian, slaughtered one of the hogs he had been raising to supplement his income for food (Goodrich, 1970). A few months later, he and the members of his family who had eaten the meat, including his pregnant wife, began to suffer serious side effects. Hardest hit were three of his children, particularly 8-year-old Ernestine Huckleby who suffered quadriplegia, blindness, seizures, and severe mental retardation. As had happened with the Minamata victims, doctors were initially unable to
identify the cause of the symptoms, but by January had identified the cause of the disease as mercury poisoning, leading to a local panic and the quarantine of hogs and impoundment of potentially contaminated grain. The Huckleby incident made the national media in February of 1970, making the New York Times on the first of the month, and televised on the NBC evening news on February 17. Ernestine Huckleby would become the most tragic victim of the incident; National Geographic published a heartbreaking picture of the blind, mute, and motor-impaired girl, eyes wide (but unseeing) as she clutches a stuffed bear (Davis et al., 1994; Goodrich, 1970).18

On 2 April 1970, not too long after the Huckleby poisoning had reached national awareness, the American embassy in Ottawa, Canada, notified the State Department that the Canadian government had discovered serious mercury contamination in boundary waters between the two countries, particularly Lake St. Clair on the Ontario-Michigan border. Federal and state agencies in the United States quickly responded, collaborating on a comprehensive sediment and fish sampling study across numerous boundary waters between the two countries, with dismaying results: The Federal Water Quality Administration (1970, p. 1) issued a report noting that mercury contamination was an “international and interstate environmental problem of major scope.” The months following that report showed the agency had understated the problem. Throughout the summer of 1970, state and federal agencies looked for mercury in water bodies around the country, and to their distress, usually found it. At one congressional hearing in 1970, the deputy director of Michigan’s Department of Natural Resources cited Minimata, Niigata, and Sweden when remarking on the “paradox” of “the lack of knowledge and

18 The picture of Ernestine Huckleby appeared in a special National Geographic issue called As We Live and Breathe: The Challenge of Our Environment in June 1971.
apprehension over mercury” in the United States. Numerous environmental managers remarked on the suddenness of the awareness that environmental mercury was even a problem (Effects of Mercury on Man and the Environment, 1970, pp. 6, 20-21, 59).

Primed by the Hucklebys and the discovery of mercury saturation in American waters, as well as recent news of the Iraqi grain poisoning (“Mercury Poisoning in Iraq is Said to Kill 100 to 400”, 1972), the public then was faced with a fuller picture of the tragedy of Minamata. The government and media, and to a lesser extent the public, had become aware of the Minamata poisoning, but accounts were typically brief (e.g. Salpukas 1970; Oka, 1970). But in 1970 Associated Press photographer W. Eugene Smith, who, along with his wife Aileen had spent three years in Minamata, living among and chronicling the lives of the victims, brought the tragedy to the American public in a far more emotionally salient way. On June 2, 1972, shortly after the brutal attack Smith suffered, Life Magazine published a photo essay of the Minamata outbreak in their June 2 issue, not only describing the severe physical and mental impacts of the Minamata Disease outbreak he and his wife had witnessed, but also showing the readers in vivid, oftentimes disturbing detail what the villagers had suffered. His photograph Tomoko Uehara in Her Bath (Smith, 1972), showing a mother bathing her severely disabled daughter, would become world famous, and has been referred to as “the pietà of our industrial age” (Morris & Morris 2002 p. 275; Thornton, 1975).

Only days after Smith’s essay was published, copies of the magazine were rushed to Stockholm, Sweden, where representatives of 113 different countries were convening for the first United Nations Conference on the Human Environment. The issue made a significant impression on participants at the conference (Thornton, 1975). However, the
communities hit by Minamata Disease had also sent their own ambassadors in person – including Shinobu Sakamoto, a wheelchair-bound victim of the poisoning whose photograph had also appeared in Smith’s photo essay alongside Tomoko’s; fifty years after suffering the effects of the poisoning, Sakamoto still advocates on behalf of the Minamata victims (Hirano, 2016).

If the American media had been caught unaware by environmental mercury risks, they made up for their lack of attention in the first few years of the 1970s. A January 29, 1971 Life Magazine article addressing mercury risks noted that in light of Minamata, Iraq, and the Huckleby incidents, “we should have been” more alert to mercury dangers. The United States government took some quick action to protect against environmental mercury. The sudden media attention regarding environmental mercury’s health risks into the national consciousness continued through the 1970s. National Geographic ran a story in October of 1972 entitled “Quicksilver and Slow Death,” noting the “sudden[]” awareness of mercury’s “double nature” (Putnam, 1972). In March of 1972, the American media also reported on a mercury poisoning event in Iraq, where 100-400 people died from eating wheat seed coated with a mercury fungicide (“Mercury Poisoning in Iraq Is Said to Kill 100 to 400,” 1972).

Most of the pollution control laws created in the 1970s would eventually include mercury among the numerous toxic substances they regulated, including the Clean Water Act, the Clean Air Act (see Chapter 5), the Toxic Substances Control Act, and the Comprehensive Environmental Response, Compensation, and Liability Act, more commonly known as Superfund. With the fungicide-related poisoning events of Iraq and Sweden in recent memory, mercury-containing pesticides were an early target of the
federal government. In 1970 President Nixon transferred authority over pesticide regulation under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) from the notoriously agribusiness-friendly Department of Agriculture to the nascent Environmental Protection Agency (EPA). EPA then moved quickly to deregister a number of mercury-based pesticides, removing them from the market (Comptroller General, 1973, pp. 11-13). The EPA also restricted emissions of mercury vapor under the Clean Air Act from sources such as chlor-alkali plants (the type that had poisoned Minamata Bay) and waste sludge and medical waste incineration (see Chapter 5). In 1974 the FDA changed a 0.5 ppm limit guideline for mercury in fish to an “action level,” allowing the agency taking legal action to prevent sale of fish containing more, though a federal court forced the EPA to raise that limit to 1 ppm (U.S. v. Anderson Seafoods, 1980).

Although the American media ran stories about environmental mercury’s dangers particularly regarding seafood throughout the 1970s and 1980s, after the initial burst in the 1970s, such stories became somewhat rarer. For example, a search of the New York Times archive for “mercury and fish” retrieves 35 relevant stories between 1 January 1970 and 31 December 1979, but only three in the 1980s. Mercury’s toxic risks had moved from sudden – and therefore frightening – risk to just one of many environmental contaminants that had been discovered to permeate through the industrial landscape. Public concern over the environment generally continued to run high, however. While media preoccupation with environmental issues may have waned at least somewhat from its Earth Day peak in the immediate years following that event, pro-environmental attitudes overall in the United States appeared to have remained stable through the 1970s.
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and 1980s, with a significant increase in the late 1980s and early 1990s. Certainly, the late 1970s and early 1980s saw extensive media attention paid to environmental contaminant risks and hazards, most famously through the Love Canal controversy, but also through the Warren County PCB landfill protests in 1982, and the Bhopal disaster in India in 1984.19

Regarding mercury specifically, state governments continued to increase the number of mercury-based fish advisories covering their waters. Accurate aggregate mercury-based fish advisory data is difficult to find prior to the 1990s, though the general trend since the 1970s has been of a significant increase in the number of waterbodies for which states issue mercury-based advisories. For the years 1993-2011 the total lake areas under mercury advisory increased from approximately 3,000,000 acres in 1993 to over 16,000,000 acres in 2011, and the total river miles under such advisories increased from less than 100,000 in 1993 to more than 1,000,000 in 2011, with both numbers peaking in 2008. Like many of the environmental hazards realized during the early 1970s, initial optimism over the potential of federal environment laws to remove those hazards later gave way to the realization that the environmental impacts of industry are hard to remove from the landscape. For example, some advisories issued in the 1970s were still listed as active into the 2000s.20

The spike in pro-environmental attitudes among the public in the late 1990s led to the Clean Air Act Amendments of 1990, which significantly rewrote the original law and

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19 Though there is a relative lack of comprehensive survey data about environmental attitudes in the United States, the data that does exist suggests this pattern; see Dunlap (2002) and Eberlein (2012, p. 50).
20 Data about water bodies under advisory come from the 2011 edition of the National Listing of Fish Advisories General Fact Sheet (EPA, 2011a). Information about specific advisories comes from the EPA’s National Listing of Fish Advisories database (https://fishadvisoryonline.epa.gov/advisories.aspx). The data discussed applies to mercury specifically, though other areas may be under advisories of other highly bioaccumulative contaminants such as PCBs and dioxins.
significantly increased the number of air toxics regulated under the Act. The Amendments required major sources of those toxics to use the Maximum Achievable Control Technology (MACT) to limit such emissions (for a more detailed account, see Chapter 5). Though coal-fired electric power plants, the largest source of anthropogenic mercury emissions in the United States, would otherwise qualify as a major source under those amendments, the law instead required a series of reports by the EPA and the National Institute of Environmental Health Sciences – in 1999, Congress also required a subsequent report from the National Academy of Science examining the EPA’s mercury-related health findings. This led to a surge in government-led scientific research into mercury’s health effects; while those studies were concluding, however, reports of a possible new source of mercury risk unanticipated by those reports emerged into the public consciousness in the United States: the mercurial vaccine preservative, thimerasol.21

4.5 Thimerosal and the Anti-Vaccine Movement in the United States

Most medicinal uses of mercury had proven either ineffective or inferior to available alternatives, but its antiseptic properties still had a use. While vaccine use had significantly reduced death and suffering from a variety of formerly-widespread diseases such as pertussis (whooping cough), early vaccines often became contaminated with bacteria, sometimes leading to numerous deaths and illnesses. While many early vaccine preservatives could reduce the potency of the vaccine itself, researchers at Eli Lilly and Company discovered that an ethylmercury compound it had helped develop, thimerosal,

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21 For a comprehensive overview of the Clean Air Act Amendments of 1990 by one of their architects, see Waxman (1991). For a historical account of mercury emissions regulations for coal-fired power plants under the Clean Air Act, see Chapter 5.
was not only extremely effective as an antibacterial agent at low dosages, but also did not negatively impact the biologically active components of vaccines. While some scientists questioned its efficacy, there were few challenges to thimerosal’s safety specifically before the late 1990s, and following its introduction, and the introduction of other organomercurial vaccine preservatives, instances of bacterial contamination of vaccine dropped. The FDA conducted a formal review of thimerosal use in biological products in 1976, holding it unlikely that vaccine use would lead to dangerous levels of mercury (Baker, 2008; Ball, Ball & Pratt, 2001).

4.5.1 The Recurring Vaccine Skepticism Movement

That is not to say, however, that vaccine safety generally was not a contentious issue. Public antipathy to vaccines has been a recurrent phenomenon since vaccines themselves were developed. Anti-vaccination movements sprung up in England in response to compulsory vaccination laws in the mid-1800s, often ideologically like contemporary anti-vaccination movements, with their adherents opposing government mandate and professionalized medicine, and supporting both patient choice in medical treatment and the efficacy of alternative, “holistic” medicine. They have reoccurred there and arisen around the world, both in developed and developing countries, across different segments of society (Durbach, 2005 p. 27; Spier, 2001). For example, widespread resistance to vaccination programs in the Boston area in the late nineteenth through early twentieth century led to the Supreme Court holding in Jacobson v. Massachusetts that states could mandate vaccination and publish those who refused them (though not force vaccination). In the 1970s, anti-vaccine sentiment again rose, particularly as it related to the DPT (diphtheria/tetanus/pertussis) vaccine, as media reports of adverse health
reactions possibly linked to the vaccine created cycles of increased public anxiety. The 1970s saw significantly reduced vaccination rates in several developed countries, including the U.K., Ireland, the Soviet Union, and Australia. A confluence of factors may have caused this, including a countercultural context that saw citizens of developed nations particularly turn against traditional norms of governmental and expert authority, as well as towards formerly unconventional “natural” lifestyle choices that had become increasingly popular among mainstream society (Conis, 2014; Gangarosa et al., 1998; Walloch, 2007).

Historian Elena Conis links American anti-vaccine sentiment of that time at least partially to a second-wave feminist movement that sought to “wrest control of women’s health issues from the predominantly male medical profession” (Conis, 2014, p. 114). In 1982 a TV broadcast entitled *DPT: Vaccine Roulette* aired across the country, warning viewers of “serious questions about the safety and effectiveness of the [DPT] shot,” at one point juxtaposing videos of developmentally disabled children with medical experts arguing over those questions. Shortly after, in 1985, the influential vaccine sceptic book *DPT: A Shot in the Dark*, warned both of possible allergic reactions to the “mercurial preservative” thimerosal in the pertussis portion of the DPT vaccine, and a possible connection between the vaccine and autism, though he did not link the two together (Coulter & Fisher, 1985, p. 71, 216; NBC, 1982).

Fears over the pertussis portion of the DPT vaccine, as well as large awards won by litigants against vaccine makers, led to Congress passing the National Childhood Vaccine Injury Act of 1986, which established the National Vaccine Injury Compensation Program (Vaccine Program) providing a fund and procedure for allowing
children and their guardians to seek compensation for adverse reactions. Ultimately, however, the vaccine at issue was replaced with a new type, and retrospective studies in the 1990s found no evidence of a causal relationship between it and neurological injury (Wentz & Marchus, 1991). It was researchers in the United Kingdom, where the anti-vaccine movement had long been stronger and more pervasive than in the United States that focused attention on thimerosal, albeit initially indirectly.

4.5.2 Andrew Wakefield and the Anti-Vaccine Resurgence

A British researcher and physician, Andrew Wakefield, published a paper in the prestigious medical journal *The Lancet* with several co-authors that among other things, purported to show a potential relationship between the administration of the mumps/measles/rubella vaccine (MMR) vaccines to children and development of symptoms of a type of autism (Wakefield et al., 1998).

While the article itself was framed conservatively, it quickly came to public attention after a press conference starring Wakefield that would be televised throughout England. While *The Lancet* paper had suggested that “environmental triggers” might explain chronic bowel abnormalities and developmental disorders, during the press conference Wakefield not only posited a direct MMR-autism connection, but declared he “cannot support the continued use of the three vaccines given together.” With tape recorders running, the dean of the hospital, surprised by Wakefield’s comments, immediately warned that reducing vaccination rates could lead to child deaths (Flaherty, 2011; Mnookin, 2011, pp. 107-108).

*The Lancet*’s editors had already been skeptical of the report by Wakefield and his collaborators, and had taken the unusual step of commissioning a critical analysis of the
report before publication by two American vaccine specialists at the Centers for Disease Control which had been published in the same issue as Wakefield’s. The authors criticized the report for a number of flaws, including that it was based on cases referred to Wakefield’s group, leading to possible selection bias, as well as the paper’s reliance on prior studies by Wakefield that later researchers were unable to replicate (Chen & DeStefano, 1998).

Other researchers quickly weighed in to assail the Lancet paper and Wakefield’s claims about the MMR-autism link (e.g. Walker, 1998; Taylor et al., 1999). Ten out of eleven of Wakefield’s co-authors would later publish a “Retraction of an interpretation” of the Lancet paper, arguing that the paper itself did not establish a causal link between the MMR vaccine and autism because of insufficient data, and retracting any interpretation of such a link (Murch et al., 2004).

Neither The Lancet paper nor the press conference contained the word “mercury” or “thimerosal,” and the MMR vaccine itself did not even contain thimerosal; why, then, did thimerosal and mercury become so connected with both autism and The Lancet paper in the public mind, particularly in the United States? Several organizations and researchers, including the legendary vaccinologist Maurice Hilleman, had previously questioned whether thimerasol could result in an unsafe level of mercury, and the governments of Sweden, Denmark, and Norway had banned thimerosal in vaccines, but such actions had little impact in the United States or United Kingdom (Mnookin, 2011, p. 131).22

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22 Hilleman was the most productive vaccinologist in history; for example, he and his laboratory developed vaccines for, among other things, measles, mumps, meningitis, and hepatitis A and B, in forms which are still used today.
The source of the connection could be blamed on the United States Congress. The mid-to-late 1990s saw more attention paid to mercury in American government, particularly anthropogenic mercury emissions. The Clean Air Act Amendments of 1990 had required the EPA and the National Institute of Environmental Health Sciences to conduct studies of the health impacts of mercury emissions from electric power plants, particularly those that burned coal, which at the time had become the primary source of environmental mercury. During this time, the successful Food and Drug Modernization Act of 1997 required the FDA review mercury-containing products, including drugs (Mnookin, 2011, pp. 121-123).

The FDA had previously determined benchmark levels of methylmercury at one part per million, above which they could stop the sale of food containing such levels (FDA, 1995). Vaccine dosages could lead to mercury levels above that; though ethylmercury is less toxic than methylmercury, and while recognizing the importance of vaccines and the lack of evidence of harm, the American Academy of Pediatrics and the United States Public Health Service issued a statement that “because any potential risk is of concern,” vaccine manufacturers should eliminate or reduce the amount of mercury in their vaccines (Pediatrics, 1999).23

Anti-vaccine activists, victims, and parents of children with autism, many primed by Wakefield’s work, quickly seized upon a potential thimerasol-autism link, despite the lack of any evidence that such a link existed. Even parents who had not previously considered a connection between vaccines and their autistic children seized upon a

23 There have been several cases of thimerasol poisoning in the medical literature, though all involved amounts far in excess of what is found in vaccines, see FDA (2017) (“Thimerasol in Vaccines,” 2017. Retrieved from https://www.fda.gov/BiologicsBloodVaccines/SafetyAvailability/VaccineSafety/UCM096228.
mercury-autism connection (Mnookin, 2011, p. 138). Wakefield’s 1998 claims and the AAP/USPHS call for thimerasol to be phased out of vaccines seemed to be conflated by many members of the public, even though the MMR vaccine investigated by Wakefield did not actually contain thimerasol.24

While the medical community reacted largely with skepticism to both Wakefield’s claims and the AAP/USPHS report, a rapidly organizing anti-vaccination movement in the United States seized on both. At the same time, they used the rapidly expanding internet to connect and collaborate with each other. Several such people formed the group SafeMinds; members even published a (non-peer-reviewed) paper purporting to demonstrate a link between thimerosal and autism (Bernard, Enayati, Redwood, Roger & Binstock, 2001).

As vaccine sceptics and those impacted by autism seized on thimerosal as a likely cause of autism, scientific critiques of Wakefield’s work not only grew but quickly turned personal. In 2004, The Lancet issued a statement addressing questions raised over study participant recruitment and Wakefield’s role in a pilot project to investigate grounds for a lawsuit brought on behalf of allegedly vaccine-damaged children, finding that Wakefield and his co-authors had been less than transparent in some aspects of their research (Horton, 2004). Despite significant medical consensus that the MMR vaccine was safe, the public reacted with dismay, and England saw a significant drop in MMR vaccination rates, and a subsequent increase in the number of measles cases, after the Wakefield press conference (Flaherty, 2011). Investigative reports that Andrew Wakefield had been funded by – and coordinated with – attorneys contemplating vaccine-related lawsuits, and

24 Wakefield himself would later argue that there was a high likelihood that thimerosal-containing vaccines could also lead to autism (Wakefield, 2016).
that there were significant flaws in data collection and analysis methods), would eventually lead to Wakefield losing his license to practice medicine (e.g. Deer, 2004).25

Of course, individuals can have negative reactions to vaccines; in 1986 Congress passed the National Childhood Vaccine Injury Act to provide a streamlined, no-fault adjudication of such potentially vaccine-based injuries, largely to protect pharmaceutical companies from large monetary judgments that threatened to drive many vaccines off the market altogether. In the aftermath of The Lancet article, autistic children and their parents and guardians in the United States poured into that court. Faced with thousands of petitioners now claiming that MMR and thimerosal-containing vaccines had caused autism, in 2002 the court set up an Omnibus Autism Proceeding that took in a handful of test cases to first establish whether the MMR vaccine and/or thimerosal-containing vaccines could be legally shown to cause autism. The test cases went on for years, while the remaining autism claims waited for their resolution. On February 12, 2009, the Special Master hearing the case concluded that there was no thimerasol-autism link; on August 27 of the following year, the United States Court of Appeals for the Federal Circuit affirmed the Special Master’s decision, bringing the Omnibus Autism Proceedings as they related to the thimerasol-autism link to an end (Cedillo v. Secretary of Health and Human Services, 2010).

Furthermore, the consensus among most autism researchers is that the condition has both genetic and environmental causes (Lai, Lombardo & Baron-Cohen, 2014). For example, a large population-based study in Sweden that examined over two million families found that autism risk increased significantly with increasing genetic relatedness.

25 For the General Medical Council’s decision regarding Wakefield’s research, see GMC (2010).
to individuals with autism, and concluded that the heritability of autistic spectrum disorders was approximately 50% (Sandin et al., 2014). As Lai et al. (2014, p. 899) note, “[u]nderstanding of gene-environment interplay in autism is still at an early stage.” However, over two decades of both epidemiological and pharmokinetic studies and meta-studies of possible links between autism and childhood vaccines specifically have found no significant evidence of such linkage (e.g., Parker, Schwartz, Todd & Pickering, 2004; Taylor, Swerdfeger & Eslick, 2014).26

4.5.3 Anti-Vaccine Activism as Manifestation of Industrial Age Anxiety

Did the dramatic media accounts of the effects of environmental mercury in the early 1970s drive at least some of the sentiment behind the thimerosal-related anti-vaccine movement? Baker suggests the anti-vaccine movement’s focus on thimerosal was driven partially by the history of poisoning events such as Minamata, along with a lack of public knowledge as to the chemical properties of mercury; he notes that “[p]erhaps unfairly, history has endowed mercury in all of its forms with a notoriety that is not easy to erase” (Baker, 2008).

Indeed, an entire industry of books skeptical of vaccine safety have sprung up in the past two decades after the Wakefield and AAP/USPHS announcements, both before and after The Lancet retraction, with authors advocating things ranging from modifying typical vaccination schedules for young children all the way to outright avoidance of all vaccines. Such books are often framed as “how-to” guides for parents and soon-to-be-parents. Many prominent anti-vaccine authors and advocates have invoked Minamata in

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26 Following Wakefield (1998), a small core group of researchers and activists, some with medical training but several without, have published papers purporting to link autism and vaccination (e.g. DeLong, 2011; Geier & Geier, 2007; Geier, Sykes & Geier, 2007). Their arguments have been overwhelmingly rejected by most researchers and medical organizations.
their argument against thimerasol in published works. Similarly, posts on a popular anti-vaccination site, ageofautism.com, reveal numerous references not just to the Minamata poisoning itself but also the response of Japanese governmental and industrial officials who downplayed, lied, or intimidated the Minamata victims, with suggestions that they – the antivaccination activists – are in the same situation, victims of government cover-ups and malice.

For many antivaccination believers, therefore, poisoning events like Minamata are not linked solely to thimerosal danger by mercury alone but also to government and industry forces working together to sacrifice human health (and most egregiously child health) for financial expediency. Power disparities (or perceived power disparities) drive risk perception; the fact that the “establishment” – whether the government, the medical profession, or the pharmaceutical industries – has pushed vaccines is therefore sometimes offered as evidence of their danger. The transitive cultural models of physical phenomena – like the intransitive mercury – therefore often involve social or cultural factors that should have no impact on the physical or biomedical characteristics of the substance. But conceptions of disease and suffering involve what the medical anthropologist Sherine Hamdy has referred to as “political etiologies,” where “the ways in which people make sense of illness are inevitably political moves that either ignore or speak to power” (Hamdy, 2008, p. 563). For many of its immediate or familial victims, autism is only

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For example, David Kirby (2010, p. 258) argued that the symptoms seen in Minamata victims were similar to autism. Olmsted and Blaxill (2010) even suggest that the Niigata mercury poisoning itself may have led to an autism outbreak in area children. Cave and Mitchell (2001) argue experts must look to Minamata for data on what thimerosal can do to the body. Kennedy (2015) and Geier et al. (2007) invoke the poisonings in Minamata, Iraq, and Ghana to highlight mercury’s risk. Prior to his anti-vaccine work, Kennedy developed a reputation as a prominent environmental activist, particularly in regards to water pollution issues (Waterkeeper, 2017).

See, for example, Conte (2014).
made sense of as something that was done to the victim by external forces, and it was
easy to blame such forces when they have a history of ignoring health and environmental
impacts on the public. Such scapegoating appears to be an inherent characteristic of
human psychology. For example, Rothschild et al. have developed a dual-motive model
of scapegoating that posits that such scapegoating “can serve two meaningfully distinct
motives: (a) maintaining perceived personal value by minimizing feelings of guilt over
one’s responsibility for a negative outcome and (b) maintaining perceived personal
control by obtaining a clear explanation for a seemingly inexplicable negative outcome . .
.” (Rothschild & Keefer, 2012). Vaccines can serve both functions when it comes to
autism, a disease simultaneously inexplicable but thought to have some sort of genetic
component. As Spier notes, “[t]he anti-vaccine movement derives its strength from
intellectual currents that are deeply embedded in the human condition” (Spier, 2001, p.
S83).

Unsurprisingly, then, the removal of thimerosal from almost all childhood
vaccines in the United States, and the final rulings in the Omnibus Autism Proceedings
have thus not stopped cases still claiming thimerasol-laden vaccines caused autism (e.g.
*Hardy v. Secretary of Health and Human*, 2016).29 In a nation where most infants receive
multiple vaccinations, for any given subset of children exhibiting early onset diseases
they are likely to have received a vaccination in the relatively recent past. For parents
who must deal autism day-to-day, external scapegoats may assuage conscious or
subconscious guilt. For some parents, alternatives to vaccine-caused injury may be too
unbearable to accept; in one recent Vaccine Program case, a mother blamed vaccines for

29 Opinions and orders from the Vaccine Claims Court can be accessed at
her son’s death, despite overwhelming evidence that his death was a result of asphyxia because she co-slept with him (Pelton v. Secretary of Health and Human Services, 2017). One consistent theme throughout anti-vaccine texts (including court filings) is a resistance to genetic reductionism, with the belief that while susceptibility to vaccine-born mercury may have a genetic component, that some environmental factor – like a vaccine – must play a part. Parents who accept genetic explanations sometimes blame themselves for that genetic expression (Decoteau & Underman, 2015).

By identifying thimerosal, anti-vaccine activists and believers were able to call on cultural models of risk that may have combined not only risk models engrained in the aftermath of Silent Spring and Minamata, but also a growing antipathy towards expertise and authority; one popular vaccine book encapsulates all of the above in its title, Vaccine Epidemic: How Corporate Greed, Biased Science, and Coercive Government Threaten Our Human Rights, Our Health, and Our Children (Habakus, Holland and Rosenberg, 2011).30 In his book Callous Disregard: Autism and Vaccines, the Truth Behind a Tragedy, Wakefield himself characterized his story as one of “how the powerful deal with threats to their interests” (2010, p. 4). Just as unrestrained industry had poisoned formerly clean land, water, and organisms with mercury, unrestrained industry had poisoned young children and stolen not just something physical but through autism something of their very mental essence. Such a charge is leveraged by not just Minamata but innumerable events of industrial crimes in the United States and abroad; why should activists believe the government and the medical-industrial complex now when they have

30 The book is published by Skyhorse Press, which publishes numerous books linking vaccines to autism and other adverse health impacts, including several of the books cited herein. See http://www.skyhorsepublishing.com/search?q=vaccine+%22vaccine%22&f=1.
demonstrably misled the public on so many occasions before? Individual medical practitioners often receive little more credibility in the minds of anti-vaccination activists; their engagement with medical professionals is tinged with failure and disappointment: there is no known cure for autism.

Deeply contextualized, cultural models “once learned, cannot be easily unlearned” (Atran et al., 2005, p. 24). Models of mercury perception that see thimerasol as poison are buttressed by both political etiologies based on institutional distrust and historical accounts of mercury’s poisonous effects. That may help explain why neither the overwhelming scientific consensus that thimerasol is safe nor the fact that it has been removed from almost all childhood vaccines (including the DPT vaccine) – and that it was never in the MMR vaccine in the first place – has done much to reduce the fervor of anti-vaccine activism in the United States. Some anti-vaccine activists have focused their anger on influenza vaccines, the multi-dose versions of which still may contain thimerasol (Moms Against Mercury, n.d.-a). Others have simply proposed non-thimerosal forms of mercury can cause autism, such as emissions from coal combustion or mercury dental amalgams (SafeMinds, n.d.-a; Moms Against Mercury, n.d.-b, n.d.-c). Some have also begun to advocate for removing thimerosal for vaccines in the developing world where it may still be used frequently due to lack of refrigeration (Barry, 2015, Ch. 7; SafeMinds, n.d.-b; Selin, 2014).

As Forrester recognized long ago, mental models are “fuzzy . . . incomplete . . . [and] imprecisely stated” (Forrester, 1971, p. 12). Ultimately, the intransitive reality of the MMR vaccine is that it does not contain mercury and is not linked to autism; the transitive cultural model of the vaccine is not so limited. The temporal proximity of the
Wakefield paper and the AAP/USPS call for vaccine manufacturers to remove thimerasol from their formulations may have simply become intertwined for many anti-vaccine believers and activists. That the vaccines at issue may not have mercury in many cases is beside the point; cultural models are by definition simplified representations of the real world, and constrained by evolutionary limitations of the human brain. Dealing with the biomedical complexities of vaccines may simply result, in many cases, in a model that reduces vaccine risk to mercury, and mercury to the toxic form which caused so much damage to the victims of Minamata.

The impact of the recent thimerasol-driven anti-vaccination movement is uncertain. Looked at broadly, overall vaccination rates in the United States (including vaccines that formerly had thimerasol) have tended to remain stable, both before and after The Lancet paper and the AAP/USPHS statement. However, those rates can hide high vaccination refusal rates at the local level; several areas of the country have seen sharp decreases in their vaccination rates leading to outbreaks. For example, pertussis cases (whooping cough) increased significantly in the early 2000s, going from 7,580 in 2001 to over 25,000 in the years 2004-2005, and peaking at 48,277 in 2012. The impact of mandated vaccination laws at the state level (or the relaxing of such laws) can also impact vaccination rates.

4.6 Conclusion

Humanity has grown up with mercury, from simple cave drawings using cinnabar to modern telescopes using mercury as a reflective mirror. Alternately potent and dangerous, its shifting, liquid physicality serves as a metaphor for its own role in human

33 See Child Trends (https://www.childtrends.org/indicators/immunization/).
34 See CDC VaxView (https://www.cdc.gov/vaccines/vaxview/).
history. But mercury as a historically constituted cultural model is not just driven by perceptions (and misperceptions) of its physical and chemical impacts; drawn into those models are conceptions of modern industrial society and technocratic authority that affect mercury’s biophysical impact in the minds of those who must deal with it.

Cultural models of mercury change but also retain old concepts. Mercury as remedy may have been mostly purged from the corpus of acceptable medicine outside vaccine use, but it still maintains an important part of folk medicines outside of modern medicine. Mercury-containing medicine can be found in ethnic enclaves in the United States, including in Chinese herbal remedies (Wong, 2004) and in the botánicas serving Caribbean communities where mercury-based medicinals are sold to followers of the indigenous Caribbean religions espiritismo, voudoun, and Santeria (Zayas & Ozuah, 1996). Religious use of mercury-containing products can range from the relatively benign practice of carrying it around in sealed pills for luck (Ojito, 1997) to highly-dangerous injections of it to “ward off evil” (Prasad, 2004, p. 1326). On the other side of the mercury risk chasm, anti-vaccine activists imbue safe levels of thimerasol with the unsafe characteristics of the more toxic methylmercury, seeing them as harmful agents of an unfeeling, profit-driven government-medical-industrial complex.

Though emissions controls have improved, the rapidly increasing number of coal-fired power plants in the developing world, especially China and India, have become a major source of anthropogenic mercury. At the same time, increases in global gold prices have led to a massive increase in the use of mercury in artisanal small-scale gold mining (ASGM) in the developing world, which now makes up the largest anthropogenic source of mercury on a global level. Using techniques not much more advanced than that used
thousands of years ago to purify mined materials of non-gold elements, and often working on legal and societal fringes, ASGM miners and refiners risk not only mercury inhalation risk but also discharge large amounts into the environment (UNEP, 2013c).

As a result, governments around the world are engaging with mercury risk at an unprecedented level. For example, representatives of over 100 countries around the world signed the Minamata Convention on Mercury on October 10, 2013. The Convention is a global treaty that when in force will impose binding obligations on its adhering countries to, among other things, reduce anthropogenic mercury emissions to the environment and address mercury’s risk to human populations. After economic development, largely unrestrained by environmental considerations, China – one of the largest emitters of mercury – implemented a comprehensive mercury mitigation plan in 2012. In the United States, almost 40 years of debates over the regulation of mercury emissions from coal-fired power plants, the country’s most significant anthropogenic source since at least the early 1990s, came to an apparent end when the EPA finalized rules regulating such emissions – though the Trump administration has indicated it may revise or remove the rule. The comment period for the initial proposed rule drew over 900,000 public comments, most in support of the rule (see Chapter 5).

But policy initiatives to deal with environmental risk cannot ignore that risk is a social construction. Scientific models of mercury actions and mechanisms may become more accurate, but that does not necessarily mean that cultural models will follow. Legal and regulatory efforts to protect human beings not only from mercury but also from infectious diseases that vaccines prevent are subject to seemingly irrational reasoning and decision-making that have either overestimated mercury’s risk or underestimated it for
too many people. Mercury fish advisories have been issued since the 1970s in the United States, but there is significant noncompliance with such advisories, leading to potentially unsafe consumption habits, particularly in poor communities and communities of color (Beehler, McGuiness & Vena, 2001).

This is not unique to mercury; the transitive cultural models about climate change, about other contaminants, and about other health risks have proven difficult to change; the rationalist “information deficit” approaches to improving public decision-making, which assumes that the solution to inaccurate reasoning is to provide better scientific information, has proven severely flawed (Owens, 2000). Cognitive scientific frameworks like cultural models offer a theory of reasoning that seem to more accurately explain how humans actually behave.

However, current cultural/mental models approaches to human-environment interactions have tended to focus on creating “snapshot” models that elicit and report mental models of specific groups at a specific place in time, with the focus of improving decision-making processes by both individuals and groups. But as such models are historically constituted, understanding the processes by which people understand, reason, and make decisions about environmental hazards could benefit from historical perspectives that examine the transmission of knowledge over time. Such an interdisciplinary approach to environmental cultural models could result in better historical analysis as well as better environmental decision-making research that can inform policy improvements and create healthier outcomes for the public.
Chapter 5
Alchemical Rulemaking and Ideological Framing: Lessons from the 40-year Battle to Regulate Mercury Emissions from Electric Power Plants
5.1 Overview

On June 12, 2016, the Supreme Court denied certiorari to industry petitioners seeking to vacate the Environmental Protection Agency’s (EPA’s) rule regulating the emissions of mercury and other Hazardous Air Pollutants (HAPs) from coal- and oil-fired electric generating units (EGUs) under §112 of the Clean Air Act (2012) (CAA) (White Stallion Energy Center v. EPA, 2016). That ruling appeared to signal the end of a 40-year debate over EPA regulation of EGU-sourced mercury, a conflict that intensified after a 2000 rule promulgated by the Clinton administration regulating EGU-sourced HAPs, and escalated over the next 16 years as successive administrations attempted to put in place mercury regulations that reflected dramatically different environmental ideologies. However, as had happened several times before, the future of EGU-sourced mercury emissions regulations is now in doubt again. In response after the Trump administration announced that it was “reviewing” the rule. The latest ruling comes

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35 Following academic convention, I refer to CAA bill section numbers in the text (e.g., §112), while referring to their parallel U.S. code provisions in references (e.g., 42 U.S.C. §7412).
36 Petitioners sought to overturn the D.C. Circuit’s decision to remand the rule to EPA rather than vacate it.
37 As will be discussed in more detail below, the rulemaking history concerning EGU-sourced mercury and other HAPs is convoluted: EPA initially promulgated a rule regulating such emissions from EGUs in 2000 during the Clinton administration (Regulatory Finding, 2000), attempted to reverse that decision in 2005 during the Bush administration (Revision of December 2000 Regulatory Finding, 2005), re-“confirmed” the 2000 rule in 2012 during the Obama after it had been reversed by the D.C. Circuit Court invalidated the attempted 2005 revision (National Emissions Standards, 2012), but then had to revise the original 2000 listing decision after the Supreme Court held it had impermissibly failed to account for costs (Supplemental Finding, 2016). That final revision was appealed, and after the Trump administration took office it attempted to halt that litigation while it “reviewed” the revision (Murray Energy Corp. v. EPA, 2016). Principal proposed and final rules are discussed herein; as with many complex rulemaking processes, numerous minor technical corrections are published through the Federal Register, but are not referenced unless substantively relevant to the discussion at hand. The relevant rules, laws, and other legal instruments are included in Appendix A.
38 The recent election of Donald Trump, who has taken office with Republican majorities in both the House and Senate, and who has called for significant rollbacks in environmental protection laws, renders the issue slightly more uncertain than it appeared prior to November 8, 2016. As will be discussed in more detail below, at the time of writing the Trump administration has announced that it will revisit the regulations currently in place; this chapter therefore may function not just as a work of environmental legal history but a possible blueprint to future attempts to weaken or withdraw the regulation.
almost a year after the Supreme Court invalidated the same rule on the grounds that it impermissible failed to incorporate costs into the decision to regulate EGUs under §112, leading the D.C. Circuit Court to remand Obama administration’s attempt to put into effect stringent HAP emissions restrictions opposed by the EGU industry, in *Michigan v. EPA* (2015).

Until recently the decades-long debate over whether EGU-sourced mercury should be regulated under the HAP provisions of CAA has been consistently resolved in favor of the EGU industry and a “wait and see” approach that used scientific uncertainty as a rationale to avoid regulations the energy industry sees as financially undesirable, even as evidence has increasingly shown that environmental mercury may pose a risk to a significant number of Americans, particularly children and the unborn.

Over the past several decades, increased understanding of the mercury cycle and the potential health impacts of environmental mercury has led to legal and regulatory mechanisms both domestically and abroad intended to mitigate such health risks.39

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39 A number of state and federal statutes and regulations regulate mercury from a variety of sources in products, food, and the environment, though a comprehensive discussion of such regulations is beyond the scope of this chapter (EPA, 2017; Thomas, 2004). The focus here is on EGU-sourced mercury emissions regulations under CAA because those emissions currently make up the largest single source of anthropogenic mercury emissions in the United States, and because the complex regulatory history concerning them offers a compelling case study in the evolution of, and difficulties inherent in, the U.S. system of federal environmental governance. Furthermore, the federal environmental regulatory scheme is enormously complex, and other environmental laws and regulations can, in theory, regulate EGU-sourced mercury indirectly; for example, the Clean Water Act (CWA) requires states to report waterbodies containing certain levels of pollutants, including both mercury generally and methylmercury specifically, that may have been deposited from EGU emissions. Also beyond the scope of this chapter is an in-depth treatment of the Minamata Convention, a global treaty created in 2013 to regulate mercury releases to the environment and to which the United States is a party; the Convention is discussed in detail in Chapter 6. While Article 8 of the Minamata Convention requires the U.S. to take steps to reduce EGU-sourced mercury emissions, it currently stands as a sole executive agreement entered into under the President’s executive authority, meaning that as of now compliance with the Convention will be carried out through the CAA rulemaking discussed here. Such efforts could be abandoned by the new administration. For a discussion of legal issues relating to the domestic implementation of sole executive agreements, see Clark (2007).
However, such regulations are complicated not only by significant uncertainty in how mercury moves through the environment and to what extent it affects humans and other organisms once it has entered the body (see Chapter 2), but also by political and economic interests that impact the success and stringency of regulations.\textsuperscript{40}

One of the most significant anthropogenic sources of environmental mercury is the EGU sector.\textsuperscript{41} Despite growing scientific and public concerns in the 1960’s and 1970’s over anthropogenic mercury in the United States, and the creation of CAA which allowed Federal enforcement of airborne toxics, EPA has historically been largely unwilling to directly regulate EGU-sourced mercury. While EPA began regulating atmospheric mercury emissions under §112 from certain other sources as early as 1973 (Asbestos, Beryllium, and Mercury, 1973), it did not attempt to regulate EGU-sourced mercury as a HAP until 2000, a decision which the second Bush administration would attempt to retract, leading to lengthy court battles, a subsequent attempted re-implementation by the Obama administration in 2011, the Michigan decision and its aftermath.

The historic failure to regulate EGU-sourced mercury has not been driven by any single factor. Legitimate scientific uncertainty complicates the issue; while evaluating the health or environmental risks of air pollutants generally is rife with uncertainty, mercury science particularly has suffered from significant knowledge gaps in how it moves and

\textsuperscript{40} For earlier accounts of EGU-sourced mercury regulation, see Heinzerling and Steinzor (2004a, 2004b), Rugh (2004), Ruhl (2008), and Thomas (2004).

\textsuperscript{41} The majority of EGU mercury emissions come from coal-fired electric utility generators, though oil-fired generators also emit mercury in smaller amounts. Gas-powered EGUs do not emit mercury in any significant amount; for the purposes of this chapter, and consistent with the EPA’s own definition, “EGUs” without any qualifier as to type refers to coal- and oil-fired utility units generating electricity for sale, typically found in electric utility installations.
cycles through the environment, as well as how it impacts human populations (Gribble et al., 2016; Subir, Ariya & Dastoor, 2013; UNEP, 2013c). However, as will be argued below, scientific uncertainty has often been used as a discursive weapon to delay or weaken regulation, and many decisions in mercury regulation specifically can be credibly attributed to what environmental policy theorist Wendy Wagner (1995) defines as the “science charade” - or regulatory agencies’ use of putatively scientific rationales (in this case scientific uncertainty) to avoid accountability for underlying policy decisions.

This “science charade” has been driven largely by the powerful energy utility and coal lobbies and pro-industry administrations generally hostile to environmental regulations, and enabled by a successful multi-decadal push by anti-regulatory think tanks, lobbying groups, and advocacy organizations to not only normalize cost-benefit approaches to managing environmental health, but also do so in a way that maximizes industry costs and minimizes public benefits of potential regulatory approaches. These actors have crafted effective anti-regulatory, pro-capitalism “policy stories” that have significantly changed the regulatory landscape, particularly since the 1980s (Shapiro, 2017, p. 6). When the more easily quantifiable costs of mercury emissions control are measured against the far more uncertain risks of those emissions, it is easy for opponents to justify waiting for greater scientific certainty – “‘the degree of scientific certainty demanded is proportional to the cost of doing something about it.’” (Oreskes & Conway, 2010, p. 64). Furthermore, and as will be shown below, anti-regulation policymakers and their allies in the public and private sphere have become especially adroit at minimizing, weakening, and delaying regulatory measures through indirect approaches that use a
putatively pro-environmental narrative frame while implementing rules that favor industry.

This chapter attempts to trace how EGU-sourced mercury escaped regulation for so long under the CAA despite growing scientific and societal awareness of the dangers of environmental mercury that saw other anthropogenic sources of the element become more tightly regulated. While several articles have been published addressing specific regulatory debates in EGU-sourced mercury regulations (e.g., Heinzerling & Steinzor, 2004a, 2004b; Rugh, 2004; Ruhl , 2008), this chapter updates those debates to the present as well as examines that regulatory history over the life of CAA, situating that history in the context of the larger ideological conflicts that grew to define the environmental policy discourse in the United States following the implementation of the federal environmental regulatory apparatus, and the various discursive strategies anti-regulatory actors have used to prevent the regulation of mercury emissions from EGUs.42

As political scientist and environmental policy analyst Judith Layzer has noted, “[a]n exclusive focus on overt policy debates and formal decisions can obscure ‘the subterranean political processes that shape ground-level policy effects,’ as well as the ways that powerful actors shape and restrict the political agenda, ensuring that some issues are never seriously considered” (Layzer, 2012, p. 11). Drawing on a similar framework, the analysis below examines regulatory debates over EGU-sourced mercury as “struggles to define problems and characterize solutions within a rhetorical and institutional context.” (Layzer, 2012, p. 11). This chapter examines the historical large-

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42 It takes, in other words, a diachronic approach, following Cooper and Brady (1981, p. 988) who argued that “the concepts and measures required to provide an adequate basis [of current structures] need to be developed through diachronic, rather than merely static analysis”. 
scale regulatory, ideological, and political narratives that have impacted mercury regulation decisions, with a particular focus on the discursive practices and tactics used in different policymaking processes to show how different actors have “define[d] problems and characterize[d] solutions” surrounding environmental mercury in a way that has served economic and ideological interests but not necessarily public health. The discursive analysis taken here seeks not simply to “tell[] a story” but to do so in a manner that will offer insight into how policy is developed and how such discursive strategies can push implementation of laws in directions unforeseen – and unwanted – by the lawmakers who created them (Litfin, 1994, p. 191).

**Part I** forms the largest and most central component of this chapter, examining the creation of the CAA and the history of mercury emissions regulations under it, focusing on the legislative and regulatory battles over EGU-sourced mercury, and how those battles fit into the larger policy debate about air toxics regulation over the past 40 years. It divides the 40-year history of mercury emissions regulations into three different historical periods, representing: (1) the creation of the CAA until 1989; (2) the passage of the 1990 CAA Amendments until the 2000 Listing Decision; and (3) the period from the 2000 Listing Decision until the present, analyzing each period in the context of that larger narrative. **Part II** concludes by discussing the evolution of regulatory narratives over EGU-sourced mercury and the historic costs of this inaction in terms of human health, and offering suggestions to improve future legal and regulatory decisions about mercury specifically and other air toxics in general.

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43 As articulated by Prof. Litfin (p. 194) the value of a discursive approach to environmental policy analysis is that it can “offer important insights into the policy process in general and perhaps into future events . . . It can alert the analyst to certain misconceptions that might arise, and it can also alert the practitioner to the importance of alternative discursive strategies.”
5.2 Background

In 1997 EPA estimated EGU-sourced mercury emissions in the United States at 47 tpy (EPA, 1997a) a number that was used as a baseline in EGU mercury emissions regulatory debates though about 2011, though subsequently other CAA regulations and state regulations were projected to reduce mercury emissions to an estimated 29 tpy in 2016 (EPA, 2011b, p. 8).\textsuperscript{44}

5.3 Mercury Emissions Control

Due to its low concentration and chemical characteristics, controlling mercury emissions from combustion sources like EGUs can be difficult (Government Accountability Office (GAO), 2009; Northeast States for Coordinated Air Use Management [NESCAUM], 2010; United Nations Environment Programme (UNEP), 2015). EPA has identified four general control techniques: (1) pre-combustion pollution prevention measures (such as product substitution or process modification); (2) coal cleaning; (3) alternative approaches (e.g., emissions trading or use taxes); and (4) flue gas treatment technologies (EPA, 1997A, p. ES-8). Because almost all coal contains mercury, and because coal cleaning (removing mercury pre-combustion) has limited effectiveness, technical approaches typically focus on developing flue gas treatment technologies to remove mercury from flue gas after combustion but before it leaves the smokestack (GAO, 2009).

The technical and economic feasibility of using specific mercury control technologies at a given EGU are dependent on coal used, boiler design, and the types of

\textsuperscript{44} The 29 tons figure represents a baseline figure not reflecting any mercury-specific EGU pollution controls.
pollution control technologies already in place, though GAO has predicted that sorbent-injection systems will be able to substantially reduce mercury emissions at a relatively low cost for most plants (GAO, 2009, p. 27).

5.4 Early Legal and Regulatory Approaches to Mercury Health Risks

While by the early 20th century numerous laws regulating mercury had been implemented at the state level, they focused solely on protecting the public from direct exposure to mercury products (e.g., Minn. Stat. §2337, 1908; Revisal 1908, N.C. ch. 95 sec. 4489, 1908). No such regulations existed at the Federal level.45 In the wake of the first Earth Day and responding to a public that demanded concerted action by the federal government to mitigate pollution, the then-existing patchwork of state and federal approaches to pollution control was supplanted in large part with more comprehensive federal frameworks. The new federal laws would largely supplant rather than supplement traditional tort claims over environmental contaminants.46

Even before the creation of EPA and the environmental laws it would implement and enforce, mercury ranked highly as a contaminant of particular concern; members of the Senate held two days of hearings in the summer of 1970 on the threat environmental mercury posed to both humans and the environment (Effects of Mercury on Man and the Environment, 1970). Similarly, the second annual report of the Council on Environmental Quality (CEQ) recognized toxic mercury pollution as “a serious national problem” (1971, p. 9).

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45 The Pure Food and Drug Act of 1906 outlawed the sale of “adulterated” food in general, but mercury was not specifically listed as an adulterant in the statute or the implementing regulations of the time (Pub. L. No. 59-384).

46 The preemption of traditional common-law tort causes of action were established by a number of different Supreme Court decisions (e.g., American Electric Power Company v. Connecticut, 2011; Middlesex County Sewerage Authority v. National Sea Clammers Association, 1981).
5.5 Mercury Regulation Under CAA

Most of the contemporary debate and controversy over regulating mercury emissions has taken place in the context of CAA, arguably the most important – and most fought-over – federal statute arising in that “golden age” of federal environmental law. CAA and the implementing regulations promulgated by EPA have been the primary regulatory instruments through which the Federal government (and by delegation, state governments) regulates atmospheric emissions of pollutants and potential pollutants from both stationary and mobile sources.

CAA replaced earlier, more limited federal air pollution measures which had been created in the preceding decades in response to growing public concern over air quality. While some states had already taken steps to statutorily abate such pollutants (Degler, 1969), such moves were hampered by air pollutants’ tendency to move across state borders (Muskie, 1969). The Air Pollution Control Act of 1955 was the first federal statute to address air pollution, providing funding for research and technical assistance; however, as its drafter reassured his colleagues, it was not intended to intrude on the states’ authority to control air pollution (Bailey, 1998, pp. 91-110). While the Federal government’s advisory role was maintained in amendments to that act in 1960 and 1962, growing public (and legislative) support for federal intervention into pollution abatement led to the passage of the Clean Air Act of 1963, amended in 1967, which allowed the Department of Health, Education, and Welfare to set emissions criteria. However, the

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47 By 1963 only 14 states had air pollution control laws at a state-wide level, though after the passage of the CAA of 1967 this would grow to 46 by 1969. However, not all states with authority to regulate air pollution used that authority. Only four states (Alabama, Maine, Nebraska, and South Dakota) had no statutory authority under state law to regulate air pollution, though they could do so under nuisance statutes (Degler, 1969, pp. 1-32; Kennedy & Porter, 1955).
Department’s enforcement ability was limited to requesting the Department of Justice to bring a suit for pollution abatement, and even then, could only request such a suit after a long series of administrative procedures had been followed (, 1964, §§1857d(c)).

Public concerns over pollutants during this time period tended to focus on more visible pollutants. Priority was given to chemical components or precursors of highly visible, predominately urban air pollution, particularly the ozone relating to photochemical smog, as well as particulates and sulfur dioxide (SO₂), a noxious, terrible-smelling compound known for causing lung irritation and illness (Bailey, 1998, p. 129; OTA, 1989, pp. 209-210; Dorries, 2014). However, through the 1970’s scientists, policymakers, and the general public had become more aware of invisible toxics, thanks in large part to Rachel Carson’s seminal 1962 work, *Silent Spring*, which likely helped drive creation of the HAP provisions of the CAA.

Dissatisfied with what was perceived as ineffective regulation under the earlier Clean Air Act of 1963 (and its 1967 amendments), and faced with growing clamor from the states for federal intervention, Congress essentially rewrote the then-current air pollution regulatory scheme in 1970 with CAA, implementing a comprehensive statute which, among other things, established procedures for EPA to set and enforce emissions standards and strengthened enforcement mechanisms. While regulation of mercury seems fairly straightforward –the dangers of environmental mercury were fairly well-known then, and a Senate committee report during the drafting process expressly suggested “Examples of substances which the Administration informed the Senate were likely to be

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48 Though focused on pesticides, particularly DDT, the book held one reference to mercury, referring to it as a “poison” used in some crabgrass killers (Carson, 1962, p. 80).
controlled under this [§112] provision [include] mercury” (A Legislative History of the Clean Air Act Amendments, 1974, p. 133) – attempts to do so under CAA have been piecemeal and, when it comes to EGU-sourced mercury, unsuccessful for most of CAA’s history. CAA and implementing regulations contain several different mechanisms for limiting air pollutants from both stationary and mobile sources, though only the stationary source provisions are of significant relevance to mercury regulations. An enormously complex statute, CAA has numerous provisions applying to different pollutants, areas, and sources; addressed below are the primary regulatory tools for governing general pollutants from stationary sources like EGUs.

5.6 Pollutant Regulation Provisions of CAA Applying to Stationary Sources

5.6.1 CAA §108: National Ambient Air Quality Standards

To control the ubiquitous, large-scale pollutants like ozone, SO₂ and nitrogen oxides (NOₓ) which affect air quality over large areas, Congress enacted CAA §108, which requires the creation of state- or EPA-designated air quality regions and the designation of national ambient air quality standards (NAAQS) for pollutants which “which may reasonably be anticipated to endanger public health or welfare [and] the presence of which in the ambient air results from numerous diverse mobile or stationary sources” (Clean Air Act, 2012, §7409(a)-(b)). Such standards restrict the level of criteria

49 Unless otherwise specified, the general provisions described here have been a part of the CAA from its passage in 1970 until the time of this writing, with cites to the statute based on the present U.S. Code. Mercury is not emitted from mobile sources in any significant quantities, so provisions of CAA applying strictly to mobile sources are not discussed.

50 Both primary and secondary standards are set, with the primary standards designed to protect public health “allowing an adequate margin of safety,” and less stringent secondary standards aimed at protecting the “general welfare” (CAA, §7408, 2012). As currently codified, the distinction is not particularly important since air quality regions are considered non-attainment under CAA § 107(d) if they fail to meet either primary or secondary standards.
pollutants permitted in the ambient air in a region, with states then directly regulating sources within their jurisdiction through State Implementation Plans (SIPs) tailored to meet those NAAQS requirements.\textsuperscript{51} Failing to meet NAAQS deadlines, or submitting SIPs that do not meet EPA approval, may subject states to potential penalties (Clean Air Act, 2012, §7413). While nothing in CAA’s original text precluded mercury from being regulated as a criteria pollutant, regulation under §112 (discussed in Section 5.7 below) as a HAP shortly after passage barred mercury’s designation as a criteria pollutant, and the 1990 Amendments firmly established that mercury emissions, including EGU emissions, were to be regulated under §112.\textsuperscript{52} Since CAA’s passage, §108 has never been used or proposed as a direct mercury regulatory mechanism, though as discussed in Section 5.9 below, controls for some types of criteria pollutants can also reduce mercury emissions as a co-benefit.

### 5.6.2 CAA §111: New Source Performance Standards

While §108 allows states some flexibility in the actual emissions standards set in SIPs so long as the region’s ambient air quality goals can be met, §111 requires EPA to directly regulate emissions standards for new sources of pollutants “caus[ing], or contribut[ing] significantly to, air pollution which may reasonable be anticipated to

\textsuperscript{51} In 1971 the EPA promulgated regulations designating six NAAQS criteria pollutants: SO$_2$, particulates, carbon monoxide, photochemical oxidants, hydrocarbons, and NO$_X$ (36 Fed. Reg. 8186, 1971) (codified as 40 C.F.R. §§50.4-50.18). In 1978 the EPA designated lead as a criteria pollutant, but has not designated any additional criteria pollutants since then (43 Fed. Reg. 46246, 1978).

\textsuperscript{52} A separate but related provision is CAA Part C, designated as Prevention of Significant Deterioration of Air Quality (“PSD”) which require the EPA and state governments to implement additional permitting requirements ensuring that air quality is not degraded in other areas that have attained NAAQS standards. As originally implemented in the 1977 Amendments, PSD restrictions could be placed on non-criteria pollutants, including mercury. 42 U.S.C. §§160 (1980); see also Alabama Power Co. v. Costle (1979), which notes in \textit{dicta} that “the fact that mercury is not [regulated under §112 does not] mean[] that mercury is not a pollutant subject to regulation [under PSD].” However, following the 1990 Amendments, §112 HAPs are excluded from regulation under the PSD provisions (Clean Air Act, 2012, §7412(b)(6)).
endanger public health or welfare” (CAA, 2012, §7411). A “new source” under the statute means one that is constructed or modified in a way that increases its emission of any air pollutant after emissions standards have been set by EPA. Standards are based on the best emissions reduction system achievable, taking into account costs, and energy and non-air environmental impacts (CAA, 2012, §7411(a)(1)). The section provides that the states may implement and enforce EPA’s new source standards through SIPs, though §111(c)(2) allows EPA to directly enforce standards for those new sources (CAA, 2012, §7411(c)(2)). The sole major attempt to regulate EGU-sourced mercury under the §111 New Source Performance Standards (NSPS) provisions was under the Bush-era EPA’s Clear Skies Plan, discussed in more detail in Section 5.9.1 below.

Under the NSPS sections as originally enacted, EPA could also apply the new source emissions standards to already-existing sources, but only if those pollutants were not already regulated as criteria pollutants (under §108) or HAPs (under §112); this provision was intended primarily to serve as a “‘gap-filling’ measure for ‘pollutants which cannot be controlled through the ambient air quality standards and which are not hazardous substances” (Cross, 1986, pp. 215, 233). Whether that provision survived the 1990 Amendments without substantive change is uncertain, however, as due to a legislative error arising out of the 1990 Amendments, §111(d) currently may preclude regulating those sources that are already regulated as HAP, even if the specific pollutant itself is not regulated.53

53 The Senate and the House of Representatives passed different versions of §111(d) in the Clean Air Act Amendments of 1990. The Senate version prevents EPA from regulating pollutants under §111(d) that are regulated also regulated under §112, while the House version prevents EPA from regulating sources that are regulated under §111(d). While the issue came up in West Virginia v. EPA regarding the Clean Power Plan, it has not yet been resolved (e.g., Childers, 2016).
5.6.3 CAA §112: Hazardous Air Pollutants

Historically, however, the CAA section most relevant to mercury regulation are the HAP provisions under §112. This section mandates that EPA set emissions standards for HAPs that pose a “threat of adverse human health effects . . . or adverse environmental effects” (CAA, 2012, §7412(b)(2)). The statutory language is ambiguous as to whether a pollutant should be regulated as a NAAQS criteria pollutant or as a HAP, as has been interpreted over the lifetime of the CAA criteria pollutants tend to be more ubiquitous and dangerous in larger amounts, while HAPs tend to be found in smaller amounts and/or in fewer places, but are significantly more toxic (NRC, 2004; Williamson et al., 1993, p. 705). As with NSPS, EPA sets specific national emissions standards itself rather than through individualized SIPs, though this does not preclude state-level emissions standards that are more restrictive, and the states can and typically do handle permitting and enforcement regarding compliance with the HAP regulations.54

The original CAA required EPA to designate a substance as a HAP if it “may cause, or contribute to, an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness” (CAA, 1988, §7412(a)(1)). While as written it did not expressly permit EPA to limit HAP regulations by source, shortly after the statute’s creation EPA interpreted it as doing so (EPA, 1973, p. 100),55 and in 1990 Congress

54 The initial version of CAA provided that “[i]f the Administrator finds the [submitted] State procedure is adequate, he shall delegate to such State any authority he has under this Act to implement and enforce such standards . . .” (CAA, 1970, §112(d)). The Clean Air Act Amendments of 1990 reserved the right of the Federal government to delegate implementation and enforcement procedures to the states, but provided more detailed information on state responsibility, and provided for research and management assistance.

55 The relevant opinion states: “[W]e believe that §112 standards should be made applicable only to designated sources. Whenever it appears that additional sources may emit the pollutant in question in unsafe amounts, we will immediately investigate the situation and propose and promulgate regulations as necessary to protect the public health.”. The EPA’s decision to list HAPs as limited to those from specific sources appears to have gone largely unchallenged, though the President’s Council on Environmental Quality originally took a different interpretation in their second annual report, where they noted that
codified this interpretation (CAA Amendments of 1990, 1990, §301(c)). Unlike with §111, all sources of emissions are regulated, whether old or new. When setting those limits EPA was required to, within 180 days, propose standards that were “at the level which in [EPA’s] judgment provides an ample margin of safety to protect the public health from such hazardous air pollutant,” with no allowances for cost (CAA, 1988, §7412(b)(1)(B)). Even when, as shown below, the 1990 amendments liberalized how emissions standards were determined, the focus of CAA §112 has remained on public health.

When first passed, Congress clearly intended the CAA to force aggressive EPA regulation of HAPs under CAA §112(a)(1) (CAA, 1988, §7412(b)(1)(B); Graham, 1985, p. 110). The Nixon Administration was less enthusiastic, recommending unsuccessfully during Conference proceedings that the entirety of §112 be removed (Clean Air Act, §7412(b)(1)(B); Graham, 1985, p. 110). In practice, however, the first two decades of the CAA’s existence saw little action taken by EPA to designate and control substances as HAPs.

5.7 Regulating Mercury as a HAP: 1971-1989

5.7.1 Mercury Emissions and HAP Regulations in CAA’s First Decade

Despite the nominal strength of the HAP provisions, their reliance on the initiative of the executive branch quickly proved a barrier to regulation. Shortly after the creation of both EPA and the CAA, the Nixon administration, worried particularly about the cost of CAA regulations, quickly put in institutional measures to limit EPA’s effective power by allowing the Office of Management and Budget (OMB) a significant

“Asbestos, mercury, and beryllium have been designated as hazardous air pollutants for which Federal emissions standards, applicable to all sources, will be promulgated.” (emphasis added) (CEQ, 1972).
oversight role (Durant, 1985; Percival, 1991, pp. 131-133; Rodgers, 1972). Nixon’s willingness to limit EPA’s effectiveness so quickly after its creation was likely a result of personal frustration; after disappointing results from the 1970 Congressional elections, and resentful over a perceived lack of credit from environmentalists for what he accomplished, Nixon likely saw far less political gain to be had from siding with those environmentalists of whom he characterized in a meeting with auto industry executives as interested in “destroying the system” (Flippen, 2000, p. 142; Lazarus, 2004, p. 77).56 The CAA especially was “[c]onservative critics’ main target during the 1970s” (Layzer, 2012, p. 64).

Nevertheless, in 1971 EPA did include mercury in its first proposed list of HAPs, but proposed standards only for chlor-alkali and ore processing facilities (List of Hazardous Air Pollutants, 1971; National Emissions Standards for Hazardous Air Pollutants, 1971). EPA failed to promulgate actual emissions standards within the statutory deadline following listing, finally doing so in 1973 after being sued by the Environmental Defense Fund (EDF) (EDF v. Ruckelshaus, 1973; National Emission Standards for Hazardous Air Pollutants, 1973). EPA’s final rule applied only to the proposed sources, and then only to prevent emissions of 1 ppm or over—in other words, levels that were considered high enough to be potentially dangerous outside any bioaccumulation process. In implementing this rule, EPA acknowledged that methylmercury was “by far the most hazardous mercury compound, particularly via the

56 For a more favorable view of Nixon’s environmental legacy, see Train (1996, pp. 185-196). The first EPA Administrator, William Ruckelshaus, would later state that Nixon was uncurious about the EPA and the issues it addressed, noting that “he [Nixon] never asked me about anything going on in EPA. Never.” (EPA, 1993) (emphasis in original).
ingestion of fish,” but declined to regulate source mercury emissions based on whether they increased environmental mercury as a whole, offering as a rationale that “[c]urrent data on the environmental transport of mercury do not permit a clear assessment of the effect of mercury emissions into . . . aquatic and terrestrial environments.”

When the first HAP standards for mercury were promulgated there existed a large and proliferating body of research on bioaccumulation and biomagnification, and health effects, and an awareness that EGUs emitted mercury (Lambou, 1971, pp. 14-19, 28). However, the same time period also saw EGUs having difficulty meeting electricity needs of the public, shortfalls that many at the time believed would be exacerbated by environmental regulations (Boffey, 1970). By the time the final rule was promulgated in April of 1973, the economic outlook was grim, as the stock market had crashed a few months before, and an energy crisis was clearly on the horizon. When Gerald Ford succeeded Nixon as President in the wake of the Watergate affair, the country was firmly in the grips of that crisis. While environmentalists had some hope that Ford would be friendly to environmental initiatives given his experience as a Federal park ranger, he took little action on the environmental front either for or against regulation, ending with an “environmental slate” that was “clean, albeit empty” (Switzer & Switzer, 1998).

In 1974, upon petition from the EDF, EPA proposed amending the HAP list to include among regulated sources of mercury incineration and drying of wastewater treatment plant sludges, limiting mercury emissions from those sources to 3,200 grams a day, which EPA calculated would ensure the same 1 ppm mercury limits on ambient air adjacent to the source as applied to ore processing and chlor-alkali plants (Proposed Amendments to National Emission Standards for Hazardous Air Pollutants, 1974).
Again, while recognizing the potential danger of bioconcentration of environmental mercury in fish, it still purported to find too much scientific uncertainty to take action on that issue:

The Agency has become increasingly concerned about the total environmental burden of mercury, however, and is initiating studies to determine how this aspect can most effectively be addressed under the provisions of the Clean Air Act and other authorities (Proposed Amendments to National Emission Standards for Hazardous Air Pollutants, 1974, p. 38068).

On October 14, 1975, EPA published its final rule governing mercury emissions from wastewater treatment plant sludges (Amendments to Standards for Asbestos and Mercury, 1975). It noted that during the comment period some participants had suggested other sources, including coal-fired EGUs, be included, but rejected such an approach, stating that none of those sources “emit mercury in such quantities that they are likely to cause the ambient mercury concentration to exceed one microgram per cubic meter” (Amendments to Standards for Asbestos and Mercury, 1975, p. 48,298). In 1987 EPA implemented a minor administrative rule to the mercury standards for chlor-alkali plants (National Emissions Standards for Hazardous Air Pollutants, 1987), and again considered (or purported to consider) but rejected a commenter’s request that the Agency re-evaluate the decision not to regulate EGU-sourced mercury emissions, as well as a separate request that EPA generally “take into account total human exposure to mercury, including deposited mercury in its more toxic methylated forms” (National Emissions Standards for Hazardous Air Pollutants, 1987).57 There would be no significant mercury

57 While conceding that some coal sources had mercury levels of 8 ppm for subbituminous coal and 3.3 ppm for bituminous coal, and conceding also that under worst case scenarios a large coal-fired plant using 8 ppm coal would reach a ground concentration of 1.0 μg/m³, the agency concluded that “typically, mercury emissions from coal-fired power plants are expected to be well below the ambient guideline level.” The EPA’s rationale seems somewhat inconsistent with the fact that the EPA had been willing to regulate mercury emissions from sludge incineration even though it “estimate[d] that the largest mercury
emissions regulations until after the 1990 Amendments; EPA took little action during the Carter administration on regulating HAPs, a decision that disappointed environmentalists (Graham, 1985, p. 110), though Carter did successfully see CAA renewed, and even strengthened in some places (Clean Air Act Amendments, 1977; Layzer, 2012, p. 68).\textsuperscript{58}

During his administration, the National Science Council released a comprehensive assessment of environmental mercury and its possible health impacts, warning that mercury emissions from EGUs were of “special concern,” since such emissions were “currently uncontrolled and the use of coal [was] expected to increase significantly” (NRC, 1978, pp. 28-29).\textsuperscript{59}

Despite EPA’s refusal to consider bioaccumulation and biomagnification processes when regulating mercury under CAA, during the 1970’s both EPA and the FDA did consider it in other contexts. In 1973 the FDA promulgated an action level of .5 ug/g of mercury (or .5 ppm) for seafood, allowing them to remove seafood meeting that action level from the market (Action Level for Mercury, 1974). EPA’s own position on mercury-based pesticides and fungicides played out far differently than it did for EGU-sourced mercury. The Fungicide, Insecticide, Fungicide and Rodenticide Act of 1947 (FIFRA)\textsuperscript{60} originally allowed the Department of Agriculture to suspend registrations of pesticides that posed an “imminent hazard to the public,” (FIFRA, 1970, §§136 et seq.), though the notoriously agribusiness-friendly Department did not vigorously use that power. When that power was transferred to EPA (Reorganization Plan No. 3, 1970) the

\textsuperscript{58} As noted above, the PSD provisions were implemented through the 1977 Amendment.
\textsuperscript{60} 7 U.S.C. §§136 et seq. (1970).
agency quickly took action to cancel the registration of mercury-containing pesticides and fungicides based substantially on their environmental and health impacts, primarily based on their tendency to bioaccumulate and biomagnify through food webs (EPA, 1972). In administrative proceedings, an EPA administrative judge upheld the cancellation, noting that “in the aquatic environment . . . highly toxic methyl mercury by natural biomethylation poses a significant risk to man and the environment” (In Re Chapman, 1976, p. 214). Though recognizing the danger through bioaccumulation and magnification when it came to pesticides, EPA was far more hesitant to regulate mercury emissions to the air on that basis during that time period.

Of course, FIFRA was one of the few environmental statutes of the era that (once EPA challenged the safety of the substance) placed the burden of proof on the manufacturer or emitter to show their product was safe (EDF v. Ruckelshaus, 1971). While the Federal Food, Drug and Cosmetic Act (FFDCA) places a similar burden on drug manufacturers (FFDCA, 2012, §355), most environmental laws like CAA placed the burden on EPA to show that a substance was dangerous before they could regulate. For example, both the Clean Water Act (CWA) and Safe Drinking Water Act (SDWA) require EPA to specifically designate unregulated contaminants to be regulated under those laws (CWA, 2012, §1312; SDWA, 2012, §300g-1(b)(A)(iii)). Without that designation, water bodies containing such contaminants go unaddressed. When the burden to decide whether to regulate or not is placed on presidential administrations who were highly resistant to enacting pollution control regulations as a matter of principle, environmental rulemaking can become mired in delay.
5.7.2 1980-1989: The Anti-Regulation Backlash and the Reagan Revolution

Whatever the evolving scientific consensus stated, the 1980 election of the fiercely anti-regulation Ronald Reagan made serious oversight of EGU emissions by the executive branch extremely unlikely; the 1980s would see particularly bruising legislative fights over environmental protections, particularly those regarding air pollution (Graham, 1985, pp. 114-115). The seeds of the anti-regulatory backlash had been planted in the 1960s and 1970s through the development of a “conservative infrastructure” in the form of think tanks and lobbying organizations funded by industry and staffed by fiercely pro-business conservative intellectuals; in President Reagan they found a champion willing to enthusiastically, and publicly, fight against environmental protection measures. Accordingly, while Nixon had sought political capital from a public display of environmental advocacy, Reagan in many ways did the opposite – intentionally and publicly attacked environmental regulations as a pro-business regulatory reformer (e.g., Kraft & Vig, 1984, pp. 427-431; Layzer, 2012, p. 91). Under his administration EPA officials were heavily recruited from the private sector, including regulated industries, and selected for their “ideological purity” by the White House rather than screened by EPA’s professional personnel, with Reagan’s choice for EPA Administrator the notoriously anti-regulation Anne Gorsuch, who slashed her own budget, relaxed environmental regulations, and reduced enforcement action. Eventually Gorsuch was forced to resign after increasingly public battles with Congress and significant press coverage of not only her extreme antipathy towards environmental regulation but also on allegations of political favoritism and corruption (Mintz, 2013, pp. 57-58).
Faced with significant public and Congressional scrutiny over the state in which Gorsuch left EPA, the Reagan administration attempted to bolster its environmental credibility by re-appointing William Ruckelshaus, EPA’s first administrator, as Gorsuch’s successor, a moderate Republican who was fairly well-regarded in both political and environmental circles. However, Ruckelshaus was also highly concerned with the potential costs of environmental regulations in general, particularly regarding toxics. His second term as EPA administrator eventually received a mixed review from environmentalists and pro-regulation politicians, though he was considered by some of his environmentalist critics to be “the best Administrator they could hope for while Mr. Reagan was in the White House” (Shabecoff, 1984, p. 88). On HAP regulation, he did little other than promise impending regulatory measures that in large part failed to ever materialize. In a statement given to the House Subcommittee on November 7, 1983 Ruckelshaus addressed the failure of EPA to regulate many proposed HAPs by blaming in large part the language of §112 itself:

> In implementing the provisions of Section 112, the EPA has had to make some uncomfortable compromises. We took it as given that Congress did not intend for us to virtually ban a number of major industrial chemicals. We have, therefore, made judgements about safety, about the appropriate balancing of risks and cost. . . We believe that we are in accord with the real intent of Congress and that the flexibility to balance risks and costs is an essential part of EPA’s ability to carry out its mission. (EPA’s Air Pollution Control Program, 1983, p. 17).

Materials provided to Congress indicate that in the early 1980s at least some EPA employees’ intended to carry out health assessments of a number of potential HAPs from

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61 Ruckelshaus’ reputation for integrity (Nixon referred to him as “Mr. Clean”) led to him being appointed acting director of the FBI, and then Deputy Attorney General, as the Watergate affair began to take its toll on the Nixon White House. See, e.g., Emery (2013, pp. 397-399).
sources not already regulated, but at the same time the agency itself also appeared to intentionally put up procedural roadblocks to delay those assessments (EPA’s Air Pollution Control Program, 1983, p. 144). In 1983 GAO investigated EPA’s management of regulation under §112 in light of its failure to list additional HAPs, including 37 priority ones already identified (GAO, 1983). In its report, the GAO concluded that a number of institutional barriers prevented effective regulation under §112, particularly extensive internal reviews of health assessment documents, a lengthy Science Advisory Board review process, and EPA’s insistence on collecting “economic and technological factors” impacting HAP regulation – which the GAO noted were improper under the statute in light of the fact that §112 did not provide for those kinds of analyses (GAO, 1983, pp. 21-23, 28-35, 43-44).

5.7.3 **Mercury and Toxics Regulations During the CAA’s First Two Decades: Context and Conclusions**

While environmentalists hoped that CAA would significantly limit what industry could emit to the air, when it came to HAPs that optimism proved unwarranted through the CAA’s first two decades. While restrictions on criteria pollutants did prove somewhat effective, restrictions on HAPs were scant. Legitimate scientific uncertainty was certainly a factor in this inaction; the health and environmental effects of toxics, particularly those like mercury, which are naturally present in trace amounts and undergo complex transformations in both the environment and organisms, are difficult to detect. The inherent statutory requirements of CAA §112 also likely led in some cases to bureaucratic paralysis; as noted above, once a pollutant was listed as a HAP, EPA was required to propose emissions standards, and do so quickly, and they had to provide an “ample margin of safety” to protect the “public health,” without any consideration of cost
or feasibility (Clean Air Act, 1988, §7412(b)(1)(B)). For many candidate HAPs, that “ample margin of safety” would require an unrealistic zero emissions; as one Federal Register notice put it, “[e]vidence has accumulated that indicates that the no-threshold concept can be applicable to chemical carcinogens” (Health Risk and Economic Impact Assessments of Suspected Carcinogens, 1976, p. 21,402; Graham, 1985, p. 119). In other words, once EPA listed a HAP, it was forced to create a rapid and potentially cost prohibitive regulatory scheme, with little flexibility to avoid potentially economically catastrophic consequences. Several commentators during that time period argued that it was for this reason, not because partisan affiliation or environmental ideology, that led to inaction. For example, Graham (1985, p. 116) argued that:

EPA’s failure to implement section 112 is not simply a reflection of sinister political forces. . .[t]he persistence of implementation problems throughout the section’s history suggests that there may be fundamental statutory and administrative obstacles – in addition to technological and economic barriers – to expeditious control of airborne carcinogens.

Cross (1986, p. 220) similarly cautioned at the time that “given the current state of scientific knowledge, there [wa]s no demonstrably safe level of human exposure to a carcinogen [and] such a total prohibition ma[d]e[] the agency avoid regulation.” EPA implied as much when its Assistant Administrator for Air and Radiation testified to during a Senate hearing in 1984 that “an automatic listing requirement might make us make decisions . . . not always in the best interest of the country” (Clean Air Act [hearings], 1984, p. 9). Several years later, a former EPA official put it more bluntly to a Congress losing patience that §112 was “an example of the perfect being the enemy of the good . . . because of the burdens put on the Agency in trying to do something that isn’t doable, the process got paralyzed” (Clean Air Act Amendments [hearings], 1989, p.
Simply put, reducing EGU-sourced mercury in particular also would have been difficult during this time because stringent mercury reduction technologies were unavailable. While anti-regulation forces during this time period failed to substantially weaken CAA due to strong Congressional and public resistance, the wide discretion the executive branch enjoyed in rulemaking and enforcement actions allowed EPA to delay regulations, and minimize the impact on industry of those that did get through.

5.8 The CAA Amendments of 1990 and their Aftermath: 1990-2000

5.8.1 Development of the 1990 Amendments

By the end of the 1980’s, and despite EPA’s earlier promises to Congress, EPA had still only listed eight HAPs under §112, proving “unwilling or unable to mount an effective regulatory program in its twenty-year effort to implement section 112” (e.g., Waxman, 1991, p. 1,774). The frustrated chair of one House committee opened a 1983 hearing by complaining that “[a]t this moment more than 25 substances are candidates for [HAP] listing at the EPA. . . they have been candidates not for weeks or months, but for years. That is a sorry record” (Clean Air Act [hearings], 1983, p. 2) In 1988 Congress was faced now with a president who had indicated a greater willingness to accept environmental regulations (e.g., McIntosh, 1993; Page, 1988) and, distrustful of EPA in light of its actions during the Reagan administration, the more pro-environment-minded members of Congress began work on what would become the 1990 Clean Air Act Amendments, which incorporated some of the elements of the earlier HAP-related bills but went much further (Clean Air Act Amendments of 1990, 1990).

While earlier unsuccessful Congressional bills had attempted to force EPA to take action on a number of potential HAPs, the 1990 Amendments went much further, listing
189 pollutants as HAPs and requiring EPA to either remove those pollutants from the list – if it could determine there was adequate data that showed no adverse health or environmental effects – or set emissions standards for each over a ten year period for “major sources” of those pollutants (CAA, 2012, §7415(b)(1)-(3), (e)(1)). The Amendments defined “major sources” to be those that release 10 tpy of any HAP or 25 tpy or more of any combination of HAPs (CAA, 2012, §7412(a)(1)).

As an apparent concession to critics’ charge that the §112 rulemaking process could result in burdensome results with little flexibility take into account logistical and economic complications, the 1990 Amendments also fundamentally changed how HAP emissions standards were to be set. Dropping an absolute requirement that EPA set those standards that “provide[] an ample margin of safety to protect the public health” (CAA, 1970, §7412(b)(1)(B) the 1990 Amendments instead allowed emissions standards for both new and existing sources that reflected “the maximum degree of reduction in [HAP] emissions . . . taking into consideration the cost of achieving such emission reduction, and any non-air quality health and environmental impacts and energy requirements” (CAA, 2012, §7412(d)(2)). The standards developed to implement this “maximum degree of reduction” for HAPs was characterized as the Maximum Achievable Control Technology, or MACT standards. For new sources, the minimum standard, or MACT floor, could not be less stringent than the “best controlled similar source.” (CAA, 2012, §7412(d)(3)). For existing sources, however, the MACT floor could be set at a less

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62 A subsequent Congressional joint resolution removed hydrogen sulfide from the list (Pub. L. 102-187, 1991). Since the CAA Amendments were passed, the EPA has only successfully removed three HAPs through the §112(b)(3)(A) delisting process (40 C.F.R. 63.6061, 1990).
63 As with the NSPS provisions of §111, a “new source” refers to a stationary source constructed or modified after emissions standards have been promulgated (CAA, 2012, §7412(a)(4)).
stringent standard – “the average emission limitation by the best performing 12 percent of the existing sources.” (CAA, 2012, §7412(d)(3)(A)).

5.8.2 EGU-Specific HAP Provisions of the 1990 Amendments

When it came to regulating EGUs as a source of HAPs, however, Congress implemented a “unique procedure” (Michigan v. EPA, 2015). The original Senate version of the bill sent to Conference gave EPA five years after enactment to regulate mercury and particulate HAPs from sources that accounted for at least 90 percent of the aggregate emissions – which would by necessity include EGUs for mercury as well as other HAPs (S. 1630, 101st Cong., 1990, §112(c)(6)) (as engrossed in the Senate). Even given a five year deadline, the proposed standards deadline for EGU-sourced mercury particularly faced significant resistance from industry and its allies in Congress, nominally due to both scientific and technical uncertainties, including over whether acid rain provisions in the bill would also control EGU-sourced HAPs sufficiently to obviate the need for separate HAP standards (Michigan v. EPA, 2015, p. 2715; Library of Congress, 1998, p. 779).

During conference, therefore, language was added to the §112 amendments exempting EGUs from the same regulation schedule as other major sources of the 189

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64 As will be discussed later, the EPA has a significant amount of leeway in deciding what makes up that 12% of best performing existing standards. The 1990 Amendments also require the administrator to review residual risks not addressed by MACT standards within 8 years of emissions standards promulgation, and if need be, institute more stringent controls. Id. §7412(f)(2).
65 Justice Kagan mentioned this in her Michigan v. EPA dissent, noting that Congress had refrained from regulating EGU-sourced HAPs immediately “because the 1990 amendments established a separate program to control . . . emissions contributing to acid rain, and many thought that just by complying with those requirements, plants might reduce their emissions of [HAPs] to acceptable levels.” During conference debate of the negotiations, Senator Burdick, Chair of the Senate Environment and Public Works Committee, relatedly noted that “[A] full control program . . . would double the cost of acid rain control with no expectation of perceptible improvement in public health. . . .” (Library of Congress, 1998, p. 779).
pollutants. Instead, the 1990 Amendments required EPA to first carry out a study ("Utility Study") to evaluate the risks from EGU-sourced HAPs, particularly mercury, before deciding whether it was "necessary and appropriate" to regulate EGUs under §112. Additionally, §112(n) required two other reports to follow: (1) a National Institute of Environmental Health Sciences report on the level at which mercury becomes dangerous, also due within 3 years; and (2) an EPA study of EGU-sourced mercury and its potential health impacts, due within 4 years; the EPA study would come to play an outsized role in subsequent debates (CAA, 2012, §7412(n)(1)(A)-(C)). Once the Utility Study was issued, EPA was required to rely on it to determine whether it was "appropriate and necessary" to regulate EGU-sourced HAPs.

In 1992, during the time in which the statutorily required studies were in process, President Clinton had assumed office. Though a Democrat, his administration disappointed many environmentalists who felt he was too willing to compromise with regulated industries, and through most of his tenure EPA mercury and HAP reports went unreleased (Kline, 2011, p. 148; Peterson, 2004, pp. 162-164).

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66 EGUs would otherwise automatically qualify as "major sources" due to the fact that they release – or have the potential to release – well in excess of the 25 tpy limits of §112(a)(1), most of that in the form of hydrogen chloride (CAA, 2012, §7412(a)(1)). See EPA (1998, p. 3-18-19) for HAP emissions inventories from characteristic coal- and oil-fired EGUs.

67 The EPA was also tasked with a fourth study to be conducted in cooperation of the National Oceanic and Atmospheric Administration ("NOAA") examining the contribution of atmospheric HAPs generally to pollution loading in the Great Lakes and coastal waters (CAA, 2012, §7412(m)).

68 While the 1990 Amendments did not state the purpose of the NIEHS and EPA studies, the engrossed Senate bill had originally intended them to be filed on the EPA rulemaking docket and used when setting post-listing emissions standards (S. 1630, 101st Cong., 1990, §112(e)(5)).

5.8.3 The EPA and NRC Mercury Reports: Conclusions and Controversies

The NIEHS finished its report in 1993 and transmitted it to Congress (NIEHS, 1993), but EPA’s reports were delayed well past their deadlines, drawing Congressional pressure. In May of 1997, Sen. Patrick Leahy introduced a resolution on the Senate floor urging EPA to release the mercury report to Congress as required by the 1990 Amendments (S. Conn. Res. 28, 1997) though it would die in Committee; however, pressure on EPA appeared to work and on December 1997, four years after the statutory deadline, EPA transmitted to Congress its CAA §112(n)(1)(B)-mandated report to Congress (EPA Mercury Report). That was followed up shortly after by the Utility Study in February of 1998 (1998 Utility Study).

The 1998 Utility Study identified 67 of the 188 HAPs designated by Congress in the 1990 Amendments as potentially emitted by EGUs (1998 Utility Study, p. ES-4). Of those 67 HAPs, 14 were identified as “priority” HAPs due to their health impacts, including mercury (1998 Utility Study, p. ES-6). While reportedly close to releasing the report that focused on EGU-sourced mercury and its health impacts in early 1995, that report languished at EPA in draft form until 1998, most likely due to pressure from not

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70 By the time the other reports were released, the NIEHS study had become somewhat dated and does not appear to play a significant role in the post-1999 EGU-sourced mercury debate; its results were effectively assimilated into or superseded by the later EPA and NAS reports. The Mercury and Air Toxics Rule explained that 9370) “Because NAS completed its study 5 years after the NIEHS Study, and considered additional information not earlier available to NIEHS, for purposes of this document we discuss the content of the NAS Study as opposed to the NIEHS Study.” (2012, p. 9370).

71 The proposed resolution: “A concurrent resolution expressing the sense of Congress that the Administrator of the [EPA] should take immediate steps to abate emissions of mercury and release to Congress the study of mercury required under the Clean Air Act . . .”).

only the utility industry but also representatives of the seafood industry who were worried about public perception of mercury risks from fish (Dieter, 1997).

What the 1997 EPA Mercury Report lacked in timeliness it made up in scale; it consisted of eight volumes and included in-depth analyses of anthropogenic sourcing, fate and transport, human health and environmental exposure, and potential mercury control technologies with their attendant costs. Reviewing the scientific literature, the report concluded that there was “a plausible link between mercury emissions from anthropogenic combustion and industrial sources and mercury concentrations in air, soil, water and sediments. . . and methylmercury concentrations in freshwater fish” (1997 EPA Mercury Report, Vol. II, pp. 3-20). The 1997 EPA Mercury Report also concluded that EGUs had surpassed municipal waste combustors and medical waste incinerators as largest “identifiable” anthropogenic sources of mercury emissions to the atmosphere; it estimated EGU emissions at approximately 52 tons in 1994-1995, accounting for 33% of total anthropogenic emissions (1997 EPA Mercury Report, Vol. II, pp. ES-4, ES-10, Table 4-2).

The Report was drawn on by both proponents and opponents of EGU mercury regulations, with the former arguing it showed action was needed to protect the vulnerable populations identified, and the latter claiming it showed that for most Americans methylmercury in fish was not a significant threat (Gerstenzang, 1997; Nichols, 1998). In regards to the vulnerable populations identified in the Report, debates focused on both the limited and contradictory epidemiological data available, and the relative importance of EGU-sourced mercury as a contributor to methylmercury in fish; the lead scientist for the Seychelles Islands study described in Chapter 2 testified that the
results of that study “indicate[d] no adverse developmental effects from prenatal methylmercury exposure in the range commonly achieved by consuming large amounts of fish” (Regional Haze and Mercury Pollution, 1998, pp. 30-32, 38). Industry actors seized upon the Seychelles results as well, with a program manager for the industry-funded Electric Power Research Institute testifying at the same hearing that the “Seychelles . . . findings, if they’re supported in later analyses, imply that a given mercury level in fish may be less of a threat to human health than formerly believed” (Regional Haze and Mercury Pollution, 1998, p. 33). Faced with the potential for imminent and costly mercury control standards, members of Congress successfully pushed to have the Report’s health assumptions scrutinized by the National Academy of Sciences (NAS), a tactic that had become a frequent means to both delay environmental decisions as well as subject agency decisions to what was perceived as a more scientifically conservative standard of review; Jasanoff (1990, p. 59) notes:

> [R]isk assessment guidelines . . . were generally characterized [by industry representatives] as science, suitable for resolution by accredited expert bodies like the National Academy of Sciences. Industrial groups were convinced that these technocratic organizations would reach conclusions that were scientifically more conservative.

Heinzerling and Steinzor (2004, p. 10,301) similarly argue that “[i]n the last few years, referral of regulatory controversies to NAS peer review panels has gone from being a useful tool in complex regulator decisionmaking to becoming a central tactic used to forestall or delay regulation of toxics.” Oreskes and Conway (2010, p. 64) note:

> Most historians of science would say that the Academy has an intrinsic conservatism stemming from its dependence on the executive branch . . . Moreover, Academy reports are normally consensus reports . . . [t]he result is often a ‘least common denominator’ conclusion, with text innocuous enough that everyone involved can agree.
The scientific targets here were the assumptions used by EPA as to what level of mercury level in fish constituted a health risk.\textsuperscript{73} Congress therefore required EPA to contract with NAS to “perform a comprehensive review of mercury health research and prepare recommendations on the appropriate level for a mercury exposure reference dose [RfD]” (H.R. Rep. No. 105-276, 105\textsuperscript{th} Cong., 1998). If the NAS referral had been a tactic to forestall or thwart mercury regulation, however, it was not particularly successful. In July of 2000 the NAS’s National Research Council (NRC) released a report (2000 NRC Report) that drew on more recent data from the Seychelles, Faroe, and New Zealand studies, examined the existing body of toxicological and physiological information, and concluded EPA’s RfD was appropriate (2000 NRC Report, pp. 326-327).\textsuperscript{74} The 2000 NRC Report stated that based on this “over 60,000 newborns annually might be at risk for adverse neurodevelopmental effects from in utero exposure to [methylmercury]” (2000 NRC Report, p. 325).

\textsuperscript{73} In examining the potential health impacts of the organomercury forms accumulating in fish, the 1997 EPA Mercury Report used an RfD, or “[a]n estimate . . . of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime,” of .1 \(\mu\)g/kg/day, or one ten millionth of a gram per day (1997 EPA Mercury Report, Vol. I, p. 0-2. That RfD had been developed based on clinical data from the 1972 Iraqi grain poisoning incident referred to in Chapter 4. RfDs are determined through an oftentimes complicated process: after a toxic hazard is identified, “dose-response” assessments using epidemiological and/or animal experiments identify the highest level of exposure for which no observed adverse effect is seen. This dose is then multiplied by an “uncertainty factor” to account for scientific uncertainty (and occasionally a “modifying factor” derived through the evaluators’ professional judgment) in order to create the RfD, which can then start as the base from which to evaluate the health impacts of the toxic chemical on human populations. The less data available, the higher the uncertainty factor is set and therefore the lower the RfD. Somewhat paradoxically, even where additional research shows a substance is more toxic than originally believed, the RfD might go down because there is less need of uncertainty levels. For a discussion of the uncertainties inherent in the NAS report’s analysis of the methylmercury RfD, see Dourson, Wullenweber & Poirier (2001).

\textsuperscript{74} The NRC dose-response assessment resulted in a benchmark dose level of 12 ppm, as compared to the EPA’s 11 ppm.
5.8.4  The 2000 Listing Rule: EPA Finally Regulates EGU-Sourced Mercury

On December 20, 2000, faced with an incoming administration that was likely to be far less friendly to pollution control regulations, and armed with strong scientific support from the new NRC report, EPA promulgated the 2000 Listing Rule, holding that it was “appropriate and necessary” that EGUs be regulated under CAA § 112(c) (2000 Listing Decision, p. 79,826). Citing the 1998 Utility Study, the Rule discussed multiple HAPs of concern being emitted from EGUs, but relied principally on EGU-sourced mercury to justify its determination, noting that there was a “there is a plausible link between methylmercury concentrations in fish and mercury emissions from [EGUs]” (2000 Listing Decision, pp. 79,821-79,830). The rule did not impose specific regulatory requirements, stating that EPA would later subcategorize EGU source categories and set emissions “floors” for those categories for mercury and the other HAPs (2000 Listing Decision, p. 79,830).75

5.8.5  Mercury Emissions Regulations in the 1990’s: Context and Conclusions

While the 1990 Amendments dramatically reshaped air toxics regulations under CAA, EGU-sourced mercury and other HAPs escaped mandatory regulation pending further investigation. 1992 saw a Democratic administration come to power perceived as somewhat more amenable to regulation and more focused on the benefits of environmental regulations rather than simply the costs. However, President Clinton still employed a more pro-business, anti-regulatory-cost rhetoric than many Democrats preferred, and in 1994 a conservative Republican majority captured both houses of

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75 An industry group quickly appealed the 2000 Listing Decision to the D.C. Circuit, but the case was dismissed on the grounds that HAP listings under 42 U.S.C. §7412(e)(4) are not subject to review until emissions standards are set (Util. Air Reg’y Group v. Envtl. Prot. Agency, 2001).
Congress, and made removing or weakening environmental protection laws and regulations one of their primary goals through both substantive statutory changes as well as significantly reducing EPA’s budget for enforcement of environmental laws, particularly of CAA and the Clean Water Act (Lazarus, 2004, pp. 125-140). These political fights may have resulted in a level of caution at EPA that delayed release of the reports until late in President Clinton’s second term, possibly aided by industry pressure, as mercury control technologies were “still at least several years away” (1998 Utility Study, Vol. II, p. I-36). Throughout the 1990’s the number of fish consumption advisories based on mercury levels increased, though for most of the decade regulations under CAA remained in stasis pending the outcome of the various statutorily-required reports on mercury and HAP. The 2000 Listing Rule, however, would lead to a far more active debate in the 2000s and beyond.

5.9 Regulatory Battles and Atmospheric Ideologies: 2001-Present

5.9.1 The Anti-Regulatory Redux: George W. Bush’s Pollution Policy

Under CAA §112(c)(5), the 2000 Delisting Rule required emissions standards for EGU-sourced mercury and other HAP be promulgated within 2 years. Shortly after the 2000 Listing Decision, however, George W. Bush assumed office of the President. A former oil company executive (like his Vice-President, Dick Cheney) who ran on an explicitly anti-regulatory platform, his time in office saw attempted rollback of the fairly modest regulations issued by the Clinton-era EPA and significant efforts to substantially relax federal pollution control laws, particularly the CAA (e.g. NRDC, 2005). The Bush administration had promised in its 2002 budget to “reform the current single-pollutant approach to regulating existing electric utility plants with a multi-pollutant approach,
which would provide regulatory certainty to utilities, phase in reductions over a reasonable period, and make use of market-based incentives to further clean up the environment” (OMB, 2001). EPA justified multi-pollutant approaches on the grounds that that many pollutants had common emissions sources, control technologies, and interacted with each other in a way that impacted exposure pathways and risks (EPA, 2008). A multi-pollutant approach was not a new one; that policy approach grew out of converging trends of technological advancements in emissions controls in the 1990s that could eliminate multiple contaminants, as well growing scientific awareness that air pollutants interacted with each other in the atmosphere and human bodies in ways different than when by themselves (Shelley, 1995). While environmentalists initially considered President Bush’s ascension to the Presidency a potential environmental catastrophe in light of his anti-regulatory rhetoric, oil industry experience, and his pro-industry record as governor of Texas (Yardley, 1999), his administration did support a multi-pollutant approach in theory, particularly in light of EPA Administrator Christine Todd Whitman’s public acknowledgment that global warming was occurring and suggestion that carbon dioxide regulation would be included as a co-regulated pollutant (Pianin, 2001).76

5.9.1.1 The Clear Skies Plan and Mercury

In February of 2002 Bush released more details about his “multi-pollutant” approach with his “Clear Skies Initiative,” an approach to EGU emissions which sought to replace traditional emissions standards approaches with a multiple-pollutant, cap-and-

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76 Shortly after, Whitman would be informed by President Bush that he had changed his mind, and that he had made a mistake calling CO₂ a pollutant (Fialka & Cummings, 2001).
trade plan similar to the one that had been created to control acid rain in the early 1990’s. As originally announced, the Initiative promised to reduce sulfur dioxide emissions by 73%, nitrogen oxide emissions by 67%, and mercury emissions by 69%, by 2018 (“President Announces Clear Skies & Global Change Initiatives”, 2002). The Initiative was criticized by environmental groups, who felt that the bill did not go nearly far enough in reducing EGU emissions of SO₂ and NOₓ (Layzer, 2012, p. 284). The standards would also be far less stringent than the 90% reduction in mercury emissions EPA had predicted under the post-2000 MACT standards. Introduced as identical bills in both the House and the Senate on July 29, 2002, and reintroduced in substantively identical form in 2003, and in 2005 in the Senate the Clear Skies Act was the cornerstone of the Bush administration’s air pollution policy (H.R. 5266, 2002; S. 2815, 2002; H.R. 999, 2003; S. 485, 2003; S. 131, 2005).

The Clear Skies Plan and its proposed implementing legislation caused a massive backlash from the environmental community, and were fiercely opposed by Democratic members of Congress from the beginning, never making it out of committee (Rugh, 2004). Though Republicans attempted to keep different versions of the Clear Skies Act alive over the next few years, after March 2005 it was effectively dead as a legislative proposal (Curtius & Hamburger, 2005). During the fight over the Clear Skies Plan, Democrats introduced competing multi-pollutant bills that would have led to more significant reductions in mercury emissions, though none were successful either.⁷⁷

⁷⁷ In the Senate, Vermont’s James Jeffords introduced the Clean Power Act, which sought to reduce EGU-sourced emissions of SO₂, NOₓ, CO₂, and mercury through a new CAA provision (Clean Power Act, 2001; Clean Power Act, 2003). His colleague Sen. Carper would later introduce the Clean Air Planning Act, which offered a more stringent cap-and-trade program for mercury as well as SO₂, NOₓ, and CO₂ (Clean Air Planning Act, 2003; Clean Air Planning Act, 2007). The Energy Information Agency conducted a comparative analysis of the three competing plans, finding reductions in all pollutants, particularly mercury, were highest under the Clean Power Plan and lowest under the Clear Skies Plan (EIA, 2004).
5.9.1.2 A Change in Strategy: Instituting a Cap-and-Trade Plan Through the Rulemaking Process

Through 2004, even while President Bush was trying to convince Congress to accept his Clear Skies alternative, EPA still appeared to moving (if slowly and grudgingly) towards finally releasing MACT standards under §112 (Heinzerling & Steinzor, 2004b, p. 10,488). The agency had convened a Working Group which met 14 times between March 2001 and March 2003 to discuss the proposed §112 rule and the members of the group were charged specifically to determine an appropriate MACT standard for mercury (2004 Proposed CAMR, 2004, p. 4,656; Heinzerling & Steinzor, 2004a, p. 10,307). In December of 2001 EPA had informed an industry group that the MACT standards under development could reduce EGU mercury emissions by 90% by 2008 (Clean Air Task Force & NRDC, n.d.).

However, behind the scenes Bush EPA appointees appeared to have been secretly working on a different objective. The following year, the Natural Resources Defense Council would show that at an April 2001 meeting the Edison Electric Institute, an influential industry group, a lobbyist assured energy sector representatives that the Bush administration would use EPA rulemaking to institute both criteria and hazardous pollutant restrictions that “won’t be . . . robust” with the “goal here . . . to gain a foothold, an irreversible foothold on the next generation of reasonable cost effective SO2 and NOx reduction, plus air toxics that we can all live with and that someone else can’t undo.”

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78 For a comprehensive account of the circumstances that led up to the 2004 Proposed Rule, see Heinzerling and Steinzor (2004).
79 The following year, the Natural Resources Defense Council would show that at an April 2001 meeting the Edison Electric Institute, an influential industry group, a lobbyist assured energy sector representatives that the Bush administration would use EPA rulemaking to institute both criteria and hazardous pollutant restrictions that “won’t be . . . robust” with the “goal here . . . to gain a foothold, an irreversible foothold on the next generation of reasonable cost effective SO2 and NOx reduction, plus air toxics that we can all live with and that someone else can’t undo.” The Clear Skies Act of 2005: Hearing Before the S. Comm. On Environment and Public Works, 109th Cong. 254 (2005) (transcript of speech by Quinn Shea, Senior Director for Environmental Activities, Edison Electric Institute, April 2001).
an irreversible foothold on the next generation of reasonable cost effective SO₂ and NOₓ reduction, plus air toxics that we can all live with and that someone else can’t undo.” (Clear Skies Act, 2005). While the MACT group was meeting to develop the MACT standards, political appointees at EPA’s Office of Air and Radiation quietly worked to implement a version of the Clear Skies Act’s failed cap-and-trade scheme for mercury through EPA rulemaking. On April 1, 2003, a planned 15th meeting for the MACT Group was canceled by and never rescheduled, though the head of EPA’s Air and Radiation Office assured suspicious members of Congress that while EPA advocated passage of the Clear Skies Act, it still would provide a MACT standard (Clear Skies Initiative, 2003; Hamburger & Miller, 2004; Heinzerling & Steinzor, 2004b; Pianin, 2003).80

When EPA finally released its “Proposed National Emission Standards for Hazardous Air Pollutants” (2004 Proposed CAMR), it did propose §112 MACT restrictions that EPA forecast would reduce mercury emissions by 34 tons in 2010 and 31 tons in 2020 – standards far weaker than what the Working Group had anticipated.81 Because no existing EGUs had installed mercury-specific emissions reduction equipment, EPA had significant freedom in determining the MACT floors for both new and existing sources, and took advantage of it by subcategorizing EGUs by coal type, then using a combination of emissions tests, mercury composition of the coal used, and a statistical corrective that assumed each plant was emitting mercury at its peak level (2004 Proposed

80 When asked about whether MACT mercury modeling had been done, the head of EPA’s Office of Air and Radiation hedged, stating “[w]e are doing all the analysis we need to do.” (Clear Skies Initiative, 2003, p. 95).
81 The proposed rule only applied to EGUs of more than 25 megawatts generating capacity that provided electricity for sale (2004 Proposed CAMR, p. 4,727). In addition to mercury, the Proposed CAMR also proposed regulating nickel emissions from oil-fired utilities, but none of the other HAPs discussed in the 2000 Listing Decision (2004 Proposed CAMR, p. 4,689).
The proposed standards for new sources were based on the statutorily required “best-controlled similar source” which EPA determined were PM and flue gas control measures, with emissions standards calculated through a similar process as determined the MACT floor for existing units (2004 Proposed CAMR, p. 4,677-4,693).

As surprising as the extremely weak MACT standards were to observers (including the MACT Working Group), even more surprising were the non-MACT-based cap-and-trade alternatives that EPA proposed. The first proposed cap-and-trade rule was based on a provision in §112(n)(1)(A) that required EPA to report “alternative control strategies for emissions” in the 1998 Utility Study. EPA had followed this requirement in the report, describing in detail “Alternative Control Strategies for Hazardous Air Pollutant Emissions Reductions,” including technological controls like coal cleaning and gasification, as well as energy conservation and management practices, but did not include cap-and-trade as a control strategy for mercury (1998 Utility Study, §13). In the 2004 proposed CAMR, EPA argued that this reporting obligation also gave it the

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82 For a detailed critique of the means by which the EPA calculated the MACT floor, see New Jersey Dept. of Environmental Protection (2004).’tl Prot., EPA’s Proposed MACT Floor Standards for Mercury Emissions from Coal-Fired Utility Units: A Statistical and Analytical Assessment (July, 2004). Henry Waxman, one of the primary architects of the 1990 Amendments, had been concerned about the possible abuse of determining MACT standards by categories shortly after passage (Waxman, 1991, p. 1,777). While Rep. Waxman notes that in §112(c)(1) Congress mandated that any such categories “be consistent with the list of source categories established pursuant to section 111 [the New Source ] and part C [prevention of significant deterioration provisions],” the actual language of the provision only requires the EPA do this to “the extent practicable,” and explicitly states that “nothing in [the sentence cited by Rep. Waxman] limits the Administrator’s authority to establish subcategories under this section, as appropriate” (CAA, 2012, § 7412(c)(1)).
authority to *implement* one of the alternative control strategies, apparently including one that it never reported on in the Utility Study (2004 Proposed CAMR, p. 4,661-4,662).  

The proposed rule also offered a parallel cap-and-trade plan under §111(a)(1), a provision which while it does not explicitly allow such a program, does not explicitly foreclose on one.  

However, before implementing such a cap-and-trade plan under §111, EPA would have to somehow delist mercury as a HAP, since pollutants cannot be regulated under both §111 and §112. Both the §111(d) and §112(n)(1)(A) cap-and-trade alternatives would cap mercury emissions at an undisclosed amount in 2010 determined by the co-benefits of SO₂ and NOₓ reductions projected from another proposed rule published that day, the proposed Clean Air Interstate Rule (2004 Proposed CAMR, p. 4,698; Proposed Interstate Air Quality Rule, 2004).  

The caps were based on the proposed §112 MACT floors, but the cap-and-trade system would allowed not only banking of unused allowances, but provided a “safety valve” provision that capped allowance costs at $2,187.50 per ounce, making it potentially less expensive for some EGUs to simply buy allowances instead of even attempting to limit emissions (Proposed CAMR, p. 4,704).  

EPA followed the 2004 Proposed CAMR with a Notice of Data

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83 The proposed rule argued specifically that “[b]ecause Congress directed EPA to develop control strategies that would be alternatives to the usual section 112(d) MACT standard, it is reasonable to conclude that Congress authorized EPA to implement such alternatives.”

84 The relevant CAA provision defines “[t]he term ‘standard of performance’ [to mean] . . . the application of the best system of emission reduction . . . taking into account the cost of achieving such reduction and any nonair quality health and environmental impact and energy requirements.”

85 Unusually, the Proposed IAQR, a cap-and-trade plan for SO₂, NOₓ, and ozone, had been accepted by both industry and environmental groups; however, it would be overturned in 2008 after a small group of utility companies challenged some of its provisions (*North Carolina v. EPA*, 2008).

86 While control costs vary depending on factors such as coal and boiler type, costs for activated carbon injection, generally the most effective mercury control technology, could reach $50,000 per pound, or $3,125.00 an ounce (*NESCAUM Report*, 2010, p. xvi).
Availability, proposing a process for quantifying the mercury deposition and bioaccumulation impact of the proposed rule (Notice of Data Availability, 2004).

5.9.1.3 The Backlash Against the Proposed CAMR

While environmentalists have frequently invoked the accusation that industry is often allowed to write the regulations, for the 2004 Proposed CAMR this was not hyperbole; the proposed rule contained numerous legal arguments that mirrored almost exactly memoranda submitted by attorney lobbyists from the law firm at which both the head of EPA’s Office of Air and Radiation and his principle deputy had worked before joining EPA – who argued for a cap-and-trade system (Pianin, 2004; Eilperin, 2004; American Lawyer, 2005). The cap-and-trade plan and the circumstances surrounding its development evoked quick opposition from internal EPA staff, environmental groups, many states, scientific experts on the mercury issue and members of Congress (“Comments submitted by New Jersey Attorney General et al.”, 2004; Lee, 2004). MACT Working Group members and EPA staff reported that technical experts at the Agency were cut out of the process (Hamburger & Miller, 2004). Members of the Senate Environment and Public Works Committee were suspicious of the process resulting in the 2004 Proposed CAMR, and requested analyses of the proposed rule from EPA’s Office of the Inspector General (OIG), and from GAO, both of which released reports highly

87 Pianin (2004) notes that “[a] side-by-side comparison of one of the three proposed rules and the memorandums prepared by Latham & Watkins . . . shows that at least a dozen paragraphs were lifted, sometimes verbatim, from the industry suggestions.” EPA Air of Office and Radiation head Jeffrey Holmstead would later disclaim personally knowing that the language was from Latham & Watkins, saying it “came to us through the interagency process,” and that “[o]ur technical folks who did subcategorization used it” (Pianin, 2004). The EPA formally responded to the criticism through the rulemaking docket, though very briefly, in a March 15, 2005 Response to Comments, stating “[t]he material in question was provided to the EPA through the Clean Air Act Advisory Committee working group process established under the Federal Advisory Committee Act (FACA) and, thus, we do not feel that its use was inappropriate” (“Response to Significant Public Comments”, 2005, pp. 10-4-1-5).
critical of the Proposed CAMR and the process by which it was created (GAO, 2005 [2005 GAO Report]; OIG, 2005 [2005 EPA OIG Report]).

EPA OIG conducted an internal investigation and concluded that the §112 MACT standards proposed had been arrived at through a pretextual calculation; rather than determine the best controlled 12% of existing sources required by §112(d)(3), EPA senior management had simply instructed staff to take as a given that a MACT-based standard was to result in 2010 emissions of 34 tons, and then develop a MACT methodology that would result in that number (2005 EPA OIG Report, p. 13). They did this through modifying various assumptions, and modifying variables and re-running models until the latter projected the 34 ton number (2005 EPA OIG Report, pp. 14-15).

Furthermore, the OIG concluded that the true basis for the 34 tons – the co-benefits projected under the Clean Air Interstate Rule – did not comply with the MACT requirements of CAA. As to the cap-and-trade plan, the OIG criticized its lack of stringency and implicitly questioned the veracity of the drafters (2005 EPA OIG Report, p. 15). The OIG also found that staff had been pressured to base the benefits analysis of the proposed rule on the public comments solicited through the NODA (many of which came from utilities), rather than on the scientific literature (2005 EPA OIG Report, p. 33).

Finally, the OIG noted that several documents it had requested had not been provided by EPA, including statistical analyses for MACT model runs, inter-agency communications, and information as to how the Latham & Watkins memoranda language got into the proposed rule (2005 EPA OIG Report, pp. 9, 41). In its response to the OIG’s draft report, EPA had simply disputed several of the factual assertions – including that it
had started with the 34-ton emissions goal and manipulated MACT calculations to meet it – but did not address the report’s recommendations (2005 EPA OIG Report, App. E).

The GAO also investigated the 2004 Proposed Rule, specifically the cost-benefit analyses used to compare the proposed cap-and-trade plan with the MACT rule, and found such analyses significantly lacking. While EPA examined the costs of the MACT rule by itself, it analyzed both the costs and benefits of the cap-and-trade plan in the context of the CAIR rule, making comparison between the two impossible. Perhaps most critically – and inexplicably—EPA’s cost-benefit analysis of the two options failed to quantify the actual primary health benefits of mercury emissions reductions (2005 GAO Report, p. 12). Instead, EPA calculated the secondary health benefits accruing from the reduction of fine particles, such as decreases in respiratory diseases and heart attacks (2005 GAO Report, p. 12). As did the OIG, the GAO also faulted EPA for its lack of transparency in developing the proposed rule (2005 GAO Report, p. 4).

5.9.1.4 The Clear Skies Act Reborn: Reversing the 2000 Listing Rule and Implementing Cap-and-Trade Under CAMR

Largely ignoring the criticism from Congressional members, environmentalists, EPA’s own inspector general, and the GAO, EPA ultimately promulgated the §111(d)-based cap-and-trade plan in their final Clean Air Mercury Rule (CAMR),88 followed by the 2005 Delisting Rule (Standards of Performance for New and Existing Stationary Sources, 2005 [2005 CAMR]; Revision of December 2000 Regulatory Finding, 2005 [2005 Delisting Rule]). EPA characterized the new cap-and-trade plan as “the best method for encouraging the continued development of [emissions control] technologies

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The 2010 cap under the 2005 CAMR was even higher than the EPA OIG had anticipated, at 38 tons, with a 15 tpy cap coming into effect in 2018 (2005 CAMR, p. 28,606). According to EPA, the caps would reduce mercury emissions by “up to 70%,” significantly less than the 2000 Regulatory Finding proposed (EPA, 2005b, p. 3-3). Direct health benefits of the mercury reductions from the 2005 CAMR were projected at a modest 0.2 to 3 million dollars a year by 2020 (2005 CAMR, p. 28,643). As had been promised in the 2004 Proposed Rule, the final Phase I cap would not require additional mercury-specific mitigation technologies, as the 38 tpy figure was the estimated amount of mercury reduction as a co-benefit from already-existing SO2 and NOx rules (2005 CAMR, p. 28,617). As had been proposed in the 2004 Proposed CAMR, EGUs would be able to bank allowances for future use, but the “safety valve” provision was removed (2005 CAMR, pp. 28,629-28,630). The cap-and-trade system would be implemented by the states pursuant to State Implementation Plans subject to review by EPA, with states failing to participate still required to reduce emissions below their cap (2005 CAMR, p. 28,607).

Under the 2004 Proposed CAMR the cap for the cap-and-trade plan would have been based on concurrently offered CAA §112 new source MACT standards, which would equal the “best controlled similar source.” (2005 CAMR, p. 28,615). However, purportedly responding to commenters who argued that even that was too strict for §111 emissions standards – which require explicit consideration of cost – EPA revised the cap upwards (2004 Proposed CAMR, 4,690; 2005 CAMR, p. 28,615).89 Those caps were not based on mercury-specific control technologies, but rather on controls that would be

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89 Depending on source subcategory, the final standards were less stringent by factors of approximately 2 to 5.
installed to control PM$_{2.5}$ and SO$_2$, as EPA argued that stringent mercury-specific control technologies could not be installed and operated on a national scale by the 2018 final cap deadline (2005 CAMR, p. 28,615). Even given those limitations the mercury emissions released from the “best controlled similar sources” upon which the caps were based also assumed particularly high levels of mercury in source coal (2005 CAMR, p. 28,615; EPA, 2005c).

Two weeks after publishing the 2005 CAMR, EPA issued the 2005 Delisting Rule removing EGU-sourced mercury as a §112 HAP. The conventional HAP delisting process under §112(c)(9) would have required EPA determine that no EGU – or EGU category – would release mercury emissions above a level adequate to protect public health and preclude adverse environmental effects (CAA, 2012, §112(c)(9)(ii)). Even the Bush-era EPA seemed unwilling to make such a clearly implausible determination, so instead the 2005 Delisting Rule simply concluded that the delisting requirements of §112(c)(9) need not be met, that the “appropriate and necessary” standard gave EPA significant discretion in how to treat EGU-sourced HAP, and thus “nothing precludes [EPA] from revising [the] appropriate and necessary finding” based on initial error or new information (2005 Delisting Rule, pp. 16,002, 16,033). EPA’s position was that the 2000 Listing Decision was fundamentally unwarranted at the time it was made, and it

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90 While the 1997 EPA Mercury Report had concluded that reliably controlling mercury emissions from coal-fired EGU was “several years away,” in the years since that report was published a joint DOE-industry pilot program had made significant gains by the time of the 2005 CAMR (1997 EPA Mercury Report Vol. VIII, p. 6-2; Pavlish et al., 2003).

91 An EPA memo explicitly admitted that “[u]sing the highest [mercury] fuel content ensures that the developed NSPS limit are achievable by a unit located anywhere in the United States” (EPA, 2005c, p. 3).

92 Requests for reconsideration of both the 2005 Delisting Rule and CAMR were filed with the EPA, but were denied in a subsequent rule that only made minor substantive changes to State mercury allocations and some of the §111(d) new source standards (Revision of December 2000 Clean Air Act Section 112(n) Finding, 2006).
offered a lengthy argument that EGU-sourced mercury did not pose a significant health hazard, particularly after the mercury reduction co-benefits of recent regulation were taken into account. Such marginal health benefits, argued the 2005 Delisting Rule, would be substantially outweighed by the costs of compliance were mercury to be regulated under §112.

5.9.1.5  *New Jersey v. EPA*

EPA’s new mercury strategy was met with intense criticism; members of Congress introduced joint resolutions to disapprove the rule under the Congressional Review Act, which if successful would have forced EPA to issue a MACT-based rule, though the resolution did not pass (S.J. Res. 20, 2005; Congressional Review Act, 2012). Dissatisfied with the lack of stringency, many states would go on to issue their own EGU-sourced mercury regulations that went well beyond the 2005 rule (McCarthy, 2007). Predictably, a number of environmental groups and states appealed the 2005 Rule to the D.C. Circuit Court (*New Jersey v. EPA*, 2008). On February 8, 2008, the D.C. Circuit vacated the 2005 Rule in *New Jersey v. EPA*, finding EPA’s delisting decision violated the plain text and structure of §112 because EPA did not make the necessary findings required to delist HAP under §112(d)(9) (*New Jersey v. EPA*, 2008, p.

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93 That argument was supported by EPA modeling described in the rule (2005 Delisting Rule, pp. 16,015-16,021) The EPA based its conclusions on modeling runs using CMAQ, its general-purpose atmospheric processes model; when applied to mercury the CMAQ had at that point shown a tendency to predict smaller aqueous mercury concentrations than other mercury models commonly used by scientists and governmental agencies (Ryaboshapko et al., 2002, pp. 3,881, 3,894). A 2005 peer review panel that evaluated the CMAQ model noted that the CMAQ results for the 2005 CAMR were not particularly robust. Amar et al., 2005, p. 13). Generally, the results of even good faith modeling can show dramatically different results based on model parameters and assumptions.

94 S.J. Res. 20, 109th Cong. (2005); see also Congressional Review Act, 5 U.S.C. §§ 801 et seq. (2012). Of course, overturning the 2005 Delisting Rule would have likely led to further battles on the suitability of the MACT standards already developed by the EPA (McCarthy & Beth, 2009).

95 The Congressional Research Service would also analyze the 2005 CAMR rule and come to a similar conclusion as the EPA and 2005 GAO reports (Shea, Parker, McCarthy & Chaptman, 2005).
EPA raised different statutory construction and deference arguments but the Court rejected them, holding that Congress had intentionally removed significant discretion from the HAP listing process – and that included the EGU-sourced mercury process – precisely because it considered EPA too reluctant to list HAPs (*New Jersey v. EPA*, p. 583).

Because the court concluded that the 2005 Delisting Rule was invalid, EGU-sourced HAP including mercury remained regulated under §112, precluding them from regulation under §111 and resulting in the Court vacating both the 2005 Delisting Rule and the 2005 CAMR. The *New Jersey* decision came out shortly before President Bush was to leave office, and future EGU mercury emissions regulations would wait for his successor; one of the last actions the administration would take on EGU-sourced mercury emissions was to cancel DOE field tests of mercury emissions reduction technology – once they started to show low-cost reduction of 90 percent or more of emissions was possible:

> [W]hile a number of short-term tests achieved mercury reductions in excess of 90 percent, the amount of sorbent injection that achieved the reductions was often decreased during long-term tests to determine the minimum cost of achieving, on average, 70 percent mercury reductions. Beginning in 2007 – near the end of the research program—DOE field tests aimed to achieve reductions of 90 percent or greater mercury at low costs. However, DOE reported that federal funding for the DOE tests was eliminated before the final phase of planned tests was completed.” (GAO, 2009, p. 6).

Bills were again introduced in Congress to force EPA to implement strict EGU-sourced mercury emissions limits, though none passed (Healthy Air and Clean Water
Act, 2007; Mercury Emissions Control Act, 2008; Mercury Emissions Reduction Act, 2007).96

5.9.2 2008-2016: The Obama Administration and Air Pollution Control

President Obama’s entry into the White House signaled a change in EPA’s approach to pollution control, particularly regarding atmospheric pollution. His environmental record as a state legislator in Illinois and the U.S. Senate had been mixed, because “as a state senator . . . he usually supported bills sought by coal interests, according to legislative records and interviews” (Dilanian, 2008).97 however, in light of his pro-environmental campaign rhetoric, and the fact that his immediate predecessor compiled what they widely considered to be one of the worst environmental records, if not the worst, in U.S. history, environmentalists were optimistic (Goldberg, 2009).98 Immediately after taking office he quickly moved to halt the flurry of “midnight regulations” the Bush EPA had attempted to push through the regulatory process at the end of that administration, though with mixed success (Kolbert, 2008; Rubrecht, 2009; Smith, 2008; Walsh, 2008).99

96 The Mercury Emissions Control Act would have required EPA to promulgate regulations that reduce mercury from new and existing EGUs by “not less than 90 percent.” The Mercury Emissions Reduction Act would have amended §112 to require EPA to promulgate EGU-sourced emissions standards within one year. The Healthy Air and Clean Water Act would have set mercury emissions limits for EGUs at .6 lbs per trillion Btu.

97 The League of Conservation Voters (LCV) awarded him a cumulative score of 72% on his “National Environmental Scorecard” during his Senate tenure; though they record him as voting against environmental protection only twice, he did miss numerous votes on environmental legislation, driving down his score (LCV, n.d.).

98 Goldberg (2009) quotes a Sierra Club spokesperson stating “[h]e [Bush] has undone decades if not a century of progress on the environment . . . [his] administration has introduced this pervasive rot into the federal government which has undermined the rule of law, undermined science, undermined basic competence. . . .”). Vidal (2008) quotes the president of Defenders of Wildlife Action Fund stating “[i]t is difficult to describe the damage done by the Bush administration’s misguided and destructive environmental policies.” The Natural Resources Defense Council takes a similarly dim view of Bush’s early environmental record, stating that “[o]ver the course of [his] first term, [Bush] led the most thorough and destructive campaign against America’s environmental safeguards in the past 40 years” (NRDC, 2008).

99 For a comprehensive listing of President Bush’s attempted “midnight regulations,” see ProPublica (2017), though updates on the status of each were years out of date at the time of retrieval.
5.9.2.1 The Obama EPA’s Mercury and Air Toxics Rule

President Obama had certainly previously indicated his willingness to take action on mercury: while a Senator he introduced two pieces of legislation aimed at reducing environmental mercury emissions (Missing Mercury in Manufacturing Monitoring and Mitigation Act, 2006; Mercury Export Ban Act, 2008). and had been a co-sponsor of the unsuccessful resolution to nullify the 2005 Delisting Rule. Shortly after he won the 2008 election, several non-profit groups brought suit in D.C. District Court to compel EPA to create an EGU-sourced mercury MACT standards, and EPA entered into a consent decree requiring promulgation of MACT standards in 2011, with final regulations to follow in 6 months (American Nurses Association v. EPA, 2008).

The proposed regulations, published on May 3, 2011, would impose stringent controls on EGU-sourced HAP, including mercury, under §112 (National Emission Standards [2011 Proposed MATS], 2011). Under the proposed standards, mercury reductions would be reduced from a baseline projected 29 tpy to 6 tpy by 2015, with additional reductions in the other HAP identified in the Utility Study (2011 Proposed MATS, p. 25,073). The propose rule drew significant attention; EPA received a recordbreaking 900,000+ public comments, far more than any similar proposed regulation (2012 MATS Rule, p. 9,306). Many, particularly from individual members of

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100 The first would have amended the Toxic Substances Control Act to phase out the use of mercury in chlorine and caustic soda manufacturing. The second amended the Toxic Substances Control Act to prohibit federal agencies from selling or conveying mercury, and to ban the export of mercury outside the United States. The first bill would die in Committee, though the second would be signed into law by President Bush.

101 State and industry actors unsuccessfully sought to prevent the Consent Decree, but did not prevail. Further proceedings were mooted when the EPA promulgated of emissions standards in December of 2011.

102 The 2011 Proposed MATS was also projected to reduce hydrogen chloride by 68,000 tpy and through HAP control co-benefits, SO2 by an additional 2.1 million tpy, NOx by 100,000 tpy, hydrogen chloride by 68,000 tpy, PM2.5 by 83,200 tpy, and CO2 by 26.67 million tpy (2011 Proposed MATS, p. 25,073).
the public, strongly supported stringent regulation of EGU-sourced mercury, though the
EGU industry and its allies protested heavily EPA’s scientific and legal rationales for
both the “confirmation” of the 2000 Listing Rule and the proposed standards.103

On February 16, 2012, EPA issued the final 2012 MATS Rule, slightly modified
from the proposed Rule but instituting similar emissions standards that would reduce
EGU-sourced mercury emissions from a newly projected 27 tpy down to 7 tpy (2012
MATS Rule, p. 9,424).104 In terms of mercury emissions standards, the 2012 MATS Rule
used a more stringent analysis to determine the MACT floor than had the 2004 Proposed
CAMR or 2005 CAMR.105 While EPA conducted a thorough analysis of the costs of the
2012 MATS Rule, concluding that they were outweighed by the benefits, it also
concluded that it did not need to account for costs before regulating EGU-sourced HAPs
(2012 MATS Rule, pp. 9,425-9,432).106 Likely foreseeing legal and political pushback
from the EGU industry, EPA also conducted extensive new modeling of mercury risk,107
and relied heavily on its independent Scientific Advisory Board (“SAB”) to review its
methodologies and assumptions (2012 MATS Rule, pp. 9,312-9,318). Significant
changes were made to the scientific technical and evaluation, but even after the suggested
modifications were made, the models still showed that, contrary to the conclusions

103 The EPA aggregated, summarized, and responded to many of these comments in the final rule
(Response to Public Comments, 2011a, 2011b).
104 Projected emissions reductions had changed for other HAPs as well, as did projections of baseline HAP
105 For example, existing EGUs using bituminous coal—the most common type—would have had their
emissions limited or capped to .021 lbs per gigawatt hour ("lb/GWh") by both the 2004 Proposed CAMR
and 2005 CAMR, but now were limited to .013 lb/GwH by the 2012 MATS Rule (2004 Proposed CAMR,
p. 4,662; 2005 CAMR, p. 28,615; 2012 MATS Rule, p. 9,367). The 2012 MATS Rule also included
emissions standards for other HAPs, while the 2005 CAMR only regulated mercury and nickel (2012
MATS Rule, p. 9,367).
106 Many of the stated benefits were based on co-benefit reductions of particulate matter (2012 MATS Rule,
p. 9,432).
107 This new modeling was extensively documented in EPA (2011).
reached by EPA when justifying the 2005 Delisting Rule, EGU-sourced mercury posed a discrete hazard to human health. EPA used the same deposition model to support the listing decision in the 2012 MATS Rule as they had for the 2005 Delisting Rule, but incorporated more data and used different modeling assumptions and higher spatial resolution (EPA, 2011).

5.9.2.2 Michigan v. EPA

The Final Rule was appealed in Michigan v. EPA, this time by impacted companies, industry and labor groups, and states, while environmental groups, other industry groups and states intervened in support of the Rule (White Stallion Energy Center v. EPA, 2014). The central argument by petitioners was that EPA improperly decided that it was “necessary” and “appropriate” to list EGU-sourced mercury without considering the costs, as it was implausible that Congress would want no attention paid to cost considerations (White Stallion Energy Center v. EPA, 2014). A D.C. Circuit court rejected that argument, siding with EPA and intervenors and holding that under the plain language of CAA §112(n)(1), EPA was ordered to list EGU-sourced mercury as a HAP if it “found such regulation appropriate and necessary after considering the results of the [EPA and NIEHS studies],” and thus the decision to list was therefore predicated solely on the determination of whether EGU-sourced mercury was a public health hazard (White Stallion Energy Center v. EPA, 2014, pp. 1,238-1,239). Any cost considerations would then be incorporated when actually setting MACT emissions limits. Industry and state

108 Sensitivity analyses examine how changing model variables – in this case for example, only looking at high-mercury-deposition watersheds, or changing consumption patterns – altered the overall population risk values derived by the model, and found that such changes did not significantly reduce that risk.
actors opposing the rule appealed to the Supreme Court on the cost consideration issue under the MATS Rule.

As the Supreme Court noted in *Whitman v. American Trucking Associations* (2001, p. 467), it had previously “refused to find implicit in ambiguous sections of the CAA an authorization to consider costs that has elsewhere, and so often, been expressly granted” (*Whitman v. American Trucking Associations*, 2001). On its face, the Court seemed to be addressing a similar situation when reviewing EPA’s “appropriate and necessary” determination: the CAA, particularly after the 1990 Amendments, explicitly requires EPA to consider costs before making regulation decisions in a number of provisions. In the amended §112 provisions at issue, Congress had not only failed to expressly require EPA to consider costs when making the “appropriate and necessary” determination, but had mandated that it only make such a determination after considering the results of the 1998 Utility Study, the statutory requirement of which was purely a public health analysis (CAA, 2012, §112(n)(1)(A)).

The legislative history of the 1990 Amendments to §112 also strongly suggested that §112’s sole focus on health survived the 1990 Amendments, with EPA being required to add a substance to the HAP list generally “upon a showing . . . that emissions . . . are known to cause or may be reasonable anticipated to cause adverse effects to human health or adverse environmental effects” (CAA, 2012, §112(b)(3)). Indeed, as noted above the provision that excepted EGU-sourced HAP from automatic regulation

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109 See, for example, CAA §111(a)(1), which requires EPA to take into account “the cost of achieving such reduction” when setting standards of performance for new stationary sources. Similarly, CAA §245(k)(1) requires EPA “tak[e] into consideration the cost of achieving such emissions reductions” when setting standards for reformulated gasoline.” Finally, CAA §247(a)(3) requires emissions standards for nonroad engines and vehicles be “the greatest degree . . . achievable . . . giving appropriate consideration to the cost of applying such technology.”
was added in conference and then only because Congress seemed reluctant to regulate where the separate acid rain provisions of the 1990 Amendments might remedy the problem. For HAPs from all other major sources not likely to be impacted by the acid rain provisions, EPA was only to consider costs in the emissions standards stage of regulation, and even then the MACT floor required a certain minimum emissions standards, notwithstanding the cost (CAA, 2012, §212(b)(2)-(3)). Furthermore, giving the ambiguity of the “appropriate and necessary” determination, EPA would seem to have significant discretion under *Chevron v. NRDC* to determine just what that meant.\(^\text{110}\)

However, rejecting the applicability of both *American Trucking Assns.* and *Chevron*, the Court ruled 5-4 in favor of petitioners, holding that it “strayed far beyond [Chevron’s] bounds” when it made its “appropriate and necessary” listing decision without paying attention to cost considerations (*Michigan v. EPA*, 2015, p. 2,607). Arguing that such a “capacious[]” phrase required that “all relevant factors” be considered, the opinion reasoned that for its listing decision to be “appropriate,” at least some attention to cost must be paid; otherwise, the potential could arise that billions in economic costs” might be incurred in return for “a few dollars in health or environmental benefits” (*Michigan v. EPA*, 2015, p. 2,607). Conceding that other §112 listing decisions were based on the threat to human health or the environment, the *Michigan* majority characterized the EGU-specific “appropriate and necessary” section as Congress enacting different and “unique” requirements to be met before regulating EGU-sourced HAP (*Michigan v. EPA*, 2015, p. 2,710). The four justices dissenting argued that EPA had, in fact, paid significant attention to costs throughout the entire process, and would do so

\(^{110}\) *Chevron*, coincidentally, was addressing a similar issue; the EPA’s discretionary authority to define a term under CAA.
again, faulting the majority for unduly focusing on the one initial stage of the regulatory decision where cost was not required under the statute (Michigan v. EPA, 2015, p. 2,718).

5.9.2.3 Regulating EGU-Sourced Mercury Post-Michigan

Ironically, the Michigan decision to invalidate the MATS Rule did not significantly impact the Rule in the long term, though it may have signaled less deferential judicial oversight of agency actions generally. The Supreme Court reversed and remanded the Michigan case, but did not vacate the rule, and the D.C. Circuit in turn remanded the MATS Rule back to EPA also without vacatur, giving the agency an opportunity to promulgate a rule that complied with the Supreme Court’s cost reconsideration (White Stallion Energy Center v. EPA, 2015, ECF #1588459). The D.C. Circuit, Chief Justice Roberts, and later the rejected pleas to stay the 2012 MATS Rule (Supreme Court, 2016a, 2016b). In December of 2015 EPA solicited comments on a proposed supplemental finding that in light of cost analyses it was still appropriate to regulate EGU-sourced HAP (Proposed Supplemental Finding, 2015). Three months later, EPA released its final supplemental finding (2016 Supplemental Finding) that examined the costs and determined that in light of those costs it was still “appropriate and necessary” to regulate EGUs under §112 (Supplemental Finding [2016 Supplemental Finding], 2016).

In that analysis it conducted comprehensive cost analyses; the one it presented as its preferred approach simply examined whether the costs of the 2012 MATS Rule were “reasonable” and if comparing those costs to the “substantial hazards to public health and the environment posed by HAP emissions from power plants” caused the agency to alter its conclusion to regulate (2016 Supplemental Finding, p. 24,424). Building on studies
already conducted before promulgation of the 2012 MATS Rule quantifying the health benefits of co-benefits like PM$_{2.5}$ reduction, EPA now also analyzed the cost to the EGU sector in light of the sector’s size and revenues, and whether the industry could comply with the Rule while still performing its primary goal: to reliably provide electricity to customers at a reasonable cost (2016 Supplemental Finding, p. 24,424). EPA also noted that they also conducted a more traditional cost-benefit analysis and found that such an analysis, while not necessary, would still support the decision to regulate EGU-sourced HAP (2016 Supplemental Finding, p. 24,421). On June 13, 2016, the Supreme Court denied certiorari to state and industry appeal of the D.C. Circuit’s decision to remand the 2012 MATS Rule to EPA for re-analysis that considered costs (White Stallion Energy Center v. EPA, 2014).

5.9.3 The Trump Administration and the Future of the Mercury and Air Toxics Rule

While many observers had assumed in the wake of the Supreme Court’s denial of a stay on the 2012 MATS Rule that the final rule would stand, Trump’s election and his appointment of Scott Pruitt – who had himself litigated against the 2016 MATS Rule as Attorney General of Oklahoma – has called that into question. A number of parties appealed the 2016 Supplemental Finding on various grounds, arguing *inter alia* that the cost analyses done by EPA did not comply with Michigan or CAA, and impermissibly counted the co-benefits of reducing non-HAP pollutants (Opening Brief, 2016).

Though Obama’s EPA had opposed the appeal along with a number of state and non-governmental organization intervenors, the Trump EPA would later move to continue the oral arguments on petitioners’ motion, because “[i]n light of the recent change in Administration . . . to give the appropriate officials adequate time to fully
review the Supplemental Finding” (Respondent EPA’s Motion to Continue, 2017, p. 1).

EPA further notes that those officials may “reconsider the rule or some part of the rule.” (Respondent EPA’s Motion to Continue, 2017, p. 5).

The D.C. Circuit Court of Appeals granted the motion, requiring the agency to report on the status of its review every 90 days, but not giving any specific deadline to complete that review (Murray Energy Corp. v. EPA, 2017c). EPA left unclear how exactly it would “reconsider the rule or some part of the rule” in light of the requirements of §112. Instead, EPA vaguely references “[a]gencies[‘] . . . inherent authority to reconsider past decisions and to revise, replace or repeal a decision to the extent permitted by law. . . .” (Respondent EPA’s Motion to Continue, 2017, p. 5). The primary difficulty in “reconsider[ing]” the rule, of course, is as the D.C. Circuit Court noted in New Jersey v. EPA (discussed in Section 5.9.1.5 above), it is far more difficult for EPA to add a pollutant to the HAP list – CAA §112(b)(3)(A) forbids removing EGU-sourced mercury as a HAP absent a finding that “emissions, ambient concentrations, bioaccumulation or deposition of the substance may not reasonably be anticipated to cause any adverse effects to the human health or adverse environmental effects.” In the case of mercury this would be impossible – there is no dispute that bioaccumulation can cause adverse effects to human health and the environment. Still, as the 2005 Delisting Decision and 2005 CAMR demonstrated, even regulatory decisions that appear on their face to be invalid can delay stringent regulations for years while they work their way through the rulemaking and court systems.

111 Though EPA does not reference New Jersey v. EPA in its motion to continue, in each of the others’ responses, they note that under New Jersey EPA lacks the authority to simply withdraw the “Necessary and Appropriate” finding based on any review outside this process.
Additionally, in terms of real-world effects, even were the 2016 Supplemental Finding to be successfully withdrawn (or, withdrawn for a number of years while the inevitable litigation worked its way through the court system), the vast majority of EGUs have already complied with the 2012 MATS Rule’s emissions requirements or, in the case of older plants, have shut down. Furthermore, coal-fired EGUs are increasingly disadvantaged economically in comparison to natural gas and renewable energy. Removing the rule might, however, allow plants to save money by both allowing them to turn off control technologies as well as not be subject to reporting requirements or enforcement actions. In any event, the Trump EPA’s position likely signals that the multi-decade EGU-sourced mercury emissions debates will in fact go on longer, though the 2012 MATS Rule may have already fulfilled most of its goals.

5.9.4 The Evolving Mercury Emissions Discourse, 2000-present: Context and Conclusions

Discerning the why of the second Bush administration’s attempt to head off stringent mercury regulations is not difficult; he, his vice-president, and many of his appointees were veterans of the energy industry who adhered to a fiercely anti-regulatory ideology that saw environmental regulations dangerous not just to the immediate economy but capitalism, and American economic pre-eminence itself. The specific how, however, requires a deeper inquiry. Taking to heart many of the lessons of the past that direct challenges to environmental regulations faced Congressional, public, and judicial resistance in a way that could be both politically damaging and result in legislative action that removed significant agency discretion over environmental policy domains – for example, the HAP provisions of the 1990 Amendments – anti-regulatory actors both inside and outside government relied increasingly on “low profile” challenges that
attempted to reframe and redirect regulatory discourse in a way that sought to hide goals in arcane rulemaking processes and technical language (Layzer, 2012, p. 22; Lazarus, 2012).¹¹² Indeed, this strategy switch can be prominently seen with the second Bush Administration’s Clean Skies Plan; defeated in Congress and facing significant public backlash, its architects simply attempted to implement it under the CAA’s rulemaking process.

Both procedural and technical discursive practices were leveraged to frame, analyze, and regulate mercury emissions in a way that would minimize industry burdens. On a procedural level President Bush’s appointees shut out agency and independent scientists, incorporated industry-provided materials ranging from modeling results to actual industry-drafted language, and drafted both the rules and the technical documentation alleged to support them in lengthy and arcane language – the 2005 CAMR and 2005 Delisting Rule made up a combined and densely technical 135 pages of the Federal Register, while the Regulatory Impact Analysis document EPA produced to support those rules made up 570 pages. The architects of the 2005 CAMR complemented those tactics by framing their approach in a way that emphasized uncertainty and downplayed risks; for example, the 2005 CAMR attempted to undermine EPA’s health assumptions as to the level at which mercury in fish is likely to cause adverse health effects, stating that “[t]he RfD is an estimate [] with uncertainty spanning several orders of magnitude . . . [i]t is also important to note that the RfD does not define a bright line, above which individuals are at risk of adverse effect (2005 CAMR, p. 28,646). As

¹¹² Not that such attempts were successful in terms of long term strategy; Lazarus (2012, p. 106) notes that “the ironic upshot of the Reagan attack on federal environmental law was most likely more, not less, demanding federal environmental legislation.”
presented to the public, the overall projected emissions of the Clear Skies Act generally were framed as beneficial to human health, though they only appeared so when compared to a mercury emissions baseline which involved no additional mercury emissions regulations whatsoever (“President Bush Announces Clear Skies & Global Climate Change Initiatives, 2003).

Perhaps the most unusual aspect about the 2005 CAMR process was that even after many of these tactics were exposed not only by the OIG and GAO reports as well as by significant media coverage, and even after EPA’s own employees warned that the CAMR was likely unlawful under CAA (Pianin, 2004), the CAMR’s architects simply proceeded to implement it. Considering the substantial public record of irregularities in the rulemaking process, as well as the almost legally indefensible 2005 Delisting Decision, it seems possible that they expected the 2005 CAMR to not survive judicial scrutiny. But even delay served the EGU industry sector, allowing them to put off significant costs and profit from highly-polluting EGUs that were operating well past their expected lifespan. As the Union of Concerned Scientists noted in 2012 (p. 1), “more than three-quarters of U.S. coal-fired power plants have outlived their 30-year lifespan— with 17 percent being older than half a century.” Indeed, in response to the 2012 MATS Rule many of the oldest plants have closed rather than pay to install mercury control technology (EIA, 2016).

Why did the Bush administration face so little political or electoral fallout from its intense anti-environmental record?113 Several explanations offer themselves. Increasing political polarization and partisan animosity is one; in 1970 environmental regulations

113 While President Bush ended his presidency with historically low approval ratings, there is little to suggest they were driven by his environmental policies (CNN, 2008).
were supported by large proportions of both the public and politicians; for example, CAA passed without a single nay vote in the Senate, and with a single representative voting against it in the House (Kenworthy, 1970). However, the electoral politics have shown widening between those supporting environmental protection measures and those opposing them (e.g., Dunlap, Xiao & McCright, 2001). Among the general public there is still significant support for environmental protection measures, but the past two decades have also seen significant political polarization generally; even if a conservative and/or Republican voter had supported stronger EGU-sourced mercury emissions generally, they might be less likely to vote based on that single issue in light of general political self-identification (Dunlap, 2001).

When the Obama administration took power, they brought their own discursive framing to bear. Representing a sharp break from the anti-regulatory ideology of his predecessor, President Obama pursued the most muscular emissions control policy since the beginning of the CAA, attempting to place significant controls on not only mercury and other EGU-sourced HAP, but also greenhouse gas emissions through the rulemaking process with the Clean Power Plan. To head off potential attacks on the scientific conclusions reached by EPA in enacting the 2012 MATS Rule, the Obama-era EPA relied heavily on the SAB to vet its research, and addressed each of the recommendations.

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114 Dunlap and his co-authors chart a significant widening gap between Democratic and Republican lawmakers on environmental issues from 1973-2000, driven by movement on both sides – over time Democratic lawmakers increasingly voted for pro-environmental measures, while Republicans increasingly voted against those measures (Dunlap et al., p. 29). The gaps between both Democratic and Republican, and liberal and conservative, members of the public showed less of an overall trend, though self-identified Democrats and liberals consistently had more pro-environmental views than Republicans and conservatives. (Dunlap et al., pp. 31-32).

115 Certainly the EPA appointees who had masterminded the CAMR avoided any negative effects outside their personal reputations, particularly among environmentalists, as they successfully re-entering the EGU lobbying industry when their tenure at the EPA was over.
and requests brought by the SAB in response (2012 MATS Rule, pp. 9,313-9,319).

Where the Bush-era 2005 CAMR often read like a work of legal advocacy, the Obama-era 2012 MATS Rule more frequently read like a scientific article or report, with frequent references to articles in scientific journals that supported the point under discussion (2012 MATS Rule, p. 9,352). Like the Bush-era EPA, EPA under Obama framed not only the legal and technical aspects of their program in a way that counseled taking its chosen policy approach, but also framed opposing viewpoints by summarizing and framing public comments opposing stringent mercury regulations in ways that made them seem less credible or as arguing for patently unlawful or unreasonable interpretations of CAA (2012 MATS Rule, pp. 9,319-9,362).

Though it is early in the Trump administration, his EPA has already signaled a major rollback of environmental regulations (National Geographic, 2017). The fact that petitioners in Murray Energy Corp. v. EPA (2017a) have attacked, inter alia, the economic modeling assumptions underlying the 2016 Supplemental Finding – and the fact that the current EPA Administrator represented one of the petitioners (p. 4 [of ECF document]) – indicates that EPA’s review may involve the same kind of approach to modeling assumptions used by the Bush-era EPA to justify the 2005 Delisting Rule and the 2005 CAMR (discussed above in Section 5.9.1 above).

5.10 Conclusion and Policy Recommendations

If the first (1970-1989) and second (1990-2000) eras of CAA-based mercury regulatory decisions were defined by inaction and delay, the third (2001-present) has seen vigorous battles played out in Congress, EPA rulemaking process, and the federal courts over how to regulate EGU-sourced mercury. From CAA’s creation until the present, a
surgent anti-regulatory movement has emerged and environmental issues have become increasingly polarized, with an executive branch frequently controlled by politicians either unable or unwilling to fully implement CAA provisions, particularly regarding HAP. As overt attempts to weaken or delay CAA provisions proved less effective, politicians and policymakers interested in reducing environmental regulations’ burdens on business instead turned over time to lower-profile mechanisms to implement industry-friendly rules. No process shows this evolution in such sharp relief as President Bush’s Clear Skies Plan and the controversial implementation of its mercury provisions as the 2005 CAMR. Framed as a means to reduce the dangers posed by, inter alia, EGU-sourced mercury, created a regulatory mechanism that essentially placed no mercury reduction requirements on EGUs for several years.

This should not be interpreted to mean that the Clean Air Act generally, or even the HAP provisions specifically, have been largely a failure. The Clean Air Act has improved air quality immensely over the past several decades, if not always to the extent hoped for when it first went into effect. Concentrations of each NAAQS pollutant in the atmosphere of the United States has shown a steady downward trend over the past few decades, with particularly significant decreases in the smog precursors SO₂ and NOₓ (EPA, 2017). Hazardous air pollutant emissions are somewhat harder to track due in part to their variability, though emissions for many (but not all) HAPs have been similarly reduced over time (e.g. Hafner, McCarthy, Wheeler & Koerber, 2004; McCarthy, Hafner & Montzka 2006).

Nor should this chapter be interpreted to mean that CAA failures are due to either political machinations or lack of will. The creators of CAA appeared to underestimate the
technical and procedural difficulties involved in reducing air pollutants in terms of both NAAQS and HAPs (e.g., Graham, 1985; Davis, Kurtock, Leape and Magill, 1977). The scope of the HAP issue may have been somewhat underestimated as well when CAA was created and for several years afterwards – the NAAQS provisions were certainly considered the “cornerstone” of CAA (Davis, Kurtock, Leape and Magill, 1977, p.4). It is possible that CAA drafters, their scientific and technical advisors, and EPA regulators may have assumed that controlling NAAQS criteria pollutants such as particulates, would also indirectly reduce HAPs (e.g. EPA’s Air Pollution Control Program, 1983, p. 30).

However, there can be little doubt that the anti-regulatory ideology of many presidents taking office after the creation of CAA has also reduced pollution less than either the law anticipated (and may have required) and that was technologically achievable. In the case of some environmental rulemaking (or lack of rulemaking) such decisions may have been squarely within those administrations’ discretion. However, the §112 HAP provisions placed an affirmative duty on EPA Administrators to regulate toxics like mercury (and the 1990 Amendments specifically to make a decision on EGU-sourced HAPs, including mercury). Despite this, for four decades such decisions have been delayed and deferred.

tactics used to do so including modifying scientific and technical assumptions to increase projected costs while reducing projected benefits, all within a rhetorical framing that strove to appear objective and “scientific.” One particularly common strategy has been afforded by – and likely partially the cause of – an increase in the length of regulations. The 1973 rule regulating mercury emissions from chlor-alkali plants made up 31 pages, including pages discussing beryllium and asbestos, with most of the Rule
setting forth technical and procedural processes to ensure compliance (National Emissions Standards, 1973).\textsuperscript{116} The 2005 CAMR, on the other hand, was more than three times as long, and relied on even longer technical analyses filed separately on the docket (pp. 28,605, 28,615, 28,622).\textsuperscript{117}

Despite the Trump presidency, environmentalists ultimately may be victorious in the mercury emissions dispute. The \textit{Murray Energy Corp. v. EPA} petitioners are treading well-traveled ground, and arguing for considering that even if the Trump administration successfully withdraws the 2012 MATS Rule, most affected power plants have already implemented control technologies. However, taken in the context of the 40-year history of § 112 whatever happens the EGU industry could arguably be construed as the real winner. While it has been the primary source of mercury emissions since at least the 1990s, it has avoided mercury regulations through appeals to scientific uncertainty and purportedly unreasonably high costs of control, aided by a well-organized ideological movement against environmental regulations that has been highly effective not only in Republican administrations but also Democratic ones (Layzer, 2012, pp. 66-82, 187-256). As shown above, while anti-regulatory actors were unable to substantially weaken the CAA itself or delay stringent mercury regulations indefinitely, by prolonging the debate they were able to let EGUs reap those financial benefits for decades.

The health costs resulting from this inaction may be substantial. From 1993 until 2011, the percentage of total lake acres and river miles subject to chemical contamination

\textsuperscript{117} Of course, such attempts are also served by ever-increasing “additional procedures, analytical requirements, and external review mechanisms” that have greatly contributed to the size of published regulations generally, and the time it takes to move from proposed to final rule (Garrity, 1992).
advisories – with mercury being the most common contaminant – increased from less than 5% to over 35% for the former, and from less than 15% to over 40% for the latter (EPA, 2011). The comprehensive technical analysis produced by EPA for the 2012 MATS Rule, revised in response to peer-review by SAB, suggests that vulnerable groups especially may be exposed to dangerous levels purely due to EGU emissions alone, even at the decreased mercury levels then found in the environment (EPA, 2011, pp. 110-111). In the context of CAA’s history, then, the delay in regulating EGU-sourced mercury may have negatively impacted generations of children, particularly in vulnerable communities where freshwater fish consumption may be particularly high.

Secondly, the new Presidential administration has expressed an overt hostility to environmental regulations, particularly those regarding emissions, meaning that even the final mercury emissions rule for EGU-sourced mercury might ultimately be revisited – as difficult as it has been historically for the executive branch to reduce toxics standards, as opposed to not implement new ones (e.g., Jasanoff, 1990, p. 198).118

While it is likely too soon to determine whether the new mercury control measures are effective in reducing mercury in waterbodies from which fish are taken, initial data suggests that they may already be effective in reducing localized mercury pollution near EGUs that have installed control technologies (Castro & Sherwell, 2015). Furthermore, the costs of such controls have not proven especially excessive, and the

118 The public has historically been resistant to regulations weakening toxic standards. For an example of public opposition to rollbacks on toxic substances, in 2001 the second Bush administration attempted to block an arsenic standard promulgated under the Clinton EPA; Bush would later admit that it was one of the worst moves of his administration (Seelye, 2001).
sorbent injection controls themselves may be even more efficacious than previously thought by industry actors (GAO, 2009, p. 18).

What policy recommendations can be gleaned from the EGU-sourced mercury debate? For one thing, it provides an almost textbook example of the fundamental difficulties of the modern environmental regulatory apparatus; striking the appropriate balance between giving agencies like EPA sufficient discretion to regulate pollution in a flexible manner, but not giving them so much discretion that agency actors hostile to environmental regulation use that flexibility to weaken or delay regulations protective towards human health. In many cases, this meant “[t]he original authorizing statutes often provided little direction other than broad, sometimes vague, and occasionally contradictory goals” (Williamson et al., 1993, p. 645). But as the history described above demonstrates, even where EPA has not been given discretion, it will in many cases take it – with the most recent example being the 2005 CAMR. The history of the EGU-sourced mercury debate also provides a clear example of the shift from overt challenge or resistance to CAA requirements to a more covert approach that uses a pro-environmental narrative framing and control of technical analyses to put into place regulations that benefit industry as much as possible.

What is the best way to regulate either EGU-sourced mercury or other toxics emissions in the future? In the case of mercury and a number of other pollutants, the current multi-pollutant approach seems more effective than a single-pollutant one, allowing multiple layers of pollution mitigation regulations that can reduce a potentially expansive array of pollutants.\textsuperscript{119} For mercury specifically, increased government funding

\textsuperscript{119} Of course, as the history of the 2005 CAMR demonstrates, the multipollutant narrative can be framed to justify inaction.
for scientific research into areas that are still uncertain, particularly atmospheric cycling and population-level health effects, would help, as would implementing a more comprehensive national mercury deposition monitoring network, as discussed in more detail in Chapter 2.

Dealing with the technical and scientific dimensions of air pollution control generally may end up being less difficult to resolve than clashes of ideology. How can environmental regulations be effectively implemented when EPA is controlled by those ideologically opposed to such regulations at a fundamental level, and have developed sophisticated procedural and discursive strategies they can leverage when they have political control of EPA? While environmental advocates have successfully headed off many such attacks in the courts and before legislative bodies, anti-regulatory interests often hold the advantage because they can frequently achieve their goal by simply delaying regulations as long as possible. Furthermore, even when though the regulatory debate over EGU-sourced HAP emissions seem to have reached a denouement, uncertainties still remain, particularly in light of the change in administration – just like the 2000 Delisting Rule, the 2005 CAMR, and the 2012 MATS Rule, final decisions often do not remain final. Finally, it is at least possible that future research will suggest that regulating EGU-sourced mercury and other HAPs was not necessary. Perhaps future such regulatory debates would be served best by a more explicit engagement of ideological disputes, and moving away from a technical or scientific framing of uncertainty towards debates over values: in the face of uncertainty, how much risk is the public willing to suffer – and who should bear that burden of uncertainty?
Chapter 6
Mercury as a Global Pollutant: Negotiating the Minamata Convention


6.1 Overview

On October 10, 2013, the Minamata Convention on Mercury was opened for signature in Kumamoto, Japan, a site which sixty years prior had seen one of the largest and most serious mercury poisoning events in history. The Convention had been several years in development, its proximate cause a 2007 United Nations Environment Programme Governing Council (UNEP GC) decision, taken in the face of a large body of research demonstrating mercury’s global health risks, to develop a global governance regime to limit those risks. The debate as to what form this regime should take – whether through a binding legal agreement or through voluntary measures – lasted several years, but ultimately resulted in a consensus that a binding agreement was necessary. At the time it opened for signatures, the Minamata Convention was the first new global environmental agreement in over ten years. On May 18, 2017, the 50th party ratified the Convention, triggering the ninety-day period after which the Convention goes into force and binds parties to various rules regulating inter alia how they govern domestic mercury emissions, primary mining, product use, import and export.

A number of accounts and analyses have been published regarding the Minamata Convention, addressing its development (e.g., Andresen, Rosendal & Skjærseth, 2012; Eriksen & Perrez, 2014; Eriksen & Xaver, 2014; Selin, 2014; Templeton & Kohler, 2014), scientific and technical analyses of its provisions (e.g., Evers, Keane, Basu & Buck, 2016; Kwon & Selin, 2016; You, 2015), changes in negotiating postures of actors (e.g., Andresen et al., 2012; Stokes, Giang & Selin, 2016) and discussions of source-

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120 In February 2013, the members of UNEP GC agreed to rename the group the “United Nations Environment Assembly of the UNEP” (UNEA). For this chapter, I will refer to the organization as UNEP GC when discussing its actions prior to the name change.
specific Convention provisions such as dental amalgam use (e.g., Mackey, Contreras & Liang, 2013), mercury waste disposal (e.g., Mackey et al., 2013), and artisanal gold mining (e.g., Spiegel, Keane, Metcalf, Veiga & Yassi, 2014). Most of the literature has focused on the large-scale political and scientific developments that led to its creation, or the significance of the Convention at a global scale.

In this chapter I seek to add to that existing body of literature by examining in depth some of the specific processes through which the Convention was created, most notably during the negotiating sessions held from 2009 through 2013. I examine these processes largely from the perspective of the United States and its negotiators, exploring the interactions between domestic and international sociopolitical processes at that focal point, though I attempt to put those interactions in the larger context of the negotiations as a whole.

Consistent with the critical realist frame adopted throughout this dissertation, I explore the multiplicity of causative mechanisms that impacted how the treaty developed, in this case by examining the social interactions “on the ground” during the negotiations and attempting to connect them to larger global structures. Beginning with a grounded theory approach to the material (Glaser & Strauss, 1979), I subsequently develop a constructivist framework to describe how the Convention developed. Consistent with both critical realism generally and the constructivist project in international relations specifically, I am particularly interested in describing “the dynamic, contingent, and culturally based condition of the social world” (Adler, 2013, p. 114) as it pertains to the Convention. I take as a starting assumption that what led to the Minamata Convention in its current form cannot be reduced to any single cause, but must be disentangled from
complex social, political, and scientific discourses over time. Using this approach, I hope that what “[I] may lose in parsimony, [I] may gain in depth and understanding” (Adler & Haas, 1992, p. 368).

In the first part of the chapter, I provide a historical account of the Minamata Convention’s development, placing it in the larger context of the evolution of multilateral environmental agreements (MEAs) governing chemicals and waste over the past few decades. After describing the Convention’s development, I then summarize the text itself, and then examine in-depth two of its most important – and hard-fought – provisions: Article 7, governing mercury used in artisanal small-scale gold mining (ASGM); and Article 8, governing atmospheric emissions of mercury from point sources.

In the second part of the chapter, I begin by analyzing the Convention’s development, and explore possible explanations as to why the negotiation processes unfolded as they did. I select two possible causal mechanisms to discuss in depth: (1) the regime change in the United States; (2) the operation of a global chemicals epistemic community. I then examine two possible complications that could impact the ultimate efficacy of the Convention and its implementation: (1) again, regime change in the United States; and (2) the difficulties inherent in monitoring and regulating ASGM and informal mercury primary production, using the resumption of large-scale primary mining in Mexico over the past several years as an example. Finally, I conclude with a general summary of the Convention and discussion of its future.

6.2 Theoretical Approach

International relations theorists have developed different analytical paradigms developed in the field of international relations to explain transnational interactions
between nations. The approaches most dominant through the past several decades have been neorealism and neoliberal institutionalism. For neorealists, the world exists in a state of anarchy; without any central authority to create and enforce laws, states are forced to take whatever steps they can to protect themselves from their neighbors (Waltz, 1979). Predictably, under this view international relations are seen to be dominated – and driven – by the strongest states, who are powerful enough to compel weaker countries to act in the former’s best interest. Like many other positivist approaches to social inquiry, neorealists assume actors – in the neorealist account, states – act rationally to maximize their own benefits (or at least what they believe to be their rational best interest), which they typically measured in military and economic advantage and the safety those things provide. The analytical focus of neorealist research is on the nation-state as the key actor. Though they tend to accept the inherent anarchy in the international system, followers of the second major paradigm, neoliberal institutionalism, are more optimistic about – and interested in studying – institutions that reduce anarchy and foster international cooperation (Keohane & Nye, 1989). Like neorealism, neoliberal institutionalism tends to “take goals and interests as given” (Litfin, 1992, p. 2), and makes the rationalist assumption that nation-states will act to fulfill them.

While both paradigms offer parsimonious explanations that can often be incorporated easily into economic or game-theory models, they both have run into the same problem as other positivist, rationalist social sciences: They do not explain observed real-world behavior with much accuracy. This has become especially noticeable as increasing globalization has led to more complex cultural, political, and economic

121 The “realism” in neorealism appears to refer not just its adherents’ realist approach to social inquiry, but also in the vernacular sense a belief that theirs is a clear-eyed, non-utopian view of global politics.
interactions around the world, and to the evolution of non-state actors – including international organizations like the United Nations, non-governmental organizations (NGOs), multinational corporations, and terrorist groups. Harold Koh (1997, p. 2631) has characterized it as: “global decision-making functions are now executed by a complex rugby scrum of nation-states, intergovernmental organizations, regional compacts, nongovernmental organizations, and informal regimes and networks.” Environmental agreements have proven particularly resistant to neoliberal or institutionalist analyses because the factors that tend to drive such agreements are caught up in scientific and economic uncertainty, and the “interests” driving such agreements are often difficult to discern, and a wide variety of nongovernmental actors including environmental advocates and scientists, have taken a key role in them.

In the past two decades a third approach, constructivism, has offered a more interpretivist approach to international relations inquiry that rejects the rationalist assumption of competing objective interests, assuming instead that “the main impediments to cooperation lie in malleable beliefs and conventions rather than in the comparatively solid structures of the neorealists and institutionalists” (Litfin, 1994, p. 3).122 Instead, it seeks to “uncover the causal social mechanisms and constitutive social relations that make IR more intelligible” (Adler, 2013, p. 6). Focused on the discursive and cognitive relations between actors in the international relations process that drive actual decision-making, constructivism thus pays more attention to “the role of intersubjectivity and social context, the co-constitution of agent and structure, and the rule-governed nature of society” (Adler, 2013, p. 4).

122 Constructivism can be subsumed under a larger “reflectivist” approach to international relations, corresponding with the “postpositivist” approach to other social sciences.
I take a constructivist approach for several reasons. First, constructivism is compatible with the critical realist metatheoretical framework described in Chapter 3, and indeed influential early constructivist scholars explicitly relied on Bhaskar’s work in setting epistemological and ontological parameters (Litfin, 1994, pp. 28-30; Wendt, 1987). From an ontological perspective, like critical realism “constructivism accepts that not all statements have the same epistemic value and consequently there is some foundation for knowledge” (Adler, 2013, p. 3). Secondly, in this case, even a cursory examination of the history of the Minamata Convention development shows that a rationalist – whether neorealist or neoliberal institutionalist – focus on power and rational self-interest does not provide useful explanations of the course of the negotiations and the form of the final Convention.

Though constructivism incorporates a wide range of analytical techniques, one that seems particularly useful to the analysis of MEAs is epistemic communities theory. Developed to account for the increasing importance of expertise in driving transnational policy development, epistemic communities are “network[s] of professionals with recognized expertise and competence in a particular domain and an authoritative claim to policy-relevant knowledge within that domain or issue-area” (Haas, 1992). Epistemic communities represent knowledge-based actors who can exert power through “shared causal views” (Litfin, 1994, p. 48). The exact boundaries of what makes up an epistemic community have been contested by different scholars working within international relations, with most researchers limiting their analysis to scientific communities (Cross, 2013). In this chapter, and taking into account the social dynamics specific to the Minamata Convention negotiations, I take a broader view of epistemic communities
similar to that proposed by Cross (2013); in Section 6.6.2 below I will discuss in more
detail the epistemic communities theory, as well as similar concepts developed in the
international relations literature and related fields. I will argue that the epistemic
communities involved in and around the Minamata Convention negotiations were a broad
group of not just scientists and engineers, but activists and government-associated
bureaucrats and diplomats united by a common culture of professionalism developed
across a disparate range of chemicals regimes.

6.3 Methods and Methodological Limitations

I rely on a number of different qualitatively-focused data sources for this chapter,
including the text of the Convention itself, both American and United Nations archival
records, academic literature, media accounts,123 scientific and technical reports, and semi-
structured interviews of American negotiators to the Convention (n=6), other American
agency personnel specifically involved in international and domestic mercury policy
implementation (n=3), and Minamata attendees not affiliated with any government (n=4).
Most interviews were conducted in person, with the remainder conducted via telephone,
and all but one was recorded. All interviews were conducted one-on-one, except for one
where an interviewees’ co-worker was present. Potential subjects were identified from
the Minamata Convention negotiating records, by interviewees themselves, and through
informal discussions with other researchers and agency personnel involved in mercury
issues. The interview protocol was reviewed and approved by the University of Miami’s

123 Though UNEP, the Minamata Convention, and the other institutions described in this chapter produce
official records of their proceedings, where available I rely principally on the International Institute for
Sustainable Development’s Earth Negotiations Bulletins for accounts of such meetings. I do this because
Earth Negotiations Bulletins tends to provide a more detailed account of such proceedings than the official
bodies, and its accuracy has been validated by multiple interviewees. Furthermore, most other authors
examining the Minamata Convention negotiations have relied on its accounts of the negotiations and other
events (e.g., Andresen et al., 2013; Eriksen & Xaver, 2014; Stokes et al., 2016).
Institution Review Board (#20150029). The perspectives of non-American negotiators and other stakeholders were also gathered from other academic research that reported the results of interviews of such stakeholders (Andresen et al., 2013; Stokes et al., 2016).

In approaching the material, I took a primarily grounded theoretical approach (e.g., Glaser & Strauss, 1979); initial interviews were semi-structured and interviewees were given relatively wide latitude in what they discussed. From the interviews taken I selected seven key Minamata participants, including six negotiating team members, one American agency staff member heavily involved with implementing international mercury policy initiatives, and one NGO representative who had taken a leading role in the negotiations and continues to work on Convention implementation issues. Those interviews were transcribed and important themes were coded. Codes were then added to or modified through a review of textual sources, particularly accounts of the negotiations and official documents produced therein, and remaining interviews, to serve as a guide for important themes and events of which to account for; a listing of codes is attached as Appendix B.

Several difficulties presented themselves during this study. First, numerous American negotiators were involved at different phases of the Convention’s development; though I was able to interview several members of the core negotiating team, i.e., individuals involved in negotiating and implementing particularly important Convention provisions, several additional potential interviewees did not respond to, or refused, requests for interviews. Second, while the formal negotiations started in June of 2009, and the Convention was finalized on January 18, 2013, interviews were begun in January of 2015 and concluded in February of 2017. While interviewees tended to have strong recollections of the later negotiating sessions, they were less able to discuss in
detail events further back in time. Third, government agency interviewees especially were constrained by both professional norms of conduct and the reasonable caution that most such employees would exhibit when discussing sometimes politically contentious issues with an outside interviewer. To account for these issues, I have promised government interviewees that I would not quote them by name without their express approval, attempted to validate statements with other interviewees (including interview data reported in the academic literature), and governmental and media reports.

6.4 The Minamata Convention in Historical Context: Chemical Contaminants and Global Governance

International environmental agreements are a relatively recent phenomenon. The first half of the 20th century saw the development of bilateral and multilateral agreements to govern natural resources such as fisheries and migratory birds, but agreements seeking to reduce or mitigate environmental pollution were exceedingly rare through the first half of the twentieth century (Weiss, 2011).124 The late 1960s and early 1970s, however, saw a growing focus on global environmental issues in the global community, at least in terms of public discourse, if not usually concrete action. Thus, while the First United Nations Conference on the Human Environment, held in Stockholm, Sweden in June 1972 had resulted in a Statement of Principles pledging the signatories to improve environmental governance. Particularly relevant to global environmental governance are Principles 21 and 24 of the Statement. Principle 21 establishes that states had “the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the

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124 As described by Weiss (2011), prior to the 1970s almost all environmental agreements dealt with natural resource management, particularly things like fisheries and migratory birds, though a 1909 treaty between the United States and Canada did contain, in vague terms, responsibilities not to pollute common waterways.
environment of other States or of areas beyond the limits of national jurisdiction.”

Principle 24 asserts that “[c]ooperation through multilateral or bilateral agreements is essential to effectively control, prevent, reduce and eliminate adverse environmental effects.”

However, it was not until 1979 that the first multilateral environmental agreement (MEA) specifically tasked with reducing transboundary pollution at a global level was created, the Convention on Long-Range Transboundary Air Pollution (LRTAP), and until 1983 that it went into effect.\textsuperscript{125} While LRTAP sought to limit cross-boundary atmospheric emissions, its focus was on Europe – and to a slightly lesser extent, North America – with no parties outside those regions. LRTAP had developed out of the realization by European states in the 1970s that their air and precipitation quality were affected by other countries in both East and West Europe (UN, 2004, p. 3). After the 1975 Helsinki Conference on Security and Cooperation in Europe led to the establishment of the European Monitoring and Evaluation Programme (EMEP), which clearly demonstrated the effects of transboundary pollution (UN, 2004, p. 10). That would then lead to the negotiation of LRTAP under both the auspices of the United Nations Economic Commission for Europe, with advocates for that Convention successfully expressly invoking Principle 21 of the Stockholm Convention to push for agreement (UN, 2004, p. 10). Despite its regional focus, LRTAP has also been credited with helping to inform similar agreements in other regions and globally (UN, 2004, p. iii).

\textsuperscript{125} LRTAP and the other treaties and legal instruments referenced herein are set forth in Appendix A.
The decade following LRTAP produced a small number of additional MEAs – as well as many more “pious declarations” to do more (Williamson, 1990, p. 725). The most successful agreement dealing with transboundary and global pollution was the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer, a protocol to the earlier Vienna Convention for the Protection of the Ozone Layer in 1987; the former largely phases out the use of stratospheric ozone-depleting chemicals. Following the Montreal Protocol, other pollution control agreements began appearing, aimed at a wide range of contaminants. LRTAP, for example, was extended through the adoption of protocols covering sulfur emissions (1985, 1994), nitrogen oxides (1988), heavy metals (1998, 2012), persistent organic pollutants (POP) (1998), acidification, eutrophication, and ground-level ozone (1999) (UNECE, 2017). Growing awareness of just how insidious many hazardous pollutants could be led to LRTAP being joined by three additional major environmental conventions with a more global reach than LRTAP, all of which influenced the structure of the eventual Minamata Convention as well as the negotiating process. These were:


(2) The Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (hereafter the

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\(^{126}\) A number of African nations adopted the Bamako Convention on the Ban of the Import Into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes Within Africa, which utilizes a similar format to the Basel Convention, but is far more stringent, prohibiting the importation of all hazardous waste.
Rotterdam Convention), which opened for signature on September 11, 1998, and entered into force on February 24, 2004; and


Each of the above Conventions govern different risks posed by transboundary movement of hazardous contaminants, and share not only structural similarities but also often include the same individuals and organizations in planning, implementation, and governance. The three Conventions have in recent years been converging towards formal coordination under a joint head (“History of Joint Managerial Functions for the Secretariats of the Basel, Rotterdam and Stockholm conventions,” n.d.), which will be addressed in more detail in Section 6.6.2 below.

6.4.1 The Turn of the Millennium and a Global Refocus on Mercury

Though the health costs of environmental mercury pollution had reached the world stage in the late 1960s and early 1970s as news accounts of the Minamata Bay poisoning extended beyond Japan, and as significant environmental mercury pollution was discovered in several countries, including Sweden, the United States, and Canada, most mercury-related laws and regulations dealt specifically with the problem at a regional or national level, though this began to change in the late 1990’s. The original 1989 text of the Basel Convention designated mercury-containing waste as hazardous and thus subject to control under that Convention. CLRTAP’s 1998 Aarhus Protocol on Heavy Metals also committed parties to reducing atmospheric mercury emissions by specific numbers, though its efficacy in regards to global mercury pollution is reduced by
a number of factors: For one, the emissions limitations set in the Protocol were largely consistent with domestic limitations already followed by the parties.\textsuperscript{127} For another, many of the largest mercury emissions sources are located in non-party nations, such as coal-fired electricity production in China and India, and artisanal gold mining in much of the developing world; Europe and North America contributed less than 25\% of global anthropogenic emissions (Pacyna & Pacyna, 2002). Finally, that Protocol only addressed point source emissions to the air, ignoring ASGM and mercury in products, much of which entered the air and water in significant amounts.

The Basel Convention and the Rotterdam Convention both covered mercury-containing substances to some extent. The Basel Convention includes mercury-containing waste under its reduction, disposal, notice and consent requirements. The Rotterdam Convention implements certain notice requirements for the movement of mercury-containing pesticides across borders. Though organic mercury compounds would likely qualify as “persistent organic pollutants,” the Stockholm Convention did not include mercury compounds, though that Convention’s focus on anthropogenic releases of POPs would likely make such inclusion ineffective: most anthropogenic releases are in the elemental form, with transformation into organic forms occurring largely in the environment.

While mercury was well-established as a potential contaminant under LRTAP and the Basel and Rotterdam Conventions, by the end of the 20\textsuperscript{th} century mercury had again

\textsuperscript{127} For example, the Aarhus Protocol set limits on mercury emissions for municipal waste incineration at 0.08 mg/m\textsuperscript{3} (Aarhus Protocol, Annex V), lower than the restrictions that several European nations already implemented (Licata, Hartenstein & Terracciano, 1996, p. 714). Mercury emissions limits from coal-fired power plants were not directly set by the Aarhus Protocol, though reduction of particulate matter from such plants was set at 50 mg/m\textsuperscript{3}, an easily-met goal for its developed world parties considering the particulate control devices available at the time.
begun to work its way to scientific, governmental, and public consciousness as something that was in some way uniquely deleterious to the environment, or at least something that might need to be governed on its own. Despite the imminent entry into force of the Aarhus Protocol in 2003, some LRTAP parties still believed further efforts were needed on mercury, and requested that Convention’s Executive Body request UNEP to conduct a mercury assessment and consider future action (ECE 2001, p. 21). As noted in Chapter 3, Schroeder et al. (1998) had discovered that mercury in the air column could rapidly be oxidized and scavenged from the troposphere in the Arctic, most likely by reacting with halogens like bromine, and then enter marine environments. Following this and other research into the danger mercury posed to arctic environments, The Arctic Council, an organization made up of the eight signatories of the 1991 Arctic Environmental Protection Strategy, also requested that UNEP address the global mercury problem (Arctic Council, 2001).

Furthermore, though mercury pollution from ASGM had been of concern in the international environmental community since at least the late 1980s (de Lacerda, Pfeiffer, Ott & da Silveira, 1989) the growing scale of artisanal gold-mining through the early 2000s raised global concerns. While gold prices had trended downwards through the 1980s and 1990s, prices had started to rapidly increase after 2000, making the practice more profitable at the same time mercury commodity prices were at record lows. Due to the difficulty in studying artisanal gold miners and refiners who often work secretly

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128 According to U.S. Geological Survey (f) data, mercury prices reached a high of $85,300 per metric ton (all prices in 1998 dollars) in 1965, but then saw a significant drop from the 1970s through the early 2000s, after which prices began to rise again, possibly in response to increased demand from ASGM (USGS, 2017). In 1997, it reached a record low of $3,970, but from 2003-2004 more than double in price. As of 2015 the price per metric ton was $39,900 (USGS, 2017).
and at the margins of society in remote areas, determining exactly how much ASGM is being carried out is difficult, but the number of people involved in the activity appeared to have increased substantially from the 1980s through the 2000s, at which point it involved an estimated 10 to 15 million people globally in 55 countries, including 4.5 million women and 600,000 children (Veiga, Maxson & Hylander, 2006). Global awareness of the mercury risk posed by ASGM also grew throughout this time period due to increased attention from the international scientific community (Kristensen, Thomsen & Mikkelsen, 2014).

6.4.2 The First Global Mercury Assessment and the Creation of the Global Mercury Partnership (2001-2005)

As concern grew over the global impact of mercury pollution, the United Nations Environment Programme (UNEP), the United Nation’s international environmental governance agency focused more attention on mercury governance issues. During UNEP’s Governing Council (GC) meeting in 2001, the United States proposed a global assessment of mercury, which the GC agreed (Bai et al., 2001). The resulting report was issued in December 2002 by the Inter-Organization Programme for the Sound Management of Chemicals (IOMC), a cooperative entity created under the auspices of UNEP, the World Health Organization (WHO), and several other intergovernmental agencies. Collecting and reviewing an international body of research over mercury biogeochemical cycling, sourcing, and public health impacts, the report cautioned that not only did mercury have “significant impacts at local, national, regional and global levels,”

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129 UNEP had been created as a direct result of the Stockholm Declaration of 1972, and had coordinated the creation of the Basel, Rotterdam, and Stockholm Conventions.
but that due to the global cycling of the pollutant, local and regional action would not be sufficient to address the problem (UNEP 2002, p. 4).

UNEP GC took up the report at its 22nd session in February 2003, but was unable to come to an agreement about what international action should be taken regarding mercury. The European Union (EU), Norway and Switzerland pushed for a legally binding instrument, but were opposed by Australia, New Zealand, and the United States; ultimately, UNEP GC deferred the issue until its 23rd session in 2005 (Ganzleban, Sherman, Spence, Vavilov, & Wilkins, 2003). That session again saw no widespread agreement on what kind of measures should be taken to deal with environmental mercury, though it did conclude that “further long-term international action is required.” (Bai et al., 2005, p. 5). At its 25th conference in 2007, UNEP GC was still paralyzed to some extent by competing demands for either a binding or voluntary approach to global mercury risk mitigation, but did decide to convene an “ad hoc open-ended working group of Governments, regional economic integration organisations and stakeholder representatives to review and assess options for enhanced voluntary measures and new or existing international legal instruments” (UNEP, 2007, p. 11). The open-ended working group (OEWG) was to meet twice, and present a report to UNEP GC during its 25th regular session in 2009, during which it would decide on whether to move forward on a new global initiative on mercury, and if so what form it would take. Despite the movement on both a formal Global Mercury Partnership and the OEWG, the political situation at UNEP GC’s 24th session remained tense in terms of global mercury policy;
one non-governmental attendee referred to UNEP GC 24 as “just hostility and the US government being recalcitrant, not just them but they were the ringleaders.”

6.4.3 The Open-Ended Working Groups: Setting Parameters (2007-2009)

The OEWG sessions started slowly; the first OEWG, held in Bangkok in November 2007 adopted procedural rules and elected a Bureau to manage the OEWG process, but otherwise consisted largely of statements made by attendees on behalf of their countries. In addition to national representatives, representatives of both the Basel and Stockholm Conventions attended, as well as representatives of other United Nations bodies, intergovernmental organizations, and environmental, health, development, and industry NGOs. While the atmosphere of the first OEWG may have been at least on the surface one of unity and commitment – though parties were already starting to discuss issues that would later prove contentious – the second OEWG, which took place in Nairobi, Kenya, was significantly more fractious. UNEP GC had created a process to explore what, if anything, should be done about global mercury issues, but gave little concrete guidance. Numerous possible options had been floated by UNEP GC, including mercury-specific extensions to the Rotterdam, Basel, and Stockholm Conventions, a new stand-alone Convention that could be binding or voluntary, and an intensified policy framework supported by formal systems of partnerships.

The starting positions of the parties towards binding agreements ranged from advocacy to antipathy. Consistent with both their long histories with environmental mercury problems, as well as strong pro-environment political systems, Sweden and Norway quickly established themselves as strong advocates for binding – and stringent –
obligations to reduce, restrict, or eliminate mercury emissions. The United States, though nominally a strong supporter of mercury research and global partnership, resisted any binding agreement; it was joined by a number of other nations in both the developed and developing world.\textsuperscript{131} With the binding versus non-binding argument unresolved, the delegates prepared two separate “implementation modalities” for mercury policy to present to UNEP GC in 2009, at its 25\textsuperscript{th} meeting: (a) a free-standing, binding treaty, and (b) enhanced voluntary measures (OEWG, 2008, Annex I, p. 15).

6.4.4 UNEP GC 25: American Regime Change and a New Consensus (2009)

When UNEP GC started its 25\textsuperscript{th} meeting in 2009, and was presented the proposals created at the OEWG sessions, the conflict between those supporting a binding agreement and those seeking enhanced partnership or voluntary measures remained, though the United States’ position was somewhat uncertain. At the beginning of 2009 the United States administration, which had been fiercely opposed to environmental laws and regulations at both the domestic and international level, had been replaced by the Obama administration. President Obama had indicated he would govern from a far more pro-environmental standpoint, though historically the United States, even under Democratic presidents, had been often resistant to binding MEAs. However, the extent to which the United States completely reversed its position and strongly endorsed a legally binding instrument to reduce global mercury risk surprised even some experienced diplomats. Eriksen and Perrez (2014) characterized it as “the decisive turning point.” The \textit{Earth}

\footnote{The use of the terms “developing” and “developed” has been heavily criticized for, among other things, erasing important and often sharp distinctions in economic and technological capabilities, and diverging interests, within each category, and its assumption that traditional Western economic development processes are or should be a universal goal. (e.g., Escobar, 2013; Joshi, 2013; Stokes et al., 2016). I use the terms provisionally here because (a) they are used in the Minamata Convention text itself, and (b) in the negotiations themselves parties on both sides tended to use the terms to refer to themselves and each other. To the extent that the developing/developed distinction breaks down, it will be addressed in the text.}
Negotiation Bulletin account notes that while “most participants expected an American position change . . . there was an air of wonder and exhilaration when the US . . . voiced its unreserved support for a legally binding instrument.” (Appleton et al., 2009, p. 14). An American NGO attendee characterized it as “jaws were on the ground. . . people [who] could not believe . . . that this was happening.”\(^\text{132}\) A member of the U.S. negotiating team put it slightly less dramatically: “when we suddenly came to the table and said we’re in . . . . we may have surprised some of our friends and so I think some of the other countries came to the table but had long been opposing binding action.”\(^\text{133}\) UNEP GC convened a third ad hoc working group meeting that met from October 19-23, 2009, to recommend rules of procedure and arrange for intersessional work by UNEP for the actual negotiating sessions, which would begin in June 2010.

6.4.5 The Minamata Negotiating Sessions (2010-2013)

The first Minamata negotiating session (INC 1) was held June 2010 in Stockholm, Sweden. Other than election of a chair and members of the Bureau, little substantive work was done. One non-governmental attendee characterized it as a “feel-good” event with a “lot of opportunities for countries to make statements” – though at the time had thought it seemed “a bit of a waste of time.”\(^\text{134}\) That same participant did, however, suggest that it in fact may have been useful in creating “a sense of commitment” that ultimately proved beneficial. Some delegates also expressed disappointment over the lack of contact groups and other opportunities for negotiations on specific matters (Ashton, Kantai, Templeton & Xia, 2010, p. 2).

\(^{132}\) [Interviewee A1 (NGO Representative)].
\(^{133}\) [Interviewee A2 (American Negotiating Team Member)].
\(^{134}\) [Interviewee A1 (NGO Representative)].
INC 2, held in January 2011, saw the first substantive negotiations, with the first discussions of draft provisions that had been prepared by UNEP for the meeting, and the formation of contact groups that sought to find consensus for issues that were proving too contentious to be resolved in plenary sessions. From INC 2 until INC 5 the delegates followed an iterative drafting process: before each session UNEP would create and distribute a draft Convention text based on the previous session; those draft provisions would be debated in plenary and renegotiated in contact groups; and then finalized provisions would be sent to a separate legal drafting group who would return it to the end to UNEP. Subsequent modifications and comments would be reflected in a new draft text by UNEP that would be distributed at the next meeting, and go through the same process (e.g. UNEP 2011, 2012a, 2012b, 2013a). During intersessional periods, the UNEP GC would work on preparing draft text and requested reports for the next session, and parties, NGOs, and other groups would meet to discuss issues related to the Convention.

Throughout the negotiating sessions, the most contentious issues tended to arise from the tension between the developed world and the developing world, with the latter repeatedly invoking the principle of “common but differentiated responsibilities” (CBDR) originally formalized in the United Nations Framework on Climate Change (UNFCCC) in 1992, and referenced by UNEP GC in their decision to negotiate a binding, mercury-specific MEA. CBDR recognizes that while all countries have a responsibility to address environmental issues that affect the entire world, the scope of such responsibilities for individual countries can differ based on their specific economic and technological capabilities. Developed countries are therefore expected both to do more to protect and mitigate, and often are called upon to extend financial and technological
assistant to developing countries. Though the United States implicitly accepted CBDR (though not under that name) when it ratified the Montreal Protocol, it has subsequently been proven controversial domestically, where it has been heavily resisted by both parties.

Springing from this tension were discussions as to how much developing countries could be bound to concrete requirements, considering both the difficulty in implementing those requirements and the possible economic disadvantages emission reductions requirements may incur. For example, China and India particularly saw strong atmospheric emissions reductions as a potential threat to development goals, with China especially bringing online new coal-fired power plants at a rapid pace. Smaller, less-developed countries where ASGM mercury use takes place often expressed agreement that its dangers had to be addressed, while emphasizing that significant financial and technical assistance would be needed to deal with it; as multiple interviewees also noted, in many places ASGM is an important source of income for poor communities in the developing world.

While the need for some sort of financial mechanism was universally accepted, the exact form it would take was also a matter of sharp disagreement. Developing countries tended to argue for a Convention-specific funding mechanism, like the one created for the Montreal Protocol, arguing that there were “meager additional resources” in MEA-specific funding mechanisms, and that the GEF was “slow and cumbersome.” (Ashton, Kohler & Xia, 2011, p. 9). Developed countries tended to prefer to use the GEF, which already had a well-established mechanism in place, and had a history of funding mercury-related projects (GEF, 2013); one American negotiator deeply involved in
funding mechanism negotiations noted that the U.S. preferred to use already-existing institutions partly because it was easier to provide money through them than allocate budgetary resources to a completely new institution.\textsuperscript{135} She also noted that a developing world Convention attendee had complained that it could be difficult to get project proposals accepted by GEF. In regards to funding provisions, a negotiating team member noted that the United States wanted developing countries to use such funding as effectively as possible.\textsuperscript{136} A recurrent debate throughout the negotiations was whether compliance and enforcement provisions would be created only upon the creation of an acceptable (\textit{i.e.}, mandatory) financial and technological assistance mechanisms, as developing countries advocated (Selin, 2014).

By the last scheduled negotiation, INC 5, the draft text was approaching completion, though there were still some outstanding issues, including the funding mechanism provision (UNEP, 2013b). By the second-to-last day of the negotiating session, the contact groups worked through the night, but managed to get consensus text on each provision. Many of the more contentious debates were simply deferred to some extent. For example, for the funding mechanism, the parties finally agreed that the Convention would rely both on the GEF as well as an individual funding mechanism to be developed later. In October 2013, the Convention’s Conference of Plenipotentiaries opened in Kumamoto, Japan, to formally approve the Convention. Ironically, the United States – which had spent millions on assistance to other countries through the mercury partnership, and billions funding the GEF since its inception – could not afford to send an

\textsuperscript{135} [Interviewee A3 (American Negotiating Team Member)].
\textsuperscript{136} [Interviewee A2 (American Negotiating Team Member)].
official delegation to the Conference due to a federal government shutdown.\textsuperscript{137} However, because the final Convention was already consistent with existing mercury regulations in the United States, an intentional goal of the American delegation, the United States did become the first country to ratify the treaty, on November 6, 2013.

6.5 The Minamata Convention: Structure and Function

The Convention as opened for signature in Kumamoto consisted of 35 Articles and five separate Annexes, with a comprehensive mixture of binding substantive and procedural provisions, as well as voluntary measures and aspirational goals. The provisions are listed and summarized in the attached Appendix C. An abridged list of the most significant substantive provisions is listed below on Table 1.

Table 6.1. Significant substantive control provisions in the Minamata Convention.

<table>
<thead>
<tr>
<th>Article</th>
<th>Title</th>
<th>Substantive Control Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Mercury supply sources and trade</td>
<td>Binds parties to prohibiting new primary mercury mining after Convention goes into force, and phase out existing mercury mining within 15 years.</td>
</tr>
<tr>
<td>4</td>
<td>Mercury-added products</td>
<td>Prohibits the manufacture, import, or export of certain designated mercury-containing products listed in Annex A.</td>
</tr>
<tr>
<td>5</td>
<td>Manufacturing processes in which mercury or mercury compounds are used</td>
<td>Prohibits designated mercury-using manufacturing processes.</td>
</tr>
<tr>
<td>7</td>
<td>ASGM</td>
<td>Requires parties to attempt to reduce or eliminate mercury use in ASGM.</td>
</tr>
<tr>
<td>8</td>
<td>Air emissions</td>
<td>Requires parties control, and where feasible reduce, air emissions of mercury from designated point sources (e.g., coal-fired power plants) using best available techniques and best environmental practices within five years.</td>
</tr>
<tr>
<td>9</td>
<td>Releases</td>
<td>Requires parties with significant point sources of mercury (not addressed elsewhere in the Convention) to control, and where feasible to reduce mercury releases to land and water.</td>
</tr>
<tr>
<td>10</td>
<td>Non-waste mercury storage</td>
<td>Requires parties ensure interim storage of non-waste mercury is done in environmentally sound manner.</td>
</tr>
<tr>
<td>11</td>
<td>Mercury waste</td>
<td>Requires parties manage wastes in an environmentally sound manner, taking into account Basel Convention guidelines and requirements developed by Conference of Parties.</td>
</tr>
<tr>
<td>12</td>
<td>Contaminated sites</td>
<td>Parties shall endeavour to develop strategies to identify and assess mercury-contaminated sites, and actions to reduce site risks shall be performed in an environmentally sound manner, and are encouraged to cooperate in same.</td>
</tr>
</tbody>
</table>

\textsuperscript{137} One American negotiator did note that a small number of American agency officials traveled to Kumamoto to ensure the Convention to be signed was consistent with what had been negotiated, but left before the diplomatic conference began [Interviewee A4 (American Negotiating Team Member)].
In addition to substantive obligations, many of the source-specific mercury provisions in the Convention also institute record-keeping and reporting requirements. Though nominally a standalone instrument, the Convention references the Basel Convention and the Rotterdam Convention in the Preamble, and the former when promulgating guidelines for Article 10 (non-waste mercury storage), and Article 11 (mercury wastes). For Article 10 the Convention mandates that the Conference of Parties adopt guidelines on storage of non-waste mercury “taking into account any relevant guidelines developed under the Basel Convention.” Article 11 incorporates waste definitions under the Basel Convention that are either binding (for parties to the Basel Convention) or guidance (for non-parties).

Throughout the negotiation process, the draft text of the final Convention – particularly of substantive control requirements – shifted through multiple versions and forms, largely due to the developing/developed world tension that largely defined debate. Below, I examine the development and final codification of two of the most contentious provisions, which apply to the two largest sources of anthropogenic mercury: ASGM (Article 7) and atmospheric emissions (Article 8). Because of their significance as global sources, the United States focused on both of those sources according to one agency member.138 For that reason, and the fact that both sources strongly implicate the developed/developing world tension that framed the Convention negotiations, I will address certain important parts of them in more detail below relevant to the binding/voluntary tension.139

138 [Interviewee A5 (Minamata Observer, Current American Agency Staff)].
139 Selin (2014) offers a more in-depth analysis of other Convention provisions, and the debates behind them.
6.5.1 Article 7: ASGM

The growth of ASGM through the late 1990s into early 2000s was one of the primary causal elements leading to the development of the Minamata Convention as well as a number of global partnerships focusing on both reducing or eliminating mercury’s use in ASGM and developing protective measures for those engaged in it. UNEP GC was particularly concerned during its 24th meeting over ASGM (UNEP, 2009). While there was universal agreement that something would have to be done to limit mercury use and exposure in ASGM, one interviewee noted that it was expected to be the most contentious provisions debated, though ultimately negotiations on them went smoother than expected.

Still, the ASGM provisions of the Convention went through several changes through the negotiating process. For example, an early preliminary draft text applying to ASGM, and circulated at INC 2, proposed a provision mandating that parties “shall reduce, and where possible eliminate” use of mercury in ASGM, and prohibited the transborder trade in mercury if it was to be used in ASGM (UNEP, 2010b). By the beginning of INC 3, that text had been changed from “shall reduce” to the weaker “shall take steps to reduce,” though transborder trade in mercury for ASGM use was still prohibited (UNEP, 2011b). By INC 5, the trade issue was still under dispute, and finally the United States, supported by the European Union, proposed that trade of mercury destined for ASGM be allowed, subject to the notice requirements of the Article 3 trade provisions. The decision was not universally accepted, particularly among some of the more influential NGOs. The International POPs Elimination Network (IPEN) still requested mercury use in ASGM be banned completely, while the Zero Mercury
Working Group (ZMWG) pushed unsuccessfully for indicating in the Convention that mercury trade for ASGM would at least “not continue indefinitely” (Kohler et al., 2013, p. 2).

The final Article 7, however, just mandates that parties that have ASGM activities within the borders “take steps to reduce, and where feasible, eliminate, the use of mercury in . . . and the emissions and releases . . . from mining and processing.” It also requires parties in which such ASGM activities are “more than insignificant . . . [to] [d]evelop and implement a national action plan in accordance with Annex C.” While Annex C does require the national action plans (NAP) to, among other things, include “[a]ctions to eliminate” certain types of mercury use in ASGM, as well as steps to regulate their ASGM sectors, other than the creation of NAPs there are no substantive requirements to implement them, other than the general injunction to “take steps to reduce” mercury use in ASGM. Furthermore, in neither Article 7 nor the mercury trade article (Article 3) is cross-border trade in mercury prohibited, with the exception that mercury derived from primary mining cannot be so traded.

Though developing countries had been the loudest voices through the Convention regarding the difficulty in regulating ASGM, including cross-border trade of mercury to be used in ASGM, ultimately it was the United States and the European Union who successfully pushed for the removal of a general ASGM mercury trade ban. This appeared to be based largely on the realization that ASGM cannot be addressed through command-and-control top regulations, but would have to be addressed “on the ground” through nation- and area-specific programs.

One American negotiator phrased it thus:
[P]eople understood that . . . a hammer and a nail approach was not going to work there. And if you look at the provisions there, and . . . it’s not you know . . . an illegal activity under the treaty. Why? Because these aren’t people who respond well to laws. Right? I mean, there was, I think there was a very good sense that . . . the industrial side versus the human side, that those were different, you needed a different approach within the treaty to address that. If you even wanted a chance.140

The legal impact of Article 7, though binding in the sense that “steps” must be taken to reduce mercury use in ASGM, does not require, or set a schedule for, any quantitative emissions reductions. Whether the ASGM provisions in the Convention will have to be evaluated later, Evers et al. (2016) predict most ASGM countries will have begun to implement their action plans within a six-to-12-year period after the Convention goes into force. The efficacy of Article 7 during that time period will be driven by a number of factors, including global and national economic conditions and the extent to which GEF and developed countries are willing to fund projects to address ASGM. Spiegel et al. (2014) caution that in addition to the national action plans, governments need to change policy focus from top-down control towards active engagement with ASGM communities to effectively address the social and economic reasons for why mercury is used.

6.5.2 Article 8: Emissions

Globally, atmospheric emissions are the second largest source of anthropogenic mercury emissions, following ASGM (UNEP, 2013c). Like ASGM, the emissions issue is heavily intertwined with the developed/developing world dichotomy; the largest atmospheric mercury emitters in the world are China and India, which together are estimated to emit more mercury into the atmosphere than every other country on earth

140 [Interviewee A6 (American Negotiating Team Member)].
combined (Rafaj, Bertok, Cofala & Schöpp, 2013). Most of these emissions come from coal-fired power plants, which in both of those countries – as well as the rest of the developing world – have tended to lack the level of emissions control equipment found in the developed world. On the developed world side, elemental mercury emitted from point sources like coal-fired power plants can remain in the atmosphere on the order of about one year and thus be transported globally (Schroeder & Munthe, 1998). Several of American agency personnel interviewed specifically referenced the fact that foreign sources account for most of the mercury deposition in the United States, making the emissions regulations of particular focus during the negotiations. The U.S. focus on emissions is not surprising, given the global transport of mercury emissions – several of the U.S. negotiators specifically remarked that 70% of deposition in the United States came from foreign sources.

Similarly, while Europe does not receive as much deposition from China and India as the United States, it still faces increased deposition from uncontrolled intercontinental sources and thus has a vested interest in reducing emissions overseas (UNECE, 2010, pp. 103, 125). Considering the economic and environmental implications of emissions restrictions it is not surprising, as Eriksen and Perrez (2014) note, that “[e]missions to the atmosphere was one of the most disputed substantive areas.” One American negotiator characterized the emissions negotiations as a “Sisyphean task for a while.” Though China and India were firmly against binding emissions regulations throughout the

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141 For example, one negotiator noted that in the United States’ view, the treaty should focus on air emissions because those are what circulates globally and causes global impacts. [Interviewee A4 (American Negotiating Team Member)].
142 [Interviewees A3, A5, A6 (American Negotiating Team Members)].
143 [Interviewee A3 (American Negotiating Team Member)].
negotiations, other developing countries took varying stances on whether emissions standards should be binding, with African countries tending to favor binding obligations, as did indigenous groups (Selin, 2014).

Like Article 7 on ASGM, the emissions article started off stronger than it ended, with the draft language introduced at INC 2 mandating that parties “shall reduce and, where feasible, eliminate the source categories listed in Annex E.” (UNEP, 2010b). For existing sources, parties would need to promote (though not require) “best available techniques and best environmental practices,” while new sources would require best available techniques within a specific deadline (UNEP, 2010b). Included among the proposed source categories in Annex E were coal-fired power plants, as well as a few other major sources. Throughout INC 1 and INC 2 both China and India, as well as a number of other countries, fought mandatory emissions targets or timelines, with China calling voluntary efforts “the only solution” (Ashton, Kantai, Templeton & Xia, 2010). The draft provision went through various proposed forms with different options; by INC 3 the draft provision now listed an option of changing “shall reduce” to “shall take steps to reduce,” as well as option to combine the emissions article with the (land and water) and releases article (ultimately Article 9) (UNEP, 2010). By INC 5 the draft emissions article still contained alternate proposals of binding and non-binding provisions, until near the end of negotiations the Chinese negotiating team “made a sudden, clear, and unanticipated break with India” and indicated they would agree to binding restrictions on emissions restrictions, including for existing sources, if parties had some flexibility in what emissions control measures they implemented (Stokes et al., 2016, p. 17). With China agreeing to binding emissions restrictions, Article 8 was quickly finalized as
requiring new major mercury emissions sources – like coal-fired power plants – to have such emissions controlled (and where feasible, reduced) by “best available techniques” and “best environmental practices,” while for existing sources they must enforce one of a number of measures, the least stringent such measure to be simply quantifying mercury emissions control goals.

6.6 Analysis: Did the Convention Succeed? And If So, Why?

The following section evaluates the Convention generally and investigates possible causal mechanisms to explain why the Minamata Convention developed in the way it did, what such mechanisms may mean for the future of global environmental governance, and potential difficulties and problems in implementing the Minamata Convention going forward. I first evaluate the efficacy of the Convention negotiation process itself from the perspective of participants, observers, and academics. I then offer two theories of causal mechanisms that appeared to have had a major impact on the Convention negotiation and text. I then explore complications and difficulties that may impact the Minamata Convention’s successful implementation. Finally, I conclude with a summary of the chapter as a whole, analyze what the Minamata Convention development might tell us about global environmental governance going forward, and then explore possible future research avenues.

6.6.1 Assessing the Convention Negotiations

As an initial matter, evaluating the success of the Convention itself is difficult if not impossible at the time of writing. Several provisions of the agreement require the Conference of Parties to develop mercury management guidelines in the future. Furthermore, for some of the largest sources of anthropogenic mercury, control
requirements are vague and/or non-binding, and thus their ultimate efficacy will be
dependent on the actions taken domestically by those nations. For example, while ASGM
now makes up the largest single source of anthropogenic mercury emissions, there are no
binding substantive provisions to directly reduce the amount of mercury released through
such activities. Instead, Article 7 simply requires that parties with ASGM activities in
their borders “take steps to reduce, and where feasible eliminate” mercury use in mining
and the resulting emissions to the environment. Similarly, Article 8 requires that parties
only “control[] and, where feasible, reduc[e]” mercury point source emissions like coal-
fi red power plants – after ASGM, the second largest anthropogenic source of
environmental mercury. Though Article 8 requires parties implement best available
techniques (BAT) to new sources within five years, BAT standards are defined under
Article 2 as “taking into account economic and technical considerations.”

However, in terms of the goals set by UNEP GC, its development as a legal
instrument, and the political, cultural, and economic constraints inherent in regulating
something like mercury, most participants and observers appear to consider the
negotiations as a success, at least provisionally. The first major implementation hurdle
passed on May 18, 2017, when the European Union and seven of its member states
ratified the Convention, pushing the number of parties past fifty and triggering its entry
into force on August 16, 2017 (UNEP, 2017). American negotiators interviewed
universally agreed that the Convention negotiations had been undertaken fairly
successfully. One member of the U.S. negotiating team phrased it as “we’re very happy
with the outcome of the Convention . . . it’s better than I thought we could have gotten,
it’s the best we could have gotten in light of a hundred and ninety plus countries.”\textsuperscript{144} Another opined that in terms of sources of environmental mercury, the level of obligation for the Convention provisions “is about right,” also noting that “if you look at the positions that countries were taking and you look at the outcome you see a little bit of what everybody needed in the agreement.”\textsuperscript{145} She also characterized it as a strong base with the opportunity for evolution. One American negotiator cautioned that “it doesn’t achieve anything until it’s actually implemented,” but did state that “it has the potential to do an awful lot.”\textsuperscript{146}

Academic analyses and observer accounts have similarly been positive. Larson (2014) referred to the Convention’s development as a “heroic effort,” though she cautions it would not be an “easy path to implementation.” Templeton and Kohler (2014, p. 219) refer to “[t]he success of the mercury negotiations in balancing finance with compliance” though also note that “following through” on financial and technical assistance “will be essential to the success of the Minamata Convention.”

Advocacy groups’ response were mixed but generally positive. Even NGOs that had unsuccessfully pushed for certain provisions were on the whole complimentary of the Convention – at least publicly. SafeMinds, which had pushed for stronger restrictions on mercury-containing drugs, including vaccines, publicly welcomed the Convention though they urged additional action on such drugs (SafeMinds, 2013). IPEN, on the other hand, expressed disappointment that “[t]he two biggest sources of mercury [ASGM and emissions] have only weak controls on them” (Larson, 2013).

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\textsuperscript{144} [Interviewee A3 (American Negotiating Team Member)].
\textsuperscript{145} [Interviewee A6 (American Negotiating Team Member)].
\textsuperscript{146} [Interviewee A7 (American Negotiating Team Member)].
6.6.2 Why did the Minamata Convention Negotiations Succeed?

Taking, at least for the sake of argument, that the negotiations were a success even if the Convention itself cannot be judged yet, then why did they work? How did a general consensus that something had to be done about environmental mercury in the early 2000s result in a Convention about which the NRDC stated: “the very existence of a multilateral environment agreement of any kind, in this age of global discord . . . [is] a minor miracle” (Keane, 2013). How did this “minor miracle” occur?

At the time it opened for signature the Convention was the first major global environmental agreement to be created in more than ten years, and the first substantively binding new MEA to be ratified by the United States since the 1987 Montreal Protocol.147 One NGO member reminisced about “the naysayers who said it would never be concluded, and then you know it finally got concluded, and all the people who said it would never get ratified, and now it’s getting ratified.”148 In the section below I discuss two different possible causal mechanisms that may explain why the Convention negotiations resulted in the way they did, and what they may tell us about global environmental governance. These hypotheses are not intended to be exhaustive explanations of why the Convention development process unfolded as it did, but rather elaborate on a small number of particularly important possible causes.

6.6.2.1 Regime Change in the United States

There is little dispute that the United States took an uncustomarily dominant role in driving the world first towards a binding agreement, or that its complete reversal on

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147 The United States did ratify the UNFCCC in 1992, although its provisions are not substantively binding. The U.S. also ratified the Aarhus Protocol on Heavy Metals in 2001, but that was a protocol to LRTAP rather than a new MEA.

148 [Interviewee A1 (NGO Representative)].
that issue was “the decisive turning point” in the creation of a global consensus that a
binding agreement should be created (Erikson & Perrez, 2014, p. 209). There is also little
dispute over why the United States’ position changed: a few weeks before UNEP GC 25,
President Obama had assumed office, succeeding President Bush.

Prior to UNEP GC 25, the United States had taken the position, at least
nominally, that voluntary partnerships were a better avenue for reducing global mercury
risk because they offered “a better means of reducing and eliminating risks of mercury
contamination than a legally-binding treaty.” Andresen et al. (2013) argue that the
eventual “US policy reversal indicates that the arguments in favor of the pro-voluntary
approach were rhetorical . . . rather than expressing substantial effectiveness concerns.”

While this is certainly plausible, it does not automatically follow. While a minority
position among environmental policymakers – and certainly one among
environmentalists – there are certainly academics, often working in economics, who
argue that binding international environmental agreements are largely ineffective (e.g.,
Carraro & Siniscalco, 1993; Kellenberg & Levinson, 2014). Even a representative of an
NGO long hostile to the Bush administration noted there were precedents to such
voluntary agreements being successful, for example the Partnership for Clean Fuels and
Vehicles which had successfully eliminated leaded gasoline from most of the world.149 In
terms of internal politics, one American negotiator suggested the Bush administration’s
position may have been based on a lack of interest in pursuing a “one-size-fits-all”
measure like a new MEA.150 Certainly “soft law” approaches to international governance
have been growing in importance in the international stage, at least partially due to the

149 [Interviewee A1 (NGO Representative)].
150 [Interviewee A3 (American Negotiating Team Member)].
fact that they are easier to implement domestically (Williamson, 2003, p. 63). Such “soft law” approaches can also lead to later, more binding commitments, as appeared to happen with LRTAP (Danish, 2008). Furthermore, by the time of the mercury discussions, the formerly sparse landscape of environmental treaties had grown to more than 170 negotiated conventions, many lacking effective implementation (Lidskog & Sundqvist, p. 79). This may have led to a palpable sense of “‘treaty congestion’” (Lidskog & Sundqvist, 2002, p. 79) or “treaty fatigue” (Selin, 2014, p. 6).

While his predecessor had generally been considered hostile to environmental regulations either domestically or internationally – NRDC accused Bush of “le[ading] the most thorough and destructive campaign against America’s safeguards in the past 40 years” (Cousins, Perks & Warren, 2005, p. iv) in just his first term alone – Obama advocated for increased environmental protection measures during his campaign. Furthermore, as a Senator Obama had sponsored both the unsuccessful Missing Mercury in Manufacturing Monitoring and Mitigation Act of 2006, and the successful Mercury Export Ban Act of 2008, indicating he had a particular interest with environmental mercury issues specifically. Furthermore, he had previously inquired of the Bush administration as to why it was opposed to a binding agreement, suggesting a disagreement with that decision (Obama, 2006).

The question as to why so many of the other nations who had sided with the United States in favor of voluntary partnerships suddenly reversed their course as well is a more difficult question to answer. Andresen et al. (2012) propose that the confluence of three forms of leadership characterized by power, knowledge, and interests drove the consensus to go forward with a binding agreement rather than voluntary measures. In
terms of power leadership, the United States’ change created a political cost of “naming and shaming” for more environmentally-friendly countries (Andresen et al., 2012). They also credit UNEP for convincing formerly recalcitrant countries to support a binding agreement through interest-based leadership. The impression on the American negotiating team is somewhat consistent with this argument. One American negotiator phrased it as “you can hide behind the biggest leaf, right?” The observers chronicling UNEP GC 25 for Earth Negotiations Bulletin phrased it as “[c]ountries hiding behind the [United States] were left with a stark choice: stand alone, or be swept along” (Appleton et al., 2009, p. 14).

However, as Andresen et al. (2013) note, China and India would likely be “insensitive to the political cost of fronting opposition to a [legally-binding agreement] alone.” Regarding China’s concession to negotiating a binding agreement specifically, Poldervaart (2009) credits the Swiss delegation’s direct diplomacy for “establish[ing] a basis for a shift in the Chinese position,” towards a binding agreement, though he does not explain what form such diplomacy took, and it seems unlikely that such diplomacy could have too much impact. Stokes et al. (2016) offer a more comprehensive and convincing analysis of China’s acceptance of binding environmental regulation – though they examine China’s behavior during the later Convention negotiations rather than during the UNEP GC 25th meeting. They credit, among other things, a growing domestic public demand for improved environmental quality and the already existing need for China to deal with its own domestic mercury emissions (Stokes et al., 2016). A similar explanation might hold for China’s earlier 2007 decision to agree to at least negotiate a

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151 [Interviewee A6 (American Negotiating Team Member)].
binding legal agreement, as China had taken significant steps in the several years previously to improve environmental regulation and enforcement domestically (van Rooij, 2006). One American negotiator similarly attributed China’s acceptance of a binding agreement to the country’s understanding – which “seemed clear to everybody” – that it had to change its approach to environmental regulation in general.\textsuperscript{152} India grudgingly agreed to participate in the negotiations for a binding agreement after China switched its position, though it would resist binding obligations during the negotiations themselves, particularly in regard to emissions. India ultimately signed the Convention only after a change in its government in 2014, and it still has not ratified the agreement.

The significant funds the United States contributed to agencies like the GEF and its independent funding of environmentally focused projects overseas may have also contributed to the desire for many countries, particularly in the developing world, to be on the same side as it. Furthermore, the United States’ significant resistance to global environmental action on things like climate change under the Bush administration, and the high international unpopularity of the outgoing President, may have created a spirit of optimism for a new era of international cooperation, and the somewhat unusual advocacy of the United States may have helped overcome “treaty fatigue.”

The United States’ influence extended, of course, to the negotiations themselves and the final form the Convention took. Because of the overt hostility of the Republican party towards international agreements generally, and MEAs particularly, the only way the Obama administration could successfully ratify the agreement was through sole

\textsuperscript{152} [Interviewee A6 (American Negotiating Team Member)].
executive action. In the case of the Minamata Agreement, this significantly restricted the ability of the American negotiating team as to what they could compromise on. Due to the Republican’s general antipathy for MEAs generally, their ongoing hostility during the negotiating period to domestic mercury regulations (see Chapter 5), and the fact that no party has held a two-thirds majority in the Senate since 1967, it was clear to the Obama administration and its negotiators that ratification would have to be done by a means whereby the United States would comply with its obligations under existing law. Furthermore, because of court challenges any new regulations might take years to successfully implement – for example, the Mercury and Air Toxics Rule promulgated in 2012 was the subject of litigation at the time, and its status was not established until 2016 – requiring that such regulations be firmly ensconced in domestic regulations.

Such requirements to conform Convention requirements with what national legal and regulatory regimes can effectively deal with are, of course, not limited to the United States. One negotiator noted that “not just the United States but many other countries would need flexibility to make their national laws line up with the commitments.” Multiple American agency interviewees stated that the provisions were negotiated with the understanding that the final result should allow the United States to comply with the substantive requirements of the Convention through already-existing laws and regulations.

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153 The implicit premise of a sole executive agreement is fairly simple: If the President has authority under either the Constitution or the U.S. Code to take an action on his or her own, then that action should not be predicated on Senate approval.
154 [Interviewee A4 (American Negotiating Team Member)].
6.6.2.2  *Epistemic Communities and the Convergence Towards a Global Chemicals Regime*

While the strong stance taken by the United States in regards to Minamata (at least after 2008) helped both drive the agreement on a binding legal instrument and constrained what the final Convention provisions could look like, the relative speed and efficiency in which the negotiations took place appears to have been driven largely by the experience-driven expertise of UNEP and many of the negotiators and observers participating.

One of the key insights offered by the constructivist approach to international relations is the recognition that transnational interactions are social processes that cannot be reduced to national interests or goals. Like all international agreements, MEAs are created and negotiated by individuals. Heads of government can set parameters for their negotiators (and, of course, decide whether or not to ratify what is developed) but ultimately much of the decision-making regarding provisions is carried out by individuals who are actually on the ground. Though the Convention was initiated as a stand-alone instrument subject to its own rules, governance structure, and procedures, close analysis of the record and interviews with negotiators and observers suggests that a more useful interpretation of the Minamata Convention is as a part of a larger chemicals regime emerging out of synergies created by the prior chemicals conventions – Rotterdam, Stockholm, and Basel – and other agencies and intergovernmental agencies, partnerships, and institutions were heavily linked to the Minamata Conventions. These institutions included the Strategic Approach to International Chemicals Management (SAICM) the Global Mercury Partnership and the Global Mercury Project, the Mercury Emissions from Coal workshop organized by the International Energy Association, and influential
NGOs like NRDC, IPEN, and the multi-NGO Zero Mercury Working Group. Selin (2014, p. 2) notes that “[i]n certain instances, institutional linkages and previous adoption of principles and mandates under other treaties facilitated the mercury negotiations.”

Inherent in the Convention’s overt engagement with other leading global chemicals governance institutions is the concomitant creation of the epistemic community formed by this unified group of chemicals policymakers, scientists, NGO representatives, and activists. Epistemic communities are networks of “knowledge-based experts” (Haas, 1992) that form to deal with complex, often highly-technical subjects that generalist politicians or policymakers are unable to deal with on their own, yet over which political decisions must be made. Much of the constructivist literature on international environmental relations focuses on epistemic communities theory to explain the role of science, scientists, and expert knowledge in international and transnational decision-making (e.g., Cross, 2013; Haas, 1992; Litfin, 1994). Epistemic communities are not just members of some profession – say atmospheric scientists or physicians – but rather specialists with a “shared set of normative and principled beliefs . . . (2) shared causal beliefs . . . (3) shared notions of validity . . . and (4) a common policy enterprise.” (Haas, 1992). Adler and Haas (1992, p. 374) argue such communities “play an evolutionary role as a source of policy innovations and a channel by which these innovations diffuse internationally.” Koh (1997) proposes that such epistemic communities can also help enforce agreements once they are made.

A number of similar concepts have been proposed to capture the increasingly complex dynamics of international coordination and decision-making.
Adler (2008, p. 196) proposes that epistemic communities and similar networks are subsets of “communities of practice,” or “like-minded groups of practitioners who are informally as well as contextually bound by a shared interest in learning and applying a common practice.” According to Adler these communities are “not international actors in any formal sense, but they coexist and overlap with them” (Adler, 2008, p. 200). Though the communities of practice approach captures some aspects of the global chemicals management community generally and the Minamata negotiation community specifically, given its extremely broad definition, it would be difficult not to.

Marie Ann Slaughter (1997, 2004) has argued that “transnational networks” of governmental actors who coordinate across borders with their counterparts, as well as with NGOs and other international non-state actors, have taken a more important role both in global and domestic governance. In Slaughter’s view, effective international relations often come down to formal and informal connections between “disaggregated” governments, with the members of various executive agencies, courts, and even legislative bodies coordinating on specific initiatives (e.g., pursuing terrorists or managing cross-border trade) and sharing expertise. Those networks supplement, but do not supplant traditional governmental authority exercised at the national level (Slaughter, 2004, p. 6). She focuses on these transnational networks as consisting largely of such government experts, though they can work closely with international non-governmental organizations (Slaughter, 2004, pp. 4). Such networks are especially important in “‘editing’ or ‘filtering’” information in a “world of information overload.” (Slaughter, 2004, p. 177-178). Such activities are important in leveraging “soft power,” or the
“power of persuasion” (Slaughter, p. 3; see also Williamson, 2003). Such soft power might be particularly important.

Certainly the organizations that facilitated the development of the Convention follow a similar template to Slaughter’s “transnational networks,” consisting in many cases – and certainly in terms of the subjects interviewed – members of executive agencies, ministries, and departments tasked with managing environmental issues for their home countries. However, in the case of the Minamata Convention, placing too great a focus on governmental networks risks underestimating the impact of non-governmental actors – particularly international advocacy groups that played a significant role in the development of the Convention, such as NRDC, IPEN, and ZMWG, who were often able to leverage technical and political expertise greater than many developing countries, and took in some ways a more prominent role than many of the formal state negotiators.

I use epistemic community here – in particular, a broader and more inclusive version (e.g. Cross, 2013) – because I am particularly interested in the sociopolitical dynamics of knowledge-based actors, whether that knowledge relates to mercury science or policy specifically, or to negotiating effective chemicals agreements generally. As a number of interviews revealed, many of the negotiators who did not immerse themselves in scientific or technical debates brought to the negotiating table a strong understanding of, and experience with, the political science of chemicals negotiations and management. That is not to say that Slaughter’s transnational networks may not provide a more appropriate analytical framework when addressing other aspects or stages of the Minamata Convention, such as transnational coordination in harmonizing domestic laws
to comply with it. And I certainly do not suggest that epistemic communities (or transnational networks or communities of practice) are always significant or successful.

To the extent such communities exist, they are neither always effective or even evident. For example, Williamson and Böhm (2013) investigated wastewater regulators and regulatory regimes in Germany and the United States, and noted explicitly that while regulators in both systems could learn from each other, there was in fact was no indication of a larger epistemic community or transnational network operating. Where communities do exist, their effectiveness is often limited by national actors unwilling to be moved; certainly, the climate change epistemic community has long had difficulties in convincing national governments to take strong steps to mitigate anthropogenic climate change. In the arms control realm, a well-organized and passionate anti-land mine community has similarly been unable to convince important world actors to ban land mine production; while most nations have signed and/or ratified the Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on their Destruction (Ottawa Treaty), notable holdouts include the United States, China, Russia and a number of other landmine producing countries. The success of a given epistemic community is dependent on a multiplicity of factors.

What distinguishes an epistemic community from any other collection of individuals working on a specific problem has been a contentious point of debate in the international relations literature (Cross, 2013; Litfin, 1994, p. 47). Typically, epistemic communities have been narrowly defined, and typically refer to scientists working within the same subfield. They are particularly important in dealing with areas involving significant scientific uncertainty, though scientific uncertainty played a smaller role in the
Minamata Convention negotiations than may be expected from the highly uncertain state of mercury science (see Chapter 3). The greater uncertainty that the community was centered on the political and bureaucratic issues regarding the best methods to regulate mercury on a global scale. One American negotiator noted that “we weren’t debating the science . . . or even the need to control mercury, we were more debating how to control it.” Another American negotiator observed that “the Convention is crafted in a way that actually allows . . . for a lot of room . . . [c]ountries could essentially modify their national action plans, take into consideration the evolving or you know, updated science.” The Convention’s overall focus on reducing supply may have also been a result of scientific uncertainty – however mercury moves through the environment, and at whatever levels it becomes dangerous, reducing anthropogenic emissions is a clear and conclusive way to reduce risk.

Cross (2013) reformulates the definition of epistemic communities by focusing on their professionalism and internal cohesion, hypothesizing that these characteristics determine how persuasive such a community is. That definition appears to be more appropriate when examining the international chemicals community at issue here than narrower definitions that focus on professional status (like “scientist”) or shared values. Applying the definition above, and in light of the interviews conducted, the negotiations record, the records of other MEAs, and academic research, I define the relevant epistemic community for this project as consisting of a certain set of international policymakers (including diplomats, lawyers, and scientists, environmentalists, and industry representatives coordinating on transnational chemicals agreements, partnerships, and

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155 [Interviewee A7 (American Negotiating Team Member)].
156 [Interviewee A3 (American Negotiating Team Member)].
frameworks – though the exact boundaries of this community remain amorphous). These actors share a common expertise in not only chemicals management but also in the international practices and communications strategies that govern chemicals most successfully and efficiently.

Cross (2013) argues that frequent meetings both create a body of shared professional norms among members of an epistemic community as well as create a strong common culture of identification. Koh (1997, pp. 2648) suggests that epistemic communities can create and effectively enforce norms of treaty interpretation against “official” governmental positions, as occurred with the ABM treaty. This common identity facilitates negotiations, and even leads to situations where governmental negotiators and diplomats will try to convince their governments to change positions that might threaten that common culture (Cross, 2013).

These kinds of patterns have emerged through interviews with American negotiators regarding the United States position on Minamata. For example, one American negotiator expressed pride in having kept the ASGM issue “on the radar screen” from the beginning, despite facing skepticism among some in her home agency who thought the United States lacked both expertise in the subject and interest in managing it, though later discovery of the role ASGM plays in global mercury vindicated that position.157 How information is presented by experts and “ground level” bureaucrats to nominal decision-makers in government can similarly influence decisions from the bottom-up. While the decision to advocate for a binding agreement at UNEP GC 25 was made by President Obama, that decision was based on information prepared by agency...

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157 [Interviewee A4 (American Negotiating Team Member)].
personnel; according to one negotiator who worked on the memo, it was presented as she believed it was more of an “options memo on you know, paths that this new administration could take . . . a ‘you have an opportunity should you choose to take it, and the rest of the world would like you to take it.”\textsuperscript{158} Minamata negotiators in the State Department also coordinated informational meetings with staff members in Congress to present the executive branch’s approach to the negotiations.\textsuperscript{159}

This potential bottom-up influence extends beyond the United States. Stokes et al. (2016, p. 23) credit China’s agreement to a binding mercury agreement, and their eventual concession to even binding emissions restrictions, partially to the development of a “large group of scientific researchers that focus on China-specific mercury issues,” members of which made up part of China’s negotiating team. On the other hand, they note that India’s continued resistance to the agreement may be at least partly due to the lack of such domestic expertise, with the few mercury researchers in India appearing to have less influence on government policy than Chinese scientists.

One Minamata observer who had also attended the Stockholm Convention noted that some of the same people were there.\textsuperscript{160} A first-time attendee similarly noted how surprised she was by how many of the delegates and observers knew each other.\textsuperscript{161}. One American negotiator and chemicals expert who worked on the Minamata negotiations was also deeply involved in the technical support negotiations for the Basel Convention noted the waste provisions of the former were informed by recent technical discussions

\footnotesize{\textsuperscript{158} [Interviewee A6 (American Negotiating Team Member)].
\textsuperscript{159} [Interviewee A3 (American Negotiating Team Member)].
\textsuperscript{160} [Interviewee A8 (Nongovernmental Observer)].
\textsuperscript{161} [Interviewee A9 (Nongovernmental Observer)].}
on the mercury waste provisions of the latter. Another American negotiator also involved in the waste and storage negotiations noted that the existence of the Basel Convention “was very helpful to this Convention,” as it “handles 90% of what needs to be done.”

This community was in constant contact through various intercessional meetings. Scientific conferences like the annual International Conference on Mercury as a Global Pollutant appeared to play a significant role in coordinating scientific and technical research, while formal and intersessional regional meetings meant that negotiators and other stakeholders in the Convention were in constant dialogue. For example, American negotiators met with counterparts in the regional negotiating group JUSCANZ (the name is derived from Japan/U.S./Canada/New Zealand, though a number of other developed but non-European Union nations are members) to coordinate on their similar negotiating positions. Similar regional organizations would also meet intersessionally to coordinate negotiating strategies and work on proposed Convention text.

Through it all, UNEP itself played a key role in collecting scientific, technical, and economic data and compiling reports to be distributed to negotiators and other stakeholders, particularly through its UNEP chemicals program. Andresen et al. (2012) note that UNEP allowed NGOs an unusually prominent role in the negotiations, which led to some complaints by parties that the nominally neutral UNEP was framing reports to encourage a legally binding agreement.

The influence and cohesiveness of this “chemicals community” may increase in the future, particularly in light of the complex technical requirements of the Convention,

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162 [Interviewee A7 (American Negotiating Team Member)].
163 [Interviewee A6 (American Negotiating Team Member)].
as well as the formal “Synergies” initiative launched collectively by the Conferences of Parties for the Basel, Rotterdam, and Stockholm Conventions for “enhanced cooperation and consideration” (AHJWG, 2005). Such MEA “clustering” has become a central element of UNEA’s (formerly UNEP GC) proposal to improve the functioning “of a widely fragmented and diluted international environmental governance architecture.” (Wehrli, 2012).

Epistemic communities, of course, do not preclude disagreement; even negotiators for the same country may clash over provisions. But the same community dynamics that help resolve negotiating problems between members of epistemic communities also work in subgroups of those communities. One American negotiator said that while negotiating team members were usually in agreement, occasionally minor tensions and disputes arose often both within her agency and between the agencies whose representatives made up the American negotiating team, frequently about strategy issues, but the participants were always able to work them out.164 Another stated she “liked to joke that interagency negotiations were harder than international ones.”165

In some cases, though, some NGOs and their representatives played significant roles in driving the negotiations. For example, the Natural Resources Defense Council (NRDC) and its representatives played a leading role in both the Convention’s development as well as international mercury policy generally, according to one observer affiliated with the organization, as well as to members of the negotiating team.

Institutional expertise and credibility determine the extent to which non-governmental representatives can move the agenda. Anti-vaccine activists were unsuccessful generally

164 [Interviewee A4 (American Negotiating Team Member)].
165 [Interviewee A2 (American Negotiating Team Member)].
in getting negotiating parties to agree to binding restrictions on vaccines, just as advocates against the use of mercury-based dental amalgams were unable to restrict those to any meaningful extent.

Compounding the problem with MEAs are the fact that different nations have different philosophical approaches. Some may go to general philosophical approaches to environmental governance generally, particularly from economically and politically powerful actors like the United States and the European Union, which can use their dominant positions to push towards MEA provisions consistent with those philosophies. For example, the European Union tends to take a precautionary approach to environmental governance both nationally and transnationally, while the United States tends to incorporate cost-benefit analyses more often. Negotiating strategies may be different as well. One U.S. negotiator noted that “when the EU goes into . . . a negotiation they like to set the standard . . . and use that as a motivator to try to improve things [domestically] they wish they could improve anyway,” while the United States prefers not to negotiate a treaty that is not tenable domestically first, instead trying to “get everything in place that we can . . . to try and get the kinds of regulations in place that would allow us to pull the rest of the world along.”

However, one of the central benefits of an epistemic community is the ability to transcend such different interests, values, and positions – or at least counterbalance them with a community norm that can help negotiators move past those differences.

Procedural expertise grows as well. Eriksen and Perrez (2014) also argue the spacing of the INC sessions, with 7-9 months between them, facilitated the development

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166 [Interviewee A2 (American Negotiating Team Member)].
of the Convention through giving parties sufficient time between sessions to “digest the outcomes of the meetings, to prepare relevant documents, interact informally between sessions, further develop national positions and prepare for the next meeting. When asked whether she thought the Convention would enter into force in time for the first Conference of Parties in September of 2017, one NGO representative responded that “these are professionals, they’re not going to schedule something and announce it without having pretty good feeling that it’s going to happen.”

In the case of the Minamata negotiations, cultural cohesion and shared experience was also intentionally cultivated – not just through the typical social events found at most such negotiations, but also through other gestures. For example, during the Stockholm Convention negotiations, an indigenous group had given a Canadian representative a sculpture of a mother holding a child, presumably representing the health dangers from persistent organic pollutants to expectant mothers, children, and the unborn; the sculpture had been taken to each of the Stockholm meetings. For the Minamata negotiations, an Argentinian sculptor had provided a statue of a silvery fish, what one interviewee referred to as the negotiation’s “mascot,” which was also brought from negotiating session to negotiating session. The band Queen became an official soundtrack for the Convention, presumably because of its lead singer, Freddy Mercury. The Queen song “Under Pressure” played during the tense final negotiation session at INC 5, its tune hummed by delegates throughout the evening, and its lyrics later quoted by one indigenous representative when discussing that her people were no longer able to eat their traditional foods: “[i]t’s the terror of knowing what this world is about” (Kohler, Morgera, Ripley,

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167 [Interviewee A1 (NGO Representative)].
Schabus & Tsioumani, 2013, p. 2). After the Convention had been successfully negotiated in INC 5, Queen’s “We Are the Champions” was played (Kohler et al., 2013, p. 22). During INC 1, IPEN and another NGOs tested the hair of fifty delegates and presented the results, which may have “lifted the veil of abstraction” (Kessler, 2013); one of the American negotiators similarly suggested that in terms of people from developing countries and island states, it “would not surprise her if it gave them a slightly more personal take on what they should be advocating at home.”168 Another NGO focused on mercury-containing dental amalgams tested delegates’ breath for mercury (Ashton, Kantai, Templeton, & Xia, 2010).

Epistemic communities may be especially important when it comes to what Williamson (1990, p. 741) has referred to as “complex regimes,” or regimes that “cover[] a set of interrelated topics or problems . . . adopts a series of interlocking measures (some binding, some not) toward a common (if not precisely agreed upon) goal.” An effective complex regime will have numerous interacting hard, soft and non-law factors, including information sharing, financial assistance, and the efforts of international organizations (Williamson, 2003, p. 81). Cohesive epistemic communities would appear especially well-suited to coordinating these interactions.

6.6.3 Current and Future Complications

The efficacy of the Convention, of course, can only be evaluated after it goes into force – and then only after many years of working experience. The international legal regime is undergoing a period of transition, as nations like China take more of a central role in international governance, particularly international environmental governance.

168 [Interviewee A6 (American Negotiating Team Member)].
Below I discuss two separate yet interrelated issues that may impact effective functioning of the Convention. As with the previous section, this should not be construed as exhaustive or comprehensive.

6.6.3.1 Regime Change in the United States (Again)

During the pendency of this project, another complication arose that cast a shadow over future implementation of the Convention: the election of Donald Trump as President. Under normal circumstances, it would be highly unlikely for the United States to withdraw from an MEA like the Minamata Convention, since the country already complies with its substantive provisions of the Convention through domestic laws and regulations, and seems to enjoy significantly higher potential benefits from the Convention than costs, considering most domestic mercury deposition comes from foreign sources.

However, the new administration has indicated an extreme antipathy to environmental regulations, and indicated in June 2017 it was withdrawing from the Paris Agreement, a protocol to the UNFCCC, despite wide support from the scientists, the public, and the private sector. Moreover, while the Minamata Convention has remained largely off the radar of the public as a whole, the current EPA Administrator, Scott Pruitt, may be more familiar with mercury issues generally as he represented the State of Oklahoma while litigating against the Mercury and Air Toxics Rule promulgated by the Obama-era EPA (White Stallion Energy Center v. EPA, 2014). While withdrawal from the Convention would require only an executive decision by President Trump to do so, absent legislation or rulemaking the United States will still be bound by domestic law to carry out the substantive requirements of the treaty. Furthermore, under Article 33 of the
Convention, withdrawal can only be made “after three years from the date on which this Convention has entered into force for a party,” after which withdrawing party must wait an additional year for it to be made effective. There is no legal way to enforce that withdrawal process, though the Trump administration has indicated that it is following the similar withdrawal in the Paris Accord (Shear, 2017). That administration could also try to change the regulations under which the United States fulfills its obligations, though this would be difficult as multiple interviewees noted the regulations under which the United States fulfills its obligations have long been ensconced in Federal rulemaking, with more recent mercury regulations like the 2012 Mercury and Air Toxics Rule (see Chapter 5) not necessary to comply with the Convention. However, it remains a theoretical risk, particularly as Congress could simply erase any regulation through simply passing a law.\footnote{At the time of writing, this would be difficult; while a full treatment of the political and legislative complexities of U.S. lawmaking are outside the scope of this dissertation, it would be unlikely that Trump would be able to successfully abolish or substantially change the relevant federal environmental laws and regulations. However, he can certainly weaken them.}

However, a likely greater threat is the likely retrenchment of American participation in the Global Mercury Partnership and voluntary partnerships. The proposed budget released by the administration proposes a significant reduction in American funding of the GEF, from $168 million in 2017 to $102 million in 2018 (OMB, 2017, p. 801). While the budget is only a proposal – Congress must pass an actual one – with Republicans controlling both houses of Congress it is very likely that whatever ultimate budget is passed will include reductions on foreign environmental aid spending. One NGO representative interviewed in early 2017 indicated that she had not heard international partners expressing concern directly, though she thought there might be
anxiety over a diminished role by the United States in driving mercury partnerships, even if the country still remained a party to the Convention.\textsuperscript{170} Considering the prominent role that the United States has played in the Global Mercury Partnership, and the steps taken by the current administration to dramatically reduce the United States’ financial assistance to other countries, the less effective, particularly for areas like ASGM that are not just immensely complex, but immensely complex in different ways between countries and regions.

6.6.3.2 \textit{Primary Mining and ASGM in the Developing World: The Example of Mexico}

While significant attention has been paid to disparities in financial and technological resource disparities, between the developing world, the lack of bureaucratic and governance structures may also impact compliance and efficacy of the Convention. The case of primary mining in Mexico offers both a cautionary example as well as a specific complication to the treaty that may ultimately result in less environmental mercury reductions than had been anticipated at INC 5, at least in terms of supply from primary mining and use by ASGM.

While Mexico had been in a significant producer of mercury from primary mining, such mining activities slowed significantly through the early 1990s, and had, at least according to official government records, completely stopped by 1995 (CEC, 2013, p. 71). While primary mining of mercury in Mexico had officially stopped in 1994, it is uncertain if it ever truly went away; in any event, Mexico disclosed to its North American

\textsuperscript{170} [Interviewee A1 (NGO Representative)].
Free Trade Association (NAFTA) partners that it was mining mercury apparently since before the Convention had been finalized.

There does not seem to be much evidence of intentional subterfuge; as one interviewee familiar with the case noted, Mexico has been open about its mercury exports, duly reporting them to COMTRADE, the United Nations international commodity trading database. COMTRADE shows Mexico reported significant exports of mercury in 2013 (295 tons), 2014 (331 tons), 2015 (306 tons), and 2016 (293 tons) (COMTRADE, 2017). It is unlikely that Mexico could have exported that much mercury without engaging in primary mining, though the existence of such mining was not disclosed until after INC 5 according to several interviewees. One U.S. government negotiator suggested it may have been an unintended consequence of the United States’ Mercury Export Ban Act of 2008 (MEBA), which severely limited exports of mercury from the United States starting January 1, 2013. Another State Department official involved in international mercury policy agreed, noting that “[i]t seems to be a relatively recent occurrence”, and maybe one of the unintended impacts of MEBA was that it left “a vacuum in the supply.” A NAFTA Center for Environmental Cooperation (CEC) report on mercury production in Mexico predicted that MEBA and similar import restrictions in Europe could lead to increased international demand, and that formal mercury mining could be reinitiated in that country (CEC, 2013, p. 68).

Because China was using most of its mined mercury in vinyl chloride monomer (VCM), where it can be far more easily recovered, its use was of less concern the negotiators than primary mining of mercury for export, with primary mining “the least

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171 [Interviewee A1 (NGO Representative)].
172 [Interviewee A3 (American Negotiating Team Member)].
desirable source of mercury continuing use” (UNEP, 2010b, p. 6). An American negotiator said the discovery of Mexico’s primary mining was “a big disappointment . . . and a shock . . . we were all very taken aback by that.”\textsuperscript{173} One Minamata participant suggested that had the parties known about Mexico’s mining operations, the 15-year phaseout of primary mercury mining may have been shorter, since that was provision was agreed to based largely on China’s VCM needs.\textsuperscript{174} She also characterized it as “just sort of the perfect story about how governments are siloed.”\textsuperscript{175}

This “siloing” of governmental agencies, particularly in the developing world, can lead to difficulties in the Convention’s implementation even if financial resources and the will to comply are nominally present. While financial and technical capabilities are important, governance infrastructure is important as well. One American negotiator involved in both international and domestic waste management noted we have “the physical and bureaucratic infrastructure . . . [t]here are lots of countries that have almost none of that.” Perhaps most concerning is the fact that Mexico is a fairly developed “developing” country; in many areas of the world, informal mercury mining goes on with even less oversight.

While Article 3 to the Convention (“Mercury supply sources and trade”) prohibits export of mercury for ASGM after the agreement goes into force, or August 16, 2017, informal mining tends to go on in countries that lack this “bureaucratic infrastructure” and thus often cannot halt or control trading across oftentimes porous borders. One negotiator likened the black- or grey-market trade in mercury as somewhat analogous to

\textsuperscript{173} [Interviewee A7 (American Negotiating Team Member)].
\textsuperscript{174} [Interviewee A1 (NGO Representative)]. VCM can be used to produce the plastic, poly vinyl chloride.
\textsuperscript{175} [Interviewee A1 (NGO Representative)].
the drug trade, a comparison some of her colleagues found valid. Another NGO representative noted that “a lot of mercury trade goes across very porous borders . . . a ton of mercury fits in the back of a pickup truck.” A significant amount of secondary mercury mining occurs in Mexico such as recovery of mercury from industrial sites and tailings from precious stone mining, meaning that in some cases it may be difficult to determine whether a shipment crossing a border for ASGM use is illegal or not.

There is little dispute over the argument that addressing ASGM will be the most difficult task of the Convention and its parties. Paradoxically, the more successful the parties are in reducing mercury supply on a global level, the more motivation there is for informal primary mercury miners to continue or expand their activities. Counteracting such grey-market and black-market movement of mercury faces similar difficulties to dealing with it once it reaches ASGM sites.

6.7 Conclusion

The Minamata Convention on Mercury is the first major international agreement in almost ten years, and the first chemicals Convention to focus on a pollutant’s entire lifecycle, from production to disposal. It is also the first major MEA since the Basel Convention in which the United States has played a central role in development, and the first since Montreal Protocol since it played that role and then ratified it. Though a stand-alone treaty, the Convention and its development are and were intricately linked with an evolving global chemicals governing network of MEAs (like the Basel, Stockholm, and Rotterdam Conventions) and partnerships and voluntary frameworks (like the Global Mercury Partnership and SAICM). Managing this network is an epistemic community of

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176 [Interviewee A1 (NGO Representative)Interviewee A10 (American Negotiating Team Member)].
177 [Interviewee A1 (NGO Representative)].
diplomats, bureaucrats, scientists, and environmental and health advocates who have been able to refine governance strategies and leverage various strategies. Though the administration change in the United States may lead to reduced funding globally, at least during the current administration’s tenure, it seems unlikely that the United States will completely remove itself from the Convention or its customary role in international chemicals management.

While the Convention is an impressive achievement in light of the political, economic, and technical difficulties it faced, a true evaluation of its effectiveness in reaching its goals will not be possible for several years. Several of the most important provisions of the Convention will be difficult to implement and enforce. Article 7 (ASGM) poses an especially difficult problem because while ASGM is the largest anthropogenic source of environmental mercury, it can be carried out by individuals or small groups often working at the margins of society. Such a problem may be exacerbated by the resumption of primary mercury mining in Mexico, with such mercury potentially fueling significant ASGM activities carried out in Central and South America, despite the nominal illegality of such trade under the Convention.

Optimism over the second largest source of anthropogenic mercury, emissions from coal-fired power plants, may be more warranted. Though India has still not ratified the Convention, and is responsible for a significant percentage of such emissions, China is the largest source of such emissions and its agreement to binding emissions restrictions as well as its domestic engagement with pollution control may significantly reduce total global emissions from such sources. Perhaps ultimately more importantly, the worldwide boom in solar power, particularly in China, may lead to far fewer mercury emissions than
were anticipated during the Convention negotiations even absent strong enforcement of Article 8.
Chapter 7
Concluding Remarks and Synthesis
7.1 Overview

Mercury is a toxic contaminant of profound physical complexity; dealing with it from a policy viewpoint has proven profoundly complex as well. Over the past several decades politicians, scientists, and the public have come to realize that the environmental problems that have resulted from the development of modern industrial society need to be addressed through some form of policy response. Early “policy scientists’” optimism about the potential for public policies to be designed and implemented by impersonal experts using generalized methods quickly ran aground on the complexity of open natural and social systems. Environmental governance has tended to be a much slower and harder process than was originally anticipated during the early 1970s, when the American – and the global – public called for environmental protection. The optimism of Earth Day quickly gave way to scientific, technical, and political barriers that have proven far more intractable than initially expected. As noted in Chapter 6, the 1972 Stockholm Declaration had held that cooperation through global treaties was necessary to protect the environment, but the creation of such instruments proceeded at a slow pace. Similarly, as described in Chapter 5, the initial ambitious scope of the Clean Air Act of 1970 would not necessarily be fulfilled by the rulemaking of the presidential administrations that followed it.

In the face of these difficulties, academics working in environmental policy have increasingly moved away from more neopositivist, technocratic approach to policy-making, developing new methods of policy analysis and development that are more flexible, critical, and engage more pragmatically with, the political and cultural difficulties inherent in environmental governance. This dissertation is an attempt to
further that mission by engaging with the history of environmental mercury risk and regulation in all its messiness, uncertainty, and irrationality, and trying to come out the other side with a better idea of the difficulties inherent in such “wicked” problems, and possible ideas as to move past them in the future.

In this final chapter I first summarize the preceding chapters, and their conclusions, and then explore certain common threads and themes that emerge when they are considered in aggregate. I conclude with a discussion about what environmental mercury governance may look like going forward, and potential future avenues of research.

7.2 Dissertation Summary

Though the chapters were written as self-contained academic works, I have structured them as a building-block study of the cultural, scientific, and political decision-making regarding mercury:

In Chapter 2, I reviewed the scientific literature relating to mercury’s movement through the environment and its impact on human health, focusing on areas of scientific uncertainty particularly relevant to policymaking. I concluded that incorporating mercury science into regulatory decisions involves multiple layers of uncertainty, and identified important research gaps.

In Chapter 3, I first explored certain fundamental philosophical questions inherent in environmental policy analysis of complex environmental problems. Conceiving environmental policy analysis as an applied social science, I examined the epistemological foundations and limitations of the two dominant theoretical paradigms in that study: neopositivism and interpretivism. Discussing the strengths and weaknesses of both, I then offered a third epistemological foundation upon which to build
environmental research, critical realism.

In Chapter 4, I set the environmental mercury policy problem into its historical context, examining human use of mercury throughout history and the evolving understanding of its risks, particularly over the past several decades. I provide in-depth historical accounts – and draw connections – between two mercury-related phenomena in particular: (1) The Minamata Bay poisoning event of the 1950s and its aftermath; and (2) the anti-vaccine movement in the United States as it related to thimerasol.

In Chapter 5, I conducted an in-depth historical, legal, and political analysis of mercury regulation in the United States under the Clean Air Act as it relates to electric generating units, the most significant anthropogenic source of mercury emissions in the United States. Finally, in Chapter 6, I analyzed the development of the Minamata Convention on Mercury, a global multilateral environmental agreement (MEA) created in 2013 and set to go into force in August 2017.

7.3 Emergent Themes

In Chapter 3 I suggested that understanding complex environmental problems and their social and legal implications policy analysis can benefit from a critical realist epistemology. That critical realist framework assumes that complex phenomena in open systems typically should be understood as historically unique because they are the result of a multiplicity of causal mechanisms that are unlikely to have been the same in every situation. This does not, mean, however, that we cannot identify and isolate specific tendencies in similar phenomena, even if we cannot ultimately set them forth as invariant universal laws (Manica, 1998, p. 324). Consistent with that approach, in addition to the conclusions I reach in the individual chapters, three additional points are supported by the
dissertation as a whole and are consistent with the critical realist epistemological framework set forth in Chapter 3. These are as follows:

First, that examining and understanding large-scale environmental problems like environmental mercury requires an intensively interdisciplinary approach. Policy analysis too often examines the social dimensions of policy creation and implementation but takes scientific and technical analyses at their word, or vice versa: Analyzing the scientific or technical characteristics of a problem, and assuming that once that is resolved conforming law and regulation to be consistent with those findings should be straightforward. In Chapter 2 I critically review different areas of mercury-related science, from biogeochemical cycling to global inventory determination to health impacts, concluding that each emergent level contains significant uncertainties that impact decision-making. In Chapters 4, 5, and 6 I show how such uncertainties are used, distorted, exaggerated, minimized, or ignored in the pursuit of what are often ideological and/or economic goals or values. Such phenomena seem to be a fundamental characteristic of modern culture that reoccurs across time and across borders; the arguments made by the Chisso Corporation in the 1950s and 1960s are similar to the American power industry’s arguments against mercury regulation in the 2000s and 2010s, and echo the posture of the Indian delegation during the Minamata Convention negotiations in their attempt to weaken provisions on atmospheric mercury emissions.

Second, that understanding both past policy decisions and future policy directions requires not just interdisciplinary understanding, but accounts of such phenomena must be historically situated to understand how they function in the present – in other words, analyzed diachronically (e.g., Bhaskar, 2010, pp. 12-13; Cooper & Brady, 1981). Such
historical analyses frame much of this dissertation. In **Chapter 4**, I examined the modern historical development of the understanding of mercury risk through a cultural models lens, suggesting that current public understanding of mercury is driven, at least partially, by media and government accounts of historic mercury (and other industrial) poisoning events, with the Minamata Bay poisoning the most well-known and influential. In **Chapter 5**, I described the history of mercury emissions regulations for coal-fired power plants under the Clean Air Act and showed, among other things, that historical regulatory decisions have impacted the modern development of the law. For example, EPA decided in 1973 that rather than designating a contaminant a “hazardous air pollutant” then regulating all sources of it, it would instead make its designation by source – despite the fact that the plain text of the Clean Air Act did not allow for that – and that decision allowed EPA to restrict mercury emissions under the Clean Air Act from some sources while leaving one of the largest, coal-fired power plants, unregulated for decades. Similarly, the Supreme Court's holding that Congress would assume an "appropriate and necessary" determination would take costs into account is inconsistent with the history of the relevant provisions of the Clean Air Act, but is consistent with the series of bureaucratic roadblocks set up by a procession of Presidential administrations, many of them either hostile or indifferent to the environment, which normalized such approaches. Those working in future environmental policy processes in the United States should take regulatory history seriously, especially considering that at the time of writing the final rule on mercury emissions from power plants is once again under review by an administration with an avowed hostility towards environmental regulations.
Third, that traditional neopositivist “rationalist” approaches to environmental reasoning and decision-making processes do not adequately explain those processes. While this is certainly not a novel observation – much of the environmental policy literature over the past couple of decades has demonstrated this – in this dissertation I extend and strengthen that argument by looking at the history of mercury policy decision-making. Though I examine “cultural models” in Chapter 4 and political “ideology” in Chapter 5, these are two sides of the same “mental models” coin. Developing largely out of the interdisciplinary field of cognitive science, and used by researchers working across a number of disciplines, mental models theories propose that human beings reason and make decisions by constructing and referencing internal, simplified models of the real world.

These models are constructed through a person’s history and experiences, and influenced by a number of experiential and cognitive factors. Proponents of the mental models idea have suggested that these mental models evolved as a way of simulating ways to move in the physical environment, a flexible adaptation advantageous to humans and other organisms (Nersessian, 2002). Incorrect or inaccurate reasoning processes may be based on inaccurate mental models of the world; mental models can be resistant to change, meaning simply providing accurate information to individuals may not improve reasoning or decision-making, though framing that information in a way that is consistent (as possible) with that model may be more effective (Abel, Ross & Walker, 1998; Forrester, 1971). While a number of researchers have used mental models theories to examine environmental reasoning and decision-making (e.g., Bostrom, Morgan, Fischhoff & Read, 1994; Lynam et al., 2012; Sterman & Sweeney, 2007), they have used
them to examine specific subjects using primarily psychological survey and interview methods; I argue here that the method can be extended and used as an interpretivist tool to examine potential historical trends in human behavior.

The mental models approach is only one of several connected attempts to explaining the gap between knowledge and action through cognitive science approaches. Herbert Simon (1956) proposed that human beings were fundamentally rational but limited by lack of information and limited computational capacities. Later decision science researchers, most prominently Kahneman and Tversky, extended Simon’s theory of bounded rationality by empirically investigating situations in which human beings make irrational, non-optimal, or inconsistent decisions, in order to determine replicable heuristics and biases which may influence those decisions (Tversky & Kahneman, 1974). Other researchers have focused on the affective or emotional components of decision-making (Damasio, 1996; Lerner & Keltner, 2001; Slovic et al., 2003). Heuristics-based cognitive research and mental models research study the same processes, if from different sides and at different scales, and opportunities exist to combine insights from both fields to the benefit of both (Galotti, 1989; Johnson-Laird, 1993; Shafir, 1996).

7.4 The Future of Mercury Policy and Research

In the face of decades of slow, incremental changes in pollution control technology and legal restrictions in the developed world, mercury releases to air, land, and water levels in those countries have likely decreased significantly over the past few decades (Pirrone et al., 2010). However, any gains made in the developed world regarding mercury may be more than made up for by increased emissions from the developed world, particularly from the two largest sources of anthropogenic mercury in
the environment, small-scale artisanal gold mining (ASGM) and emissions from coal-fired power plants. Mercury policy focus will likely be increasingly on global and developing country issues.

Reducing mercury emissions from ASGM poses a particularly difficult problem. Though it currently makes up the largest estimated source of global anthropogenic mercury, the exact scope of those emissions is hindered by significant uncertainty (see Chapter 2). ASGM is carried out on the margins of society, often by extremely poor and vulnerable communities, across the globe. Reducing mercury use in ASGM and safeguarding miners, refiners, and those around them from harmful mercury vapor will require significant resources to examine it in the dramatically different cultural, economic, environmental, and technological contexts in which ASGM is carried out. ASGM particularly requires interdisciplinary research and flexible – and individualized – analysis incorporating fields ranging from engineering to health communication to anthropology – to successfully intervene in the different areas in which it is carried out.

Mercury emissions from coal-fired power plants in the developing world are also a cause for concern, but may ultimately be an easier problem to address. The two largest emitters, China and India, committed to binding obligations on controlling emissions under the Minamata Convention, though at the time of this writing India has not ratified the Convention. Point sources like coal-fired power plants are far more amenable to direct regulation by national governments than ASGM, and China particularly has demonstrated a growing willingness to address its domestic air pollution (see Chapter 6). Furthermore, China’s investment in solar power and other renewables has dramatically increased over the past several years, leading to less coal-fired power plant production
than expected only a few years ago (Forsythe, 2017). While India will likely not follow to the same extent, China is currently the largest source of mercury emissions by far, and the combination of increased pollution controls and the move to renewable energy sources may have a significant impact in controlling global emissions, though actual reductions would be largely dependent on what China does with its already-existing coal-fired power plants.

In terms of future research, though emissions control technologies have reached a high level of efficacy, there are still large gaps in the biogeochemical and public health cycling that impact policy decision-making (see Chapter 3). Though the Minamata Convention was created with the understanding that the existing science was conclusive enough to require a global instrument to reduce mercury risk, evaluating the efficacy of the Convention in the future will require that many of the scientific gaps be filled (see Chapter 6). Identifying atmospheric oxidation pathways are particularly important, since global transport and deposition patterns are heavily dependent on them. Though I applied the critical realist metatheoretical approach above primarily to social and coupled social-ecological systems, it was originally presented as a philosophy of natural science, and some of Bhaskar’s critiques of positivism seem appropriate to current atmospheric mercury research. Most of the current research on atmospheric oxidation patterns appear to be done through measurement and modeling studies and attempts to harmonize them with each other, while very little research appears to be done in the “causal mechanism” of oxidation – e.g., through experimental chemistry work on how the reactions themselves may be done. One scientist interviewed for Chapter 6 noted that as late as
last year some modelers were still using oxidants – and reaction rates – in their models
that had long ago been shown to be likely to be inaccurate.

7.5 Concluding Thoughts

Rapid industrialization and the explosion of scientific and technical knowledge in
the twentieth century led to both the realization that human beings needed to take steps to
protect the environment – and an overwhelming optimism that we could do so. But
environmental governance has turned out to be far more difficult than originally
expected. Purely technocratic approaches that saw complex social-ecological problems
like environmental mercury as just more challenges for the neopositivist scientist or
engineer to dispose of, but social phenomena are not as easy to reduce to “laws of nature”
as Auguste Comte predicted. Certainly, the solutions to such problems, if they exist,
require a concerted, coordinated, and collaborative effort between scientists,
policymakers, and the general public.

But the interpretivist-minded analyst’s call for increased democratization has its
own drawbacks. For one, as my discussion of the Clean Air Act in Chapter 5 suggests,
participatory processes do not always mean participation, and if many interpretivist-
minded policy theorists have expressed cynicism over the ability of powerful technocratic
institutional actors to weaken environmental regulations, they may be overly optimistic
over the ability of participatory processes to remedy that. For example, the weak (and
ultimately legally noncompliant) Clean Air Mercury Rule promulgated by the Bush
administration was done in the face of public involvement and support for stronger
mercury emissions restrictions, but that had little impact on the workings of an
Environmental Protection Agency (EPA) whose political appointees – some of them
former (and then later) energy lobbyists – were willing to ignore the public, agency and outside scientists, and ultimately the text of the law to put in extremely weak emissions restrictions. In that chapter, I noted that in cases of scientific uncertainty (and the science of environmental mercury is certainly still highly uncertain), ideological actors can take advantage of that fact to delay or weaken regulation. The most famous example of this is, of course, climate change, but it can happen with a wide variety of environmental problems.

I suggested in Chapter 5, and still suggest, that a more open engagement with questions of value might help limit the ability of those with political or economic power to derail environmental policy development in their favor. Certainly, the Minamata Convention negotiations, where questions of value took greater precedence, was a quicker process and engaged more openly and transparently with the benefits and costs of mercury regulations, although implementing its provisions will take potentially decades, if they are successfully implemented at all. And of course, questions of value differ greatly depending on where you stand.

As I also note in that chapter, when it comes to chemicals regulation in the United States, the American federal environmental legal regime has shifting burdens of proof; for example, the Federal Insecticide, Fungicide, and Rodenticide Act and the Food and Drug Act place the burden on chemicals manufacturers and distributors to show that new products do not pose an unreasonable health risk to the public. For most environmental statutes, including the Clean Air Act, the burden in is usually on EPA or other regulatory agency to show that a particular substance is dangerous before restrictions can be put in place. While the burden of proof – who has to establish the safety or danger of a
substance – may be on the government to show danger, the *standards* of proof, or the strength of the evidence needed to make that determination, may vary not only between federal statutes but within them. These standards are typically buried within complex laws and are typically the result of both the legislative negotiations that created those laws, with more specific parameters created through later rulemaking and court decisions (e.g., *EDF v. Ruckelshaus*, 1971).

In recent decades, the precautionary principle has gained support as an approach to environmental regulation.¹⁷⁶ Though there are a number of different formulations of the precautionary principle, perhaps the most widely embraced (Percival, 2001) is Principle 15 of the Rio Declaration, which states that:

> In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

The members of the European Union have adopted a version of the precautionary principle for Union-wide environmental policies in both terms of the burden of proof and the standard of proof, placing the weight of both on potential polluters (Treaty on the Functioning of the European Union, 2012, art. 191). The precautionary principle is itself controversial (e.g., Percival, 2005; Sunstein, 2003). Sunstein (2003, p. 1,004) argues that “[t]he principle threatens to be paralyzing, forbidding regulation, inaction, and every step in between,” though the European Union has appeared to avoid this paralysis. During and after the Minamata Convention negotiations a number of actors called for an open engagement with the precautionary principle or approach (e.g. Akanle, Ashton, Mwangi

¹⁷⁶ The precautionary principle is not limited to environmental policy, as it has become a similarly popular
Certainly the precautionary principle can be seen in some aspects of some federal laws – in addition to FIFRA and the Food and Drug Act’s burden of proof, CAA §112 requires EPA to ensure an “ample margin of safety” in certain emissions restrictions decisions (e.g., CAA, 2012, §§7412(c)(9)(b)(ii), (f)(2)(A)). But other environmental laws place a far higher standard of proof on EPA; for example, the Safe Drinking Water Act (SDWA) only permits EPA to regulate a newly identified contaminant if “regulation of such contaminant presents a meaningful opportunity for health risk reduction for persons served by public water systems” (SDWA, 2012, §300g-1(b)(A)(iii)). Furthermore, as discussed in more detail in Chapter 5, the United States environmental protection regime has generally tended to move towards a balance of risks and costs over the past several decades, whether through changes to the law or through bureaucratic barriers such as review by the White House’s Office of Management and Budget.

Could an overt embrace of the precautionary principle across the entire federal environmental regime resolve some of the “subterranean” disputes in the current federal rulemaking process in the United States? The approach itself would likely be accepted by a majority of Americans: polls show that a majority of both Democrats and Republicans consistently agree that the country should “do whatever it takes to protect the environment” (Pew, 2017). However, the political will to overtly embrace a whole-system precautionary approach to environmental policy may be lacking. Although most of the public has been consistently pro-environmental regulation, they tend not to make voting choices based on environmental beliefs (e.g., Gruber, 2001).
This may not remain true, however. The early 1970s saw a massive public outcry that led to CAA and other federal environmental statutes, so it is at least possible that this pro-environmental fervor could recur, or at least the public could move towards a point where politicians again feel the need to follow along, if only for their own political career (e.g., Lazarus, 2004, pp. 76-77). Currently statutes like CAA may be victims of their own success; for example, despite the critique above in regards to EGU-sourced mercury regulations (or the lack thereof), in many other ways it has largely been successful, improving the air quality immensely over the past several decades, if not always to the extent hoped for when it first went into effect (EPA, 2017; Hafner et al., 2004; McCarthy et al., 2006). That success may help explain the lack of political consequences for politicians who take an environmentally anti-regulatory stance in the face of a public that overall tends to favor environmental regulations by large margins. But the past couple of decades environmental policy analysts and other social scientists have worked on increasing public understanding of, and participation in, environmental policy decisions. Furthermore, the increasing risk of dire – and very visible – consequences of climate change may also help spur increased public interest in environmental laws and regulations, and if those consequences are as severe as many scientists predict, such involvement will be critical to dealing with them. Increasing public interest in environmental protection could help push presidential administrations into taking environmental protection more seriously and help fulfill the lofty goals of the environmental regulatory regime envisioned in the Earth Day era.

Though my research looked back on decades-old processes and debates over the best way to deal with mercury in laws and regulations, treaties and in the developing
world, it is the last area in which future mercury debates will likely be most important in the future. As messy as past future work on mercury policy has been, it will likely become even messier – ASGM has become mercury policy’s greatest global concern, and it is caught up in fundamental questions about global development and the responsibilities wealthier nations have for the world’s poor and vulnerable. The next “policy” battles over mercury will be fought in communities in the shadows of the “modern world.” Many of the Minamata Convention interviewees recognized that in much of the world, mercury is far down on the list of problems to be dealt with, and electric power – even from plants that discharge large amounts of mercury into the environment – might be worth the cost for some of the poorest communities. But that cost may be higher than any of us know. The neurodevelopmental effects of mercury are often subtle, but there is no way to know how many minds grew up that could have achieved something extraordinary had they not been dimmed by it.


http://doi.org/10.1080/15287394.2011.573736


http://doi.org/10.1080/00139157.2016.1208995


http://doi.org/10.1021/acs.est.6b05804
Environmental Defense Fund v. Ruckelshaus, 439 F.2d 584 (D.C. Cir. 1971)


General Medical Council. Fitness to practise panel hearing, 28 January 2010 (2010).


Mercury Poisoning in Iraq is Said to Kill 100 to 400. (1972, March 9). The New York Times.


NBC. (1982). DPT: Vaccine Roulette. WRC-TV.


White Stallion Energy Center v. EPA, 748 F.3d 1222 (2014).


### Appendix A

#### Legal Materials Referenced in Dissertation

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**United States Federal Agency Proposed and Final Actions**


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- Other Nations
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- Relationship to Other Conventions
  - Basel Convention
  - Hypothetical Conventions Governing Heavy Metals
  - Rotterdam Convention
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## Appendix C

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<th>Prospective CoP Measures</th>
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<td>1</td>
<td>General</td>
<td>Objective</td>
<td>&quot;The objective of this Convention is to protect the human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds.&quot;</td>
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<td>Provisions</td>
<td>Manufacturing processes in which mercury or mercury compounds are used</td>
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<td>Procedural</td>
<td>Provisions</td>
<td>Exemptions available to a Party upon request</td>
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<td>Control</td>
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<td>Contaminated sites</td>
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<td>13</td>
<td>Finance</td>
<td>and Technical Assistance</td>
<td>Financial resources and mechanisms Each party undertakes to provide resources for national activities and actions to reduce site risks shall be performed in an environmentally sound manner. Financial resources for this Convention will be provided by the Global Environment Facility Trust Fund (GEF) and a specific Programme agreed by CoP.</td>
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<td>-</td>
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<tr>
<td>14</td>
<td>Finance</td>
<td>and Technical Assistance</td>
<td>Capacity-building, technical assistance and technology transfer Parties shall cooperate to provide, within their respective capabilities, timely and appropriate capacity-building and technical assistance to developing country parties.</td>
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<td>15</td>
<td>Procedural</td>
<td>Provisions</td>
<td>Implementation and Compliance Committee A mechanism, including a subsidiary CoP Committee shall be established to promote implementation and review compliance with the Convention.</td>
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Note: The text above is a partial transcription of the document. The complete document contains more detailed information.
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<th>Prospective CoP Measures</th>
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<td>16</td>
<td>General</td>
<td>Health aspects</td>
<td>Parties are encouraged to develop and implement strategies to identify and protect at-risk populations from mercury.</td>
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<td>17</td>
<td>Information Provisions</td>
<td>Information exchange</td>
<td>Each party shall facilitate exchange of scientific, technical, economic, legal, and health information regarding mercury.</td>
<td>Requires parties to designate national focal point for exchange of information under this Convention.</td>
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<tr>
<td>18</td>
<td>Information Provisions</td>
<td>Public information awareness and education</td>
<td>Each party shall within its capabilities promote and facilitate provision of information to the public about mercury and the Commission.</td>
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<td>19</td>
<td>Information Provisions</td>
<td>Research, development and monitoring</td>
<td>Parties shall endeavor to cooperate to develop and improve, taking into account circumstances and capabilities, information on use, consumption, and emissions and releases of mercury, and assessments of mercury impact on health and the environment.</td>
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<tr>
<td>20</td>
<td>General</td>
<td>Implementation plans</td>
<td>Parties may develop implementation plans for meeting obligations under this Convention, and may coordinate on common plans.</td>
<td>Parties who develop implementation plans must transmit such plans to the Secretariat.</td>
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<td>21</td>
<td>Information Provisions</td>
<td>Reporting</td>
<td>Parties shall report to the CoP on measures taken to implement Convention and their effectiveness.</td>
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<td>22</td>
<td>Procedural Provisions</td>
<td>Effectiveness evaluation</td>
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<td>CoP shall evaluate effectiveness beginning no later than six years after date of entry into force, then periodically.</td>
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<td>23</td>
<td>Procedural Provisions</td>
<td>Conference of the Parties</td>
<td>CoP is established.</td>
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<td>24</td>
<td>Procedural Provisions</td>
<td>Secretariat</td>
<td>Secretariat is established to arrange meetings and coordinate with and between parties and other international bodies; secretariat functions shall be performed by Executive Director of United Nations Environment Programme unless CoP determines otherwise.</td>
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<td>25</td>
<td>Procedural Provisions</td>
<td>Settlement of disputes</td>
<td>Parties shall settle disputes through negotiation or other peaceful means; if necessary, the CoP may refer such disputes to the International Court of Justice.</td>
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<td>26</td>
<td>Procedural Provisions</td>
<td>Amendments to the Convention</td>
<td>Amendments may be proposed by any party, and adopted in CoP meeting through three-fourths majority vote.</td>
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<td>Procedural Provisions</td>
<td>Adoption and amendment of annexes</td>
<td>Additional annexes shall be considered at procedure.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Procedural Provisions</td>
<td>Right to vote</td>
<td>Each party shall have the right to vote in any regional economic integration organization.</td>
<td></td>
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</tr>
<tr>
<td>30</td>
<td>Procedural Provisions</td>
<td>Ratification, acceptance, approval or accession</td>
<td>Instruments of ratification, etc., shall be deposited with UNEP. Regional economic integration organizations shall declare in writing their acceptance of the Convention in the manner specified by the Commission.</td>
<td></td>
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</tr>
<tr>
<td>31</td>
<td>Procedural Provisions</td>
<td>Entry into force</td>
<td>Convention shall enter into force on the fourteenth day after deposit of the fifth instrument of ratification.</td>
<td></td>
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</tr>
<tr>
<td>32</td>
<td>General</td>
<td>Reservations</td>
<td>Reservations may be made to this Convention.</td>
<td></td>
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</tr>
</tbody>
</table>
## Appendix C (cont.)

<table>
<thead>
<tr>
<th>Article</th>
<th>Type</th>
<th>Source</th>
<th>Substantive Control Measures</th>
<th>Procedural, Monitoring, and Reporting Measures</th>
<th>Prospective CoP Measures</th>
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</thead>
<tbody>
<tr>
<td>33</td>
<td>Procedural Provisions</td>
<td>Withdrawal</td>
<td>Party may withdraw at any time after three years from the date the Convention entered into force, with withdrawal taking effect one year from deposit of the notification of withdrawal.</td>
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<tr>
<td>34</td>
<td>General</td>
<td>Depositary</td>
<td>&quot;The Secretary-General of the United Nations shall be the Depositary of this Convention.&quot;</td>
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<tr>
<td>35</td>
<td>General</td>
<td>Authentic texts</td>
<td>&quot;The original of the Convention, of which the Arabic, Chinese, English, French, Russian and Spanish texts are equally authentic, shall be deposited with the Depositary.&quot;</td>
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<td>-</td>
</tr>
<tr>
<td>Annex A</td>
<td>Control Provisions</td>
<td>Mercury-added products</td>
<td>Specialties mercury-added products covered by Article 4 and their phase-out dates.</td>
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<tr>
<td>Annex B</td>
<td>Control Provisions</td>
<td>Manufacturing processes in which mercury or mercury compounds are used</td>
<td>Specialties manufacturing processes using mercury subject to Article 5 and their phase-out dates.</td>
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<tr>
<td>Annex C</td>
<td>Control Provisions</td>
<td>Artisanal and small-scale gold mining</td>
<td>Specialties components of national action plans created subject to Article 7.</td>
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<tr>
<td>Annex D</td>
<td>Control Provisions</td>
<td>List of point sources of emissions of mercury and mercury compounds to the atmosphere</td>
<td>Specifying relevant sources of mercury emissions to the atmosphere subject to Article 8.</td>
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</tr>
<tr>
<td>Annex E</td>
<td>Procedural Provisions</td>
<td>Arbitration and conciliation procedures</td>
<td>Sets forth arbitration and conciliation procedures pursuant to Article 24.</td>
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<td>-</td>
</tr>
</tbody>
</table>