Engineering the Environment:
Regulatory Engineering at the U.S. Environmental Protection Agency, 1970-1980

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Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
In
Science and Technology Studies

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August 2, 2013
Blacksburg, VA

Keywords: air pollution, control technology, environmental regulation,
regulatory engineering, catalytic converter, scrubber,
U.S. Environmental Protection Agency

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ABSTRACT

My dissertation addresses how engineers, scientists, and bureaucrats generated knowledge about pollution, crafted an institution for environmental protection, and constructed a collective identity for themselves. I show an important shift in regulators' priorities, from stringent health-based standards to flexible technology-based ones through the development of end-of-pipeline pollution control devices, which contributed to the emergence of economic incentives and voluntary management programs. Drawing on findings from archival documents, published sources, and oral history interviews, I examine the first decade of the EPA amid constant organizational changes that shaped the technological and managerial character of environmental policy in the United States. Exploring the EPA's internal research and development processes and their relationship with scientific and engineering communities sheds light on how the new fields of environmental engineering and policy were co-produced in the 1970s.

I argue that two competing approaches for environmental management, a community health approach and a control technology approach, developed from EPA's responses to bureaucratic, geographical, and epistemic challenges. I focus on researchers and managers from the Office of Research and Development at Research Triangle Park, North Carolina, as they were engaged in (1) controversy about integrated aerometry and epidemiology research intended to correlate air pollution and health, (2) intra-agency debate about the government's responsibility for introducing catalytic converters for

tailpipe emissions reduction and responding to the potential environmental and social consequences, and (3) inter-agency activities for the demonstration of scrubbers for smokestack emissions and further application of the control technology approach in energy-related environmental problems.

My principal conceptual contribution is "regulatory engineering." I define regulatory engineering as an approach to sociotechnical problems in which engineering practices are incorporated into regulatory and organizational changes, which in turn influences technical knowledge and identity formation. As EPA activities became closely associated with energy and economic issues toward the end of the 1970s, I argue that engineers took the initiative in demonstrating and evaluating control technologies for pollution abatement and energy development, scientists carefully studied environmental and health effects of these technologies, and regulators set up pollution standards and attainment deadlines accordingly. Studying the co-production of knowledge, institution, and identity through the lens of regulatory engineering helps us to understand technoscientific and managerial aspects of environmental governance beyond the 1970s EPA where technical feasibility considerations, economic incentives, and cooperative management expanded into legislation and regulation.

Acknowledgements

As an advisor, mentor, and friend, Matt Wisnioski has shown me his tireless energy and careful guidance for the entire period from the day I met him at his first course at Virginia Tech to our goodbye lunch at Gillie's. I also appreciate Gary Downey, Saul Halfon, and Mark Barrow for their continuing advice and support. Ann Johnson from the University of South Carolina watched me and my project grow since we first met at Lisbon. Skip Fuhrman generously helped me in finding academic, financial, and life support, and the departmental staff Karen Snider, Crystal Harrell, Doris Shelor, and Carol Sue Slusser have been great in everything from coordinating last-minute submissions to the graduate school to opening Lane 132 multiple times during my last week. Chris Hays was a perfect editor and I hope I can become one for others.

There has been much institutional support outside of my department and every bit of it helped me mature. I benefitted from assistantships from the departments of Engineering Education and of Religion and Culture. The National Science Foundation Dissertation Improvement Grant (SES 1059029) funded my numerous trips to the National Archives, EPA libraries, and interview sites. I was fortunate to get long-term fellowships from the Chemical Heritage Foundation and Linda Hall Library that allowed me to focus on my research and share my results with a broad audience. Michael Gorman provided timely advice for revision of my NSF proposal; Jody Roberts, Ron Brashear, and Carin Berkowitz brightened my days at CHF; and Donna Swischer and Bruce Bradley equally brightened my LHL days.

My dissertation would have taken longer to write if I had not met my interviewees early in my research. I would like to thank them for all their time and willingness to share their histories. Chuck Elkins of the EPA Alumni Association helped me find essential contacts and background information. I also appreciate the regulators and engineers who I met in less formal settings. I would like to thank the following archivists, historians, and librarians who offered invaluable help for my project: Andrew Youngkin, Kezia Procita, Richard Steele, Susan Forbes, and Lisbeth Wells-Pratt (EPA); Ashley Augustyniak (CHF); Nancy Officer, Bill Ashworth, Nancy Green, and Christine Taft (LHL); and Bruce Pencek (Virginia Tech). Furthermore, I really appreciate the generosity of the following institutions and individuals for their permission of oral history interviews and photos: David Caruso at the CHF, Mark Greenwood, and E-Muscle.

Eunsil endured first our long-distance relationship and later seven-day work weeks with and for me. I could not finish a page without her utmost support and understanding. Our son, Aiden, increased our sense of accomplishment the last two years. I am so glad that there are more journeys ahead for the three of us. I developed my love of books and people from my father and mother and hope I can find more time to share with them what I've learned in the near future. The trust and support I received from extended family are greatly appreciated. Occasional conversations with friends, mentors, and colleagues gave me enough energy to survive the next week or month.

Writing two pages has not been easy as my daily goal. When I was stressed, I found relief and reinvigoration from my favorite Korean novelist's assurance that the daily two-page might be easier than I think and no one can write this for me. After hundreds of days and nights, I thought I became familiar with this quota. But it may not be the case. I have my last two pages in front of me. It was still difficult to write and revise. I have an additional concern that it might not be possible to mention all the help that I received for this dissertation and made me who I am. If you think we haven't talked recently, please contact me so I can give you a call or send an email full of joy and energy soon!

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AEC	Atomic Energy Commission
CAAA	Clean Air Act Amendments
CHESS	Community Health and Environmental Surveillance System
CSL	Control Systems Laboratory
DNR	Department of Natural Resources
DOE	Department of Energy, successor of ERDA
EGR	exhaust gas recirculation
EPA	Environmental Protection Agency
EPO	Energy Policy Office
EPRI	Electric Power Research Institute
ERDA	Energy Research and Development Administration, DOE's predecessor
ERDDAA	Environmental Research, Development, and Demonstration Authorization Act
ESECA	Energy Supply and Environmental Coordination Act of 1974
FDA	Food and Drug Administration
GM	General Motors
HEI	Health Effects Institute
HEW	Department of Health, Education, and Welfare
ICS	intermittent control system
IERL	Industrial Environmental Research Laboratory, CSL's successor after 1977
NAAQS	National Ambient Air Quality Standards
NAPCA	National Air Pollution Control Administration
NAS	National Academy of Sciences

NEPA	National Environmental Policy Act
NERC	National Environmental Research Center
NIEHS	National Institute of Environmental Health Sciences
NIOSH	National Institute of Occupational Safety and Health
NSPS	New Source Performance Standards
OALWU	Office of Air, Land, and Water Use
OAQPS	Office of Air Quality Planning and Standards
OEET	Office of Environmental Engineering and Technology
OEMI	Office of Energy, Minerals, and Industry
OHEE	Office of Health and Ecological Effect
OMTS	Office of Monitoring and Technical Support
ORD	Office of Research and Development, ORM's successor after July 1973
ORM	Office of Research and Monitoring, ORD's predecessor
PHS	Public Health Service
RTP	Research Triangle Park
SAB	Science Advisory Board
SOTSEP	Sulfur Oxide Throwaway Sludge Evaluation Panel
TCA	Turbulent Contact Absorber
TVA	Tennessee Valley Authority

Chapter 1. Introduction.

On February 13, 2013, forty-eight people were handcuffed and arrested outside the White House as part of planned civil disobedience by farmers, pastors, scientists, and writers expressing their concerns to President Obama about climate change and the Keystone XL pipeline project. Earlier, in September 2008, the Canadian company TransCanada had applied to the U.S. Department of State for a permit to build a pipeline system from Alberta to Texas to transport tar sands oil. The oil industry and the Canadian government had argued that tar sands were a reliable source of oil that would contribute to the stabilization of the energy supplies and reinvigorate the economy. Critics of Keystone XL, however, were concerned about the impact on groundwater from oil spills, effects on emission levels at refineries in the Gulf Coast, the toll on migratory birds, and greenhouse gas emissions over the pipeline's estimated 50-year lifespan.

Since Keystone XL involved construction and operation of pipelines across national borders, it required a Presidential Permit issued by the Secretary of State as well as an Environmental Impact Statement as dictated by the 1969 National Environmental Policy Act (NEPA).[1] Shortly after the State Department released its draft impact statement in April 2010, the Environmental Protection Agency (EPA)—which was tasked to review the draft impact statement—found that potentially significant effects had not been evaluated, and concluded that the statement was "inadequate." A year later, the State Department responded with a supplemental draft impact statement. The EPA acknowledged the State Department's diligent work, but again expressed "environmental objections." The EPA argued that the new statement provided "insufficient information," and recommended that the State Department improve the

[1] National Environmental Policy Act of 1969, Public Law 91-190, 42 U.S Code 4321-4347.

analysis of oil spill risks and impacts, health impacts, environmental justice concerns, and lifecycle greenhouse gas emissions.[2] After issuing its final environmental impact statement in August 2011, the State Department held public meetings and solicited input from state, local, and tribal officials as well as the general public. During the 90-day public review period, the State Department identified concerns about the Sand Hills region of Nebraska, which in turn sparked a special session of the Nebraska legislature.[3] In February 2012, the State Department denied a permit for Keystone XL, citing the need for information about alternative routes that would avoid environmentally sensitive regions.

Here, it seemed, was a confirmation of the power of the EPA and the success of the farseeing legislation, NEPA, both of which were brought into being amid the national environmental upheaval of the late 1960s and early 1970s. But, in May 2012, TransCanada submitted a new application to the State Department with the intent of changing its route, followed by a similar plan to the Nebraska Department of Environmental Quality. TransCanada also informed the State Department that it intended to proceed with construction of the Gulf Coast portion that does not require a Presidential Permit. Meanwhile, the State Department began a new NEPA process. The State Department issued a draft supplemental environmental impact statement in March 2013, which proclaimed no major environmental impact from the project. In an ongoing bureaucratic dance, the EPA expressed its position about the State Department's impact statement as "environmental objections-insufficient information."[4]

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[2] Paul W. Parfomak et al., *Keystone XL Pipeline Project: Key Issues* (Washington, DC: Congressional Research Service, 2013).

[3] The Sand Hills region in Nebraska is a sand dune formation with highly porous soil and shallow ground water that recharges the Ogallala aquifer.

[4] U.S. Environmental Protection Agency (hereafter EPA), "Letter to Mr. Fernandez and Dr. Jones, Department of State." (April 22, 2013).

The ongoing Keystone XL controversy raises two major dilemmas in the protection of the environment in a technological world: (1) every solution being suggested for environmental issues generates technical and political questions that involve individual and institutional actors, and (2) there is a gap between what the EPA does and what people think it can do. Despite perceptions to the contrary, the EPA is not a monolithic entity—it is made up of scientists, engineers, lawyers, and economists who sometimes disagree with each other. This disagreement is a critical part of work within the EPA, though it is not well-known to the public and sometimes is suppressed by senior leaders of the agency concerned with its image or with anticipated criticism regarding its expertise. The EPA is an independent agency, but not the only one responsible for regulating environmental issues. It maintains a coordinating role among other executive agencies whose main concerns encompass energy, transportation, flood control, health, weather forecast, and space research. Therefore it competes with other actors both in the government and outside it to shape the definition of "the environment." Even inside the EPA, it is hard to define environmental issues separate from energy, economy, and security issues. However, when the EPA is assigned a minor role compared to more powerful actors, like the State Department, environmental issues can become defined narrowly. Lastly, the EPA also works with the White House Council on Environmental Quality and the Office of Management and Budget in developing specific regulations and setting up overall goals for the administration. The White House proactively utilizes its resources and measures to take particular cases in specific directions. When there is a collision between the EPA and other agencies, the President usually has the final say.

The EPA's role in controversial cases like the Keystone XL pipeline project can be illuminated by studying the organization's origin as an independent regulatory agency with research functions, and its relationships with other executive agencies, Congress, and the courts, as well as with state and local actors. The establishment of the EPA as an independent agency came from President Nixon's political move to challenge real or imagined presidential contenders coupled with his advisors' recommendation to revitalize checks and balances among the executive branch. Unlike other regulatory commissions, which often had multiple commissioners, the EPA had a single administrator who directly reported to the President. At the same time, the EPA administrator was mandated to regulate polluters via various environmental laws that painstakingly assigned deadlines and specifically demanded that pollutants be reduced by certain percentages.

Furthermore, we can better review the EPA's accomplishments and limitations in protecting human health and the environment when we consider the fact that EPA administrators' power to negotiate with the President and the Congress depended on the support they received from their scientists and engineers. Since the EPA's establishment in 1970, its researchers have monitored pollutants in the air, water, and lands; identified increasing pollution cases; and suggested emission standards for compliance. They have also developed, tested, and recommended the introduction of technologies for monitoring and control of pollution and sometimes restoration and enhancement of the environment. Through their work, EPA researchers played an important role in promoting and shaping the configurations of environmental science, engineering, and technology. They also lived with regulatory demands from senior management and outside pressures from academic and corporate peers.

The wide spectrum in professional training and work experience among EPA employees, as well as the familiarity they gained with the regulatory process, generated competing ideas and approaches to environmental protection within the EPA itself. In the 1970s, environmental science and engineering were still emerging as academic disciplines and technical practices. Early EPA researchers thus were trained in diverse disciplines such as public health, microbiology, medicine, radiation, and subfields of engineering with a chemical, mechanical, or sanitary focus. In addition to different backgrounds and training, their previous career experience also influenced how these researchers approached environmental issues. Some had accumulated years of experience in the public and/or private sectors, while others had just begun their careers with newly minted college degrees. The wisdom and tacit knowledge of "Oldies" gained from extensive field experience competed with the brave concepts and risky methods of "Newbies." More frequent disagreement happened between researchers who had previously worked for regulatory agencies and those who had not.

In the case of Keystone XL, the EPA's objection to the plan had limited weight because of President Obama's political calculation for a second-term and the State Department's diplomatic leaning toward a reliable energy supply from Canada. Nevertheless, EPA scientists and engineers contributed to the changes and improvements in different versions of the Environmental Impact Statement by fulfilling its NEPA-mandated role of reviewing and commenting on draft statements. In addition, the EPA review led to a change in the pipeline's route and a delay in the project, which provided time for public mobilization. EPA employees' diversity in training and work experience challenged and fortified the EPA's commitment for environmental protection and its adaptation to changing national and international circumstances.

This dissertation explores the early history of the EPA to address how engineers, scientists, and bureaucrats define problems of the environment and establish management regimes by combining technology with regulation. It lies at the intersection of the history of environmentalism, engineering, and regulation. My research offers a detailed examination of the research, monitoring, and regulatory practices in the EPA. It focuses on the agency's first decade, especially the Office of Research and Development (ORD) and its offices and laboratories in Research Triangle Park (RTP), North Carolina, and their efforts to reduce and control air pollution. I explore how differing attitudes toward the role of scientific research in environmental regulation shaped the young agency. I also examine the diverse opinions within the EPA, other government agencies, industry, and academia regarding the federal government's responsibility for introducing new pollution control technologies and responding to their potential environmental and social consequences. Over the course of the dissertation, I show an important shift in the EPA's priorities from stringent health-based standards to flexible technology-based ones through the development of end-of-pipeline pollution control devices, which in turn influenced the emergence of economic incentive and voluntary management programs.

1.1 Background

1.1.1 Environmental Protection as a Technopolitical Systems Challenge

Most scholarly inquiries into the EPA and its performance have emphasized its overtly political and legal aspects.[5] Scientists and engineers, however, developed their own approaches

[5] Bruce Ackerman and William Hassler, *Clean Coal/ Dirty Air: or How the Clean Air Act Became a Multibillion-Dollar Bail-Out for High-Sulfur Coal Producers* (New Haven, CT: Yale University Press, 1981); Robert F. Durant, *When Government Regulates Itself: EPA, TVA, and Pollution Control in the 1970s* (Knoxville: University of Tennessee Press, 1985); Brian J. Cook, *Bureaucratic Politics and Regulatory Reform: The EPA and Emissions Trading* (Westport, CT: Greenwood Press, 1988); Marc Landy, Marc Roberts, and Stephen Thomas, *The Environmental Protection Agency: Asking the Wrong Questions* (New York: Oxford University Press, 1990). However, Mark R. Powell, *Science at EPA: Information in the Regulatory Process* (Washington, DC: Resources for the Future, 1999) is an exception.

to cutting-edge environmental problems.[6] Ecosystem ecologists, for example, established the concept of the environment as consisting of independent yet overlapping systems of air, water, land, and nonhuman species. Sanitary engineers brought their experience with and accumulated data on sewage and wastewater, and mechanical engineers provided advanced knowledge about fluid mechanics and pollution control methods. Monitoring all systems and measuring "total body burden"—how much of a given substance an individual is exposed to whether it comes from air, water, or land—functioned as an organizing principle to find a coherent theme for the new regulatory agency and its engineers and scientists.[7]

Research on EPA scientists' and engineers' shift in focus, from non-human species to human health, will help highlight the technopolitical aspects of environmental protection. This shift in the EPA's first fifteen years, as noted by historian Edmund Russell, suggests that EPA scientists contributed to a transition in research from ecology to cancer as public opinion shifted from safer environment to better health.[8] From the perspective of *engineering*, I want to stress a parallel transition from pollution monitoring to control technology during roughly this same time period. For one, control and management approaches to the environment had important impacts in the transition away from ecology. Decreasing interest in ecology at the EPA was traded for a growing interest in environmental engineering and technology transfer to the nascent

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[6] Jeffrey Stine, "Regulating Wetlands in the 1970s: U.S. Army Corps of Engineers and the Environmental Organizations," *Journal of Forest History* 27, no. 2 (1983): 60-75; Samuel Hays, *A History of Environmental Politics Since 1945* (Pittsburgh, PA: University of Pittsburgh Press, 2000).

[7] Joel A. Tarr, *The Search for the Ultimate Sink: Urban Pollution in Historical Perspective* (Akron, OH: University of Akron Press, 1996); Stephen Bocking, *Ecologists and Environmental Politics: A History of Contemporary Ecology* (New Haven, CT: Yale University Press, 1997).

[8] Edmund Russell, "'Lost Among the Parts Per Billion': Ecological Protection at the United States Environmental Protection Agency, 1970-1993," *Environmental History* 2 (January 1997): 29-51.

environmental technology industry.[9] Moreover, because on-the-spot monitoring of pollutants was restricted by limited budget and personnel, enforcement capacity of the EPA depended largely on the review of compliance plans from industry.[10] New technologies to control emissions, to reduce discharges, and to process toxic substances were designed, developed, and tested in research laboratories at the EPA. The EPA's framing of the environment as a technopolitical system has remained untold but is important to the agency's identity formation and its subsequent environmental policy.

1.1.2 Engineers as Moderate Environmentalists

Because early environmentalism in the United States was often framed as a critique of and an alternative to capitalism and industrialism, scholars have devoted early attention to the radical aspects of American environmentalism.[11] This approach has produced a well-informed, insightful evaluation of conceptual changes and conflicts; however, it has paid insufficient attention to reformist and moderate environmentalists. Although these environmentalists were not as well organized and attracted less media coverage, some of them stayed on and became parts of a new face of environmentalism: sustainable development.

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[9] National Industrial Pollution Control Council, *The Engineer's Responsibility in Environmental Pollution Control: Sub-Council Report* (Washington, DC: Government Printing Office, March 1971).

[10] For more examples, see EPA, *Environmental Protection Agency's Monitoring Programs* (Washington, DC: EPA, Office of Research and Development, 1973); Richard F. Hirsh, Technology and Transformation in the American Electric Utility Industry (New York: Cambridge University Press, 1989).

[11] Hal Rothman, *The Greening of a Nation?: Environmentalism in the United States Since 1945* (New York, NY: Harcourt Brace College Pub., 1998); Jeffrey Stine and Joel A. Tarr, "At the Intersection of Histories: Technology and the Environment," *Technology and Culture* 39, no. 4 (1998): 601-40; Robert Gottlieb, *Forcing the Spring: The Transformation of the American Environmental Movement* (Washington, DC: Island Press, 1993).

Engineers have played an important, but frequently overlooked, role in American efforts to tackle environmental problems. Here I include as engineers diverse groups of physical and chemical scientists, computer specialists, health specialists, as well as sanitary, mechanical, and chemical engineers and technicians. By focusing on engineers and engineering practices, my dissertation highlights often technocratic and sometimes conservative visions of environmental protection that have largely been ignored by scholars. It also partially reveals engineers' differing attitudes toward the role of technology in dealing with nature and toward their position in society in 1970s America.[12]

In its early days, not many of the career engineers and scientists in the EPA were self-professed environmentalists. Most came to the agency with some interest in the environment, but their approaches often originated from the extension of existing technical methods to the new subject, "the environment." Early environmental engineers, for example, normally maintained dual membership and identity in environmental engineering and in mechanical, chemical, or even nuclear engineering. However, once they became part of the EPA team, they increased their interest in and passion for environmental protection. The process through which the new regulatory agency influenced the identity of their employees is one of the questions I want to answer. Even when some EPA careerists moved to other governmental, corporate, or independent consulting positions, they showed continued engagement with their former coworkers, retaining parts of their identity. These flows of people and identity, I argue, reinforce the need to extend the boundary of American environmentalism to include more technological, bureaucratic, and conservative elements.

[12] Donna Riley, *Engineering and Social Justice* (San Rafael, CA: Morgan & Claypool, 2008).

A smaller group of EPA engineers and scientists, however, went beyond their traditionally defined roles and showed more enthusiasm for environmental issues. They were also more likely to become involved with other related social issues in the 1970s. Two of these engineers, chemical engineer John Moran and radiation specialist Delbert Barth, play an important role in my account. Moran, who began his EPA career developing tailpipe emission criteria, came to oppose the agency's official opinion on catalytic converters because of a concern about their environmental effects. After his disagreement with other EPA regulators, he moved to another executive agency, where he researched workers' health and safety issues. Barth, an EPA specialist on radiation health, expanded his expertise to monitoring and research of environmental and health effects but came into conflict with other EPA colleagues who focused more on the development of pollution control technologies in order to deal with growing energy production.

Discovering how these engineer-environmentalists conflicted and cooperated with each other will help us understand engineers' quest for professional identity in the EPA and the new challenges coming from competing solutions to environmental problems. Previous studies on the professionalization of experts provide important guidelines for my research. Edwin Layton and David Noble showed the role of ideology in engineers' mobilization for social responsibility and against corporate capitalism, respectively. Michael Egan, Michelle Murphy, and Matthew Wisnioski connected engineers' and scientists' practices beyond their workplaces with broader social and cultural trends in American life.[13]

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[13] Edwin T. Layton, *The Revolt of the Engineers* (Baltimore, MD: Johns Hopkins University Press, 1973); David Noble, *America by Design: Science*, *Technology and the Rise of Corporate Capitalism* (New York: Knopf, 1977); Michael Egan, *Barry Commoner and the Science of Survival: The Remaking of American Environmentalism* (Cambridge, MA: MIT Press, 2007); Michelle Murphy, "Uncertain Exposures and the

Environmental engineering in the United States emerged from professionalization efforts of practitioners and educators from sanitary engineering, chemical engineering, public health, and microbiology in the 1950s and 1960s. Sanitary engineers, for example, sought out institutional support, first from the Public Health Service and later from the EPA, to establish well-designed degree programs for research and teaching.[14] Engineers originally sought the accreditation of the curriculum and certification of individuals for autonomy and self-promotion. Later they increasingly relied on the authority of state and federal governments.[15] Funding for education and research as well as expanded opportunities for employment with subsidies and benefits were more direct ways for the government to support engineers.

My research will contribute to the understanding of different career trajectories of individual practitioners in the nascent fields of environmental science, engineering, and management in the 1970s. Finding what made their professional views separated from or

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Privilege of Imperception: Activist Scientists and Race at the U.S. Environmental Protection Agency," Osiris, 2nd series, 19 (2004): 266-282; Matthew H. Wisnioski, *Engineers for Change: Competing Visions of Technology in 1960s America* (Cambridge, MA: MIT Press, 2012).

[14] American Sanitary Engineering Intersociety Board, *Sanitary Engineering Education Directory: Schools Offering Graduate Work and Roster of Instructors* (New York: ASEIB, January 1960); Jane C. Klosky, ed., *Register of Environmental Engineering Graduate Programs* (Austin, TX: Association of Environmental Engineering Professors, 1974).

[15] For example, on October 21, 1955 the American Sanitary Engineering Intersociety Board started as an umbrella organization of sanitary engineering-related societies and associations sponsored by the American Society of Civil Engineers, American Public Health Association, American Society for Engineering Education, American Water Works Association, and the Federation of Sewage and Industrial Wastes Associations. The intersociety board identified certified sanitary engineers as 'diplomates' and maintained the roster named 'American Academy of Sanitary Engineers.' On the early history of the board and more information on board members, officers, and sponsoring organizations as well as certificate of incorporation and bylaws, see "Plans for Certification Progressing," *Journal of the Sanitary Engineering Division* 82, no. SA1, 1956-5 (February 1956): 10-12.

intermingled with social and political visions will also deepen our understanding about more recent concerns of engineers and scientists in our contemporary society, where the level of interactions have skyrocketed and ethical and legal questions are more often raised.

1.1.3 Regulators as Technology Policymakers

Previous research on regulation has focused on big concepts such as regulatory capture, command-and-control, and deregulation. These scholars have highlighted regulators' relationships with the regulated, the White House, and other branches of government.[16] In other words, they focused on the life cycle of regulation: how regulators decided what to regulate, how categories of regulation have changed, and the effects of those conceptual changes on the relationships between various actors.

As "new" social regulations emerged and voluntary regulations complemented traditional regulations in the 1970s, some scholars of regulatory politics and law shifted their eyes to governance practices and management attitudes.[17] They gave a new look at the close relationship between regulation and innovation and found that stringent environmental regulation does not

[16] George J. Stigler, "The Theory of Economic Regulation," *The Bell Journal of Economics and Management Science* 2, no. 1 (1971): 3-21; James Q. Wilson, ed., *The Politics of Regulation* (New York: Basic Books, 1980); R. Shep Melnick, *Regulation and the Courts: The Case of the Clean Air Act* (Washington, DC: Brookings Institution, 1983).

[17] Richard Harris and Sidney Milkis, *The Politics of Regulatory Change: A Tale of Two Agencies* (New York: Oxford University Press, 1989); Kenneth R. Richards, "Framing Environmental Policy Instrument Choice," *Duke Environmental Law Policy Forum* 10, no. 2 (2000): 221-286; Christopher Carrigan and Cary Coglianese, "The Politics of Regulation: From New Institutionalism to New Governance," *Annual Reviews of Political Science* 14 (2011): 107-129.

constrain technology choices; rather it drives the development and deployment of environmental technologies, and therefore spurs innovation.[18]

Broadening the definition of regulators to include engineers, physicians, and scientists who contribute to the policymaking process provides new insight into this aspect of the EPA's history. I draw from historians of technology who reviewed federal regulation cases involving complex technological systems.[19] Tracing the origins of political engagement between regulators and researchers from government laboratories to corporate proving grounds, my work highlights the institutional backgrounds of current environmental policy and uncovers its "invisible hand" in remedying market and government failures. In my dissertation, I trace the dynamics between technical experts and bureaucrats in the EPA and analyze the subsequent assemblage of engineering and regulation.

My research thus adds significant new knowledge about engineers' identity formation, federal policymaking, and environmentalists' ongoing struggles. By underscoring the boundaries

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[18] Nicholas Ashford, Christine Ayers, and Robert Stone, "Using Regulation to Change the Market for Innovation," *Harvard Environmental Law Review* 9, no. 2 (1985): 419-466; Alan Irwin and Philip Vergragt, "Re-thinking the Relationship between Environmental Regulation and Industrial Innovation: The Social Negotiation of Technical Change," *Technology Analysis & Strategic Management* 1, no. 1 (1989): 57-70; Michael E. Porter, "America's Green Strategy," *Scientific American* 264, no. 4 (1991): 96; Margaret R. Taylor, *The Influence of Government Actions on Innovative Activities in the Development of Environmental Technologies to Control Sulfur Dioxide Emissions from Stationary Sources*, Ph.D. Dissertation, Carnegie Mellon University, 2001.

[19] John G. Burke, "Bursting Boilers and the Federal Power," *Technology and Culture* 7, no. 1 (1966): 1-23; Lee J. Vinsel, *Federal Regulatory Management of the Automobile in the United States, 1966-1988,* Ph.D. Dissertation, Carnegie Mellon University, 2011; Ann Johnson and Richard Chase Dunn, "Chasing Molecules: Chemistry and Technology for Automotive Emissions Control," *Toxic Airs: Chemical and Environmental Histories of the Atmosphere*. Edited by James Fleming and Ann Johnson (Pittsburgh: University of Pittsburgh Press, in press).

where pollution control technologies and engineering practices intersect with political and regulatory measures in the federal bureaucracy, my work contributes to an understanding of decisions about the uses of technology in environmental protection and social regulation.

1.2 Approaches of the Dissertation

1.2.1 Regulatory Engineering

Environmental engineering as a field gained its legitimacy among the engineering profession more broadly due to its service in the EPA and its mediation between government and industry. Environmental engineering not only provided data and analysis for regulation, it also shaped the implementation of specific standards, including identification and classification of the subject, selection of enforcement methods, and evaluation of compliance plans.

The notion of co-production as developed by Sheila Jasanoff explains how scientific and social orders are created, stabilized, and altered through constant interaction. Jasanoff argues that controversial environmental regulation cases exemplified the emergence of new "regulatory science," which conforms to agency guidelines and is accountable to Congress, courts, and media as well as professional peers. Jasanoff contrasts "regulatory science" with "research science," which ideally adheres to scientific conventions of statistical significance and peer review. Alan Irwin and his colleagues blur the boundary between regulatory and research sciences and propose that the uncertain and indeterminate characteristics of regulatory science are in fact the nature of "normal" scientific activity. Using a case of UK regulation of agrochemicals, they argue that the hybrid and heterogeneous nature of regulatory science can explain more about key scientific and institutional challenges to contemporary science. [20]

In brief, Jasanoff's "regulatory science" is a helpful category to lay out new types of scientific practices within the federal regulatory agencies, but her description of it as a marginal activity of science, when contrasted with what she considers the more normal counterpart, research science, is problematic because her definition might result in placing research science on an epistemologically superior plane. Irwin and his colleagues further developed this concept of regulatory science in which they describe and analyze scientific and regulatory activities that become more mainstream as regulatory decisions increasingly pertain to uncertainties and indeterminacies.

I find that the concept of regulatory science is relevant to analyzing scientific activities that were increasingly related to health and environmental issues in the EPA. Scientists took the initiative by monitoring pollution and health. Regulators depended on science to set standards, establish and enforce regulations, and legitimize their place in the new field of environmental protection. Engineers supported science and regulation by developing and testing new technologies and maintaining databases.

Regulatory science is also potentially helpful for explaining how engineering practices were incorporated into regulatory measures and how regulation and policy guided the direction and speed of the development of environmental engineering. Environmental engineering was legitimized by the regulatory process that required expert advice. The co-production of

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[20] Sheila Jasanoff, *The Fifth Branch: Science Advisers as Policymakers* (Cambridge, MA: Harvard University Press, 1994). Especially 61-83; Alan Irwin et al., "Regulatory Science: Towards A Sociological Framework," *Futures* 29, no. 1 (1997): 17-31.

engineering and regulation in the EPA facilitated the generation of new knowledge, culture, and identity for the new agency.[21]

Nonetheless, while the notion of co-production has been helpful in tracing the engineers' and regulators' thoughts and activities and revealing their intermingled origins and complicated trajectories, I have come to see an alternative term, "regulatory engineering," as crucial for understanding the *product* as well as the process aspects of environmental engineering. In my case studies on the EPA's research and pollution control, I found a shift toward the end of the 1970s. Findings from archives, published documents, and interviews with mid-level engineers, scientists, and managers, enable me to argue that "regulatory engineering" is a useful concept to analyze EPA activities as they became closely associated with energy and economic issues. I define "regulatory engineering" as an approach to sociotechnical problems in which engineering practices are incorporated into regulatory and organizational changes, which in turn influences technical knowledge and identity formation.

In studying the science-engineering-regulation relationship of the late 1970s, my emerging concept of regulatory engineering seemed a clearer, more powerful explanation of that relationship. Engineers took the initiative in developing, demonstrating, and evaluating control technologies and contributed to the inclusion of technical feasibility in regulatory decisions. In other words, EPA regulators set up pollution standards and attainment deadlines according to new technology-based standards like "best available technology," "best practical technology," or "reasonably available control technology." Health and ecological research became

[21] Sheila Jasanoff, ed., *States of Knowledge: The Co-Production of Science and Social Order* (New York: Routledge, 2004); Brendon Swedlow, "Cultural Coproduction of Four States of Knowledge," *Science, Technology, & Human Values* 37, no. 3 (2007): 151-179; Peter Dear and Sheila Jasanoff, "Dismantling Boundaries in Science and Technology Studies," *Isis* 101, no. 4 (2010): 759-774.

supplementary to technological development or regulatory demand. Scientists carefully followed to make sure these control technologies and regulations did not generate serious environmental and health effects. Increasingly, federal employees became involved in the incorporation of scientific knowledge into development, testing, and demonstration of pollution control technologies. Thus, as a descriptive term, regulatory engineering has an advantage over regulatory science because it better reflects the shift in environmental regulation toward control technology.

"Regulatory engineering" can also analyze complicated relationships between government, industry, and scientific/engineering communities. When academics and industry challenged the EPA's science on pollution-health links or related technology for air pollution control, federal science and technology policy was also dismantled. The notion that experts exercised technical knowledge for the best policymaking became dubious as the boundary between "research science" and "regulatory science" or between fact-finding and regulation support became blurred. The rise of the "control technology" approach, which I look at in detail in chapters 4 and 5, clearly shows why previous efforts to define new practices as a new type of science were not very productive. Instead, I use the concept of regulatory engineering as a way to emphasize the co-production process where the development of devices to tackle environmental problems influenced and was influenced by the stabilization of ideas to manage and control individual, household, and industrial activities: Which car to buy? Where to move when relocating? What type of fuel to use for heating?

Ultimately, "regulatory engineering" allows us to see how those earlier efforts to monitor and control the polluted environment played a part in shaping the American system of environmental protection in the form of a technology-based regulation regime. Environmentalists might get the impression from my dissertation that not much has changed after the enormous investment of resources to deal with environmental problems during the last fifty years. While acknowledging previous accomplishments, I also want to point out that the current technological and managerial approaches in environmental policy have limited the possibility of reshaping society's energy consumption by foreclosing other alternatives.

1.2.2 Research Methods

In writing the history of the EPA's first decade, I draw on findings from archival documents, published sources, and oral history interviews. I captured the core of the agency's early history at the National Archives and Record Administration at College Park, Maryland; found additional documents at the libraries and repositories at RTP and in Las Vegas, Nevada, as well as oral history interview transcripts at the Chemical Heritage Foundation; located online resources from the Public Health Service's Engineer Professional Advisory Committee; and relied on a number of academic journals. I conducted ten face-to-face interviews with current and former EPA employees and visited or talked on the phone with additional managers and engineers from private and public sectors to create a lively portrait of the 1970s EPA.

Archival research provided groundwork for other forms of inquiry and became a source of insight throughout. I extensively reviewed the ORD's records at the National Archives, College Park. Most ORD records were administrative in character and required me to become familiar with the style of government documents. Prioritization proved difficult but critical when information affluence was the problem. Through reading secondary sources and conducting preliminary searches, I found three shortcuts for faster navigation through the morass of surviving government documents. First, establishing my own timeline of the cases that I wished to study and obtaining and improving organizational charts provided essential entry points. Second, following actors and small units often helped me narrow down the scope of my search. Lastly, when I found controversial topics where actors and resources were heavily involved, I realized that I was ready to start a narrative. However it was almost impossible not to take a look at other related documents, and these detours sometimes proved helpful in retrospect. For example, enforcement records of the automobile emissions hearings helped me understand that there were several EPA laboratories that conducted mobile air pollution monitoring, testing, and research activities. I also looked at the EPA's records outside of the ORD to locate documents from the other side of ORD negotiations; an ORD document I had been looking for turned up in the records of the Office of Air, received by them and kept there for the federal records.

My research on the EPA has contributed to the preservation and increased accessibility of its historical material. In the early 2000s the Office of History of the EPA closed its door. Its historical document collection at the EPA headquarters remained intact, but the collection was moved to be a storage repository, only known to a couple of staff and untouched by researchers. Once I requested boxes of documents that interested me, librarians went through a lengthy process to give me permission to review them. The library staff is now in the process of re-cataloging the collection as resources become available.

Oral history provides a way to capture voices and memories from underrepresented individuals and groups. The oral history interview primarily focuses on preserving and recording the narratives of interviewees and is composed of one or more sessions of interviews, normally lasting a few hours. It is different from the journalistic interview, where the main mission is publicity and commentary. The oral history interview also differs from ethnography, in which the ethnographer immerses him/herself in the culture being studied for extended time periods to keep written records of verbal and non-verbal communications. Oral history is most effective when it provides direct testimony about forgotten events and raises fundamental questions about what is worth "writing" about in history. It also provides insight into how historians review and select evidence.[22]

In planning and conducting the interviews for my dissertation project, I made two observations about why oral history interviews, along with research of archival and published records, can be effective. First, I found the oral history interviews were a good way to gather additional information and they provided helpful guidelines about technical details and the bureaucratic machine. While archival and published documents helped me to situate myself among the contemporary discourse about environmental issues during the 1970s, I always found interviewees had more to add to my understanding of specific events, people, organizations, or the overall climate. At the same time, it was also challenging to understand and translate esoteric terms that technical professionals and bureaucrats used. In my dissertation, I tried to either use alternate terms that are more accessible to readers or to define terms at first use.

Second, I assumed that government officials have had limited freedom of expression in sharing their personal or professional opinions about controversial issues. EPA employees that I interviewed were generally no different. Some current employees expressed reluctance in sharing their opinions. Most former employees didn't mind sharing them except in one case. It was my intention to not pressure my interviewees to speak about something they did not feel comfortable with. In some occasions, I listened to their opinions 'off-the-record' and used what was shared as

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[22] Thomas L. Charlton, Lois E. Myers, and Rebecca Sharpless, eds., *Handbook of Oral History* (Lanham, MD: Altamira Press, 2006); Jonathan Skinner, ed., *The Interview: An Ethnographic Approach* (New York: Berg, 2012).

background knowledge. In other cases, I asked my questions through email correspondence when we developed more understanding of the project and each other.

To locate potential interviewees, I first relied on archival and published sources to establish a candidate pool; I narrowed down this pool to those for whom I could find updated information using keyword searches online. To compensate for the small size of the pool that emerged, I used snowball sampling, where agreeable interviewees introduced future interview candidates from among their acquaintances.[23] Combining these methods, I interviewed ten current and former EPA employees (table 1.1).

Name	***Gender***	***Specialization***	***Time***	***Place***
Allan Marcus	M	Statistics	Jan. 4, 2011	Research Triangle Park, North Carolina
Frank Princiotta	M	Chemical engineering/management	Jan. 5. 2011 Mar. 15, 2012	Research Triangle Park
John Vandenberg	M	Health science/management	Jan. 5, 2011	Research Triangle Park
Ann Pitchford	F	Geophysics	Feb. 9, 2011	Las Vegas, Nevada
Tammy Jones-Lepp	F	Analytical chemistry	Feb. 10, 2011	Las Vegas, NV
Delbert Barth	M	Health science	Feb. 10, 2011	Henderson, Nevada
Mike Moore	M	Management	Mar. 9, 2011	Washington, DC
Anonymous	M	Not disclosed	Nov. 18, 2011	Not disclosed
John Bachmann	M	Chemistry/management	Mar. 14, 2012	Research Triangle Park
Eric Stork	M	Management	June 6, 2012	Arlington, Virginia

Table 1.1 List of Oral History Interviewees

[23] Patrick Biernacki and Dan Waldorf, "Snowball Sampling: Problems and Techniques of Chain Referral Sampling," *Sociological Methods & Research* 10 (1981):141-163; John W. Creswell, ed., *Qualitative Inquiry & Research Design: Choosing among Five Approaches* (Thousand Oaks: Sage Publications, 2007).

Based on archival, published, and oral sources, I focused on three case studies out of numerous EPA projects and activities: 1) the Community Health and Environmental Surveillance System—an air pollution monitoring and epidemiology research project; 2) catalytic converters and mobile air pollution research, evaluation, and regulation; and 3) scrubbers and stationary air pollution research, demonstration, and regulation. Most of all, the selection of the three case studies provides us with a chance to explore the diverse relationships that ORD researchers had with EPA regulators, other bureaucrats, and corporate and academic peers. I held that detailed information about regulatory engineering practices at the ORD would provide a better understanding of the EPA's core activities during its first decade. In addition to these diverse relationships that ORD researchers had, the three cases show diverse technopolitical interactions ranging from intra-agency debate, inter-agency cooperation, and nationally known controversy about topics that involved the ORD at the center. As a result, these case studies let us understand the process of co-production where planning, execution, and evaluation of research, demonstration, and development activities are convoluted with the negotiation and rule-making process at Capitol Hill and the White House.

1.2.3 Organization of the Dissertation

During its first decade, the EPA's researchers became as accountable to Congress and elite scientific communities as to their peer regulators. The agency's research priority shifted from setting up health-based standards for pollution reduction at the sources to developing "control technologies" for the end-of-pipeline treatment of pollution. I argue that the fall of "community health" and the rise of "control technology" approaches explain the gradual replacement of pollution abatement and health surveillance with technology development and economic incentives.

Among various units of monitoring, research, and development of the ORD during the 1970s, I focus on laboratories at RTP because the area has interesting characteristics to answer my questions. First, environmental research at RTP predated the establishment of the EPA in 1970, so my research provides a chance to see how the EPA incorporated and expanded existing research capacities at that site. Second, air pollution researchers and regulators were put together at RTP, and I anticipated finding interesting outcomes generated by this geographical proximity. Third, the RTP research facility also had other federal and private research and testing laboratories and manufacturing firms, which created peculiar dynamics at the site.

In chapter 2, I illustrate how competing ideas and conflicting interests shaped the early EPA's organization and practice, what challenges the EPA faced, and how the agency responded. Chapter 3 explores how controversies over the design and execution of an air pollution-respiratory disease study ballooned into an agency investigation and a Congressional hearing that led to an internal reorganization of the EPA. The focus in chapter 4 is automobile emissions control, specifically the role of catalytic converters and their possible health risks, which played out through an intra-agency debate between two groups of engineer-regulators, oriented toward "community health" versus "control technology." In chapter 5, I focus on the development of scrubbers to reduce emissions from coal-burning power plants and the expansion of the "control technology" approach in a federal interagency program. In chapter 6, I end with an account of how studying regulatory engineering is an effective tool for understanding the co-production of knowledge, identity, and institution and how governance of the environment became more technology-based from the 1980s onward.

Close examination of the environmental protection activities at the EPA provides a chance to reconsider the relationship among environmental regulation, health research, and pollution control technology during the 1970s. In the following chapters, I look at accomplishments and limitations of air pollution monitoring, health effects research, and end-of-pipeline emission control technologies with a particular focus on diverse approaches that co-existed within the EPA. This work offers insight into how technical professionals establish their credibility and boundaries, and why solutions to environmental problems themselves often generate new technical and social challenges.

Chapter 2 Establishing and Managing the Federal Environment, 1969-1973

"Despite its complexity, for pollution control purposes the environment must be perceived as a single interrelated system … a single source may pollute the air with smoke and chemicals, the land with solid wastes, and a river or lake with chemicals and other wastes."[1]

-President Richard M. Nixon

Signing the National Environmental Policy Act on January 1, 1970, President Richard M. Nixon expressed his eagerness to push environmental issues to the forefront of the nation's agenda: "[The 1970s] absolutely must be the years when America pays its debt to the past by reclaiming the purity of its air, its waters, and our living environment." He also added a sense of urgency: "It is literally now or never."[2] Through public hearings and research reports, activists and scientists had proven that smog was not limited to Los Angeles and had become a national health problem. At the same time, local authorities found insufficient resources to meet growing public demands for quality drinking water and sewage plants. Although legislators responded by enacting (and later amending) the Clean Air Act and the Clean Water Act, federal efforts remained limited. To make things worse, some federal institutions, such as military bases and research centers, were not complying with the very statutes that the federal government sought to enforce on the states. Recurring pollution episodes alerted activists and intellectuals, who mobilized a concerned public. Senator Gaylord Nelson (D-WI) organized the first Earth Day on

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[1] U.S. Congress. House. Committee on Government Operations, "Message of the President Relative to Reorganization Plans Nos. 3 and 4 of 1970," 91st Cong., 2nd sess. (July 9, 1970).

[2] Richard M. Nixon, "Statement About the National Environmental Policy Act of 1969" (January 1, 1970).

April 22, 1970. Nixon responded with Reorganization Plan No. 3 in July, and in December created the EPA, an organization designed to monitor and protect the federal air, water, and land wherever pollution occurred.

It is now common knowledge that President Nixon was not so much interested in environmental protection as he was with his reelection. He realized that his political actions on environmental issues would decrease his contenders' advantage. So Nixon took preemptive action to attract environmentally concerned voters because he wanted to challenge potential Democratic presidential candidates, including Senator Edmund "Mr. Clean" Muskie (D-ME). The activist and lawyer Ralph Nader and his group embarked on a research program regarding the safety and emissions of cars and put pressure on Muskie to become more active in environmental legislation, and therefore influenced Nixon to take the initiative in creating the new environmental agency.[3]

But, why should the federal government need a new separate unit for environmental protection? Under what circumstances did regulators gain momentum to take on powerful polluters? How did the idea that technology was the main cause of pollution influence legislative and regulatory activities? What was the guiding principle to structure diverse functions of monitoring, research, development, enforcement, and regulation?

Establishing the EPA as a new regulatory agency depended on the idea of the separation of promotion and regulation in the government's executive branch; if the Agriculture or Interior departments had been less effective in regulating pesticides or protecting the nation's waterways, the new department with sole responsibility to regulate would be more effective. At the same

[3] Lynn G. Llewellyn and Clare Peiser, "NEPA and the Environmental Movement: A Brief History," in *Managing the Environment*, EPA, 109-129 (Washington, DC: EPA, Office of Research and Development, Washington Environmental Research Center, November 1973).

time, the EPA needed to support its regulation with cutting-edge science and efficient technology through the Office of Research and Monitoring (ORM), a separate office for monitoring, research, development, and demonstration. Not everything worked out as planned though. The EPA often came into conflict with other executive agencies and the White House over authority and procedure during the rule-making process. Soon the ORM scientists and engineers accepted their dual duties of conducting basic, long-term research projects and applied, short-term studies for enforcement actions. The doubled layer of separation—EPA's separation from other agencies and ORM's separation from the rest of the EPA—pushed the ORM to become closer to the research units of other agencies, including the new Department of Energy after 1977, and to academic counterparts. I look at this tension between the independent regulatory agency and its supporting research units in the following chapters.

This chapter focuses on organizational and epistemic rationales for the EPA by focusing on the challenges its administrators, researchers, and regulators encountered in the wake of Nixon's directive. First I look at the birth of the EPA, exploring how competing ideas and conflicting interests shaped the agency's organization and practice at its various offices and programs. Specifically, I look at two major hurdles for the EPA in its early days: defining pollution research in the federal setting and establishing the agency's research network. Second, to better understand this particular construction of the EPA's regulation and research, I show how the EPA regulators and researchers responded to organizational and epistemic challenges by using combinations of two approaches: a "community health" approach and a "control technology" approach. I define these two approaches and contrast their priorities and foci with relevant examples. Reviewing administrative, political, and technical contexts of the making of the EPA in this fashion will provide background for understanding subsequent changes in environmental regulation and research at the EPA.

2.1 The Road to a New Regulatory Agency

The rise of environmentalism was one of many changes in the social and political landscape of the 1960s and 1970s. Scholars have studied this seemingly sudden increase of environmental thoughts, actions, and institutions and have pointed out many long-term factors that contributed to the making of modern environmentalism. Major pollution episodes certainly marked important turning points. The oil spill in the Santa Barbara Channel in January 1969 coated miles of waterways and beaches with crude oil. Numerous waterfowl and other aquatic life were killed. Mass media coverage of this sticky situation at Santa Barbara invited widespread attention to other ecological problems. Increasing public concerns about environmental degradation around the mid-1960s coincided with growing media coverage, recurring pollution episodes, and sporadic executive campaigns and legislative initiatives.[4]

These explanations are helpful for understanding broadly *why* the EPA was created, but are insufficient to explain exactly *how* the EPA was created and thus cannot fully explain the significant consequences of the EPA's making. In this section, I will look at how the staff members of one White House council built early visions of the agency and how Nixon responded

[4] Llwellyn and Peiser, "NEPA and the Environmental Movement"; J. Clarence Davies and Barbara S. Davies, *The Politics of Pollution* (New York: Western Publishing Co., 1970); Kirkpatrick Sale, *The Green Revolution: The American Environmental Movement, 1962-1992* (New York, NY: Hill and Wang, 1993); Samuel Hays, *Beauty, Health, and Permanence: Environmental Politics in the United States, 1955-1985* (Cambridge, MA: Cambridge University Press, 1987); Gottlieb, *Forcing the Spring*; Paul Charles Milazzo, *Unlikely Environmentalists: Congress and Clean Water, 1945-1972* (Lawrence, KS: University Press of Kansas, 2006).

to diverse opinions from various executive departments during the negotiation process through which the EPA was founded.

Environmental issues soon caught the Nixon administration's attention. In 1969, John Ehrlichman, Chief Domestic Advisor of the White House, organized a task force in the Domestic Council, the White House staff group. John C. Whitaker, Ehrlichman's aide, directed the task force to prepare the President's Message on the Environment, which Nixon delivered on February 10, 1970. Nixon proposed that federal environmental protection and natural resource programs should be combined in one department. Earlier, in his State of the Union address in January, he had emphasized the urgent need to restore nature to its natural state and called for bipartisan efforts to prevent possible environmental disaster. However, Nixon's February message was more direct and concrete. It used ecological concepts and described humans as "space voyagers on spaceship earth."[5]

In a follow-up report, the task force recommended establishing a Department of Natural Resources (DNR). The new department would replace the Department of the Interior and absorb the U.S. Forest Service, Soil Conservation Service, U.S. Army Corps of Engineers, and other pollution control units.[6] President Nixon established the President's Advisory Council on Executive Organization and appointed Roy Ash, a former head of Litton Industries, as the chairperson. The Ash Council, as it was soon called, had three groups of aides: the energy and

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[5] Alfred Marcus, *Promise and Performance: Choosing and Implementing an Environmental Policy* (Westport, CT: Greenwood Press, 1980), 31-32. Other members of the task force were John Quarles, Roger Sterlow, John Buckley, and Alvin Alm. Both Quarles and Alm later served in the EPA as Deputy Administrator.

[6] Landy, Roberts, and Thomas, *The Environmental Protection Agency*, 31.

mineral resources group, the renewable resources group, and the environmental protection group.[7]

The environmental protection group of the Ash Council took a major role in the EPA's creation. Its five staff members were three Ash Council employees, Douglas Costle, Victoria Pohle, and Eric Rubin, as well as Wilson Talley and J. Clarence Davies. Costle was an attorney who worked at the Departments of Justice and Commerce. Talley was a nuclear engineer who taught at the University of California, Davis, and served as special assistant to the Secretary of Health, Education, and Welfare. Davies was a political science professor at Princeton University and former Bureau of Budget staff.[8] This group of five opposed the creation of the proposed new Department of Natural Resources. They argued that Congress would not accept the enormous change in the committee jurisdictions. They further argued that resource development and

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[7] The Ash Council's recommendation was also critical in the expansion of the Bureau of Budget to the Office of Management and Budget. It is noteworthy that the Nixon administration's efforts to reorganize its executive agencies resulted in formalizing discussions between the White House and the EPA on environmental regulation by the establishment of the Office of Management and Budget.

[8] Marcus, *Promise and Performance*, 34; Marcus, "EPA's Organizational Structure," *Law and Contemporary Problems* 54, no. 4, Assessing the Environmental Protection Agency after Twenty Years: Law, Politics, and Economics (1991): 5-40; President's Advisory Council on Executive Organization, "Memorandum for the President: Federal Organization for Environmental Protection" (April 29, 1970); EPA, *Douglas M. Costle Oral History Interview*, Interview by Dennis Williams (Washington, DC: EPA, EPA History Program, 2001); Chemical Heritage Foundation, *The Toxic Substances Control Act: From the Perspective of J. Clarence Davies*, Interview by Jody A. Roberts and Kavita D. Hardy at Resources for the Future, Washington, DC, October 30, 2009 (Philadelphia: Chemical Heritage Foundation, Oral History Transcript # 0640). Costle later served as the EPA administrator (1977-1981) in the Carter administration after working at the Connecticut Environmental Protection Agency and Congressional Budget Office. Talley worked as Assistant Administrator for Research and Development (1974-1978). Davies later worked with the Council on Environmental Quality, Resources for the Future, and the Conservation Foundation before working as Assistant Administrator for Policy, Planning, and Evaluation (1989-1991) for the EPA.

environmental protection objectives might run against each other in one department. Instead, the group proposed to create a new and separate agency on pollution control, reporting directly to the President. They supported a more visible unit with direct access to the President and with a clear focus on environmental advocacy; they expected the new agency to gain attention within the executive branch.[9]

Cabinet and staff members were divided on this issue of the DNR versus what ultimately became the EPA. While Whitaker, Ash, and the secretaries of the Interior and Transportation supported the DNR, others were opposed to the idea. For example, the Commerce secretary expressed concerns about the challenge of coordinating mining, coal, and gas interests. The Agriculture secretary refused to give up the Forest Service and the Soil Conservation Service. The Department of Health, Education, and Welfare (HEW) wanted to keep air pollution as a health issue. The chairperson of the Atomic Energy Commission (AEC) also opposed the proposal because "his agency was slated to lose statutory authority."[10]

Nixon finally turned down the DNR proposal for a variety of reasons. First of all, Nixon didn't want Walter Hickel, the Interior secretary, to have more power than he currently held. Then, the HEW accepted the idea of creation of a separate agency. Ash finally decided to support the environmental protection group. Nixon also appreciated the environmental protection group's idea about a new and separate agency, as he would have more control over the environmental agenda.[11] He thought that a new separate agency would be more visible and innovative and liked the fact that it was a compromise between no change and total reorganization. Nixon issued an

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[9] Landy, Roberts, and Thomas, *The Environmental Protection Agency*, 31-32.

[10] Marcus, *Promise and Performance*, 40-41; John Quarles, *Cleaning Up America: An Insider's View of the Environmental Protection Agency* (Boston: Houghton Mifflin Company, 1976), 15-17.

[11] Unlike other regulatory commissions which have three to five commissioners who are selected along the party lines, the EPA has one administrator.

executive order to reorganize his administration to avoid a lengthy legislative process. After his reorganization plan No. 3 was received as an executive order in July 1970 and neither the House nor the Senate expressed opposition to the plan within the allotted 60 days, the reorganization plan went into effect in September. The EPA was then created in December of 1970.[12]

Establishing a new agency meant building a new structure for managing its personnel, budget, and resources. When EPA managers and researchers set up this structure, they incorporated their mission, tradition, and hopes into it. Understanding how they imagined their new agency, what challenges they faced, and how they responded to those challenges will deepen our understanding of the early days of the EPA. In section 2.2, I look into the challenge of integrating diverse predecessors in environmental research and regulation into the newly established agency. The functional organization of the EPA was closely related with the question critical to its mission: how to conceive and manage the federal environment. What was the benefit of having the EPA instead of the status quo? In section 2.3, I look in detail at the structures and people of the research laboratories of the EPA, and the challenge of establishing a central and state-wide system for administrative coordination and decentralization. As a newcomer in bureaucracy and politics, the EPA spent much time defining its political, and sometimes physical, boundaries. In so doing, the EPA's managers and researchers crafted a certain identity for themselves. To understand the construction of this identity, along with the creation of the entity itself—a new regulatory agency with substantial research, monitoring, and

[12] John C. Whitaker, *Striking a Balance: Environment and Natural Resources Policy in the Nixon-Ford Years* (Washington, DC: American Enterprise Institute for Public Policy Research, 1976).

development functions—I propose two competing approaches: the community health and control technology approach in section 2.4.[13]

2.2 Incorporating Diverse Traditions and New Ideals into One Agency

From the start, the EPA took on two roles: primary regulator for all the environmental pollution in the United States, and researcher-manager for the nascent fields of environmental science and engineering. Although the EPA was established as a separate agency focusing on regulation, its research function has been an important part of the EPA for two sets of reasons. First, the federal government did not have sufficient research resources on which the EPA could rely to develop its regulations. In fact, science and engineering disciplines for environmental protection were still in their early stages; also, corporate interest in pollution control research was limited by budget constraints and lack of interest. Second, early EPA managers did not want to be influenced by outside agencies like the Departments of HEW, the Interior, or Agriculture. The establishment of the EPA as a separate, independent agency meant it had to set up its independent research functions as well. Fortunately, the EPA inherited laboratories, grants, and personnel from preceding agencies and strengthened its research function quickly.

2.2.1 Inheriting Existing Agendas

Integrating people, money, and resources into the new agency proved both an opportunity and a major hurdle. At its founding, EPA engineers, scientists, and managers faced several

[13] The two terms, the community health approach and the control technology approach, are my conceptualization but actors in the 1970s seemed to be aware of the formation and different approaches in environmental protection. To understand more about the use of the term “control technology,” see section 5.3.2. Section 3.2 shows a good case of how the terms “community,” “health,” and “community health” were defined and used.

organizational challenges. First of all, the EPA inherited several units from other executive departments, which it had to integrate into a coherent structure. The following figure shows functions and units that were transferred to the EPA (fig. 2. 1).[14]

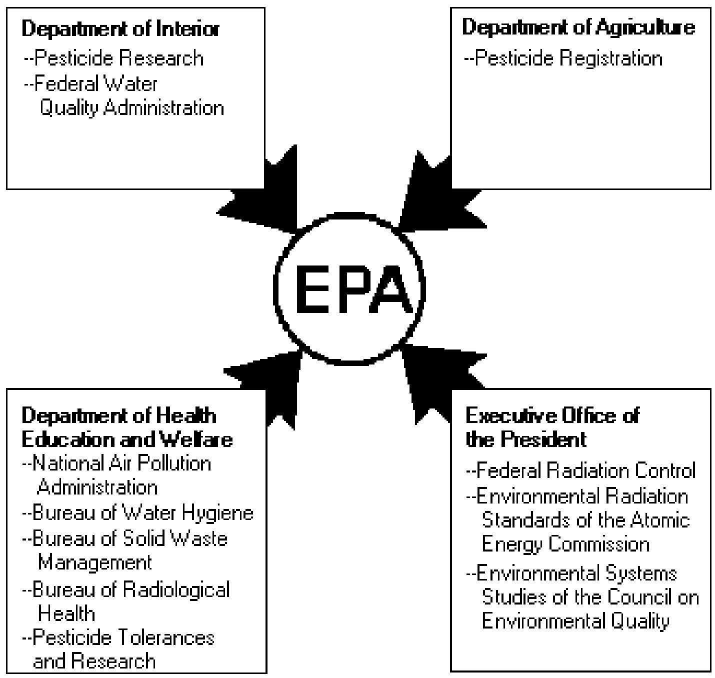

Fig. 2.1 Units and Agencies Incorporated into the EPA. *Source*: Dennis Williams, *The Guardian: EPA's Formative Years, 1970-1973* (Washington, DC: EPA, September 1993).

Before the establishment of the EPA in December 2, 1970, the departments of HEW, the Interior, and Agriculture as well as the AEC had a fragmented role in managing the federal environment and its parts: air, water, pesticides, solid waste, and radiation. According to the

[14] President's Advisory Council on Executive Organization, "Memorandum for the President: Federal Organization for Environmental Protection" (April 29, 1970); Marcus, *Promise and Performance*, 45. Noise and vibration functions were added later.

legislation and executive orders prior to the establishment of the EPA, several departments and units took on roles in research and regulation of pollution as well as providing assistance to related state counterparts. HEW had maintained a health focus and its Public Health Service (PHS) conducted several pollution research programs and offered technical assistance to state and local governments. The Interior Department, which administered public lands and natural resources, became involved in establishing and enforcing water quality standards with the cooperation of state governments following passage of federal laws in the 1950s and ’60s. The Agriculture Department had traditionally been responsible for research on the economic effectiveness of pesticides and the registration and labeling of pesticides. But it also gained the authority to suspend and cancel certain uses of pesticides as well. The AEC not only promoted the commercial use of nuclear power, but also regulated its safety by setting up standards and conducting research on radiation emissions.[15]

Organizing the agency structure became one of the first challenges that William D. Ruckelshaus, the EPA’s first administrator, and his staff had to grapple with. Ruckelshaus liked the idea of the Defense Department’s organization analyst, Alain Enthoven, who argued for constructing the EPA around functional objectives like standards setting, enforcement, and research with a highly centralized structure. Ash Council members, including Douglas Costle, however, presented a more moderate, incremental approach. Costle argued that existing federal and state pollution control statutes imposed restrictions on integration and centralization. Instead, Costle suggested combining both the traditional media centered approach and the new integrative functional approach.

[15] EPA, *Toward a New Environmental Ethic* (Washington, DC: EPA, 1971). The Energy Reorganization Act of 1974 created the Nuclear Regulatory Commission; it began operations on January 19, 1975.

Upon Costle's advice, Ruckelshaus first developed a multiphase organizational plan. In the first phase, he retained medium or pollutants-specific programs and associated commissioners. There were five of them: water quality, air pollution, pesticides, radiation, and solid waste. He also created three functional units: planning and management; standards, enforcement and general counsel; and research and monitoring (fig. 2.2).[16]

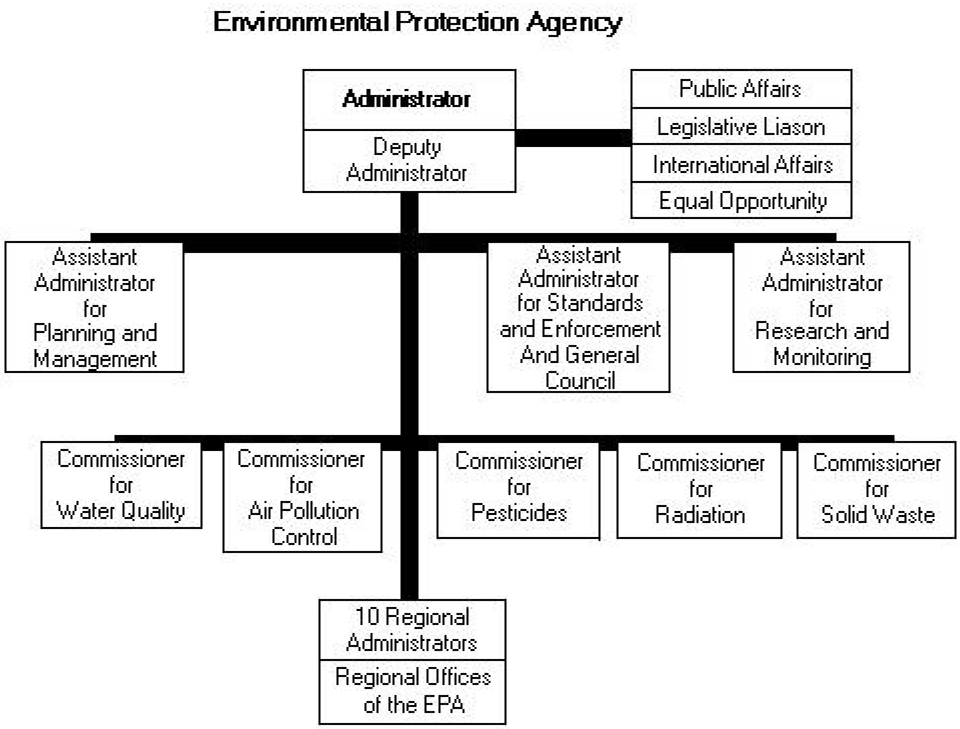

Fig. 2.2 EPA Organization, December 15, 1970. *Source*: Dennis Williams, *The Guardian: EPA's Formative Years, 1970-1973* (EPA, 1993). "Council" typo in original diagram.

Ruckelshaus launched the second phase of the reorganization strategy in April 1971. He consolidated five medium-oriented programs into two new offices. The Office of Media

[16] Dennis Williams, *The Guardian: EPA's Formative Years, 1970-1973* (Washington, DC: EPA, EPA History Program, September 1993).

Programs had programs for air and water and the Office of Categorical Programs had programs for pesticides, radiation, and solid waste management (fig. 2.3).

Ruckelshaus implemented this second phase organization as a transition to the next phase, where he would abolish previous media or pollutant programs and shape the agency by functional units. However, the third phase organization of the EPA Ruckelshaus had envisioned was never implemented. Political scientist Marcus has argued that it was Ruckelshaus's decision to focus on more important issues and to retain continuity.[17]

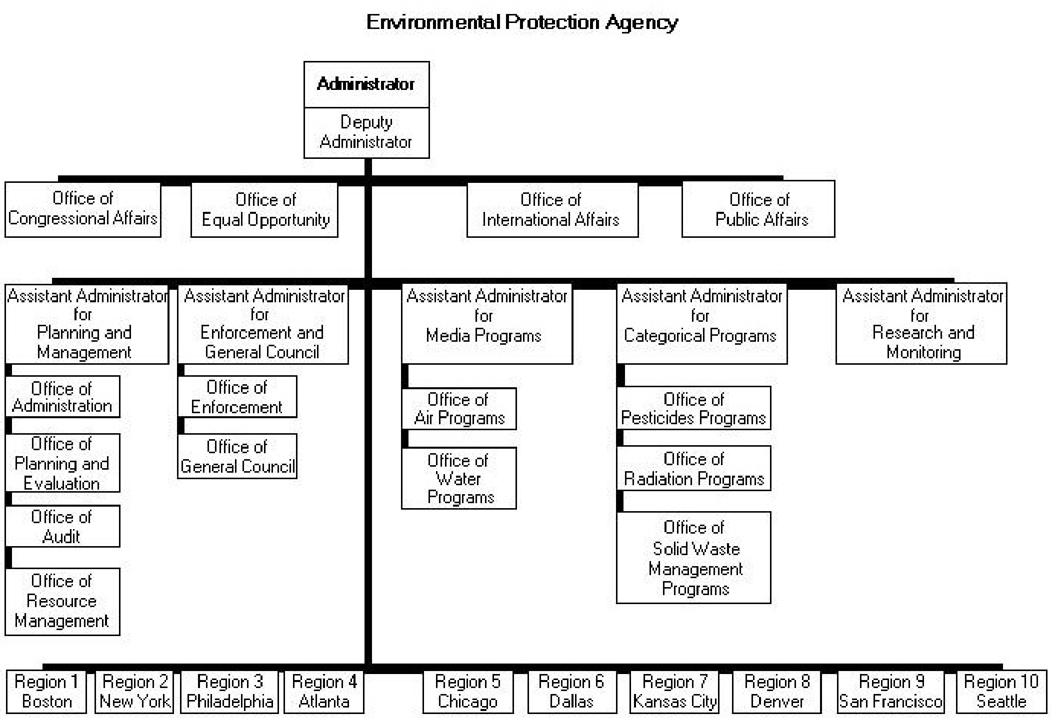

Fig. 2.3 EPA Organization, April 30, 1971. *Source*: Dennis Williams, *The Guardian: EPA's Formative Years, 1970-1973* (EPA, 1993). "Council" typo in original diagram.

[17] Marcus, *Promise and Performance,* 101-106; Williams, *The Guardian: EPA's Formative Years*; EPA, *Alvin L. Alm Oral History Interview*, Interview by Dennis Williams (Washington, DC: EPA, EPA History Program, January 1994).

Water pollution control was the biggest unit of the EPA in size and budget, which came both from the Interior and HEW departments.[18] The Interior's Federal Water Quality Administration had performed a wide range of functions since 1965, including research, standard setting and enforcement, construction grants, and technical assistance. HEW's Bureau of Water Hygiene also took up research and monitoring functions related to water pollution. David Dominick, the head of the Federal Water Quality Administration, became Commissioner for Water Quality under Ruckelshaus. The integration of the two units benefited from the fact that the former had its root in the HEW before its predecessor, the Federal Water Pollution Control Administration, was transferred from the HEW to the Interior in 1966. The former, which hired 2,670 employees, was much bigger than the latter, which only had 160.[19]

The federal air pollution control function was transferred from HEW and was the second biggest in size and budget. Since its establishment in 1968, the National Air Pollution Control Administration (NAPCA) had been responsible for research, monitoring, and regulatory functions related to air pollution. John Middleton, NAPCA's head, stayed in charge as Commissioner for Air Pollution Control. NAPCA's research function had existed under HEW since 1955 and therefore the standard-setting function pre-dated the agency's establishment in 1968.[20] Under the provisions of the 1967 Air Quality Act, NAPCA also designated air quality regions, approved state standards, and provided financial and technical assistance to state control

[18] Federal Water Quality Administration was a successor of the Interior Department's Federal Water Pollution Control Administration, which was established under the HEW in 1965 and was transferred to the Department of the Interior in 1966.

[19] Marcus, *Promise and Performance,* 45.

[20] Jack Lewis, "Looking Backward: A Historical Perspective on Environmental Regulations," *EPA Journal* 14, no. 2 (1988): 26-29. See section 5.1.1 for more detail on NAPCA.

agencies. Unlike NAPCA, HEW's environmental health research functions remained at the National Institute for Environmental Health Sciences.

Setting bureaucratic order in the area of pesticides control took a little more time and energy as Agriculture, HEW, and the Interior roots conflicted in generating a coherent agenda. Agriculture's Pesticides Registration Program registered pesticides for safe use and was transferred to the EPA. HEW's Pesticides Research and Standard-setting Program was transferred from HEW's Food and Drug Administration (FDA) to the EPA. The Interior's small research programs on pesticide effects on fish and wildlife was transferred to the EPA and merged with the Agriculture's and HEW's programs. Not all functions were transferred, however. The Agriculture department retained pesticide research activities on livestock, poultry, and plant effects and continued to conduct pest control and education programs with Agricultural Extension Services. The FDA retained responsibilities to monitor residues in foods and to regulate foods in the market.[21]

In setting up radiation and solid waste functions of the EPA, the enduring traditions from its predecessor units left them more intact than other air, water, or pesticides functions. The AEC's Division of Radiation Protection Standards and its standard-setting functions in radiation emissions into the general environment were also transferred to the EPA. The Federal Radiation Council, which set up broad guidelines for radiation protection, and HEW's Bureau of Radiological Health were also transferred to the EPA.[22] HEW's Bureau of Solid Waste Management was transferred and became the backbone of the EPA's solid waste office, led by Richard D. Vaughan as Commissioner for Solid Waste.

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[21] EPA, *Environmental Protection Agency: A Progress Report, December 1970-June 1972*, 34.

[22] EPA, *Radiation Protection at EPA: The First 30 Years* (Washington, DC: EPA, Office of Air and Radiation, Office of Radiation and Indoor Air, 2000).

The establishment of the EPA's research and regulatory units was not a one-time event. There has been continuing efforts to set up, expand, and reorganize them. *Figure* 2.4 shows how the federal government established and expanded its bureaucratic capacity in health and safety issues from 1958 to 1971: chronological changes in organizations governing air, water, solid waste, pesticides, radiation, injury control, and occupational health are tracked through time. Organizational histories of the air and water pollution control and radiation units are relatively straightforward. The PHS temporarily integrated sanitation, injury control, solid waste, and occupational health functions in the Consumer Protection and Environmental Health Service between July 1968 and 1970. The food safety function was also a part of this agency but was taken out permanently in February 1970. I will cover the frequent reorganization of the Office of Research and Monitoring in the following chapters.[23]

[23] EPA Management & Organization, Budget, Administration, Field Office Mat., 1970-1993, BOX 4, EPA Management + Organization, 1970-2001, EPA Historical Document Collection, U.S. EPA, Washington, DC (hereafter EPA Historical Document Collection).

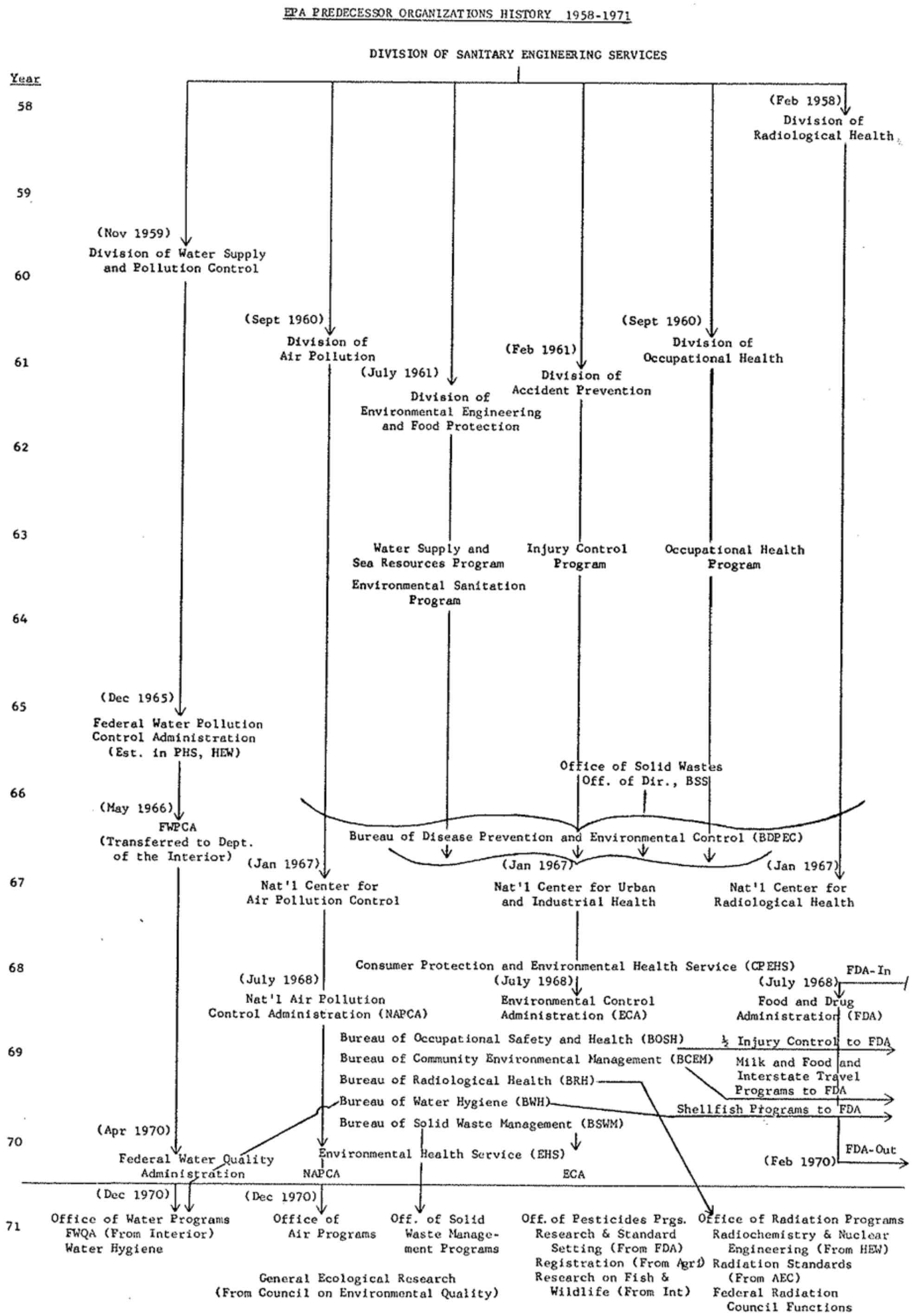

Fig. 2.4 Predecessors of the EPA's Program Offices. *Source*: EPA Management & Organization, Budget, Administration, Field Office Mat., 1970-1993, BOX 4, EPA Management + Organization, 1970-2001, EPA Historical Document Collection.

2.2.2 Inventing New Functions

The EPA's predecessors, as a whole, sometimes assumed conflicting roles in regulating pollution and promoting related monitoring, research, and development activities. The EPA had a structure in which research and regulation were distinct functions in different units. The goal of establishing the five programs on air, water, pesticides, radiation, and solid waste was to ensure the incorporation of existing units into the EPA would be quickly completed. In addition to these five units, Ruckelshaus set up three other function-based, agency-wide offices and appointed the same number of assistant administrators to lead each. As there were not many people or sufficient resources for planning and enforcement, the EPA experienced both the difficulty of setting up new units almost from scratch and the freedom to build these functions as they wanted to. For research, the EPA had the opposite problem. It inherited quite a few laboratories and offices that it had to integrate into a coherent structure.[24]

The Office of Planning and Management first provided a basic, supportive role for the agency. It administered internal analyses and prepared material to help with budget and personnel decisions for senior leadership. Soon economists and system analysts became the core of the unit. As the energy crisis and economic downturn became overarching concerns for policy-makers, this office gained more institutional status within the EPA. Especially economists in this office assumed challenging tasks to argue against other economists in the Commerce department or corporate sectors and achieved prominent status as the defenders of the EPA. The

[24] This structure was unusual, but not unique; the National Highway Traffic Safety Administration and the Food and Drug Administration also had various ranges of intramural research functions distinct from their regulatory activities. The advantage of this type of structure was that it attempted to create a balance between supporting regulatory needs and prohibiting regulators from affecting research outcomes.

office also became one of the EPA's liaisons with the Department of Energy and the White House.[25]

Alvin L. Alm's life trajectory shows well how the increasing role of the Office of Planning and Management took place against the background of a rapidly changing 1970s environment/energy scene. He began working at the Bureau of Budget, where he examined the budget of the water pollution program. After working as the staff director of the newly created Council on Environmental Quality from 1970 to 1973, Alm became the EPA's Assistant Administrator for Planning and Management. There he conducted economic analysis on water and air pollution and was involved in reorganizing the agency to take on the new responsibilities that came with new environmental legislation. After helping develop the Ford administration's energy policy, Alm became the undersecretary at the newly created Department of Energy in 1977. He also worked at Harvard University and in business sectors until his death in 2000.[26]

Like economist and analyst peers, EPA's lawyers were trailblazers, who also gained high publicity. The Office of Enforcement and General Counsel had two main roles in the agency. First, it prepared lawsuits against polluters. Second, it defended the agency from legal challenges. Ruckelshaus, himself a lawyer, recruited young, energetic colleagues to fill the new unit in the Washington office and in corresponding offices in the EPA's ten regions. As defending the EPA in courts became increasingly important toward the end of 1970s, EPA lawyers at times became more interested in "pleasing reviewing courts than in devising workable control programs."[27]

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[25] Melnick, *Regulation and the Courts*, 41; Cook, *Bureaucratic Politics and Regulatory Reform*, 9-10.

[26] Alm came back to the EPA to work as Deputy Administrator under Ruckelshaus from 1983 to 1985. EPA, *Alvin L. Alm Oral History Interview*; "In Memoriam: Former Deputy Administrator Alvin L. Alm."

[27] Melnick, *Regulation and the Courts*, 40-41. Quote from p. 41.

On the other hand, there were numerous research facilities and monitoring networks that had to be integrated into the EPA, so the Office of Research and Monitoring (ORM) embarked on major reorganization efforts.[28] We need to take a closer look at how this research arm of the EPA was established to take on organizational and epistemic challenges for the EPA. I will begin by reviewing the EPA's two roles, regulator and researcher, in the following section.

2.3 Organizing Research Laboratories for Environmental Protection

The first EPA administrator, Ruckelshaus, compared the difficulty of running the new agency to "running a 100-yard dash, while undergoing an appendectomy." [29] To cooperate with concerned environmentalists, lukewarm bureaucrats, and fearful industrialists, Ruckelshaus was busy setting up regulations, expanding the agency, and bringing polluters to court. Although he was not the first choice of President Nixon, he proved a good fit for such a demanding job. His experience at the Indiana Board of Health and the federal Department of Justice helped him to become the public face of the new regulatory agency. Ruckelshaus surely had to run much further and undergo many more surgeries between December 1970 and April 1973.[30]

On the regulatory side, the EPA was a high profile and politically contentious agency that managed its public image to establish credibility. Ruckelshaus was busy making a case to show Congress and the public the EPA's and his authority. He later recollected that "it was important for us to advocate strong environmental compliance, back it up, and *do* it; to actually show we

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[28] EPA, *Progress Report*.

[29] Quarles, *Cleaning Up America*, 32.

[30] Ruckelshaus left the EPA to become acting director of the Federal Bureau of Investigation and then Deputy Attorney General. However he resigned in protest when Nixon ordered him to fire Archibald Cox, Watergate special prosecutor. Later he came back to run the EPA under President Reagan from 1983 to 1985.

were willing to take on the large institutions in the society which hadn't been paying much attention to the environment."[31] Those institutions ranged from municipalities like Atlanta, Cleveland, and Detroit, to major industries like steel, automobiles, and pesticides. During each month in 1972 the EPA took about 15 legal actions against polluters.

For scientists and engineers employed by the EPA, however, the agency was principally oriented toward research and monitoring. The ORM's mission included specifying the thresholds of pollutants dangerous to health and well-being as well as finding the best available control technologies to achieve those thresholds. About one-third of the EPA's money and workforce went into research and monitoring, exclusive of the construction grant program. While 75 percent of all EPA research was conducted outside the agency through contracts and grants, EPA's own research was still an essential part of its function. In 1971, the EPA's intramural research budget was $125 million and almost 1,900 scientists, engineers, and technicians constituted the in-house research team.[32]

Stanley M. Greenfield, the EPA's first research head, defined two major responsibilities of the new agency: "to halt pollution and repair damage done with whatever technology is available, imperfect as it is, … [and to] perform and encourage others to perform the research, the development, the planning and the implementation to maintain a healthful, productive

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[31] EPA, *William D. Ruckelshaus Oral History Interview*, Interview by Michael Gorn (Washington, DC: EPA, EPA History Program, November 1992), 9. Emphasis in original.

[32] EPA, *Directory of EPA, State, and Local Environmental Quality Monitoring and Assessment Activities* (Washington, DC: EPA, Office of Research and Development, December 1974); EPA, *Progress Report*; Stanley M. Greenfield, "An Overview of Research in the EPA," in *Proceedings of the Interagency Conference on the Environment* (Livermore, CA: Lawrence Livermore Laboratory), 27.

environment for the future."[33] Like Nixon, Greenfield showed a sense of urgency in tackling environmental problems and felt confident about applying all the available resources. At the same time, Greenfield was a believer of the idea that the new agency must conduct and support long-term research and development in this new area. A geophysicist who came from the environmental studies manager position at the Rand Corporation, he brought the systems concept and broad social considerations into the research and management at the EPA laboratories.

Like other researchers, managers, and politicians, Greenfield argued that organizational change would enable the EPA to better conduct monitoring functions and to create an infrastructure that facilitated innovation. New technologies were insufficient to solve even well-defined problems and often produced unexpected changes in the systems and organizations to which they were applied. Greenfield rearranged the existing local and regional laboratories, monitoring sites, and field stations, in a new National Environmental Research Center (NERC) system.

Greenfield's NERC system was a response to ongoing discussions about the better utilization of federal laboratories. Since the publication of a 1960 Congressional report about the future of the AEC's laboratories, various organizations including the AEC, the Bureau of Budget, and the National Academy of Sciences expressed diverse interests in better utilizing manpower and resources of the government-owned laboratories.[34] Issues of concern ranged from the recruitment and retention of scientists and engineers to the restructuring of government research and development. As the AEC's laboratories continued to claim their expertise and commitment

[33] Stanley M. Greenfield, "Our Future is Up in the Air," *Bulletin of the American Meteorological Society* 52, no. 9 (1971): 846-847.

[34] U.S. Atomic Energy Commission, *The Future Role of the Atomic Energy Commission Laboratories: A Report to the Joint Committee on Atomic Energy* (Washington, DC, January 1960).

on pollution research, Greenfield felt a strong need for an organizational statement arguing that environmental research could be better done by the EPA. Laboratories of the National Bureau of Standards, National Aeronautics and Space Administration, Department of Defense, and Department of Commerce also had developed and expressed research interests on environmental issues during the 1960s and would maintain mostly cooperative but sometimes competitive relationships with the new EPA. On the other hand, the Bureau of Budget argued that, with the help of other agencies, long-term management of research and development functions of the federal government was desirable to make better use of existing facilities.[35] The National Academy of Sciences concurred with the Bureau of Budget that the occasional reorganization of programs and relocation of federal laboratories should be examined to deal with emerging problems of national interest.[36]

Greenfield took the middle path. His plan was a compromise between two competing goals: providing support for researchers so that they continued to focus on what they were best at and creating momentum that might enable the development of new research agendas. He also took the surrounding factors into consideration. The EPA structure was still divided by a traditional media focus. Congress also retained a committee structure that corresponded to the separate treatment of various forms of pollution, as it had before the establishment of the EPA.

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[35] Bureau of Budget, "Report to the President on Government Contracting for Research and Development" (April 30, 1962).

[36] U.S. Congress. House. Committee on Science and Astronautics. Subcommittee on Science, Research, and Development, *Utilization of Federal Laboratories*, 90th Cong., 2nd sess. (Washington, DC: March 26-April 4, 1968), 2; U.S. National Research Council, *Toward Better Utilization of Scientific and Engineering Talent: A Program for Action*, A Report of the Committee on Utilization of Scientific and Engineering Manpower, Pub. No. 1191 (Washington, DC, 1964); U.S. National Research Council, *Applied Science and Technological Progress*, A Report to the Committee on Science and Astronautics, U.S. House of Representatives (Washington, DC, 1967).

The final solution for Greenfield was to establish National Environmental Research Centers with specialized missions.

The very location of NERCs involved considerations of resources, politics, and the institutional continuity of preceding agencies. Four "thematic" NERCs were created—in Cincinnati, Ohio; Research Triangle Park (RTP), North Carolina; Las Vegas, Nevada; and Corvallis, Oregon (fig. 2.5).

Fig. 2.5 National Environmental Research Centers and Their Foci. *Source*: Author.

Ruckelshaus and Greenfield decided to officially launch each center after the initial reorganization process was completed. There were satellite laboratories from Alaska to Florida; from Rhode Island to Washington. Each of the four centers provided a strong interdisciplinary research core in cooperation with ongoing research programs elsewhere, reorganized from 42 laboratories from the preceding agencies. Greenfield believed that he could establish a network of environmental research without moving many people into new locations or dealing with resistance from local and state stakeholders. However, the required integration of limited personnel and laboratories was eventually planned and executed. I look at each center's history in the remaining part of this section.[37]

The history of Cincinnati's involvement in environmental research began in 1913 with the establishment of the Stream Pollution Investigation Station. After World War II, the Public Health Service (PHS) built the Robert A. Taft Sanitary Engineering Center to further strengthen Cincinnati's already robust capacity in water and waste research. After the establishment of the EPA, Andrew J. Breidenbach, director of PHS's Research for the Solid Waste Management Office, took charge of the Cincinnati laboratories. The charismatic leadership of Breidenbach contributed to the expansion of environmental research, but his leadership also generated tension between Cincinnati and Washington.[38]

In February 1971, Ruckelshaus decided to relocate air pollution control activities from Cincinnati to RTP. As a result of this relocation, 232 staff and a budget of $4.4 million was moved.[39] Among the transferred units was the Process Control Engineering Division's Research Laboratory Branch. The mission of this branch included engineering research, development, and demonstration programs on identification, sampling, and control of pollutants in support of pilot,

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[37] "ES&T Interview: Stanley Greenfield," *Environmental Science & Technology* 5, no. 10 (1971): 990-992; EPA, *Progress Report*; EPA, *National Environmental Research Centers* (Washington, DC, 1973), 1.

[38] Herb Pence, "Safeguarding Life's Quality: The Cincinnati National Environmental Research Center," *Cincinnati* 5, no. 12 (1972): 31-38; Smith et al., "Environmental Research in Cincinnati: A Century of Federal Partnership," *Environmental Engineer: Applied Research and Practice* 13 (summer 2011): 1-11.

[39] "A Look at the EPA, Cincinnati," EPA Management & Organization, Budget, Administration, Field Office Mat., 1970-1993, BOX 5, EPA Management + Organization, 1970-2001, EPA Historical Document Collection.

prototype, and demonstration plants.[40] Washington staff felt that Breidenbach's strong leadership could be detrimental to the overall research coordination of the EPA. Ruckelshaus and Greenfield found the new NERC system helpful to reorient the existing order and traditions developed in Cincinnati under the PHS. NERC-Cincinnati was officially created on August 13, 1971, as a center for water, wastewater, and solid waste research. NERC-Cincinnati included laboratories in the area as well as four other satellite locations.[41]

Environmental protection activities at RTP originated from the National Air Pollution Control Administration (NAPCA), a research and regulatory unit for air pollution control established in 1968. A crew of 26 from PHS's Cincinnati lab joined new employees from North Carolina and other states at NAPCA. After the EPA was established in 1970, NAPCA became the Air Pollution Control Office, which had two bureaus for research and regulation directed respectively by Delbert Barth and Bern Steigerwald. Barth was a radiation health and air pollution researcher and Steigerwald was a stationary air pollution regulator. During 1971, however, the regulatory bureau became part of the Office of Air Programs and the research bureau was renamed as the National Environmental Research Center-Research Triangle Park (NERC-RTP) under the ORM. Although being separately housed under two different offices, researchers and regulators on stationary air pollution at RTP shared their common public health tradition and maintained a close relationship due to their physical proximity. They also benefited from the same administrative support in the area.

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[40] I look at the role of this unit in detail in chapter 5. Other units transferred included the Division of Air Quality and Emissions Data, the Health Effects Research Division's Biological Research Branch, and the Physical Chemistry Branch's Particulate Chemistry Section.

[41] Managing Cincinnati and satellite laboratories became a contending issue among Breidenbach, other NERCs, and Washington administrators.

While environmental research and regulation at RTP was forming in the 1960s, the state of North Carolina made efforts to attract new business and research institutions to the Raleigh-Durham-Chapel Hill area. As a result, IBM and the National Institute of Environmental Health Sciences became part of the community. The concentration of air pollution, toxicology, and computer research functions at RTP helped NERC-RTP become one of the pillars of EPA research. I will explore in detail in the following section how researchers and regulators at RTP inherited and interpreted different traditions of understanding environmental problems and developed new ideals and practices.[42]

Environmental research in Las Vegas began in the PHS's Southwestern Radiological Health Laboratory in 1959. Due to its proximity to the Nevada Test Site, the laboratory was responsible for the public health and safety program related to nuclear testing by the AEC. Its environmental monitoring program collected samples of air, water, and milk by ground and aerial surveillance to understand the transfer of radionuclides through the fallout-air-forage-cow-milk-human chain. Using a whole-body counter, the laboratory identified and measured radionuclides deposited in the human body. In addition to active research programs, the Las Vegas Laboratory also supported other state and federal agencies through chemical analysis and computer and programming services. With the establishment of the EPA, the laboratory was renamed as the Western Environmental Research Laboratory to reflect the broader areas of interest while some functions remained in the PHS. The laboratory had six buildings on the campus of the University of Nevada, Las Vegas, as well as associated field facilities in the neighborhood area. In 1971, 226 people worked there with an operating budget of $3.5 million. Interestingly, the laboratory received more budget from the AEC ($2.2 million) than it received

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[42] EPA, *EPA at Research Triangle Park: 25 Years of Environmental Protection*. (Research Triangle Park, NC: EPA, Office of Administration and Resources Management, 1996).

from HEW until 1970 or from the EPA after 1971 (about $1.2 million maximum from each). Although the laboratory did not belong to the AEC, the subject-matter, budget, and culture certainly reflected those of nuclear research.[43]

Greenfield appreciated the growing role of the Las Vegas laboratory for environmental monitoring and suggested to Ruckelshaus it be established as the National Environmental Research Center in Las Vegas. Ruckelshaus agreed and appointed Delbert Barth, then NERC-RTP director, as the first director of NERC-Las Vegas, based on his expertise in radiation. On August 16 and 17, 1971, Greenfield held the ORM senior staff meeting at the NERC-Las Vegas. There Greenfield argued that he was certain that Las Vegas members would play "a key role in the research and development of new monitoring techniques." NERC-Las Vegas expanded its research and monitoring into areas dealing with non-radioactive pollutants by executing remote sensing and sampling of air, water, and land pollution. Using its 12 specialized aircraft, it contributed to various monitoring activities such as the Los Angeles Air Pollution Survey and photographic surveillance of oil spills. It also expanded its environmental education workshops for high school teachers.[44]

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[43] Moore, "EPA Las Vegas Laboratory Early History"; "Chronological History of EMSL-Las Vegas," EPA Organizational History, Box 7, EPA Historical Document Collection; EPA, *Western Environmental Research Laboratory: Annual Report 1970* (Las Vegas, NV: EPA, Office of Research and Monitoring, Western Environmental Research Laboratory, 1971); EPA, *Western Environmental Research Laboratory: Annual Report 1971* (Las Vegas, NV: EPA, Office of Research and Monitoring, Western Environmental Research Laboratory, 1972). Personnel and budget data from p. 4. EMSL denotes the Environmental Monitoring Systems Laboratory.

[44] EPA, *National Environmental Research Center, Las Vegas: Monthly Report July 1972* (Las Vegas, NV: EPA, Office of Research and Monitoring, National Environmental Research Center, July 1972); EPA, *National Environmental Research Center, Las Vegas: Monthly Report August 1972* (Las Vegas, NV: EPA, Office of Research and Monitoring, National Environmental Research Center, 1972); EPA, "Press Release" (August 2, 1972).

NERC-Corvallis's history began when the 1961 Amendments to the Federal Water Pollution Control Act authorized the PHS to establish the Pacific Northwest Water Laboratory at Oregon State University, one of the agency's seven regional laboratories. The facility was transferred to the Interior Department's Federal Water Pollution Control Administration in 1967 and its mission shifted from regional technical support to national research in water pollution control. After the establishment of the EPA, the Corvallis lab became NERC-Corvallis with a focus on ecology. With five laboratories inherited from the Interior's Federal Water Quality Administration, the core mission of NERC-Corvallis centered on the pollution of fresh surface water, ground water, and coastal water. In 1972, the RTP laboratory studying air pollution effects on vegetation was transferred to Corvallis. A. Fritz Bartsch, from the Interior's Federal Water Pollution Control Administration, assumed the directorship. In 1973, it had 487 permanent employees with a $25 million budget. Bartsch later became active in fighting organizational changes imposed by Washington that weakened NERC-Corvallis.[45]

2.4 Competing Approaches to Managing the Federal Environment

Setting up the new agency for the environment was not only a question of organizational structure. In order to integrate personnel, budget, and existing units into a new agency, the designers of the EPA developed new concepts and ideals that would provide a binding ethos for EPA employees of all kinds: new and old; Washington and regional; air, water, solid waste, pesticides, and radiation; and research and regulation. This section looks at two competing approaches for environmental management that developed from the EPA's responses to

[45] "WED History: The Evolution of WED"; "Corvallis and Newport Scientists Look Back on Research Milestones," *Western Ecology Division: Research Updates* (December 2000); EPA, *NERC-Corvallis Report: A Guide for Potential Users of Technical Support Services* (Corvallis, OR: EPA, May 1973).

bureaucratic, geographical, and epistemic challenges: a community health approach and a control technology approach.

A "community health" approach assumed that setting up health-based standards is the first and strongest step to alleviate rampant pollution. Influenced by PHS tradition and equity concerns, public health specialists in Research Triangle Park became early proponents of this approach. They focused on identifying pollutants and exploring the correlations between major pollutants and human health indicators. While other scientists and engineers working on pollution exposure, mobile air pollution control, and water pollution control joined public health specialists in developing this approach, it also became an easy target of complaints from Congress and industry about its long research process and insufficient evidence to prove negative health consequences. Ecologists and environmentalists also criticized the community health approach as it focused more on human health effects than ecological effects.

The Clean Air Act Amendments of 1970, for example, authorized the federal government to set up ambient air quality standards for six major pollutants based only on public health and welfare grounds. It did not suggest a particular technology to achieve these standards, nor did it include cost factors in its consideration. The Clean Water Act Amendments of 1972, or the Federal Water Pollution Control Act, similarly proposed health-based standards to regulate the discharge of pollutants from point sources.[46]

On the other hand, a "control technology" approach assumed that implementing pollution control technology would be the first and most practicable step. Scientists and engineers who worked or were trained in Cincinnati's laboratories became early proponents of this approach. They argued for the evaluation of available control options in order to bring the quick reduction

[46] Clean Water Act of 1972, Public Law 92-500, 86 Stat. 816; Marcus, *Promise and Performance*.

of pollutants into reality. Following the successful demonstration of scrubbing technologies in sulfur dioxide emission control, this approach expanded to other areas of pollution control.

Examples of the control technology approach are found in the system of regulations, standards, and guidelines established after the Clean Air and Water Act Amendments. The New Source Performance Standards of 1971, emission standards for all new and renovated plants, for example, were established by the EPA and considered factors such as technology, cost, and environmental effects. The Clean Water Act Amendments of 1972 also established a system of effluent guidelines for the best practicable technology and best available technology to control the most common water pollutants for each major industry. Using technology-based standards for water pollution control proved effective, but the question of how to apply two levels of technology—the best available one for primary standards and the best practicable one for secondary standards—remained difficult to answer solely from a technical perspective.[47]

Water and solid waste pollution researchers at Cincinnati had been accustomed to setting discharge limitations based on technological considerations.[48] Most RTP units took the community health approach due to its previous affiliation with NAPCA. One RTP laboratory focusing on stationary air pollution control, however, adopted the control technology approach.

[47] Stephen J. Gage, "Control Technology Bridges to the Future," in *Energy/Environment II.* Second National Conference on the Interagency R&D Program, EPA, 15-25 (Washington, DC: EPA, Office of Research and Development, Office of Energy, Minerals, and Industry, November 1977).

[48] Andrew W. Breidenbach, "The Development of Technology for Environmental Control," in *Proceedings of the Interagency Conference on the Environment*, 52-68 (Livermore, CA: 1973); Alfred Marcus, "Environmental Protection Agency," in *Politics of Regulation*, ed. James Q. Wilson, 277 (New York: Basic Books, 1980).

2.5 Conclusion: Creating a New Agency with a Fresh Ethos

Against the background of social movements, political shifts, and changes in public opinion, the creation of the EPA was an outcome of negotiation between various political forces. Powerful politicians and bureaucrats from the White House and Capitol Hill competed with one another to take the initiative in responding to rising demands for federal action on environmental issues.

Building the EPA through reorganization, moreover, initiated the construction of new relationships between regulation and research in which EPA scientists, engineers, and managers found strong needs and opportunities to redefine the environment as a subject of monitoring and protection and as a result, influenced subsequent environmental policy-making.

I would like to reemphasize two points that will help us to understand the case-studies that follow. First, the establishment of the EPA was not the culmination, but the beginning of a long period of changes throughout the 1970s. Reviewing its diverse traditions, micro-organizational history, and competing approaches provides a base knowledge to understand the EPA’s role in environmental policy, social regulation, and energy transitions. As we will see in the following chapters, the ORM’s offices and laboratories experienced multiple reorganizations for bureaucratic, political, and economic reasons. Many movers and shakers of the Ash Council later became involved in the EPA’s own management in various capacities.

The EPA’s structuring of its research laboratories clearly bore the imprint of the multiple challenges it faced in its early years. As a new federal agency, the EPA had to set up a coherent unit from the diverse traditions of its predecessors. To establish bureaucratic order among scattered laboratories setting up regional offices to cover all 50 states, territories, and tribal nations was also an important hurdle. Greenfield’s efforts to set up four National Environmental

Research Centers with themes expressed the current status of the rest of the agency, which was organized according to type of media.

Second, while the EPA went through these transitions, agency engineers, scientists, and managers crafted new goals and collective identities to clarify their mission and publicize their cause. As some researchers found health effects to be one of the easy indicators for pollution in the community, the making of healthy communities became one persuasive goal of environmental protection, where the most vulnerable parts of the communities can find the surrounding environment livable. Other researchers found the promotion and application of new technology for environmental protection as the most efficient way to find a common ethos among them and to persuade potential dissidents who were concerned about the high cost and low benefit of environmental protection. These two schools of thought as a whole shaped the EPA as an agency that contributed to the enhancement of public health, the support of environmental science and engineering, and the betterment of the overall environmental quality. In the following chapters, I look at these two competing approaches as they played out in three different areas of pollution research and regulation at the EPA.

Chapter 3 Environmental Protection through Community Health: The CHESS Controversy, 1969-1977

A far more effective approach to pollution control would: identify pollutants; trace them through the entire ecological chain, observing and recording changes in form as they occur; determine the total exposure of man and his environment; examine interactions among forms of pollution; [and] identify where in the ecological chain interdiction would be more appropriate.
-President Richard M. Nixon[1]

The creation of the EPA and the establishment of its authority in federal environmental management were laborious endeavors. Internally, the EPA set up bureaucratic structures to meet competing needs for continuity and change: (1) existing federal units specializing in the control of air, chemicals, radiation, solid waste, and water continued to operate as separate offices; and (2) new functional offices were established for research, planning, and enforcement. As environmental protection became one of the top political issues at the beginning of the 1970s, the EPA had to cooperate and sometimes compete with Congress, the Office of Management and Budget, and other executive departments. Dealing with continuing responsibilities and new mandates for regulation, research, and monitoring, the EPA embarked on a long and tumultuous journey of establishing its identity and building its reputation.

From multiple stakeholders' ongoing efforts to protect air, water, land, and people, EPA employees felt pressure to show their credibility in approaching the problem of environmental

[1] U.S. Congress. House. Committee on Government Operations, "Message of the President Relative to Reorganization Plans Nos. 3 and 4 of 1970." (July 9, 1970).

protection. They wanted to show their eagerness and competence to follow strict and sometimes cumbersome deadlines established by the Senate and House. They also became engaged in a contentious debate with the White House staff on the estimated cost of recent regulations. The EPA found that important questions needed to be answered before it could set up its initial approach: For what purpose did the federal government need to protect the environment? To what extent did the consideration of the current status of technology or cost of control influence the decisions of the administrator? At what point does the EPA need to share information with the public about potential dangers to the environment and human health?

As outlined in chapter 2, a “community health” approach was one important way for the EPA to legitimize its existence. According to the proponents of this approach, the primary goal of the EPA would be protecting, restoring, and enhancing human health. However, identifying the link between pollution and health proved to be a difficult task. For example, many health professionals found that pollution of the air was often linked with asthma or irritation of eyes or nose. Connecting polluted air with aggravated health, however, raised other issues and questions. A lack of detailed index and measurement devices for pollutants hindered accumulation of comparable data. Health effects research had just begun to include pollution from multiple sources to identify the causal and proportional relationship between pollutants and diseases. Existing knowledge on the transport of pollutants from point of production to the human body was insufficient to set up effective strategies to remediate large-scale pollution.

EPA researchers employed diverse health effects research traditions in order to measure pollutants’ influence on human cells, tissues, organs, organisms, and populations. Combining toxicology, clinical research, and epidemiology helped researchers to understand and complement strengths and limitations of each research tradition. *Toxicological research* involved human and non-human subjects and controlled for factors like age, gender, and nutrition. As in dose-response studies, the easier control of factors enabled experimenters to use dangerous combinations of contaminants, but the results couldn't be easily extrapolated to other cases. *Clinical research* involved small numbers of normal and diseased people or their tissues. Clinical research was valuable to retrieve precise measurements and biochemical analyses and functioned as a link between toxicological and epidemiological findings. However, it was limited in scale and entailed the relatively complex procedure of getting consent from participants.[2] *Epidemiological research* dealt with how diseases affected the community by measuring the relatively long-term effects of living in a polluted area. While epidemiological research was valuable in the exploration of real people exposed to the variety and complexity of a real environment, it also had several drawbacks. Above all, epidemiological research was time-consuming and expensive: it required managing a properly trained workforce and a multitude of data. Also, it required sophisticated communication skills of field-level researchers. Furthermore, even carefully planned studies were unable to take account of every social and environmental variable that affects human health. Therefore, when an association was inferred between a particular exposure and a health effect, it had to be "backed up with corroborating facts established by other [toxicological and clinical research] methods."[3] Relying on multiple approaches and traditions was both a reflection of the EPA's diverse origins and of its unsettled style in environmental research and management.

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[2] Rena Corman, *Air Pollution Primer*, 3rd ed. (New York: American Lung Association, 1978); John Finklea et al., "Health Intelligence for Environmental Protection: A Demanding Challenge," *Proceedings of the Sixth Berkeley Symposium on Mathematical Statistics and Probability* 6 (1972): 101-109.

[3] Corman, *Air Pollution Primer*, 57.

In this chapter, I argue that EPA scientists and engineers pursued this community health approach to integrating human and environmental health by building systems to deal with new geographical, bureaucratic, and functional challenges. I examine the case of the Community Health and Environmental Surveillance System (CHESS)—a comprehensive epidemiological study about the effects of air pollutants on the health of children, asthmatics, and the elderly in eight geographical areas. CHESS was intended not only to evaluate “existing environmental standards,” to quantify “pollutant burdens in exposed populations,” and to document “health benefits of pollutant control,” but to do so with an innovative program of research that aimed “(1) to refine exposure monitoring, (2) to improve statistical procedures, and (3) to develop and test more sensitive health indicators.”[4] Ambitious in scope and scale, however, CHESS became embroiled in a controversy over its supposed data distortion and over-interpretation, resulting in a 1976 Congressional hearing that contributed to a major organizational and conceptual reorientation of the EPA.[5]

Section 3.1 investigates EPA researchers’ ambitions to design CHESS as an exemplary research project to connect pollution and health. In section 3.2, I will focus on the explanation of five concepts comprising CHESS: *community*, *health*, *environment*, *surveillance*, and *system*. In section 3.3, I will explain how these five concepts took different forms from their initial definitions through reports, hearings, and the reorientation of the EPA. I will conclude this chapter with observations about the changes in pollution monitoring and health effects research,

[4] Riggan et al., “CHESS: A Community Health and Environmental Surveillance System,” *Proceedings of the Sixth Berkeley Symposium on Mathematical Statistics and Probability* 6 (1972): 112, 118.

[5] William B. Rood, “EPA Study-The Findings Got Changed: Research on Sulfur’s Effects on Health Stirs Power Company Furore,” *Los Angeles Times,* February 29, 1976. sec. Part One Final, A1.

the relationship between researchers and regulators, and the influence of the decline of the community health approach.

3.1 CHESS: Goals and Contexts

At the new Office of Research and Monitoring (ORM), CHESS became a showcase for the systematic integration of air pollution monitoring and health effects research in the new National Environmental Research Center (NERC) system. Stanley Greenfield, the first head of the ORM, took responsibility for integrating data from various media to maintain effective monitoring networks. State and local governments at that time had over 2,000 stations that monitored air quality, most of which only operated intermittently. While supporting state and local efforts, the ORM took over the federal monitoring network from the National Air Pollution Control Administration (NAPCA) and established the Air Pollution Control Office.[6] In addition to this continuous monitoring of the environment, the ORM conducted special studies combining environmental monitoring and health surveillance, but showing the benefit of pollution abatement to human health proved difficult to assess. In this context, CHESS was designed and implemented to produce exemplary research, combining pollution monitoring and epidemiology that could demonstrate the value of monitoring and air quality management to industry, Congress, and the public.

The first goal of CHESS, evaluation of existing environmental standards, was to demonstrate the benefit of these recent air quality standards. To implement the timely enforcement mandated by the Clean Air Act Amendments of 1970, the EPA promulgated the National Ambient Air Quality Standards (NAAQS) for carbon monoxide (CO), hydrocarbons

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[6] National Industrial Pollution Control Council, *Air Pollution by Sulfur Oxides: Staff Report* (Washington, DC: Government Printing Office, February 1971), 9.

(HC), ozone (O_3), particulates (PM), sulfur dioxide (SO_2), and nitrogen oxides (NO_X) in 1971. According to the Act, the EPA had to use the latest scientific information to set up various standards for public health and welfare, and short-term and long-term exposure.[7] Setting up the first standards proved a daunting task. Foreign cases could be a guide, but domestic research supporting a certain threshold could not satisfy all the interested parties from industry, environmentalist groups, political conservatives, and scientific communities.

Emphasis on health over technology and cost in standards setting was an important characteristic of the community health approach reflected in the 1970 Clean Air Act. Prior to the 1970s, legislation on air quality began to mandate consideration of cost and technology factors for setting up standards on air pollutants. The 1970 act, in contrast, required the achievement of specific emission levels for pollutants regardless of technology, cost, or other measures. These performance standards were supposed to protect public health without consideration of economic and technical feasibility.[8]

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[7] Clean Air Act Amendments of 1970, Public Law 91-604, 42 U.S. Code 7609. Sections 4.2.2 and 5.1.1 also talks about other provisions of the 1970 Clean Air Act. As the 1970 Act significantly amended the previous act, it is often called the 1970 Clean Air Act, instead of the 1970 Clean Air Act Amendments. The same applies to the 1977 and 1990 Clean Air Act Amendments.

[8] The intention to establish emission standards based on health criteria did not always result in regulations that responded to only health concerns. First, existing knowledge about the pollution-health relationship depended on the then-current status of pollution monitoring and health research, which together influenced subsequent controversy about the most effective strategy to enforce standards. Second, economic thoughts and practices like cost-benefit and risk-benefit analysis became gradually popular in the early 1970s and facilitated the introduction of feasibility arguments, whether economic, technical, or political, into the discussion. Best practicable technology and best available technology are good examples for the inclusion of technical feasibility into standards for water pollution control. Finally, toward the end of the 1970s, the development and expansion of the control technology approach

CHESS continued studies that had already begun prior to 1970, before the creation of the EPA, and initiated new studies. As a whole, it became a collective, longitudinal study from 1969 to 1974 on eight selected areas: Los Angeles, California; Salt Lake Basin, Utah; St. Louis, Missouri; Chattanooga, Tennessee; Birmingham, Alabama; Charlotte, North Carolina; New York City; and the New York/ New Jersey border. Like other early EPA projects, CHESS had begun in preceding agencies. When NAPCA was established in 1968 in Research Triangle Park (RTP), North Carolina, the management of various epidemiological studies was correlated with air monitoring collection, and named the Health Surveillance Network. After 1970, the existing project expanded and was renamed as CHESS.[9]

CHESS was conducted primarily by EPA researchers at RTP, as its early case studies were undertaken by NAPCA researchers also at RTP. As one of the ORM's four centers for environmental research, NERC-RTP inherited laboratories from NAPCA, the Bureau of Radiological Health, and the Federal Drug Administration. It focused on comprehensive health effects research from air pollution, including sampling and measurement methods, pollutant formation and decay, air pollution meteorology, and control technology for stationary sources.

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influenced details concerning regulatory standards and enforcement timelines along with the rise of economic incentive programs. See sections 5.4 and 6.2 for more detail.

[9] In various government and contract reports, the CHESS study areas were defined differently. I used the most frequently used definition. Confusion about the definition of CHESS were not an isolated event. In at least two government reports, the word "studies" was used instead of "system," as in the Community Health and Environmental Surveillance Studies. Statewide Air Pollution Research Center, *Community Health and Environmental Surveillance Studies California Progress Report, July 1972-April 1973* (Riverside, CA: University of California, Riverside, 1973); EPA, *Community Health and Environmental Surveillance Studies (CHESS) Air Pollution Monitoring Handbook: Manual Methods* (Research Triangle Park, NC: EPA, Office of Research and Development, Health Effects Research Laboratory, January 1976). Areas covered by CHESS also differ in various government reports, but I chose to focus on the eight areas aforementioned.

For fiscal year 1971, NERC-RTP operated on a budget of $52 million with 752 employees. The 1972 RTP annual report shows that CHESS was one of the three important studies of the year.[10]

Integrating various projects under the new title of CHESS became the first hurdle. When Greenfield assumed responsibility for CHESS and assigned NERC-RTP as its headquarters, Delbert Barth and John Finklea were already busy incorporating new and old projects. Barth had worked as a radiation health specialist in the U.S. Army and the U.S. Public Health Service (PHS) and then became the director of the Bureau of Criteria and Standards of NAPCA. With the creation of the EPA, he became the director of the Bureau of Air Pollution Sciences at RTP. When RTP laboratories were designated the third NERC in August 1971, he was named the first director of NERC-RTP. Upon Barth's move to NERC-Las Vegas, which became the fourth NERC in August 1972, Finklea took over as the director of NERC-RTP.[11] Finklea also was a former NAPCA employee. He was trained as a physician and public health administrator. He started his career in medical schools before becoming chief of the Ecological Research Branch of NAPCA's Division of Health Effects Research in 1969. He moved upward to take the directorship of the expanded Health Effects Research Laboratory at the EPA in 1971.[12]

While CHESS demanded complex scientific research combined with the collection and analysis of an enormous amount of information, the research team lacked adequate professionals

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[10] EPA, *National Environmental Research Center, RTP, NC, Annual Report - 1972* (Research Triangle Park, NC: EPA, Office of Research and Monitoring, National Environmental Research Center, Research Triangle Park, June 1973), 9-16, 19-23. The other two were control of sulfur oxides by scrubbers and the Regional Air Pollution Study.

[11] Delbert S. Barth, Interview by the author, February 10, 2011; "Biography of Delbert S. Barth, Assistant Surgeon General, Rear Admiral, USPHS (ret.)." For details about the NERC and its structure, see section 2.3.

[12] Kaye H. Kilburn, "In Memoriam: John F. (Jack) Finklea; Born: August 27, 1993, Died: December 22, 2000, Consulting Editor: 1986-2000," *Archives of Environmental Health* 56, no. 4 (2001): 293.

from engineering, statistics, epidemiology, and chemistry. Nevertheless, on short notice, supervisors directed Barth and Finklea to update air quality criteria for sulfur oxides in order to prepare for a lawsuit dealing with primary and secondary air quality standards.[13] Whether CHESS research was conducted in conjunction with or for the preparation of legal cases on stationary air pollution made an issue for later controversy.

3.2 The Co-Production of Clean Air, Healthy Bodies, and Efficient Bureaucracies

Finklea incorporated the organizational legacy and new research initiative in the context of the NERCs. Since CHESS involved conducting sophisticated scientific research that collected and analyzed an enormous amount of data, Finklea redesigned CHESS as a systematic study composed of three types of research: aerometry, epidemiology, and correlation analysis of health effects with atmospheric pollution. Unpacking the concepts embedded in its acronym can be a good way to understand the purpose and structure of CHESS. In this section, I will explain five concepts comprising CHESS as it appeared in its early stage: *community*, *health*, *environment*, *surveillance*, and *system*.

For CHESS, the term *community* was defined as a middle-class residential segment of a city containing three or four elementary schools and sometimes a secondary school.[14] The EPA justified the selection of middle-class neighborhoods by claiming that these communities had

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[13] U.S. Congress. House. Committee on Science and Technology. Subcommittee on the Environment and the Atmosphere. Committee on Interstate and Foreign Commerce. Subcommittee on Health and the Environment, *The Conduct of EPA's "Community Health and Environmental Surveillance System" (CHESS) Studies: Joint Hearing*, 94th Cong., 2nd sess. (Washington, DC, April 9, 1976), 129.

[14] Riggan et al., "CHESS," 111-123.

lower levels of population mobility.[15] The comparison of area data demanded statistical methods that accounted for demographics (age, sex, race), exposures (diet, water, smoking status, daily movement), and other local information. Each community was chosen within a specific area to represent an exposure gradient for pollutants, otherwise similar to other communities in meteorological and socioeconomic conditions. The gradients were, for example, PM with low SO_2 (St. Louis and Birmingham/Charlotte areas), SO_2 gradient with low PM (Salt Lake Basin), and SO_2 and PM (New York/New Jersey) (fig. 3.1).[16]

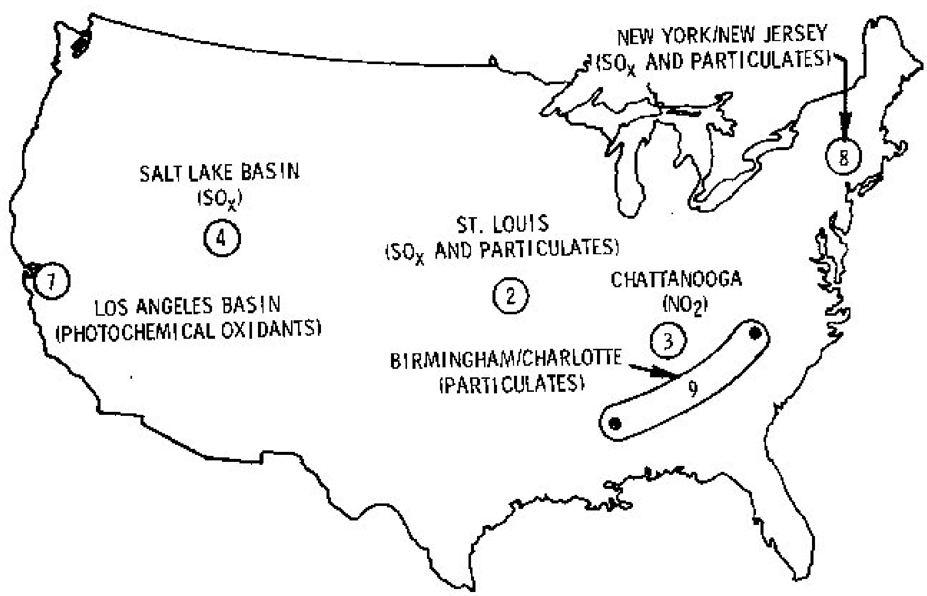

Fig. 3.1 CHESS Areas as of March 1973. *Source*: EPA, *Health Consequences of Sulfur Oxides* (Research Triangle Park, NC, 1974), 1-4. (Each number inside the area's circle shows the number of the communities included. Note that Los Angeles is misplaced on the map.)

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[15] The reference group being referred to was not made clear by the researchers. Considering other epidemiological research designs of the era, it is possible that CHESS researchers assumed that lower-class populations had a higher frequency of moving to seek lower rent.

[16] U.S. Congress. House, *The Conduct of EPA's CHESS Studies*; Riggan et al., "CHESS," 111-123.

Respiratory *health* was the second aspect of CHESS, with a focus on subsets of the population vulnerable to pollution. The Clean Air Act Amendments of 1970 required the EPA to protect public health and the environment by setting up NAAQS and demanded each state to submit a "state implementation plan" to make and achieve time-sensitive goals.[17] CHESS researchers also aimed to quantify pollutant burdens in the exposed population. While there was general agreement on the connection between pollutants and respiratory diseases, scholars still debated how much of an influence came from each pollutant.[18] That was why CHESS employed several gradients of SO_2, PM, O_3, and NO_X. In addition, researchers were still in search of other possible explanations of certain diseases. For example, asthma was considered to be aggravated by environmental exposure, but researchers also recognized other causes such as allergies, immune system abnormalities, and weather conditions.[19]

The design of health indicators in CHESS showed researchers' emphasis on showing subtle associations rather than strong causation. The chosen health indicators—chronic respiratory diseases in adults, acute lower respiratory diseases in children, acute upper respiratory diseases in families, daily asthma frequency, acute irritation symptoms during air pollution episodes, pulmonary function of school children, and tissue residues of cumulative pollutants in humans—reflected morbidity rates (the occurrence of diseases) more than mortality rates (the occurrence of death). This choice of indicators was meant to explore low-dose effects

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[17] Clean Air Act Amendments of 1970, Public Law 91-604, 42 U.S. Code 7609; Paul G. Rogers, "Clean Air Act of 1970," *EPA Journal* 15 (January/February 1990).

[18] Harry Heimann, *Air Pollution and Respiratory Disease* (Washington, DC: U.S. Department of Health, Education, and Welfare, Public Health Service, 1964).

[19] Homer A. Boushey and John V. Fahy, "Basic Mechanisms of Asthma," *Environmental Health Perspectives* 103, Supplements 6 (September 1995): 229-233.

on health. Also, there was a particular focus on children, the elderly, and asthmatics. By focusing on so-called vulnerable populations, CHESS aimed to achieve practicability and relevance for the populations most threatened by pollution. Thus, to fulfill the EPA's mandate, CHESS researchers looked at correlations between pollutant exposures and respiratory health concerns of the subgroups within the communities who needed most attention.[20]

3.2.1 Monitoring the Environment and Quantifying Health through Systems

For CHESS, the *environment* meant ambient air in the communities where research was conducted. CHESS's monitoring activities were different from the previous ones in two ways: standardization and integration. RTP headquarters was responsible for providing compatible monitoring devices to each community. Proper calibration of these devices was essential for the monitoring network to obtain reliable and manageable data. CHESS researchers used pollution monitoring guidelines to make contractors follow standard procedures.[21]

Integrating the information from the monitoring network was essentially expanding and maintaining the boundaries of the federal environmental management. For each community, the EPA built air monitoring shelters and installed particulate samplers, NO_2 bubblers, and analyzers

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[20] Finklea et al., "Health Intelligence for Environmental Protection," 101-109.

[21] The government of the modern state is, by nature, interested in the monitoring of its resources. Monitoring of its people and the environment, in return, contributed to the formation of the modern government. To understand how the state makes those resources visible and simplified, see James Scott, *Seeing like a State: How Certain Schemes to Improve the Human Condition Have Failed* (New Haven, CT: Yale University Press, 1998). On the efforts to quantify nature and society and to build a trust around it, see also Theodore M. Porter, *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life* (Princeton, NJ: Princeton University Press, 1996). On the standardization of instruments and its influence in science and industry, see Bernward Joerges and Terry Shinn, eds., *Instrumentation between Science, State, and Industry* (Dordrecht: Kluwer, 2001).

in and out of the shelters.[22] First, contractors were chosen from a pool of academic or private researchers. Then the EPA assigned contractors to be responsible for installing and checking the bubblers and filters and returning them back to headquarters at RTP. Contractors also gathered meteorological data such as wind speed and direction, outside and inside temperature, and relative humidity.[23] After successful standardization and integration, knowledge about and network for community health became applicable to the national level.

Surveillance of community health was directly related to one of the ultimate goals of CHESS, documentation of the health benefits of pollution control. Researchers collected the community health information through questionnaires, phone interviews, diaries, and function tests. They either distributed one-time questionnaires through schools to families or conducted bi-weekly telephone interviews about acute and chronic respiratory disease. Pulmonary function testing measured the lung ventilatory performance of children (fig. 3.2). The asthma panel studies recruited participants from families and requested them to report their asthma symptoms by mailing back the diaries. After each round of study, these data were coded into the op-scan sheets for data processing at the RTP facility. Surveillance of community health and the environment was a good start.

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[22] American Institute of Chemical Engineers, *Pollution and Environmental Health* (New York: American Institute of Chemical Engineers, 1961).

[23] EPA, *CHESS Air Pollution Monitoring Handbook*; Statewide Air Pollution Research Center, *CHESS California Progress Report*, 7-8.

Fig. 3.2 Pulmonary Function Testing of California School Children in 1973. *Source*: Statewide Air Pollution Research Center, *CHESS California Progress Report, July 1972-April 1973*. the EPA Contract No. 68-02-0664 (Riverside, CA: University of California, Riverside, 1973), 91.

3.2.2 Origins and Operation of the CHESS System

The ambitious goals of CHESS could not be realized unless the two *systems* of pollution and health were connected. In 1971, Greenfield announced to fellow meteorologists his “commitment to the total system concept, the inter-relation of environmental problems.”[24] CHESS’s pollution monitoring system and health surveillance system had several roots ranging from sanitary engineering to systems engineering to ecosystems theory. In this regard, CHESS itself was a giant system of research and monitoring that aimed to connect the two systems:

[24] Greenfield, “Our Future is Up in the Air,” 846.

pollution monitoring and health surveillance. In an attempt to facilitate the operation of CHESS, researchers employed logistical networks and data processing methods to correlate air pollution with health. Researchers faced several challenges in combining pre-existing frames for thinking about the environment in a systems framework.

The EPA's pollution monitoring system, inherited from NAPCA, emulated the operations research approaches of military-industrial projects.[25] The Mitre Corporation's report of a NAPCA contract shows us a schematic diagram of a nascent pollution monitoring system. The headquarters for monitoring the environment first standardized the manual of exemplary stations and disseminated it to the monitoring branches. Using a detailed timeline, headquarters assigned responsibilities and delegated authority to the branches. By setting up headquarters, branches, and communications between them, the EPA developed CHESS's monitoring network to be an infrastructure for further environmental management. The reliability of the monitoring network depended on each branch's capacity to collect data and headquarters' capacity to process and analyze it.

Another dimension of the systems idea came from sanitary engineers and public health specialists. The rise of germ theory and its targeting of water-borne diseases led to urban reform and new public works at the beginning of the twentieth century. After the gradual development of the public health system in the first half of the century, sanitary engineers encountered the challenges of growing urbanization and increasing demands for clean water and wastewater

[25] R. B. Shaller, *System Development Plan: A Systems Approach for Acquiring Air Monitoring Networks* (Washington, DC: Mitre Corporation, 1970).

treatment.[26] Sanitary engineers then accepted the new ecosystems ecology, where the environment was defined as consisting of independent yet overlapping systems of air, water, land, and nonhuman species.[27]

Researchers at the RTP headquarters understood CHESS as a data processing system that connected health and pollution systems. Through bio-environmental measurements, researchers codified health and pollution information of the communities. They processed and analyzed the data to see if there were any correlations between health conditions and air pollution gradients. After an initial test with certain sets of data and feedback, researchers corrected the methods to enhance correspondence between measurements, data collection, and information synthesis in the system (fig. 3.3).

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[26] Martin V. Melosi, *The Sanitary City: Urban Infrastructure in America from Colonial Times to the Present* (Baltimore: John Hopkins University Press, 1999); Tarr, *Search for the Ultimate Sink*; Hays, *A History of Environmental Politics Since 1945*.

[27] Bocking, *Ecologists and Environmental Politics*.

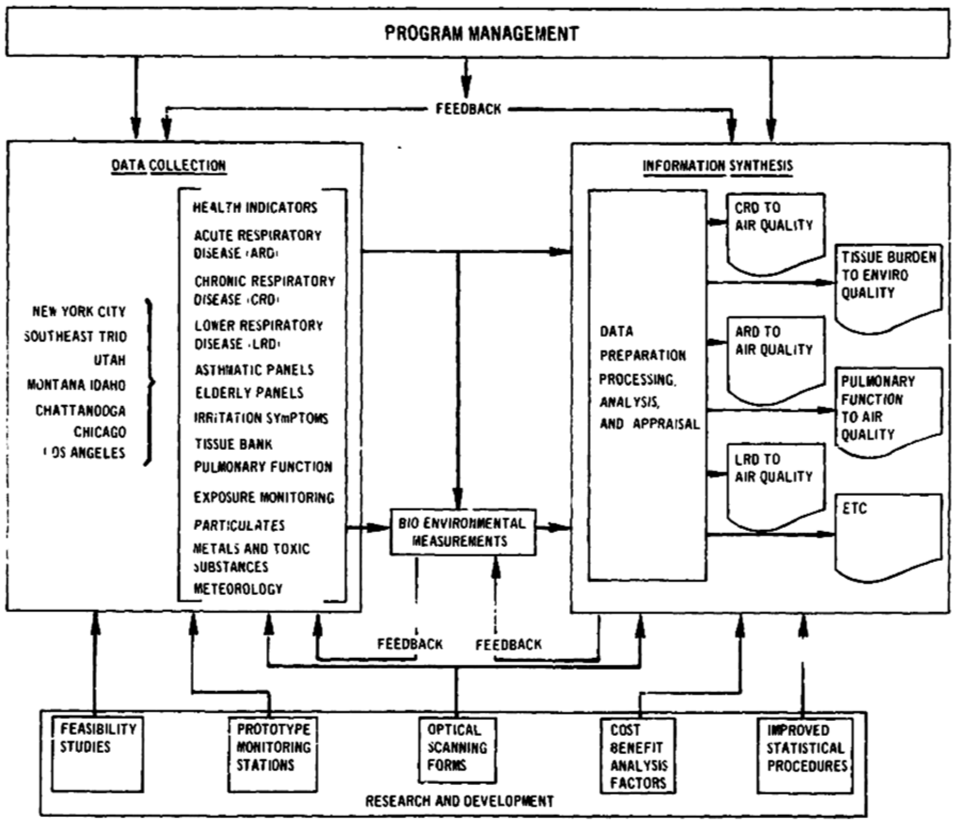

Fig. 3.3 Systematic View of CHESS Data Processing System as of 1972. *Source*: Riggan et al., "CHESS," in *Proceedings of the Sixth Berkeley Symposium on Mathematical Statistics and Probability* 6 (1972), 113.

The CHESS system, however, faced several challenges that would pose an obstacle to achieving its objectives. As the project spanned several years in various locations, it was crucial for researchers to update each other on their progress. Quality assurance, the maintenance of particular standards for both measurements and data processing, became a recurring problem. Calibration of devices and training of monitoring personnel were under-funded.[28] Furthermore,

[28] Bregman Co., *Technical Primer on Major EPA Programs: Designed for Use by EPA's Quality Assurance Community* (Washington, DC: EPA, 1970).

CHESS publications were delayed as incoming data from various areas were much more extensive than expected and data processing became more time-consuming. At the same time, the conversion from IBM 360-50 to UNIVAC 1110 took time, as data had to be re-coded into the new computer system.[29] The underestimation of the challenge of conversion and the additional resources required delayed the process leading to the accumulation of piles of unprocessed CHESS data.[30] In light of their ambitious goals for a new system of environmental protection, CHESS practitioners were not successful in controlling the quality of their data processing practices.

In the final analysis, coordination was the key challenge to CHESS on many different levels. CHESS's research design seemed flexible enough to change over the years to meet challenges in implementing and linking together pollution monitoring and health surveillance systems. Each area study was independent but also was connected with other areas' results to form a comprehensive survey. However, intractable problems emerged as the project progressed. Within each area and community, cooperation with contractors sometimes demanded more time and budget dollars. Earning and maintaining the trust of research subjects demanded the commitment of field researchers and headquarter managers for continuing the program. Database systems were still under development and required more work and funds than expected. Conversion to a new computer system delayed the processing and validation of data, which were already behind schedule. Dealing with the scientific community outside the EPA, as well as industry, media, and other executive and legislative agencies ultimately threatened CHESS itself.

[29] Andrea Kelsey, Gene R. Lowrimore, and Jane Smith, "The Conversion of CHESS and Other Systems," in *Proceedings Number 1 of the OR&D ADP Workshop*, 282-288 (Washington, DC: EPA, 1975). Workshop held in Bethany College, WV on October 2-4, 1974.

[30] Shane M. Greenstein, "Lock-in and the Costs of Switching Mainframe Computer Vendors: What Do Buyers See?" *Industrial and Corporate Change* 6, no. 2 (1997), 258-261.

3.3 Controversies and Challenges of the System

In the early 1970s, engineers and scientists at the EPA played a critical role as guardians of the environment, with CHESS as their marquee example. But CHESS soon became embroiled in a controversy that altered the relationship between research and monitoring in the EPA. Through the review and revision process of CHESS publications, in-house and outside reviewers expressed concerns about measurement techniques and the health survey and analysis methods the project was using. A 1973 National Academy of Sciences (NAS) report concluded that: "The need for a great deal of information in the shortest possible time has meant that the EPA has been forced to attempt too much too superficially."[31] Authors of the 1973 report were straightforward in pinpointing technical faults and conceptual limitations, but were cautious in questioning CHESS researchers' capacity or integrity. The report of the 1974 Rall Committee on the health effects of sulfur oxides argued for more research on synergistic effects of pollutants, more epidemiological data, and a better research data base. The committee suggested that the research team assemble a group of outside reviewers for continuing advice.[32]

However, before CHESS could invite outside comments and correct drawbacks, the issue reached the media. In February and March of 1976, the *Los Angeles Times* published a series of newspaper articles on allegations about researchers' integrity and confrontations over the revision of sulfur oxides standards. This ballooned into an agency investigation and a Congressional hearing in April 1976 that led to more stringent oversight on the direction of the

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[31] EPA, *Addendum to the Health Consequences of Sulfur Oxides: A Report from CHESS, 1970-1971, May 1974* (Washington, DC, 1980), 119.

[32] David P. Rall, "Review of the Health Effects of Sulfur Oxides," *Environmental Health Perspectives* 8 (1974): 97-121.

EPA's research and development and ultimately to the separation of its research function from the regulatory process.

3.3.1 Wide Criticism on Epidemiology, Pollutants Measurement, and Scientific Integrity

The epidemiological elements of CHESS attracted the most criticism. Assembling 20 papers based on 1970–1971 school year data, Finklea and colleagues published the CHESS monograph *Health Consequences of Sulfur Oxides* in 1974.[33] Before its publication, the authors received comments on the 1972 draft of the monograph from colleagues in and out of the agency. Critics argued that the authors were over-interpreting their data, with which the authors didn't agree. So the EPA's Science Advisory Board (SAB), a public advisory group providing extramural scientific information, established a review panel for CHESS composed of 5 specialists: two statisticians, an epidemiologist, a toxicologist, and an environmental health engineer.[34]

In a review report published in March 1975, the SAB panel first criticized CHESS's epidemiological methods. They argued that CHESS limited its sample to middle-class and suburban populations, sampling was not done on a random basis, and response rates varied too much. The panel also pointed out an ambiguous definition of respiratory disease states and symptom severity, which caused difficulties in comparing results. Panelists then recommended

[33] EPA, *Health Consequences of Sulfur Oxides: Summary and Conclusions Based upon CHESS Studies of 1970-1971*. EPA-650/1-74-004 (Research Triangle Park, NC, EPA, Office of Research and Monitoring, National Environmental Research Center, Research Triangle Park, May 1974).

[34] Whittenberger et al., "Review of the CHESS Program: A Report of a Review Panel of the Science Advisory Board-Executive Committee, March 14, 1975," in *The Conduct of EPA's CHESS Studies*, U.S. Congress. House, 316-324 (Washington, DC, April 1976). On the SAB, see Jasanoff, *The Fifth Branch,* chapter 5; Bruce L. R. Smith, *The Advisers: Scientists in the Policy Process* (Washington, DC: Brookings Institution, 1992), chapter 4.

that EPA employees publish their results more in peer-reviewed scientific journals and collaborate with academic statisticians.[35]

While the SAB criticized specific methods of CHESS, it also supported EPA's technical assumptions and regulatory goals. The SAB report argued that, once these weaknesses were corrected, CHESS would contribute significantly to the health information regarding atmospheric pollutants. In its conclusion, the SAB panel recommended the continuation of epidemiological studies as vital to the "understanding of the effects of air pollution on health."[36] Panelists Ian Higgins, an epidemiologist who participated in the 1973 NAS committee, and David Rall, the physician who was in charge of the 1974 review committee, concurred that epidemiological and statistical contents in CHESS were competent results on the health effects of environmental factors.[37]

While the SAB panelists were conducting the review for their report, Finklea and his colleagues in RTP produced another report, *The Role of Environmental Health Assessment in the Control of Air Pollution*.[38] They admitted that uncertainties existed in the estimates of the pollution thresholds for each adverse effect associated with ambient air pollutant. However, they also defended themselves by arguing that the best they could do was to define "lower boundary (worst case)," "upper boundary (least case)," and "best judgment" estimates, so policy-makers could find thresholds to get safety margins for primary ambient standards. Reemphasizing the mandate of the Clean Air Act Amendments of 1970, the authors not only reviewed

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[35] Whittenberger et al., "Review of the CHESS Program," 317-318.

[36] Ibid., 318.

[37] Ian Higgins, *Epidemiology of Chronic Respiratory Disease: A Literature Review* (Ann Arbor, MI: University of Michigan, 1974).

[38] John F. Finklea et al., *The Role of Environmental Health Assessment in the Control of Air Pollution* (Research Triangle Park, NC: EPA, 1974).

environmental health assessments used in CHESS research, but also other assessments such as sulfur oxides from steam electric power plants and health impacts of equipping motor vehicles with oxidation catalysts. After enumerating existing and new studies, the authors did not conclude with a strong argument. Instead, in the presence of evidence indicating adverse health effects and uncertainties involved in the scientific information base, they showed subtle differences among three cases. As an answer to a question about lowering thresholds for ambient air pollution standards, they saw "no reason for abruptly changing these air quality goals." On stationary air pollution, however, they found "substantial excess adverse health effects."[39] The authors became more cautious on the last issue of catalytic converters. They acknowledged the benefit of reducing hydrocarbons, carbon monoxide, and phenols, but were concerned about emerging evidence of sulfates and sulfuric acids.[40] The authors didn't relate sulfur oxides and sulfuric acids from catalytic converters with those from smokestacks in this report. But concerns about sulfur oxides and their potential hazards were widespread and it is plausible that these concerns were not restricted by sources or media. They called catalytic converters a "mixed blessing."[41] I will come back to the links between the CHESS research, catalytic converters, and scrubbers when I introduce chapter 5.

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[39] Finklea et al., *The Role of Environmental Health Assessment*, 46-47; Boyce Rensberger, "Acid in Rain Found Up Sharply in East: Smoke Curb Cited," *New York Times* (June 13, 1974), 8-9.

[40] For example, see: John F. Finklea et al., "Estimated Changes in Human Exposure to Suspended Sulfate Attributable to Equipping Light-duty Motor Vehicles with Oxidation Catalysts," *Environmental Health Perspectives* 10 (April 1975): 29-34; John H. Knelson, "Evidence for the Influence of Sulfur Oxides and Particulates on Morbidity," *Bulletin of the New York Academy of Medicine* 54, no. 11 (December 1978): 1137-1154.

[41] Finklea et al., *Role of Environmental Health Assessment*, 46-47. Catalytic converters have recently attracted scholarly interests in history of technology and regulation; see Johnson and Dunn, "Chasing

In retrospect, the SAB report and the comments it engendered show the limitations of the epidemiology practiced at CHESS. Epidemiologists failed to consider the synergistic effects of the pollutants in measuring pollution exposures. When collecting health information, they mostly depended on questionnaires and interviews. Public reports about pollution colored participants' responses and attitudes, and in some cases respondents self-reported medical symptoms, such as asthma, without evaluation by physicians, making the results vulnerable to scientific criticism.

It did not take long for criticisms to expand to the aerometry section. Coal and electric utility companies saw the CHESS controversy as a chance to call for a moratorium on clean air legislation.[42] They also lobbied for favorable amendments to the Clean Air Act.[43] Stanley Greenfield, former supervisor of Finklea and now owner of a private consulting firm in California, became a vocal critic of CHESS research. Greenfield's consulting firm conducted contract-research funded by the electric utility industry, filed a Freedom of Information Act request to get raw data, and interviewed key EPA staff for information. Greenfield expressed "a technical or professional disagreement" with the CHESS monograph from his own analysis of the raw data.[44]

Molecules: Chemistry and Technology for Automotive Emissions Control"; Vinsel, *Federal Regulatory Management of the Automobile*, chapters 4 and 5.

[42] William B. Rood, "U.S. Chamber Asks Sulfur Case Probe," *Los Angeles Times* (March 31, 1976), B16. For additional detail about the coal and electric utility industries, see chapter 5.

[43] U.S. Congress. House, *The Conduct of EPA's CHESS Studies*.

[44] Greenfield, Attaway & Tyler, Inc., *Detailed Critique of the Sulfur Emission/Sulfate Health Effects Issue* (San Rafael, CA: Greenfield, Attaway & Tyler, Inc., April 1975). Later at the April 1976 Congressional hearing, however, Greenfield expressed a critical but equivocal position. While retaining his technical criticisms, he praised Finklea and his achievement in 1974 monograph. U.S. Congress. House, *The Conduct of EPA's CHESS Studies*, 11-39. Quote from 12.

Throughout the CHESS studies, infrequent calibration of instruments used in different communities made it difficult to compare results. For example, Anthony Vito Colucci, a former EPA employee and now consultant at Greenfield's firm, analyzed CHESS aerometric samples and argued that filters used for measuring sulfate contained varying amounts of sulfate in the manufacturing process.[45] Colucci considered the source of sulfate to be the pretreatment of the glass fiber matrix with zinc sulfate by the manufacturer. Furthermore, some contractors were careless about checking and calibrating instruments, which then yielded less reliable data. Quality assurance was slowly introduced, but the inconsistent previous data from various CHESS areas hindered integrated analysis of the pollution-health relationship.[46]

The validity of remaining CHESS data was another issue between industry and the EPA as the data might be a valuable resource to revise air quality standards. The EPA, with the help of scientific and engineering communities and the Natural Resources Defense Council, argued that these data were still a meaningful contribution to pollution and health research. Carl M. Shy, a former EPA employee and professor at the University of North Carolina, assumed responsibility for analyzing the rest of the data. Contracted by the Electric Power Research Institute (EPRI) and

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[45] U.S. Congress. House. Committee on Science and Technology. Subcommittee on Special Studies, Investigations, and Oversight. Subcommittee on the Environment and the Atmosphere, *The Environmental Protection Agency's Research Program with Primary Emphasis on the Community Health and Environmental Surveillance System (CHESS), An Investigative Report*, 94th Cong., 2nd sess. (Washington, DC, November 1976), 34-39.

[46] Electric Power Research Institute, *Evaluation of CHESS: New York Asthma Data 1970-1971* (Palo Alto, CA: Electric Power Research Institute, 1977); H. Daniel Roth, John R. Viren, and Anthony V. Colucci, *Evaluation of CHESS: New York Asthma Data 1971 to 1972* (Palo Alto, CA: Electric Power Research Institute, 1981); A.R. Olsen, *Evaluation of CHESS: Utah Asthma Study, 1971-1972* (Palo Alto, CA: Electric Power Research Institute, 1983). On Roth's other research in industry's defense, see David Michaels, *Doubt is Their Product: How Industry's Assault on Science Threatens Your Health* (New York: Oxford University Press, 2008), 50-51.

representing the electric utilities and steel industry, H. Daniel Roth argued that the remaining pollution data should be abolished. After 1977, using the remaining CHESS data for policy was restricted, and no more CHESS reports were officially produced.[47]

Epidemiologists, however, continued to discuss the methodology and evidence of CHESS. In the November 1979 issue of *American Journal of Epidemiology*, British epidemiologists published a long review article supported by a grant from the American Iron and Steel Institute. The review article covered studies on health effects of particulate pollution published between 1968 and 1977. They argued that CHESS and other evidence did not substantiate the then-current standard of total suspended particulates.[48] In the next issue in December, three reviews appeared, and one of them was written by Shy, co-worker and supporter of Finklea. Shy first laid out the historical differences in legislation and science in Britain and the United States. Then he argued that the review article authors applied uneven levels of critical evaluation of various studies, offered inconsistent comments, and expressed unsupported criticisms of CHESS.[49]

In February 1976, the CHESS controversy expanded from battles among experts in academic, government, and corporate sectors to debates the public engaged in. The *Los Angeles*

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[47] EPA, *Status of the Community Health and Environmental Surveillance System (CHESS): Report to the U.S. House of Representatives Committee on Science and Technology* (Washington, DC, EPA, Office of Research and Development, Office of Health Research, November 1980); Leo T. Heiderscheit and Marvin B. Hertz, *An Assessment of the CHESS Sulfate and Nitrate Data During the Period RETA Performed the Chemical Analysis* (Research Triangle Park, NC, EPA, 1977); John Bachmann, "Will the Circle Be Unbroken: A History of the U.S. National Ambient Air Quality Standards," *Journal of Air and Waste Management Association* 57 (2007): 652-697.

[48] Holland et al., "Health Effects of Particulate Pollution: Reappraising the Evidence," *American Journal of Epidemiology* 100, no. 5 (November 1979): 525-659.

[49] Carl M. Shy, "Epidemiologic Evidence and the United States Air Quality Standards," American Journal of Epidemiology 110, no. 6 (1979): 661-671.

Times reported that John Finklea, the former head of CHESS and the then-current director of the National Institute for Occupational Safety and Health (NIOSH) since April 1975, deliberately distorted findings in the CHESS monograph. The reporter William B. Rood argued that Finklea rewrote the work of agency scientists, deleted important qualifiers, and "overrode agency scientists' objections to publishing estimates of the health impact of pollution which were either statistically dubious or unsupportable." Rood also argued that "relying heavily on the disputed CHESS studies, EPA [had] called for controls on sulfur pollution that would cost power companies and ultimately American consumers billions of dollars."[50]

Contrary to Rood's assertion, congressional staffers had a difficult time finding witnesses critical of Finklea. EPA administrator Russell Train and researchers were invited to testify about Finklea and CHESS. There were also outside commentators, some of whom had previously worked with Finklea in and out of the EPA. *Science* reporter Philip Boffey summarized the witnesses' statements that the revisions made were to establish uniformity and completeness and Finklea left out qualifying statements, but those omissions were never systematic or intentional. Although short deadlines made the situation worse, Boffey added, Finklea's draft had gone through review, criticism, and revision, and the final document was a valuable piece of research. The document employed "best judgment" approaches not "worst case" analyses.[51] Robert Buechley, an epidemiologist at the University of New Mexico and previously a public health analyst in NAPCA and the EPA until early 1973, was the most critical of Finklea, but he also acknowledged that he did not work on CHESS himself but overheard others' gripes.[52]

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[50] Rood, "EPA Study-The Findings Got Changed."

[51] Philip M. Boffey, "Sulfur Pollution: Charges that EPA Distorted the Data Are Examined," *Science* 192, no. 4237 (April 23, 1976): 352-354.

[52] U.S. Congress. House, *The Conduct of EPA's CHESS Studies*, 59-82.

3.3.2 Institutionalizing the New System of Environmental Protection

Criticism of the execution of CHESS moved to suggestions about how the Office of Research and Development (ORD, the successor of ORM after July 1973) should coordinate research and development. During heated discussions about CHESS and subsequent delays of actions in Congress, the ORD abolished its NERC system in 1974 and reorganized its offices and laboratories into four new sub-offices in 1976: the Office of Air, Land, and Water Use (OALWU); the Office of Energy, Minerals, and Industry (OEMI); the Office of Health and Ecological Effects (OHEE); and the Office of Monitoring and Technical Support (OMTS). ORD headquarters in Washington now directly coordinated laboratories that previously reported to four NERCs. The new structure emphasized the development of pollution control technology and quality assurance. Now under the aegis of OMTS, monitoring and pollution control came to encompass other functions in the ORD. The biggest circle and the bottom triangle in *figure* 3.4 symbolically show these two characteristics of the reformed system. Monitoring, equipment development, technical assistance/support, and quality assurance occupied both foundational and supportive roles within the ORD (fig. 3.4).

Congress responded by passing a new law specifying the EPA’s role and responsibility in environmental research and development. In November 1976, the House Committee on Science and Technology published a post-hearing investigative report to point out its findings and recommendations regarding CHESS. The report agreed with SAB that CHESS was a valuable combination of epidemiology, aerometric measurement, and data analysis. The report acknowledged many difficulties in novel research in epidemiology and pointed out problems in the aerometry and health measurement and analysis. But it also suggested that the EPA’s planning and management of overall research and development be reformed. At the same time, it touched on bigger issues, such as the Office of Management and Budget's intervention and lack of personnel and revenue. While acknowledging poor morale in the ORD, the investigation report warned that there should be no more reorganization at least until Fiscal Year 1977.[53]

In November 1977, Congress passed the Environmental Research, Development, and Demonstration Authorization Act (ERDDAA).[54] ERDDAA provided a statutory basis for SAB and directed the EPA administrator to submit an annual report, *Research Outlook*, and a five-year plan for research, development, and demonstration accompanied by SAB comments. It further directed that the SAB independently report to Congress on EPA's health effects research generally and on the findings and recommendations of the 1976 investigation report in particular.[55]

In the new system of environmental protection, monitoring became less visible, first in practice and then in organization. When environmental problems were defined as monitoring problems in CHESS, EPA researchers pursued technical innovations and organizational changes in an attempt to quantify pollution. They then similarly quantified community health effects and related the two to show the benefit of environmental regulation. Through pilot studies, advanced technologies, and constructive feedback, monitoring of air pollutants became routine work and was downgraded to be supportive of other long-term research and regulatory actions.

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[53] U.S. Congress. House, *The CHESS, An Investigative Report*, 25-27; EPA, *Planning and Management of R&D in EPA* (Washington, DC: June 1978). There was another reorganization of the ORD in February 1980. Titles of the five offices after the 1980 reorganization are Office of Monitoring and Technical Support, Office of Health Research, Office of Environmental Processes and Effects Research, Office of Environmental Engineering and Technology, and Office of Health and Environmental Assessment.

[54] Environmental Research, Development and Demonstration Authorization Act, Public Law 94-475, 42 U.S. Code 4361-4370.

[55] EPA, *Addendum*.

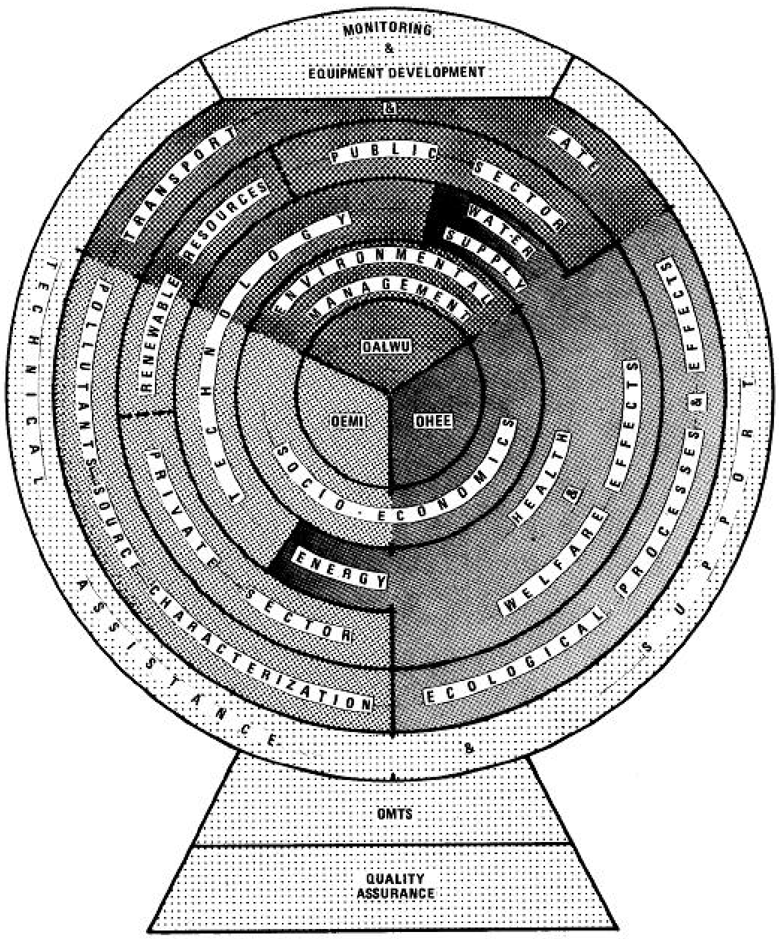

Fig. 3.4 ORD's Four Sub-offices and Their Roles in 1976. *Source*: EPA, *Environmental Research Outlook 1977-1981* (Washington, DC: EPA, Office of Research and Development, February 1977), 9.

The 1976 reorganization of the ORD was the final step in downsizing the monitoring function at the EPA. The 1974 renaming of the ORM to the ORD had already reflected the relative depreciation of monitoring within the office. No new monitoring projects were initiated, unless they were in support of urgent enforcement cases or long-term research. Long-range and explanatory research was separated from day-to-day monitoring activities and drew more attention and money. The Office of Monitoring was combined with the Office of Environmental Engineering to take only “short-term activities like quality assurance, monitoring, and analytic responses to the immediate needs of other agency programs.”[56]

Previously, downsizing of monitoring functions at the ORD provided opportunities for the proponents of the control technology approach. Results from continuous and special monitoring research projects had already contributed to technical innovation in ambient air quality measurement and related data processing. As monitoring assumed a more supportive role for other scientific and engineering functions at the ORD, a shift in focus occurred from identifying and monitoring areas of concern to developing better control technologies that could be applied nationally. The community health approach, as a result, faced growing challenges to broaden its scope to the national level.

When monitoring became more routine and less visible, industry and scientific communities each sought different goals. For industry, this change in monitoring meant tactical success. The CHESS controversy had actually overburdened the ORD and delayed the legislative efforts to update the criteria standards. For broader scientific communities, downsized monitoring also opened up chances to pursue long-term research. Elite scientists and institutions found it more attractive to redirect the EPA’s ORD to sponsor long-term, and more likely, basic research. The NAS president Philip Handler supported the House Science and Technology committee’s chairman, Representative George E. Brown, to get consensus to enact ERDDAA.

Ironically, the CHESS controversy stimulated both academic and corporate interest in future epidemiological studies, despite those studies being downsized at the EPA. Inspired by the

[56] Wilson K. Talley, “The Research Mission,” *EPA Journal* 1, no. 9 (1975): 2; U.S. National Research Council, *Strengthening Science at the Environmental Protection Agency: Research-Management and Peer-Review Practices* (Washington, DC, 2000), 28.

broad agenda of CHESS, and challenged by the attack on epidemiological research in general, James L. Whittenberger, an epidemiologist and the 1975 SAB review committee chairperson, persuaded Harvard colleagues to initiate the "Harvard Six Cities Study." As a result, CHESS helped other epidemiologists to find out the importance of indoor air quality and the close relation between particulates and cardiovascular mortality.[57] In sum, when CHESS ceased to be a pioneering project, monitoring became part of a standard problem-solution set, and epidemiological studies outside the EPA became stronger and more robust endeavors.

3.4 Conclusion: Health Research and Control Technology after CHESS

CHESS and the controversy its work engendered represented an important moment in the co-production of environmental policy, institutions, and knowledge during the EPA's first decade. Through organizational trial and error, the EPA met the challenges of defining what it regulated and proving the benefits of doing so. The EPA's research agenda and mechanisms for regulation together shaped the agency's authority and its staff's identity. With a mandate to deal with urgent pollution problems, the EPA relied on various measures: chemical monitoring, health research, enforcement, and technology development. The practices of planning, execution, and evaluation of these measures were contingent on organization, human power, and budgeting, as well as the EPA's leverage in Washington politics and state bureaucracies. Studying CHESS showcases the dynamic relationships between monitoring, technical innovations, and organizational priorities in the new system of environmental protection. Here I make two claims on the asymmetrical relationship between research and regulation and the assemblage of technical and conceptual innovations.

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[57] James L. Whittenberger, "Health Effects of Air Pollution: Some Historical Notes," *Environmental Health Perspectives* 81 (1989): 129-130; "A Tale of Six Cities," *Harvard Public Health Review*.

First, while CHESS became mired in recriminations and monitoring turned less visible, the EPA’s research agenda became more attached both to EPA’s regulatory timelines and guidelines from Congress and to elite scientific communities. Interaction between the ORD and other Program Offices was asymmetrical from the beginning. William Ruckelshaus established the ORD independently from the Program Offices on air, water, pesticides, and solid waste. Stanley Greenfield then proposed the NERC system that could focus on particular environmental concerns, such as water and air pollution, radiation, and ecological effects. Greenfield believed that ORD researchers were most productive when they were kept insulated from economic reality, regulatory needs, and influences inside and out. However, the EPA leaders expected regulators to be aware of current research outcomes, even if researchers weren’t always on top of current regulatory goals. So influence flowed more freely from the cross-cutting offices for monitoring, research, and development to the program offices of regulatory missions. This asymmetry reversed after the CHESS controversy and subsequent reorientation of the EPA. Regulators became skeptical of relying exclusively on the latest research results from the ORD. Researchers at the ORD were expected to know the EPA’s regulatory timeline and were mandated to provide an annual 5-year research outlook to Congress. Industry and scientific communities produced their own results and served as advisors or peer reviewers.

Second, CHESS researchers and their successors developed more advanced strategies to connect the pollution monitoring and health surveillance systems. EPA researchers and managers were proud of what they considered to be exemplary pollution and health research and of the progress in air pollution control, and they wanted to expand the results into other media. By designing CHESS area studies with diverse exposure gradients, Finklea wanted to show both the accomplishments from the early pollution control measures and the remaining issues that needed urgent action. Additionally, CHESS showed how monitoring and research benefited each other. Aerometry missions contributed to the development of new pollutant measurement techniques. Its epidemiological research generated health indicators to measure subtle information about morbidity. New ecological concepts and data processing technologies were introduced, tested, and revised. CHESS left new methodologies and infrastructure for subsequent research and monitoring.

In the 1970s, EPA engineers, scientists, and managers created and transformed the U.S. system of environmental protection and redefined the meaning and reality of the environment on a national scale. By looking at CHESS and its monitoring, technology, and staff against the background intention of the co-production of clean air, healthy communities, and efficient regulations, I offer a first step in tracing the development of the environmental protective system in which we live. The EPA went through major reorganizations throughout the 1970s and the rearrangement of the ORD was an important outcome of the CHESS controversy. While ORD researchers employed up-to-date technologies, they also initiated new organizational reforms to mobilize professionals and community members. The new system of environmental protection represented the downsizing of monitoring functions and the upscaling of energy related development.[58]

[58] EPA, *Interagency Energy/Environment R&D Program* (Washington, DC: EPA, Office of Research and Development, Office of Energy, Minerals, and Industry, March 1977). See also section 5.3.

Chapter 4. Shifting Gears from Community Health to Control Technology: Catalytic Converters and Regulating Mobile Emissions, 1970-1977

"Technical information of vital importance to public health, to environmental protection, and to economic well being must be more readily available to the public at large, to public interest groups, to industry and to government if our democratic society is to function for the common good." [1]

-John F. Finklea, Director, National Environmental Research Center, RTP

"The third strategy, therefore, assumes that the responsible government officials really want to learn, that they really want to find solutions that meets [*sic*] the objectives of the law without causing any more cost or disruption than is absolutely necessary. In other words, in this third strategy, the representatives of the affected company do everything that they can do to help the government figure out how to get the Job done in best possible way [*sic*]."[2]

-Eric Stork, Deputy Assistant Administrator, Office of Mobile Source Air Pollution Control

What was the role of government engineers, scientists, and managers when they learned about negative health and environmental consequences of a promising pollution control technology? Their responses were diverse. Some health effects researchers argued for a precautionary approach and shared potential risks of the technology with the public. Other

[1] John F. Finklea, "Introductory Statement," *Environmental Health Perspectives* 10 (1975): 3.

[2] Eric O. Stork, "Living with Regulation," Remarks at Automotive Emissions Seminar, General Motors Corporation. Warren, Michigan, June 19, 1973.

regulators, concerned about a regulatory vacuum when deadlines are delayed and their authority undermined, demanded the introduction of pollution control technology. As we saw in chapter 2, the EPA inherited people, facilities, and ideas from its predecessors, and regulators and researchers had diverse approaches to health research, technology development, regulatory procedure, and public service. Overall, researchers and regulators became increasingly aware of each other's needs and cognizant of peers in government, industry, and academia. As engineering practices for technology control and environmental regulation gradually influenced the knowledge, identity, and ethos of EPA employees, "regulatory engineering" became more prevalent in the EPA.

Even abruptly discontinued projects left groundwork for the next ones to develop. CHESS was an ambitious research project to link ozone (O_3), particulates (PM), and sulfur dioxide (SO_2) with respiratory diseases in the community. Despite the criticism of CHESS and subsequent organizational changes, CHESS researchers left advanced technologies and infrastructure for studying the health effects of air pollution and evaluating the pollution control devices to mitigate them. We will see how researchers and managers benefited from and built upon CHESS to deal with air pollution problems from mobile and stationary sources respectively in this chapter and the one that follows.

The catalytic converter is a device on automobiles that converts hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NO_X) into water (H_2O), carbon dioxide (CO_2), and nitrogen (N_2). From devices to protect air, catalytic converters themselves became a topic of controversy and something in need of defense—despite, and in fact because of, becoming the de facto standard for light-duty, gasoline-powered motor vehicles. Proponents of the technology justified it as a way of remediating tailpipe pollution, yet the device also changed the composition of emissions in such a way that it generated *new* pollutants and potential health and environmental effects, which in turn became another topic of research and regulation for EPA scientists and engineers. The noble-metal catalyst itself was a potential health hazard, and the possibility of increasing sulfuric acid (H_2SO_4) emissions with the use of catalytic converters aroused intense discussion among the EPA's own researchers and regulators.

After an initial period of corporate resistance, widespread application of catalytic converters in light-duty, gasoline-powered motor vehicles and the recurring suspensions of emission standards influenced future research and regulation. Automakers and regulators tested vehicles in special facilities, on roadsides, and in tunnels. There were several competing measurement methods for emissions over which government and corporate engineers could not agree. New standards were introduced for particulates (including SO_2) and other fuel additives. To make sure the converters were in compliance with the newly set emissions standards, inspection and maintenance for emissions became mandatory for car-owners in selected areas from 1977.[3]

In this chapter, I argue that emissions regulation, health research, and control technology development were co-produced during the 1970s. I explore the catalytic converter's delayed implementation and how it became "the" technology of automobile emissions control. I will also argue that the control technology approach became more dominant over the rival community health approach after the intra-agency debate on unintended effects of catalytic converters. In section 4.1, I first introduce the technical and social background of tailpipe emissions research and regulation by the EPA and its predecessors from the 1920s to the early 1970s. By focusing on the life cycle of catalytic converters in section 4.2, I explain how these devices became "the"

[3] U.S. National Research Council, Evaluation Vehicle Emissions Inspection and Maintenance Programs (Washington, DC, 2001).

control technology through sharp confrontation and strategic cooperation between the EPA, auto industry, and outside experts. In section 4.3, I focus on sulfur issues and intense discussions between industry and the EPA and among EPA's own researchers and regulators. I close with a shift in regulatory approaches from community health to control technology and its influence on EPA research on health effects of pollutants from mobile sources and alternative pollution reduction strategies.

4.1 The Origins of Tailpipe Emissions Research and Regulation

To explain why the EPA came to insist on catalytic converters in the 1970s, we need to first understand the broader contexts of tailpipe emissions research and regulation. Los Angeles and California were far ahead of other cities and states in experiencing smog and regulating automobiles, and we need to start from their history. Contrary to the Californian passion for driving and cleaner air, automakers were reluctant to introduce any device on their cars until forced by regulation or the market. This section ends with growing activities in emissions research and regulation by the federal government.

4.1.1 Lead and Smog

In 1927, the French mechanical engineer Eugene J. Houdry discovered a catalysis process to crack petroleum and yield high-octane gasoline without lead. By mass-producing cheap, high-octane gasoline in the 1930s, he paved the way for the automobile industry to develop powerful and efficient engines. After his retirement from the U.S. oil industry, Houdry became concerned about unburned hydrocarbons (HC) and smog, and he patented and produced catalytic converters from his company Oxy-Catalyst in suburban Philadelphia. His device was a ceramic honeycomb, with a large number of tiny passages, coated with catalysts, typically platinum, rhodium, or palladium.[4] His oxidation catalytic converter could reduce hydrocarbons and carbon monoxide, but lead in gasoline caused his converters to malfunction relatively quickly.

Three years before Houdry's discovery of the petroleum "cracking" process, the petroleum industries started to add lead to gasoline to increase fuel economy. Not many people realized that the widespread use of leaded gasoline lead to higher levels of lead in human blood until large-scale epidemiological research was initiated in the 1960s. Moreover, General Motors (GM) owned 50 percent of Ethyl Corporation, the biggest producer of leaded gasoline at the time. Introduction of catalytic converters and the phase-out of leaded gasoline were inconceivable for GM until they sold the Ethyl stocks in 1962. In the same year, GM engineers reported that they tested a satisfactory catalytic converter licensed from Oxy-Catalyst and Houdry announced that he had made a catalytic converter which met Californian standards.[5]

In 1954, hazy and unhealthy air in Los Angeles Basin, a new type of smog, made people in California concerned about clean air. Caltech scientist Arie Haagen-Smit began to understand that smog was caused by unburned HC and NO_X reacting with sunlight. Despite political pressure to develop pollution control technologies, automakers were slow to respond. They thought catalytic converters would cost too much, so they sought to develop other engine control technologies such as crankcase emissions control devices. For example, the positive crankcase ventilation (PCV) valve, the first emissions-control system in the early 1960s, was designed to

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[4] Tom McCarthy, *Auto Mania: Cars, Consumers, and the Environment* (New Haven: Yale University Press, 2007), 125; Air Pollution Foundation, *Field Evaluation of Houdry Catalytic Exhaust Converters* (Los Angeles: Southwest Research Institute, 1955).

[5] Bill Kovarik, "Special Motives: Automotive Inventors and Alternative Fuels in the 1920s," paper presented to the Society for the History of Technology, October 19, 2007; McCarthy, *Auto Mania*, 166-167.

use the engine's intake vacuum to draw a small fraction of leaked combustion gases in the crankcase—"blow-by" gases of HC—back into the combustion process. Automakers voluntarily installed PCV valves on Californian cars in 1961 and on all U.S. cars in 1963.[6]

Other control devices, however, were not introduced until forced by California. In 1964, the Californian pollution control board certified three catalytic converters and a thermal afterburner, which oxidized after-engine emissions with extra air and heat. Automakers were shocked and resisted installing third-party devices on their cars. In only two months, the automakers announced that they had developed engine modification technologies that better reduced pollutants than previously certified devices and would install them in the 1966 model vehicles. Small catalytic converter-makers were scooped, and Californian environmentalists and concerned people were angry about automakers' intentional delay in installing pollution control devices that they had already developed.[7]

Federal research and regulatory activities in mobile air pollution assumed both the community health and control technology approaches. Since federal air pollution research began at the Cincinnati laboratory of the Public Health Service (PHS) in the mid-1950s, two major research laboratories have formed to conduct research, testing, and evaluation of automobile emissions: Ann Arbor and Research Triangle Park (RTP). In the following two sections, I will first introduce the co-production of emissions regulation and health research in laboratories at Ann Arbor (4.1.2) and RTP (4.1.3) in the 1960s and '70s. I will contrast two EPA employees, Eric Stork and John Moran, to point out how two of the agency's laboratories took different

[6] J. Robert Mondt, *Cleaner Cars: The History and Technology of Emission Control Since the 1960s* (Warrendale, PA: Society of Automotive Engineers, 2000); McCarthy, Auto Mania, 115-129.

[7] Paul Miller and Matt Solomon, "A Brief History of Technology-Forcing Motor Vehicle Regulations," *EM: Magazine for Environmental Managers* (June 2009): 4-8; Jack Doyle, *Taken for a Ride: Detroit's Big Three and the Politics of Pollution* (New York: Four Walls Eight Windows, 2000).

standpoints about the role of control technologies in resolving automotive emissions and the responsibility of public officials in sharing the potential health concerns of using pollution control devices.

4.1.2 Research and Testing for Automotive Emissions Regulation

In 1955 Congress passed the Air Pollution Control Act which directed the Secretary of Health, Education, and Welfare to coordinate various air pollution research activities and authorized the PHS $5 million annually for research, data collection, and technical assistance to state and local governments.[8] PHS researchers at the Cincinnati laboratory began reviewing previous studies by Californian regulators, automakers, and control device manufacturers. They generated and analyzed auto exhaust by operating automobiles on a chassis dynamometer, a device for simulated road loading, and by charging radiation chambers with diluted exhaust and adding ultraviolet light to reproduce Los Angeles smog. The early focus was on concentrations of HC, CO, and NO_X and their effects on human body, but it expanded into research and testing of alternative power systems such as gas turbine and diesel engines.

In 1963, in-house and contract test programs expanded after Cincinnati automotive researchers moved to a new laboratory in nearby Fairfax, Ohio. Emission data were based on a driving cycle that was composed of a unique profile of stops, starts, constant speed cruises, accelerations, and decelerations. Each driving cycle had a different configuration to simulate average driving under diverse conditions, such as urban or highway locations. With new

[8] Air Pollution Control Act of 1955, Public Law 84-159, 69 Stat. 322.

dynamometers, testers found fuel injection systems and exhaust gas recirculation (EGR) as plausible solutions for reducing emissions.[9]

Emissions research and testing became more important as new air pollution laws were enacted. The Clean Air Act Amendments of 1963 had provisions requiring the Surgeon General to submit semiannual reports to the Senate on progress on emissions research and needs for additional legislation.[10] The 1963 act also authorized the Health, Education, and Welfare Secretary to establish a joint government-industry committee representing the department, auto manufacturers, oil refiners, and device makers. In 1965, based on committee reports, the Secretary submitted the *Automotive Air Pollution* report to the Senate. Influenced by California's emission requirement and the anticipated introduction of pollution control devices for the 1966 vehicle, the Senate Public Works Committee reviewed the need for additional legislation and held hearings. As a result, the 1965 Motor Vehicle Air Pollution Control Act was enacted to apply emission control measures within limitations imposed by technological feasibility and economic costs.[11] Accordingly, the Fairfax laboratory expanded HC and CO emissions measurement capacity and established detailed certification procedures. In 1968 Fairfax engineers moved to the Willow Run site near Detroit, and they finally found their home at the new laboratory in Ann Arbor, Michigan, in 1971.[12]

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[9] H. Christopher Frey, Alper Unal, and Jianjun Chen, *Recommended Strategy for On-board Emission Data Analysis and Collection for the New Generation Model* (Raleigh, NC: EPA, 2002), 2; Ralph C. Stahman, Kenneth D. Mills, and Merrill W. Korth, *Federal Air Pollution Efforts: The Early Years* (Warrendale, PA: Society of Automotive Engineers, 1989).

[10] Clean Air Act Amendments of 1963, Public Law 88-206, 42 U.S. Code 7401.

[11] Motor Vehicle Air Pollution Control Act of 1965, Public Law 89-272, 79 Stat. 992

[12] Stahman et al., *Federal Air Pollution Efforts*, 6-7

Eric O. Stork was the leader of the Ann Arbor lab from 1971 to 1978. He brought in diverse experience in regulation. Stork studied politics at Reed College and received his master's degree from Maxwell Public Administration School at Syracuse before beginning his career at the Interior Department.[13] He had worked in the Federal Aviation Agency (renamed as Administration after 1967) and the Food and Drug Administration then moved to the National Air Pollution Control Administration (NAPCA) to take charge of the automotive part of the pollution problem. The Mobile Source Air Pollution Control Office had headquarters at Washington, DC, and Stork, already familiar with Washington politics, was a good candidate to lead it.

Stork maintained the continuity of the organization under five bosses in seven years, from John Middleton, NAPCA commissioner, to David Hawkins, President Carter's choice for air pollution control. There were four branches at Ann Arbor: Certification, Emission Control Technologies, Administration, and Advanced Automotive Power System. Under Stork's leadership, the Ann Arbor laboratories reduced its research functions and increased its capacities for testing and technology assessment (fig. 4.1).[14]

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[13] Haynes Johnson, "A Career Bureaucrat Who Wanted 'to Make a Difference.'" *The Washington Post* (March 22, 1978), A3.

[14] Vinsel, *Federal Regulatory Management of the Automobile in the United States, 1966-1988,* 194-264.

Fig. 4.1 An Ann Arbor Engineer's Testing of a Vehicle on Chassis Dynamometer. *Source*: Documerica, National Archives. Photo by Joe Clark. http://research.archives.gov/description/549692 Accessed September 2, 2013

The Ann Arbor Mobile Source Office published a report series on emissions control. Each report had a different focus, reflected in its subtitle: technology assessment, development status, or outlook. However, all the reports had the same main title, *Automobile Emission Control*, which gave coherence to the report series and was the primary organizing principle uniting Ann Arbor employees.[15] The reports' introductory sections revealed important information about the

[15] EPA, *Automobile Emission Control: The Technical Status, Trends, and Outlook as of December 1976* (Washington, DC, EPA, Office of Air and Waste Management, Office of Mobile Source Air Pollution Control). Even though the Ann Arbor Office's research activities ultimately provided relevant

Ann Arbor Office's institutional strategy. In every report, the introduction laid out its subject, time period of interest, scope, and sources of information. Subjects and time periods varied, but the scope of the report clearly excluded air quality studies such as the projections of future air quality or the analysis of anticipated air quality requirements.[16]

4.1.3 Research on Fuel Additives and Health

When the National Environmental Research Center at Research Triangle Park (NERC-RTP) was established in August 1971, federal research on the health effects of air pollution had already been going on at RTP area under NAPCA and the National Institute of Environmental Health Sciences (NIEHS). RTP soon became known as the clearinghouse for air and toxicology research.[17] Delbert S. Barth, health physicist and the head of the Bureau of Air Pollution Sciences at NAPCA, who later became the first NERC-RTP director, published an important article on emission goals in August 1970. Barth argued for a 92-99 percent reduction of CO, HC, and NO_X from the 1967 level to meet the proposed air quality goals by 1980.[18] His data provided important guidance on setting subsequent air quality standards.

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information to the study of air quality as well as to future air pollution control legislation, the connection between regulation and health was de-emphasized. Health-related information was toned down. The Ann Arbor office acknowledged that RTP was in a better position to address the issue, but it didn't include much information about their in-house competitor's current research.

[16] After 1976, researchers at RTP and Cincinnati laboratories began a new report series, *Annual Catalyst Research Program Report*, to publish their combined research results separately from Ann Arbor. This separation, competition, and explicit confrontation among EPA units in mobile air pollution control is in contrast with the integration, cooperation, and implicit confrontation among EPA and other agencies in stationary air pollution control, which I explain in more detail in chapter 5, especially in section 5.3.2.

[17] For more detail, see chapter 2.

[18] Delbert S. Barth, "Federal Motor Vehicle Emission Goals for CO, HC, and NO_X Based on Desired Air Quality Levels," *Journal of Air Pollution Control Association* 20, no. 8 (August 1970): 519-523. He

John B. Moran was a RTP staff member who maintained his focus on the health effects of automobile emissions while he worked for Dow Chemical and the EPA in the 1960s and early '70s. After earning a metallurgical engineering degree at the Illinois Institute of Technology and serving as a Marine Corps officer, Moran began working at Dow Chemical in 1962. His work at the transportation chemical section included developing exhaust particulate control techniques, analyzing the effect of fuel and fuel additives on emissions, and managing the test fleet program. He also worked as a director for the Dow Automotive Competition Program for two years, where he oversaw Dow's role in NASCAR events, special shows, and high-speed track testing.

Moran's job description didn't dramatically change when he moved from Dow Chemical's laboratory at Midland, Michigan, to the EPA's RTP laboratory in May 1971. He designed, developed, and operated sampling and measurement equipment and in-house test facilities for studies of gaseous and particulate emissions from both mobile and stationary sources.[19] For a 33-month Dow Chemical contract research program on chemical and physical characteristics of particulate emissions in automotive exhaust, he was the primary researcher for the first twenty-two months and submitted its interim report to NAPCA, the EPA's predecessor in air pollution control, in July 1970. When the EPA published the final report in December 1972, Moran had been working at the agency's NERC-RTP for eighteen months and was about to head the new "Fuel Additive Registration, Review, and Screening Committee."[20]

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specifically proposed emission goals of CO 6.16 g/mi, HC 0.14 g/mi, and NO_X 0.40 g/mi from the 1967 average emission rates of CO 82.6 g/mi, HC 14.84 g/mi, and NO_X 5.93 g/mi to achieve the 1980 air quality goals of CO 9 ppm, HC 0.06 ppm, and NO_X 0.1 ppm.

[19] John B. Moran's resume. Author's possession; EPA, *NERC, RTP, Annual Report - 1972*, 49-52.

[20] John B. Moran and Otto J. Manary, *Effect of Fuel Additives on the Chemical and Physical Characteristics of Particulate Emissions in Automotive Exhaust: Interim Report* (Midland, MI: Dow

The fuel and fuel additives registration program was one of RTP's strongest areas of research. The program began in fiscal year 1971, and according to Section 211 of the 1970 CAAA, provided for "the registration and prohibition or control of fuels, fuel components, or fuel additives that are shown to have adverse effects on automotive emissions, performance of emissions control devices, or public health or welfare." The Special Studies Staff under the Office of the Director was engaged in this fuel and fuel additives registration program, preparing air quality criteria documents and assessment reports and coordinating the center's international activities. The registration program, under Moran's direction, required manufacturers to conduct and report tests on the effect of fuel and fuel additives on regulated and non-regulated emissions, the performance of emissions control devices, and public health and welfare.[21]

Moran's engineering background and corporate connections proved helpful in his new government job to support and conduct fuel and health research. To get a special car for emissions testing, Moran contacted a legendary car builder, Ray Nichels, whom he had known from his NASCAR work at Dow. Nichels converted a 1970 Plymouth Superbird into "EPA-75." (fig. 4.2).

Chemical Company, July 1970); EPA, *Effect of Fuel Additives on the Chemical and Physical Characteristics of Particulate Emissions in Automotive Exhaust: Final Report* (Washington, DC: EPA, Office of Research and Monitoring, National Environmental Research Center, Research Triangle Park); John B. Moran's resume.

[21] EPA, *NERC, RTP, Annual Report - 1972*, 25, 37-41. Quote from p. 25.

Fig. 4.2 John Moran's Emissions Testing with a 1970 Plymouth Superbird. *Source*: Courtesy of E-Muscle.

Senior managers at NERC-RTP were highly supportive of Moran's work. The first NERC-RTP director, Barth, supported the expansion of Moran's fuel additive registration program. When Barth left to lead a new NERC at Las Vegas in September 1972, John F. Finklea, a physician, public health specialist, and former NAPCA employee, succeeded him. Under Finklea's leadership, RTP researchers conducted a broad range of research covering the reduction of automotive emissions through oxidation catalysts, the assessment of pollution characteristics of energy extraction, and the abatement of pesticide effects on health and the environment. Finklea also provided relevant support and advice as a mentor for Moran.[22]

Throughout the 1960s and ’70s, federal efforts to understand LA smog and to find effective emissions control were rewarded by increasing research and investment by automakers. Automakers, however, preferred engine modification over catalytic converters because they didn’t want to add another third-party device to the system. Automakers were hesitant to change the status quo unless required by market forces or regulation. While the first federal regulation for mobile sources was set up in the mid-1960s, it was weak since it considered economic and technical costs more important than health or environmental concerns. Inheriting people and practices from their predecessors, Ann Arbor and RTP laboratories became clearinghouses for emissions control research/testing and fuel and health effects research, respectively. The differences in their missions, the backgrounds of their staff, and their relationships with EPA regulators as well as automotive industry engineers and managers induced a growing sense of internal competition and generated two distinct types of regulatory engineering. I will come back to these diverse configurations of regulatory engineering as they generated an important spark for later intra-agency controversy over sulfuric acid emissions from catalytic converter-equipped cars (see section 4.3).

[22] EPA, *National Environmental Research Center, Research Triangle Park, N. C., Annual Report – 1973* (Research Triangle Park, NC: EPA, Office of Research and Monitoring, National Environmental Research Center, Research Triangle Park).

4.2 The Rise of the Catalytic Converter and Its Discontents

Throughout the 1960s, legislation on air quality gradually increased funding for the federal government's research on and regulation of tailpipe gas pollution. The 1970 Clean Air Act Amendments (CAAA) did not mandate a particular technology to address mobile emissions, but required the achievement of specific emission levels for pollutants regardless of the means. These performance-based standards for mobile emissions were supposed to protect public health without consideration of economic and technical feasibility. In this section, I first look at catalytic converters and other competing emissions control solutions. Then I follow the complicated history of delayed installation of catalytic converters as it began with the 1975 model vehicles.[23]

4.2.1 Reasons Not to Choose Catalytic Converters

The chemical composition of the emissions of gasoline-fueled, internal combustion engines was determined by the combinational effects between fuel quality, the lack of complete combustion, and photochemical effects on the effluents in the atmosphere. Reducing exhaust emissions thus depended on altering the fuel supply, the combustion process, and the after-engine actions.

As a way to prevent incomplete combustion and to reduce excessive HC and CO, corporate engineers tried a variety of solutions. They first modified the carburetor, a device that blends air and fuel to provide more oxygen in a timely manner. However, this approach involved elevated redesign costs and high operating temperatures that would likely produce more NO_X, itself a pollutant. Modifying the ignition system was another possibility. In the compression

[23] Clean Air Act Amendments of 1970, Public Law 91-604, 42 U.S. Code 7609**.**

stroke of an engine's combustion cycle, the air/fuel mixture is compressed to the top of the cylinder by the piston until it is ignited by a spark plug. By advancing or retarding ignition timing, engineers aimed to reduce HC and NO_X emissions. Around 1973, the EGR valve was developed to specifically control NO_X. A portion of exhaust gas was recirculated into the air/fuel mixture to lower the combustion temperature. While NO_X emission was reduced, power loss followed.[24]

Among these competing approaches to emission reduction, when and how did catalytic converters become the most plausible solution? Catalytic converters began to gain more popularity among corporate engineers toward the end of the 1960s. But senior managers proved reluctant to commit to this technology when other cheaper and familiar options were near at hand. For example, some Ford engineers were interested in Engelhard's platinum catalytic converter and tested it. Other engineers at Ford developed a technology to maintain an optimum air-fuel ratio of 14.6:1, but didn't patent it. Senior managers didn't much care about adopting new technology unless consumers seemed willing to absorb the cost.[25]

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[24] Ad Hoc Group to the Environment Committee of OECD, "Automotive Air Pollution and Noise: Implications for Public Policy," in *The Automobile and the Environment: An International Perspective*, ed. Ralph Gakenheimer, 367-494 (Cambridge, MA: MIT Press, 1978). Especially "Appendix VI B: The Technology of Vehicle Emission Control."

[25] McCarthy, *Auto Mania*, 176-177.

4.2.2 Stringent Standards for Cleaner Cars

The 1970 CAAA mandated the auto industry achieve a 90 percent reduction of HC and CO by 1975 and a 90 percent NO_X reduction by 1976.[26] Anxious to avoid the unfulfilled promise of previous legislation, Edmund Muskie, the chairman of the Senate Subcommittee on Air and Water Pollution, set up specific standards and timelines. Automobiles were of special interest as they were known to be responsible for more than half of the total air pollution in the United States. Compared to oil refineries, electric power plants, manufacturing facilities, and incinerators spread throughout the country, automakers concentrated in Detroit proved a relatively easy target. Ongoing efforts to reduce HC and CO might raise combustion temperatures and scientists became concerned about increasing NO_X. The proposed amendments included standards and timelines that Muskie found challenging considering the realities of industry compliance, but the amendments included some provisions allowing for compromises as well. The EPA was authorized to grant a single one-year extension to the deadlines, and the National Academy of Sciences (NAS) was directed to study the feasibility of the technology, standards, and deadlines.[27]

The 1970 CAAA also required the EPA to intervene if state plans to improve air quality did not meet federal standards. On April 30, 1971, the EPA published two National Ambient Air Quality Standards: primary standards, to protect public health with an "adequate margin of safety"; and secondary standards, to protect public welfare. Within nine months of promulgation,

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[26] It was a major step in raising the federal government's role, but "primary responsibility" still lay at the state and local levels. The State of California had already established tougher standards and timelines, so it was exempted from the federal standards.

[27] James E. Krier and Edmund Ursin, *Pollution and Policy: A Case Essay on California and Federal Experience with Motor Vehicle Air Pollution, 1940-1975* (Berkeley, CA: University of California Press, 1977), 199-204. To understand more about the 1970 Clean Air Act, also see section 5.1.1.

the states were to submit an implementation plan, with the deadline set on January 31, 1972. That plan was to include emission limitations, monitoring provisions, motor vehicle inspection and testing provisions, and land-use and transportation controls. If a plan was not submitted or seemed inadequate, the EPA could implement its own measures considering public health, not economic or technical feasibility. According to the 1970 CAAA, the EPA also could ask federal courts to impose criminal penalties for violators of implementation plan rules.[28]

Based on ambient air quality standards, the EPA set up emissions standards of HC, CO, and NO_X for new automobiles in June 1971. Targets for HC, CO, and NO_X were 0.41, 3.4, and 0.41 grams per mile. Manufacturers submitted vehicles and the EPA tested and certified them if they met the specified requirements. Certifications were suspended if vehicles did not conform to standards, and non-conforming vehicles were prohibited from manufacture, sale, and import. Appeals and hearings followed. The EPA had an option to compel the manufacturer of any successful technology or system to share its control methods with the industry through mandatory licensing.[29] Automobiles on the road were not subject to the emissions standards at this point. The assumption was that new automobiles with advanced emissions control would gradually replace old vehicles on the road. To guard against the deterioration of the control system, the EPA could monitor in-use performance and recall vehicles.[30]

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[28] Krier and Ursin, *Pollution and Policy*, 204-205; Melnick, *Regulation and the Courts*, 24-52. Especially p. 29; James E. McCarthy, *Clean Air Act: A Summary of the Act and Its Major Requirements* (Washington, DC: Congressional Research Service), CRS-2.

[29] Krier and Ursin, *Pollution and Policy*, 205-208; David Gerard and Lester B. Lave, "Implementing Technology-forcing Policies: The 1970 Clean Air Act Amendments and the Introduction of Advanced Automotive Emissions Controls in the United States," *Technology Forecasting and Social Change* 72, no. 7 (2005): 767-770.

[30] U.S. National Research Council, *Evaluating Vehicle Emissions Inspection and Maintenance Programs.*

4.2.3 Denied, Delayed, and Removed

In January 1972, as called for by the law, the NAS published a report on feasibility of standards and deadlines. It did not specifically recommend the suspension of the standards, but suggested that direction.[31] U.S. major automakers and Volvo then requested a one-year suspension of the requirements. In the EPA hearings in March and April, automakers argued that technical difficulty, tight schedules, and cost made the requirements unfeasible. On the other hand, Ruckelshaus had three criteria for a possible suspension. Has the industry made good faith efforts to meet the standards? Are they lacking available technology? Does the suspension benefit public interests?[32]

Meanwhile, Ann Arbor engineers collected data from each manufacturer and tried to find out what happened in each failure. When they discovered a promising result where one automaker made a breakthrough in explaining critical parameters for failing catalytic converters, they suggested ways to improve them and shared the case with other automakers. After seeking advice from the EPA engineers during the hearings, Ruckelshaus concluded that the technology was available to meet the standards. From the information provided by catalytic converter suppliers, he believed the automakers were neither doing their utmost in their research efforts nor

[31] U.S. National Academy of Sciences, *Semiannual Report Prepared by the Committee on Motor Vehicle Emissions* (Washington, DC, 1972); Frank P. Grad, ed., *The Automobile and the Regulation of Its Impact on the Environment* (Norman, OK: University of Oklahoma Press, 1974), 338-368; Krier and Ursin, *Pollution and Policy*, 234-237.

[32] *Records of Hearings Conducted by the EPA on Automobile Emission Standards, 1973*, Record Group 412: Records of the Environmental Protection Agency, National Archives and Records Administration II, College Park, MD (hereafter EPA National Archives).

revealing updated results of their work. On May 12 of 1972, Ruckelshaus denied the request for suspension.[33]

Automakers appealed the action to the Court of Appeals for the District of Columbia Circuit. On February 10 of 1973, the D.C. Circuit Court held that the EPA administrator had failed to support his conclusion that the technology necessary to meet the standards would be available.[34] The burden of proof came back to the EPA. Soon the NAS published a second report suggesting that the delay in the 1975-1976 emission standards might be "prudent."[35] During another two weeks of public hearings, automakers argued for the slow development of catalytic converters and the EPA responded with suggestions for improvement. For example, here is a quote from the conclusion of the EPA's Ford failure case analysis. "In several cases, extrusion of the monolith from the can occurred but should be corrected satisfactorily by better mounting techniques, especially the clam shell type used now by Chrysler."[36] The EPA suggested other automakers should learn and follow the successful case of Chrysler in order to accelerate the introduction of catalytic converters (fig. 4.3). Finally, Ruckelshaus relented and granted a suspension. On, April 11, 1973, the EPA announced a one-year suspension to the 1975 HC and CO standards and set up interim standards of roughly 50 percent reductions. The State of

[33] EPA, *In re: Applications For Suspension of 1975 Motor Vehicle Exhaust Emission Standards, Decision of the Administrator* (Washington, DC, May 12, 1972).

[34] *International Harvester Co. v. Ruckelshaus*, 478 F. 2d 615 (D.C. Cir. 1973). Judge Leventhal's conclusion included sending back the burden of proof to the EPA, the difference between the EPA's decision and the NAS report, and reading the lawmaker's intentions. Sheila Jasanoff, *Science At the Bar: Law, Science, and Technology in America* (Cambridge: Harvard University Press, 1995), 75-78.

[35] Grad, ed. *The Automobile and the Regulation*, 340-360; Krier and Ursin, *Pollution and Policy*, 234-237.

[36] "Hearing on March 12, 1973", 29. *Records of Hearings Conducted by the EPA on Automobile Emission Standards, 1973*, EPA National Archives.

California was again allowed to maintain their 1975 standard and automakers were forced to use catalytic technologies if they didn't want to lose an important market. [37]

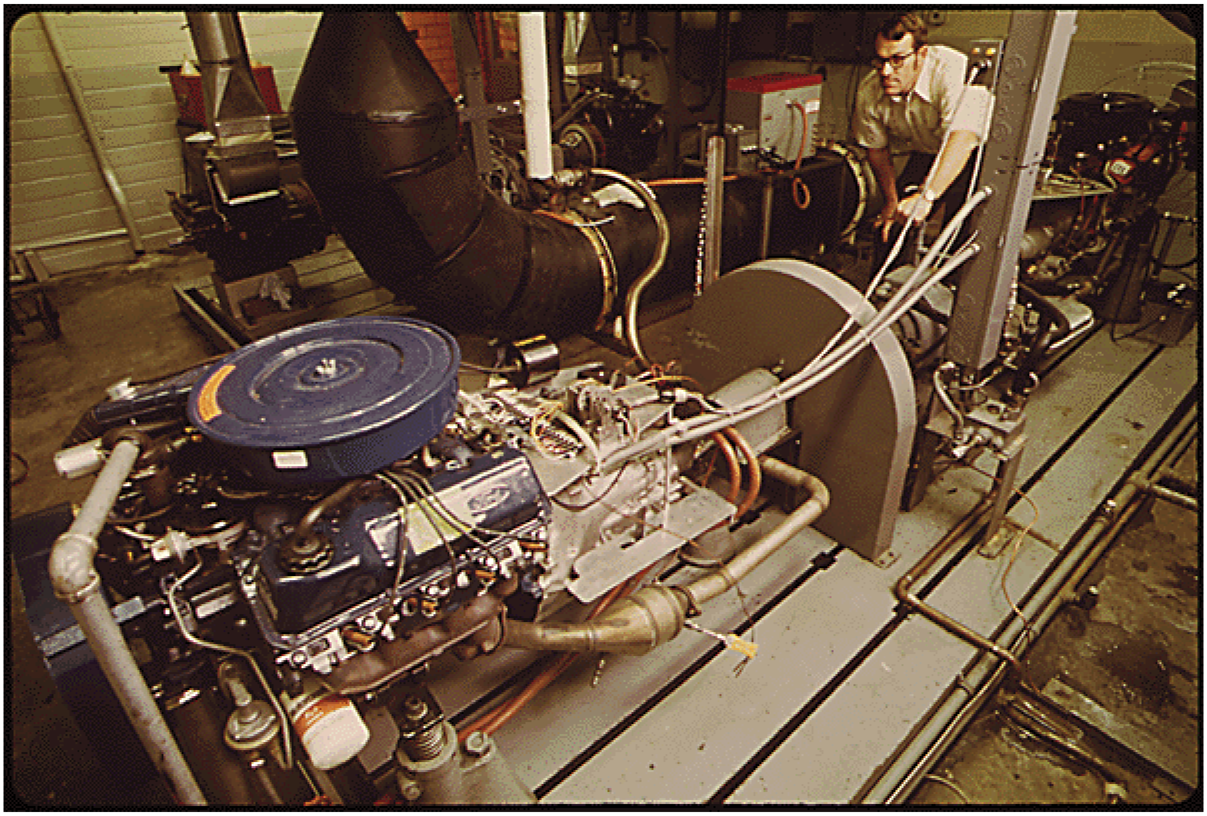

Fig. 4.3 An RTP Engineer's Testing of a Ford Engine with a Catalytic Converter. *Source*: Documerica, National Archives. Photo by Tom Hubbard. http://research.archives.gov/description/553329 Accessed September 2, 2013

In July 1973, the EPA granted the automakers a suspension for the 1975 NO_X standards and set up interim standards.[38] This decision was relatively clear cut. There was no argument

[37] U.S. Congress. Senate. Committee on Public Works. Subcommittee on Air and Water Pollution, *Decision of the Administrator of the Environmental Protection Agency Regarding Suspension of the 1975 Auto Emission Standards,* Hearings, 93rd Cong., 1st sess., April 16-18, 1973.

against the impossibility of meeting NO_X standards by 1976. Automakers, the NAS, and the EPA all agreed that there had been little progress on reducing NO_X emissions. The NO_X standard for 1975 stayed at 3.1.[39]

Unlike NO_X, there was some progress in lead regulation. Concerns about lead in the early 1970s came both from technical and health considerations. It turned out that lead poisoned catalytic converters and children. When the EPA proposed a health-based regulation of lead in gasoline in 1972, opposing arguments included claims about no documented relationship, health concerns about additives replacing lead, and worries about decreasing attention to the lead paint problem. The petroleum industry had long supported scientists who produced research on the health effects of lead and relied on them to communicate with the government and public. Through their own research on lead in dust and dirt, and with the support from other government and independent scientists on long-term changes, the EPA's proposal for health-based regulation went into effect. The 1973 health-based phase-down regulation on lead restricted average lead in all grades of gasoline produced by any refinery to 1.7 grams per gallon by July 1, 1975, and to lesser amounts each year until reaching 0.6 grams per gallon by July 1, 1978, which was about a 60 percent reduction.[40]

[38] U.S. Congress. Senate. Subcommittee on Air and Water Pollution, *The Administration's Proposal for Relaxation of Air Pollution Standards. Hearing,* 93rd Cong., 1st sess., September 18, 1973.

[39] EPA, *Scientific Seminar on Automotive Pollutants* (Washington, DC: EPA, February 10-12, 1975); Gerard and Lave, "Implementing Technology-forcing Policies," 761-778. The 1970 CAAA standard for NO_X was 0.4.

[40] Kenneth Bridbord and David Hanson, "A Personal Perspective on the Initial Federal Health-Based Regulation to Remove Lead from Gasoline," *Environmental Health Perspectives* 117, no. 8 (2009): 1195-1201; EPA, "EPA Requires Phase-Out of Lead in All Grades of Gasoline," *EPA Press Release*, November 28, 1973. Lead in gasoline became embroiled in controversy again in the 1980s and was

Among various mobile emissions control technologies, catalytic converters initially seemed less attractive to automakers as they were expensive and unfamiliar. Congress and the EPA, however, found this technology innovative and effective in achieving maximum goals at reasonable cost. The notion of technology-forcing regulation, that air quality regulation "forced" the development of technology, troubled automakers. The EPA's Ann Arbor engineers fulfilled their roles in verifying corporate reports, recommending alternatives, and testing vehicle emissions themselves. The most conspicuous issue throughout was whether catalytic converters were technically feasible and durable. The effectiveness of catalytic converters in HC and CO reduction and the need for EGR valves for NO_X control was generally accepted among government and corporate engineers. Meanwhile RTP's fuel and fuel additives registration program staff found that catalysts in the catalytic converters might increase the emission of new pollutants. There was a chance that the catalysts might become a part of the problem rather than the solution.

4.3 Environmental Consequences of a Pollution Control Technology

Increased sulfuric acid emissions from catalytic converters became an important turning point for the rise of the control technology approach among the EPA, industry, and Congress. The potential health effects of the catalytic converter proved a perplexing problem to regulators who had invested much on the possibility of a clean solution. At the same time, after the 1973 oil embargo, energy issues took priority over environmental issues in the United States. Air pollution regulation lost its urgency, opening up more opportunities for compromise between government and industry. In this section, I look at the diverse responses to the implementation of

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finally phased out on on-road vehicles in the United States by 1995. C. Schmidt, "Joel Schwartz: Full Throttle Environmentalist," *Harvard Public Health Review* (Summer-Fall 2005): 12-16.

catalytic converters by the EPA. I also show how researchers utilized emissions data obtained by regulatory requirements for health effects research. A 1973 meeting at Durham will take us to the beginning of an intra-agency contention, which shows how the control technology approach came to prevail over the community health approach.

4.3.1 New Pollutants from Catalytic Converters

In early January 1973, the fuel and fuel additives registration program held a "Working Conference on Health Intelligence for Fuels and Fuel Additives" in Durham, North Carolina.[41] Moran was a co-chair and over 30 scientists and engineers from the EPA, the NIEHS, Dow Chemical, and various universities participated in a three-day conference. The conference presentations included carcinogenesis, mutagenesis, and general toxicology research and both in-vitro and in-vivo methods. In a foreword of the conference report, Finklea, public health specialist and Moran's supervisor, pointed out that "the demands posed by new emission control systems may dictate considerable modification in existing fuels and new fuel additives" and called for more proactive toxicology research on fuels and fuel additives.[42] Finklea emphasized that the interrelation between the composition of fuels and fuel additives and the system of combustion and emissions control complicated the research process.[43]

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[41] EPA, *Working Conference on Health Intelligence for Fuels and Fuel Additives* (Durham, NC: EPA, Office of Research and Monitoring, National Environmental Research Center, Research Triangle Park).

[42] To understand Finklea's role in the EPA's early research on pollution-health correlation, see chapter 3. David L. Coffin from the EPA was another co-chair of the conference. Finklea's call was answered by follow-up research from a NIEHS scientist, Warren T. Piver. Warren T. Piver, "Potential Dilemma: The Methods of Meeting Automotive Exhaust Emission Standards of the Clean Air Act of 1970," *Environmental Health Perspectives* 8 (1974): 165-190. Piver was not on the participants list of the conference report, but his 1974 article cites substantial parts of the engineering and chemical considerations section of the conference report.

[43] EPA, *Working Conference on Health Intelligence for Fuels and Fuel Additives*, 1-2.

Finklea's insight was timely. In a few months, Ford reported a substantial increase in total particulate emissions in vehicles tested with oxidation catalysts. Stork forwarded this case to RTP laboratories. After further investigation, the RTP engineers confirmed an increase in sulfuric acid. Ford also reported a case of unusually high sulfuric acid emission.[44] The automakers' and the EPA's early concerns about potential health effects of catalytic converters amplified Moran's ongoing research program on the effects of fuel and fuel additives on public health. First, the introduction of the catalytic converter, or any other advanced or alternative emissions control system, needed to be regulated by his registration program as pre-existing fuel components or fuel additives could react differently with the addition of the new elements. Second, noble metal compounds in catalytic converters had to be regulated as they could be deactivated by thermal or mechanical processes.[45] Based on these two points, Moran pointed out the three most important health issues: 1) the production and emission of noble or base metals, 2) changes in the hydrocarbon shell of particulates, and 3) the emission of sulfuric acid aerosols and the derived sulfate salts. Moran argued that the effects of noble metals on human health were not well understood but catalysts made from them had the potential to cause asthma and lung cancer owing to the toxic compounds they might produce. Particulates, consisting of an inorganic core and organic outer shell, raised additional health concerns to Moran. After reviewing current research on polynuclear aromatics, phenols, and aldehydes, Moran argued that advanced emissions control devices reduced the emissions of these non-regulated elements. Nonetheless,

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[44] EPA, *NERC-RTP Annual Report - 1973*, 25-27.

[45] Donald E. Johnson et al., *Baseline Levels of Platinum and Palladium in Human Tissue* (RTP, NC: EPA, March 1976).

Moran expressed his concerns about the possibility that catalytic converters oxidize some of the sulfur from fuels into sulfate ions or sulfuric acid.[46]

When Russell Train moved to the top EPA position from the Council on Environmental Quality in September 1973, he found out that the sulfuric acid issue required serious attention. Recollecting the issue's urgency in his memoir, Train said that "evidence was beginning to emerge that catalytic converters themselves produced small amounts of sulfuric acid vapor, which could result in lung damage under certain conditions."[47] Ann Arbor's response to the sulfuric acid question was succinct and clear. Stork argued that without catalytic converters the emissions standards for HC and CO could not be met.

4.3.2 Energy Comes First

In October 1973, war between the coalition of Arab states and Israel broke out. President Nixon announced support for Israel, and the Soviet Union supported the Arab countries. In protest, the Arab members of the Organization of Petroleum Exporting Countries first reduced oil production and later declared an embargo against the United States. Oil price skyrocketed from 3 dollars a barrel to 12 dollars. Gasoline rationing and a lower speed limit of 55 miles/hour followed. Fuel economy became an important factor for automakers and consumers.[48]

In November 1973, Train testified before the Senate Public Works Committee on the issue of sulfuric acid. Train supported the use of catalytic converters but promised to initiate comprehensive research on the still uncertain risks from sulfuric acid emissions. In his memoir,

[46] John B. Moran, "Assuring Public Health Protection as a Result of the Mobile Source Emissions Control Program." (New York: Society of Automotive Engineers, 1974); Quarles, *Cleaning up America*, 191.

[47] Russell E. Train, *Politics, Pollution, and Pandas: An Environmental Memoir* (Washington, DC: Island Press, 2003), 167.

[48] Vinsel, *Federal Regulatory Management of the Automobile*, 323-379.

he recollected heated in-house meetings where "health experts [from RTP] warned of the potential health risks of catalytic converters" and "the 'mobile sources' pollution office … warned of the adverse health effects that would follow if catalytic converters were abandoned."[49]

The Energy Supply and Environmental Coordination Act of 1974 (ESECA) was signed by Nixon in June 1974. In his signing statement, the president emphasized two major points: amendments to the Clean Air Act for an extension of the automotive emission standards for two years until 1977 and limited authorization for power plants and fuel-burning facilities to use coal instead of oil or natural gas.[50] The ESECA also gave the auto industry the right to petition for a one-year suspension of the HC and CO standards.

In 1974 the political and economic climate shifted drastically. After the Watergate scandal and energy crisis, public interest in environmental issues declined. In early 1974 the Energy Policy Office (EPO), Office of Management and Budget, and White House suggested thirteen amendments to the Clean Air Act, including a two-year extension of the automobile emissions deadline, permitting tall smokestacks as a permanent solution to stationary air pollution, and considering economic and social effects in setting standards rather than just health effects.[51] Train fought against Bill Simon, the EPO's head, and succeeded in dropping some amendments, but the rest of the conflicts between Train and Simon went to Congress while the White House seemingly remained neutral. One former EPA official recollected that Train

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[49] Train, *Politics, Pollution, and Pandas*, 166-171. Quote from p. 167; EPA, *Russell E. Train Oral History Interview*, Interview by Dr. Michael Gorn (Washington, DC: EPA, EPA History Program, July 1993).

[50] Energy Supply and Environmental Coordination Act of 1974, Public Law 93-319, 15 U.S. Code 796; Richard Nixon, "Statement About Signing the Energy Supply and Environmental Coordination Act of 1974," June 26, 1974.

[51] On stationary air pollution control and the EPA's demonstration of scrubbers, see chapter 5.

survived only “because Richard Nixon did not.” President Ford generally was more accessible to Train, but industry lobbying to loosen environmental regulations also became stronger. Energy issues became more connected with economic issues while environmental regulations appeared a hindrance to energy sustenance and economic improvement.[52]

4.3.3 Moran’s Call and Train’s Response

In April of 1974, Finklea and Moran held a conference on “Health Consequences of Environmental Controls: Impact of Mobile Emissions Controls” at RTP. Participants of the conference ranged from the EPA’s own statisticians, biologists, and engineers and their NIEHS neighbors to Chrysler’s managers and scientists, and to Samuel S. Epstein, a physician and well-known environmentalist.[53]

From the outset, the conference centered on two absences. The first absence was that of information. Finklea set the tone by raising the issue of “accessible” information about environmental protection, public health, and economic wellbeing. He pointed out the contrast between the federal research budget on overall air pollution ($54 million) and the three big automakers’ research budget on emissions controls ($700 million). Wary of criticisms for hastily sharing preliminary research results, Finklea suggested that increased access to information from these research projects would assist the national effort to achieve environmental controls and economic well-being. He encouraged both governmental and corporate organizations to “pursue their policies of openness” and individuals at the crossroads to follow “the path of candor in the

[52] Train, *Politics, Pollution, and Pandas*, 171-204. Quote from p. 173. Original Quote from Robert L. Sansom, *The New American Dream Machine: Toward a Simpler Lifestyle in an Environmental Age* (Garden City, NY: Anchor Press, 1976), 25.

[53] The result of the conference was published in April, 1975 issue of *Environmental Health Perspectives*.

public interest.” In the long run, he hoped to see a future where “information now considered proprietory [*sic*] can be made available in a timely fashion.”[54] By sharing information with the public, even though it may be imperfect, Finklea argued that environmental and economic well-being could be reconciled.

In addition to the first absence of information, Moran pointed out the second absence, that of regulation. Here, Moran subtly emphasized his approach to emissions control. He expressed concerns about “potential health hazards” of oxidation catalysts and laid out five major issues for the conference agenda: perspectives of the problem, noble metals, emissions and measurement methods, control options/methods, and overview presentations. To provide background for the conference attendees, he explained related provisions of the 1970 CAAA. Then he discussed their relationships to the non-regulated emissions issue. He cautiously pointed out that industry’s profit-seeking motivation had shaped and finally became “the only apparent index of performance.”[55]

Moran’s 1974 paper in the Society of Automotive Engineers series also details his long-term goals for research on the health consequences of regulated and non-regulated emissions. After citing the 1970 CAAA, Moran reaffirmed that the EPA must insure that measures used to reduce CO, NO_X, and HC emissions “do not, in turn, increase harmful emissions that are not now specifically regulated.”[56]

Frustrated by the senior manager’s indifference, Moran and RTP colleagues made the sulfuric acid issue public and questioned the Ann Arbor Team’s authority and expertise on auto

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[54] Finklea, “Introductory Statement,” 3.

[55] John B. Moran, “Conference Objectives,” *Environmental Health Perspectives* 10 (1975): 5-8.

[56] Moran, “Assuring Public Health Protection,” 2.

emissions. In a press conference, Moran argued that even though catalysts reduced HC and CO, they also caused higher levels of sulfuric acid and other substances emitted from the tailpipe.

This led Train to grant a one-year suspension of the 1977 motor vehicle emission standards announced March 1975. He clearly indicated that sulfuric acid problems were a critical factor in granting the one-year suspension.[57] He also recommended to Congress that the 1975 national interim standards for HC and CO be retained for the 1978 and 1979 model years and the emission standards at the interim California levels for HC and CO be established for the 1980 and 1981 model years.[58]

Eric Stork, former EPA regulator from the Office of Mobile Source Air Pollution Control, confirmed that Administrator Train's suspension decision was due to his agreement with the EPA researchers' concerns that "unquantifiable, possible health risk from the estimated increments of exposure to sulfuric acid (H_2SO_4) simply had to be avoided." Stork further argued that sulfuric acid was a huge, controversial, and political issue, but never was a "real" problem. He pointed out that the ORD's annoyance at being excluded from decision-making in automotive matters, intra-agency competition, and bureaucratic jealousy contributed to the conflict.[59]

4.3.4 Demise of the Community Health Approach

Although Train appreciated Moran's viewpoint on sulfuric acid emissions, he was not particularly happy about the way Moran addressed the problem. For Moran, the cost of

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[57] Train, *Politics, Pollution, and Pandas*, 169.

[58] EPA, *Office of Research and Development, Research Triangle Park, NC, Annual Report – 1974* (Research Triangle Park, NC: EPA, Office of Research and Development, 1975).

[59] Eric Stork, "The United States Experience with Imposing Automobile Emission Standards," Paper delivered for the Australian Society of Automotive Engineers, Perth, Australia (September 22, 1976). Copy provided to the author by Stork; Eric Stork, Interview by the author, June 6, 2012.

demanding a tougher position to the administrator was high. Throughout 1975, Moran lost a few opportunities to publicize his position further. As we saw in chapter 3, his boss, Finklea was busy with his own troubles. As head of an epidemiology study, he had been criticized by media and other scientists for supposed data distortion and over-interpretation, culminating in a House hearing the next year. With decreased backing from RTP senior managers, Moran was not given a chance to express his research outcomes to congressional members. The House Subcommittee on Environment and the Atmosphere (Chair: George E. Brown, D-CA) specifically asked Moran to be the EPA witness at the opening of the scheduled hearing. Moran was supposed to share his research results about possible health effects from sulfuric acid emissions with the use of catalytic converters. However, Train and his legal advisors didn't want Moran to represent the EPA; he replaced him with Stork in this capacity and Moran became one of the back-up witnesses. The final testimony of Stork represented a compromise between Ann Arbor and RTP. He acknowledged the need to further assess impacts of automotive sulfuric acid emissions, but ruled out other alternatives to oxidization converters: desulfurization of gasoline and the use of other catalysts.[60]

Even though somewhat marginalized on the issue of sulfuric acid, Moran found himself busy with another interesting mission. From March to May of 1975, he was transferred to the National Vehicle Efficiency Program of the Federal Energy Administration to prepare related

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[60] "EPA Would Rather Switch Than Fight, Substitutes Stork for Moran," *Environmental Health Letter* (July 15, 1975): 3-4. Stork, in his 1976 paper given to Australian engineers, also acknowledged that he deferred the medical community to find thresholds for ambient H_2SO_4. Stork, in his 2012 oral history interview, was not fully aware of the subsequent findings from the scientific and medical research and defended that "his organization was responsible for engineering" and "did not do medical works." Stork, "The United States Experience with Imposing Automobile Emission Standards"; Stork, Interview by the author, June 6, 2012.

legislation.[61] As the new program's director, he could regain his credibility and returned to RTP for seven months until promoted to the directorship of the Monitoring Technology Division in Washington, DC in December 1975.[62]

On the issue of sulfuric acid, Ann Arbor engineers continued to rely on their preferred method of communication: they published a report on sulfuric acid emission control and promoted their views to the other units of the EPA.[63] Instead of limiting their scope of research to health issues, they focused on the evaluation of the development of pollution control technologies and programs. The reports relied on automobile and device manufacturers' responses to the EPA's request, the agency's in-house testing and contracted research, and overall technical literature. The authority of the report series *Automobile Emission Control* lay in the Ann Arbor Office's command of up-to-date corporate information and unrivaled capacity to review technical literature. Thus, in the December 1975 report, *Automobile Sulfuric Acid Emission Control* was an efficient and reasonable step for the Ann Arbor Office to build up its existing expertise on the development of pollution control technology. The report's narrow scope was perhaps less helpful for readers who were not familiar with the then-current discussions

[61] The Federal Energy Administration was established by the Federal Energy Administration Act of 1974. It collected, assembled, evaluated, and analyzed energy information. The FEA was later merged with the Energy Research and Development Administration and became part of the Department of Energy in 1977. See chapter 5 for further interactions between the two federal sectors.

[62] John B. Moran's resumé in author's possession. Moran stayed in the Monitoring Technology Division until September 1976 when he moved to the directorship of the Division of Safety Research of the National Institute for Occupational Safety and Health (NIOSH). He joined Finklea and other RTP colleagues who had already moved to the NIOSH from the EPA.

[63] EPA, *Automobile Sulfuric Acid Emission Control: The Development Status as of December 1975* (Ann Arbor, MI: EPA, Office of Air and Waste Management, Office of Mobile Source Air Pollution Control, December 1975).

about the technical feasibility, potential health effects, and durability of catalytic converters and other mobile emissions control alternatives.

How did the intra-agency debate on the health effects of catalytic converter technology influence the EPA's research and regulation? First, health concerns about catalytic converters were slowly addressed. The 1977 Amendments to the Clean Air Act added a provision requiring the EPA administrator to ban any device that contributes to an unreasonable risk to public health, welfare, or safety after 1978.[64] However, the question of increased sulfuric acid production from catalytic converters was mostly neglected until after electronically controlled converters were introduced in the mid-1980s and standards for low-sulfur gasoline were set in the early 2000s.[65]

Second, technical and economic considerations became increasingly important, but technology-forcing regulation continued with diminished public health concerns by the EPA. The Carter administration established the Department of Energy in 1977 to mobilize government resources into energy research and regulation. Economists developed tools to skillfully compare the cost of environmental degradation with the benefits of pollution control. Carter's EPA administrator Douglas Costle introduced incentives and bubble concepts for industry "to develop

[64] Clean Air Act Amendments of 1977, Public Law 95-95, 91 Stat. 685.

[65] In April 1976, EPA's RTP researchers reported that they found less-than-expected sulfuric acid emission levels in a road test. General Motors actually suggested the road test to Ann Arbor and RTP researchers on its own proving ground and they together executed a collaboration project a year before. When compared to stationary pollution sources, they reported that automobile sulfuric acid emissions were minor. Frustrated by the under-recognition of public health issues, some researchers left the EPA. It is noteworthy that concerns about acid precipitation contributed to increasing awareness of sulfuric acid emission into the air. However, compared to stationary source emission of sulfur oxides and sulfuric acid, emissions from mobile sources were limited and did not get primary attention from policymakers. R. K. Stevens et al., *The General Motors/Environmental Protection Agency Sulfate Dispersion Experiment: Selected EPA Research Papers* (Research Triangle Park, NC: EPA, Office of Research and Development, Environmental Sciences Research Laboratory, April 1976).

new, improved pollution control technologies."[66] These market-based approaches became strong contenders for a command-and-control philosophy. I will come back to this point in section 5.4.

4.4 Conclusion: Legacy of the Community Health Proponents

Catalytic converters became "the" pollution control technology for emissions from automobiles in a very short time. CAAA and health-based regulation that didn't include economic or technical consideration achieved their goals initially. However, deadlines were repeatedly delayed by the EPA and Congress. EPA regulators were too optimistic considering the lack of corporate initiatives and diminishing regulatory drive. Technical feasibility of catalytic converters and economic challenges of the oil crisis remained important criteria for regulation. Even though the EPA's regulations were not supposed to consider economic or technical factors, the history of catalytic converters shows that those factors were still important for decision-making. A shift from community health to control technology is clearly shown in mobile air pollution regulation.

Turning from the suspensions to the EPA's research and technology policy on mobile emissions control, I have two observations. First, the development of and growing dependence on the control technology approach reorganized the EPA's health effects research. Due to increasing demands for testing and assessment, the Ann Arbor Office reduced its research functions. On the other hand, the RTP program continued to focus on health effects research to analyze various emissions control options. The structural and functional division between Ann Arbor and RTP became more visible with the issue of sulfuric acid emissions. Between the EPA's dual role of regulator and researcher, regulator authority became more important than

[66] "'Bubble' Policy Added to EPA's Cleanup Strategy," *EPA Press Release*, December 3, 1979.

researcher precaution. Some RTP researchers left the agency and others remained and continued to study the health effects of catalytic converters.[67]

Second, the policy shift away from community health to control technology deprived the EPA of other mobile pollution reduction options. Around 1973 much of the EPA's resources had already been invested in the successful application of catalytic converters. In addition to introducing the control technology, CAAA provided other regulatory options for improving air quality. These included changes in fuels and fuel additives, inspection and maintenance programs, and transportation control measures. While imposing local transportation control measures such as parking surcharges, road use restrictions, or gasoline rationing met with strong public resistance, the first two options received less attention until the mid-1980s.[68]

While catalytic converters solved many problems, they also produced new ones. As environmental scientists and engineers looked at the potential health effects of new and old products and processes, the number of regulated pollutants has also increased. Once catalytic converters were on board, regulators and researchers of mobile sources pollution surely needed to give full consideration to the role and limitations of the various control technologies.

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[67] EPA, *Second Annual Catalyst Research Program Report: Summary* (Research Triangle Park, NC: EPA, Office of Research and Development, Health Effects Research Laboratory, 1977); EPA, *Third Annual Catalyst Research Program Report* (Research Triangle Park, NC: EPA, Office of Research and Development, Health Effects Research Laboratory, 1978). Major topics included emissions characterization, measurement method development, monitoring, fuel analysis, toxicology, biology, epidemiology, human studies, and unregulated emissions control options.

[68] Melnick, *Regulation and the Courts*, 299-342.

Chapter 5. Controlling the Environment for Energy Development: Scrubbers Demonstration and Smokestack Sulfur Dioxide Control, 1970-1980

"The role of the control technology we will discuss here today is to give us breathing room to make the transition to other forms of energy without disrupting our nation and our society. Control technology forms the bridge that will support us while we make the necessary economic and technological shifts."[1]

-Stephen J. Gage, Assistant Administrator for Research and Development

"This health and environmental effects research is, as it should be, an equal partner to the control technology program in making sure that we can have our energy and an acceptable environment too." [2]

-Delbert S. Barth, Deputy Assistant Administrator, Office of Health and Ecological Effects

Among various pollution issues during the 1970s, the EPA devoted much time and many resources to sulfur oxides. It was the topic of the first Community Health and Environmental Surveillance System (CHESS) monograph *Health Consequences of Sulfur Oxides*. CHESS researchers at Research Triangle Park (RTP), North Carolina, received pressure from Washington officials who asked for more data about the link between sulfur oxides and respiratory disease. EPA researchers and regulators engaged in an in-house debate on the

[1] Stephen J. Gage, "Control Technology: Bridges to the Future," in *Energy/Environment II: Second National Conference on the Interagency R&D Program*, 15 (Washington, DC: EPA, November 1977).

[2] Delbert S. Barth, "Achieving Compatibility between Energy and Environmental Goals: Program Perspectives," in *Energy/Environment II*, 27.

possible health effects of sulfuric acid from catalytic converters. The Ann Arbor team that argued for the rapid introduction of the device and further research on sulfuric acid prevailed over the RTP team that had called for a more precautionary approach. Although the CHESS monograph received nation-wide criticism and catalytic converters were introduced in 1975 model vehicles, concerns about sulfur oxides did not disappear. As the public learned more about the potential health and environmental effects of sulfur oxides from smokestacks and sulfuric acid reaching a long distance from the source, the EPA found a good opportunity to enforce emission standards and promote pollution control technology for that purpose.

From October 18th to November 2nd of 1973, the EPA held a series of public hearings in Washington, DC. The goal of the hearings was to review the status of power plant compliance with sulfur oxide emissions regulation. Witnesses represented power plants, trade associations, state agencies, vendors of scrubbers, and environmental/ public interest groups. Power plants were the largest source of sulfur oxide emissions, which had been increasing along with the national demand for more electric power. Under the state implementation plans established for the Clean Air Act Amendments (CAAA) of 1970, the power plant industry had only a year and a half left to meet the emission deadline. Flue gas desulfurizers—devices to absorb sulfur dioxide from smokestack gases, or "scrubbers" as many started to call them—were regarded as the most viable option for emissions regulation compliance. However, most power plants claimed that the scrubber technology was unreliable and expensive and produced too much waste. They instead preferred other cheaper options such as low-sulfur coal, stack height increases, and intermittent control systems.[3]

[3] EPA, *Report of the Panel: National Public Hearings on Power Plant Compliance with Sulfur Oxide Air Pollution Regulations* (Washington, DC: EPA, 1974).

The main witness on scrubber technology was Frank Princiotta from the EPA's Control Systems Laboratory. He was a chemical engineer in charge of the throw-away scrubbers section at Research Triangle Park (RTP), North Carolina. As the primary point of contact for both vendors and operators of scrubbers, he was well aware of the up-to-date materials and process problems in currently operating scrubbers. In addition, he had been involved in operating and testing three prototype 10 megawatt scrubbers at the Tennessee Valley Authority's Shawnee site and his own 0.1 megawatt pilot scrubber at his laboratory for quick test runs. Princiotta showed that major reliability problems—chemical scaling, plugging, erosion/corrosion, and mechanical problems—had already been resolved. Princiotta and other EPA witnesses acknowledged that the scrubber-generated sludge raised potential water and land pollution issues. They promised to support research and development of regenerable scrubbers, which produced sulfur or sulfur compounds for reuse. At the same time, Princiotta emphasized that two private companies had developed sludge fixation/disposal technologies that would decrease the environmental effects of sludge. On the issue of cost, the EPA witnesses claimed that the power plant industry's research and development efforts were limited in scope and amounted to less than 1 percent of their revenues. Princiotta and others compared the inaction and indifference of big American power plants with successful Japanese scrubber design and use.[4]

This short introduction to the 1973 hearings provides an explanation for the widespread use of scrubbers for smokestack SO_2 emission reduction. But it also raises several questions that need more exploration: How is it that engineers like Frank Princiotta came to the EPA's RTP laboratory to deal with coal-fired power plant emissions? What made scrubbers more attractive than other cheaper options? Were there any opportunity costs or side effects of using scrubbers

[4] EPA, *Report of the Panel*, 31-32, 36.

to deal with stationary air pollution? How did the EPA engineers demonstrate and establish the scrubbers as a successful case of the control technology approach?

By answering these questions, this chapter attempts to highlight one aspect of the current environmental protection system: an increasing emphasis on the control of pollutants by technological means. I begin the next section (5.1) by explaining what happened before the 1973 scrubber public hearings and what they meant for the growing pollution control technology approaches to environmental issues. By contrasting the power industry's reluctance to embrace scrubbers and the EPA's insistence on introducing them in section 5.2, I underscore the EPA engineers' role in demonstrating the technology, with the cooperation of scrubber vendors. I also detail the regulatory implications of pollution control technology demonstration to emphasize the dual role of the EPA as regulator of industry and supporter of technology. In section 5.3, I will argue that the EPA became reoriented toward the demonstration of technology not just for environmental protection but also for energy development. Success in the demonstration of scrubbers boosted the EPA engineers, shaping them as powerful innovators capable of not only offering solutions to the reliable production of energy, but also instigating flexible, market-friendly changes in regulatory policy.

5.1 Dealing with Smokestack Emissions at the Federal Level

To understand how Frank Princiotta applied his engineering experience and expertise in the urgent stationary air pollution issues of the time, we need to explore the status of air, its pollution, and people's response before the 1970s.

5.1.1 Stationary Air Pollution and Its Control

Prior to 1970, the federal government's role in air pollution control was limited, with air pollution abatement efforts left to the states and municipalities. The federal government slowly increased funding for pollution research, first supporting the states and later conducting its own research during the 1960s.[5] The Department of Health, Education, and Welfare (HEW) was in charge of research and regulatory activities, and in 1968 the National Air Pollution Control Administration (NAPCA) was established as a nascent organization focusing on air pollution under the HEW.[6] Standards were not stringent as they were set by considering the available technology and cost. As we saw in section 4.2, the control of mobile air pollution sources, or automobiles, was closely related with the development of engine modification technologies and catalytic converters.

In the case of stationary sources such as power or chemical plants and industrial or commercial boilers, particulate matter drew the most attention of the federal government. People living near coal-fired power plants expressed concerns about the soot and dust. Power plants, or electric utilities, have been major stationary sources of air pollution and they had already introduced "electrostatic precipitators" to reduce particulate matter from the stack gases. The federal government guided and supported the development and application of pollution control

[5] Air Pollution Control Act of 1955, Public Law 84-159, 69 Stat. 322; Clean Air Act Amendments of 1963; Air Quality Act of 1967, Public Law 90-148, 81 Stat. 485. The 1955 act provided funds for federal research and the 1963 act first addressed air pollution control. According to the 1967 act, the federal government began ambient monitoring and source inspection as well as expanded pollution research. See section 2.2.1 to learn more about NAPCA's research.

[6] National Air Pollution Control Administration, *Control Techniques for Sulfur Oxide Air Pollutants* (Washington, DC: Public Health Service, 1969).

technologies on wastes and emissions of power production. But power plants were reluctant to introduce another control technology.[7]

Meanwhile, pollution of air by emissions from stationary sources became evident in every part of the country. State and local governments had limited resources to control all these pollution sources. The federal government tried to intervene to urge their local and state counterparts to monitor pollution makers and force them to follow standards and deadlines. From steel plant emissions in Alabama to Edison plant chimneys in Manhattan, to low-hanging smog in California, and oil refineries in Puerto Rico, scientists and engineers set up stations, collected and analyzed data, and maintained the monitoring network (fig. 5.1).

The passage of the CAAA of 1970 marked the beginning of the decade of environmental protection. The 1970 Act authorized the federal government to set up National Ambient Air Quality Standards (NAAQS) for carbon monoxide, hydrocarbons, nitrogen oxides, ozone, particulate matter, and sulfur dioxide based only on public health and welfare grounds. The standards were for ambient air quality, not the air quality at the source. Maintaining the level of air quality was the primary focus, with no particular technology suggested to accomplish this. Nor were cost factors included in setting up the standards, in contrast to the previous laws. Omission of technology and cost factors in the 1970 Act made it much stronger than its predecessors.[8]

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[7] NAPCA, *Control Techniques for Sulfur Oxide Air Pollutants*; George D. Clayton, "Air Pollution," in *Industrial Environmental Health: The Worker and the Community*, edited by Lester V. Cralley, 413-454 (New York, Academic Press, 1972); Richard B. Engdahl, "A Critical Review of Regulations for the Control of Sulfur Oxide Emissions," 364-375.

[8] Clean Air Act Amendments of 1970, Public Law 91-604, 42 U.S. Code 7609; Rogers, "The Clean Air Act of 1970." See section 4.2.2 to learn more about the Clean Air Act Amendments of 1970 from mobile air pollution control perspective.

Fig. 5.1 Air Pollution in Various Regions of the United States. *Source*: Documerica, National Archives (*Top left*: Steel plants in Alabama; *right*: Edison plants in Manhattan; *bottom left*: Smog in California; *right*: Oil refineries in Puerto Rico), Photo by LeRoy Woodson, Chester Higgins, Gene Daniels, and John Vachon respectively. http://research.archives.gov/description/545410, http://research.archives.gov/description/548345, http://research.archives.gov/description/542683, and http://research.archives.gov/description/546384 Accessed September 2, 2013

With stringent laws and standards, the EPA found more chance to deal with air pollution cases that had been traditionally in the realm of state and local governments. The EPA was able to intervene with the states if their plans to improve air quality proved inadequate to meet the federal standards. On April 30, 1971, the EPA published two National Ambient Air Quality Standards: primary standards, to protect public health with an "adequate margin of safety"; and secondary standards, to protect public welfare. Within nine months of promulgation, the states were required to submit an implementation plan. Implementation plans were to include, most of all, emission limitations, as well as monitoring provisions, motor vehicle inspection and testing provisions, and plans for land-use and transportation controls. If plans were not submitted or seemed inadequate to the EPA, the EPA could implement its own plans considering public health, but not economic or technical feasibility. The EPA also could ask federal courts to impose criminal penalties for violators of implementation plan rules. As most states turned in their implementation plans by the end of 1973, the deadline for meeting primary standards was set for July 1975.[9]

The growing emphasis on the goal of public health, coupled with the exclusion of cost or technology factors in the standards setting process, shaped the 1970 CAAA as game-changer in air pollution control. This stream of “community health” approach rapidly expanded as the federal government invested a considerable amount of its limited research capacity in exploring the correlation between major pollutants and health indicators. However, the “control technology” approach was also expanding as the EPA elaborated its detailed standards for diverse cases.[10]

The EPA’s approach to new air pollution sources was more challenging and definitive than its approach to existing sources. Section 111 of the 1970 Act required the EPA to set up a standard that could be satisfied by the “best system of emission reduction,” which had been “adequately demonstrated” as determined by the Administrator of the EPA. In that section, the authors of the Act pointed out their expectation for the EPA to establish standards for public health and the environment with the consideration of the status of current technology. In other words, they showed their intended balance between environmental protection and reasonable

[9] Clean Air Act Amendments of 1970.

[10] See section 2.4 for the definition of “community health” and “control technology” approaches.

application of demonstrated technology. Based on an expectation for better performance from the new plants, the EPA set up and promulgated the initial New Source Performance Standards (NSPS) in 1971. The EPA set up 1.2 pounds of SO_2 per MBtu (Mega British thermal unit) as the NSPS, by calculating a 70 percent reduction of SO_2 of the average eastern coal.[11] Ackerman and Hassler, legal scholars from Yale, argued that this 70 percent, or 1.2 pounds standard, did not consider the difference in SO_2 per MBtu between eastern coal (3-4 pounds) and western coal (about 0.3 pounds). They also pointed out that the agency's narrow reading caused its reliance on the use of scrubbers and its initial failure to notice the environmental harms of sludge.[12] It is noteworthy, for the following story, that Congress assigned the EPA responsibility to define the adequate demonstration of emission reduction technology. The EPA managers and engineers took this responsibility seriously; they collected and disseminated information about the current status of technology to reduce emissions from stationary sources, and were finally found deeply involved in the demonstration of the "best system." To understand how this happened in the relatively short period between December 1970 and November 1973, we need to understand a key figure, Frank Princiotta.

5.1.2 Frank Princiotta's Timely Arrival

Timing is always important, and it was very much so for Princiotta and the EPA. First, managers and engineers who came under the new roof of the EPA continued to work in their own specialty area, be it air, water, pesticides, or wastes. As the offices and laboratories were reorganized and assigned duties by new legislation, it appeared that additional workers with

[11] Clean Air Act Amendments of 1970; Ackerman and Hassler, *Clean Coal/ Dirty Air*, 10-11, 19-21. 1,000 British Thermal Unit=1,055 Kjoules.

[12] Ackerman and Hassler, *Clean Coal/ Dirty Air*, 10-11, 19-21.

diverse educational and workplace background were needed. Among others, the EPA needed more engineers who were competent, versatile, and focused. Princiotta was the one who was ready to move to the newly established research center in North Carolina.

His move from Maryland to North Carolina was an outcome of previous connections and coincidence. Frank Princiotta received his chemical engineering degree from City College of New York in 1962 and did graduate work in nuclear engineering at Oak Ridge in 1963. After working at the Atomic Energy Commission (AEC) in New York and at Hittman Associates, a nuclear R&D and consulting firm in Maryland, he moved to RTP in 1971.[13] Sheldon Meyers, his previous supervisor at the AEC, was already at the EPA looking for new hires. Princiotta also thought it was accidental in the sense that it was not planned ahead.

> What was interesting is, at that time I was looking for another job, because the small company [was] having financial problems, the person I worked for at the Atomic Energy Commission had once told me that if I wanted a job with him and he was in a position to do so, he would hire me. Lo and behold, he had my job here in this operation back then, and he asked me if I had interest to come overnight. I had known very little about environmental protection quite candidly, so he put a chance on me, [the environment] not being much of my area.[14]

The diversity of the Control Systems Laboratory's workforce contributed to the execution of its mission. In the 1970s the engineering community included quite a few nuclear engineers working in diverse areas. The EPA's engineering posts were no exception. All types of engineers were welcomed as long as they could contribute to environmental protection. Princiotta's unit

[13] Frank Princiotta, Email correspondence with the author, April 23, 2012.

[14] Frank Princiotta, Interview with the author, January 4, 2011.

had both new hires like him and older staff moved from the HEW's Cincinnati lab. Their diverse experience in government and industry worked to benefit the execution of the mission as shown in the 1973 annual report of the National Environmental Research Center-Research Triangle Park: "research, development, and demonstration of equipment and systems to abate, in a timely and cost-effective manner, the emission of atmospheric pollutants from stationary sources to a level that protects public health and welfare, and to do so within the framework of our nation's energy and environmental mandates."[15] The contrast between the ends and means of control is critical. Goals of public health and welfare can be achieved by effective research, development, and demonstration. Reference to the nation's energy and environmental mandates clearly signified the challenges of balancing competing interests in energy supply and environmental protection after the oil embargo of October 1973.

As it turned out, the Control Systems Laboratory (CSL) became more involved in energy research and development. The CSL's position on the tension between energy needs and environmental concerns is also mentioned at the end of the same annual report, quoted above. "These new energy technologies must be environmentally sound if the future health and welfare of the nation is to be protected. Although environmental considerations may be subjugated to short-term energy needs, there must ultimately be a reconciliation of energy and environmental considerations." The energy needs seemed more important than environmental concerns. However, as the report states: "[a]ctive involvement by [the] EPA will ensure that environmental control systems keep pace with new energy processes."[16] The authors of the report re-emphasized that energy needs to be environmentally sound. Environmental concerns, in their plan, might conform to the energy demands for the short term, but a future reconciliation would

[15] EPA, *NERC, RTP, NC, Annual Report - 1973*, 117.

[16] Ibid., 132.

be needed. I will revisit this subtle position on environmental protection and energy technology development and its variations in the broader context of the federal interagency program later in section 5.3.2.

5.2 Engineering and Bureaucratic Solutions to Stationary Air Pollution

In this section, I detail how Princiotta demonstrated scrubbers as a successful case of pollution control technology. The co-production of emissions regulation, environmental institution-building, and control technology took place at the Control Systems Laboratory. When the electric utilities industry preferred other options to reduce or disperse sulfur dioxide (SO_2) emissions from smokestacks, the demonstration of a control technology, the scrubber, solved cost and reliability issues. However, the increasing waste from scrubbers became another topic of concern. Cooperating with the Tennessee Valley Authority, one of the main sulfur oxides emitters, and with other manufacturers of scrubbers, CSL engineers shifted the focus from pollution abatement for health benefit to development of pollution control technology for effective regulation. New knowledge about the operation and maintenance of power plants equipped with scrubbers as well as a new identity among engineers from the EPA, TVA, and contractors contributed to the co-production of technology and regulation for environmental protection.

5.2.1 Two Temporary Options

When fuels containing sulfur are burned, oxides of sulfur are produced. Among them, SO_2 has been found to irritate eyes, aggravate asthma, and damage lung function. People with chronic respiratory disease, the young, and the elderly are most susceptible to SO_2 pollution.

When exposed to moisture in the atmosphere, SO_2 oxidizes into sulfuric acid, which comes back to the land or water in the form of acid rain. Acid rain also reduces agricultural and forest production, diminishes visibility, and deteriorates buildings.

An increase in SO_2 emissions was closely tied to the rapidly expanding electric power industry. Electricity generation doubled every 10 years after the Second World War and accounted for 60 percent of the SO_2 emissions in the country by the 1970s. [17]

Scrubbers were the only control technology commercially available in the 1970s to reduce SO_2 emissions and comply with the CAAA. Switching to low-sulfur coal was costly because of limited supply and transportation. Coal cleaning had also been adopted by the industry as a standard procedure in conjunction with other technology. However, the power industry preferred tall stacks or intermittent control systems. Power plant owners argued that by increasing the height of the stacks, they could disperse the pollutants, allowing the local air to remain cleaner. The power industry's other preference was the intermittent control system (ICS), which relied on ad-hoc measures. When plants experienced unfavorable meteorological conditions like atmospheric inversions, they had options of using cleaner fuels, shutting down the units temporarily, or reducing outputs at certain plants while increasing production at others. Most sources using ICS curtailed operation only a few days each year.[18]

Environmentalists opposed both of these options and called for more constant efforts from industry. The EPA was still formulating a clear position on tall stacks and ICS. EPA managers opposed the total reliance on tall stacks or ICS. At the same time, they understood

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[17] Corman, *Air Pollution Primer*, 36-37; EPA, *Sulfur Emission: Control Technology & Waste Management* (Washington, Dc: EPA, Office of Research and Development, Office of Energy, Minerals, and Industry, May 1979), 4.

[18] Melnick, *Regulation and the Courts*, 116-118.

these two options as useful tools to meet environmental goals that could be applied on a case-by-case basis. Finally in September 1973, the EPA established their official position on ICS and stack height regulation. The EPA's Office of Air Quality Planning and Standards (OAQPS), under the Office of Air, proposed to allow the use of ICS only when "the sole alternatives are either permanent production curtailment or delay of an attainment date for the national standards."[19]

Tall stacks raised difficult questions for EPA regulators. The OAQPS approach was that ICS could be allowed if sources installed "reasonably available control technology." However, the EPA could not decide exactly how much pollution reduction was technologically feasible. Therefore, the EPA could not clearly define how much credit they could give for stack heights as pollution dispersion technology. It was the EPA and its predecessor which first allowed and encouraged tall stacks as "good engineering practice" and now limited the height of stacks by the same term, "good engineering practice."[20]

The shift in the meaning of "good engineering practice" shows how the EPA's air pollution regulators utilized engineering details to support their regulatory shift. Control of SO_2 was certainly a hot issue among the electric utility industry, vendors of scrubbers and other pollution control technologies, environmental organizations, and the EPA. Nonetheless, the EPA's regulators did not provide clear policy until late 1973.[21]

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[19] Melnick, *Regulation and the Courts*, 123-126. Quote from 125.

[20] Melnick, *Regulation and the Courts*, 124, 126. EPA, *Guidelines for Air Quality Maintenance Planning and Analysis: Volume 3 Control Strategies* (Research Triangle Park, NC: EPA, Office of Air and Waste Management, Office of Air Quality Planning and Standards, July 1974), III-51-III-56.

[21] Melnick, *Regulation and the Courts*, 124.

5.2.2 The Rise of Scrubbers through Successful Demonstration

Scrubbers, flue gas desulfurization devices, were first developed in the United Kingdom in the early 1930s and had been used in Japan and Sweden. It was not until the late 1960s, however, that some U.S. electric utilities installed limestone scrubbers on coal-fired power plants. Scrubbers were designed to remove SO_2 from gas streams by chemical reaction. It was a more expensive option than other competing SO_2 reduction technologies, like coal cleaning, but achieved higher efficiency.[22]

The slow formation of the EPA's policy on tall stacks and ICS earned time for the proponents of scrubbers. Both EPA's top officials and OAQPS's mid-level managers were slow in formulating a clear policy on scrubbers and stationary air pollution. What they produced were a series of ad-hoc responses to individual requests for advice. While scrubbers were manufactured and tested in a few coal-fired power plants, the electric utility industry in general was more inclined to accept tall stacks or intermittent control systems. Industry liked these low cost and flexible options over expensive and unreliable scrubbers. In this gap between regulator's tardy action and industry's preference, engineers at the EPA found scrubbers to be the most advanced technology to meet NAAQS by the 1975 deadline.

Scrubbers dealt with the end-of-pipeline treatment of coal-fired power plants' full cycle: from coal to sludge. After coal was mined and transported to power plants, it was pulverized, or ground to small pieces, and burned in a boiler. While the heat was used to generate electricity, several byproducts were created. Fly ash, with noncombustible minerals like ash, dust, and soot, were captured in an electrostatic precipitator and transported to a pond or a landfill. Scrubbers absorbed sulfur dioxide by reacting lime ($Ca(OH)_2$, calcium hydroxide or slaked lime) or

[22] EPA, *Sulfur Emission: Control Technology & Waste Management*; Richard B. Engdahl, "SO_2 Control: Low-Sulfur Coal Still the Best Way," *Power Engineering* 77, no. 11 (1973): 72-76.

limestone ($CaCO_3$, calcium carbonate) with SO_2 in water (wet-process) or in the air (dry-process). Sludge ($CaSO_3 \cdot 2H_2O$, hydrated calcium sulfite) or gypsum ($CaSO_4 \cdot 2H_2O$, hydrated calcium sulfate) are byproducts of these chemical reactions.[23] I will come back to the environmental consequences of and engineering responses to different types of scrubber byproducts in the next section.

The EPA's own hearing on SO_2 control in October and November of 1973 played an important role in setting up scrubbers as the most practical solution to reducing SO_2 emissions in power plants. This hearing was later called the Quarles hearing, named after its chairperson, Deputy Administrator John Quarles. During the hearing, an oil embargo was initiated and extended, and interest in energy independence skyrocketed in the United States.[24] For electric utilities, the hearing provided a once-in-a-decade chance to argue for loosening the standards and delaying the deadlines to meet the standards.

Twenty electric utilities sent witnesses to the hearing. Testimony came from small utilities like Kansas City Power and Light Company to large ones like the Tennessee Valley Authority and American Electric Power Service Corporation. The utility witnesses generally agreed that supplies of low-sulfur coal were limited and insufficient to achieve compliance with SO_2 regulations only through switching to this fuel source. Utilities expressed a strong desire to

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[23] "Fly Ash and Gypsum are Captured," Kentucky Ash Education Site by the University of Kentucky's Center for Applied Energy Research; David M. Hart and Kadri Kallas, "Alignment and Misalignment of Technology Push and Regulatory Pull: Federal RD&D Support for SO2 and NOX Emissions Control Technology for Coal-Fired Power Plants, 1970-2000." (Cambridge, MA: MIT Industrial Performance Center, April 2010).

[24] See also section 4.3.2.

use locally available high-sulfur coal. Although scrubbers could bring utilities into regulatory compliance, not many companies testified that they had plans to install the scrubbers.[25]

Most utilities argued that scrubbers had problems such as unreliable operation, high cost, and environmental effects. Various parties, from the EPA to vendors and non-governmental organizations, voiced their opinions on these three problems of reliability, cost, and sludge. Frank Princiotta, with other EPA witnesses, expressed a compelling argument against utilities and state regulators dubious about scrubber technology.[26] I will deal with two of the three issues, reliability and cost, in this section. As the last issue of sludge needs more attention and detail, I will come back to it in the following section.

Regarding reliable operations, the EPA's Princiotta and other operators of scrubbers pointed out recent improvements.[27] There were concerns of two major phenomena in operating the scrubbers successfully. Scaling, a phenomenon where hard chemicals deposited inside the scrubber, was found in many operations. The other phenomenon of concern was plugging, where soft solids built up. Testimony on Japanese Mitsui and EPA's Shawnee prototype confirmed that plugging had been overcome and scaling control was well underway by changing liquid/gas ratios and maintaining pH within limits (fig. 5.2). The photo below shows a big decrease in scaling in the Venturi/Spray Tower scrubber. In addition to operational problems, utility industry representatives voiced their concerns about mechanical problems at fans and pumps. Princiotta

[25] EPA, *Report of the Panel*.

[26] EPA, *Report of the Panel*, 32, 36; EPA, TVA, and EPRI, *Sulfur Oxides Control in Japan* (Washington, DC, November 1979).

[27] Richard B. Engdahl, "A Critical Review of Regulations for the Control of Sulfur Oxide Emissions," *Journal of the Air Pollution Control Association* 23, no. 5 (May 1973): 364-375.

and other scrubber operators showed evidence of successfully demonstrated scrubbers at a number of units to argue that these problems had been or could soon be solved.[28]

After the reliability issue of the scrubbers had been settled in the hearing, a discussion of the cost of installing and operating scrubbers followed. The authors of the hearing panel did not expect scrubbers to result in a large increase in the cost of generating electricity. General patterns from the data collected from the utilities and operators showed that setting scrubbers in new plants would be less expensive than retrofitting scrubbers in existing plants. In other words, retrofitting old plants might be difficult both for utilities and for vendors of scrubbers when more scrubbers could be applied to new power plants for the same amount of money. Instead, Princiotta and EPA experts argued that ready-to-retire or small industrial plants might find other options. The dry process was later promoted by him in the late 1970s and early ’80s.[29]

[28] EPA, *Report of the Panel*, 32-37.

[29] Princiotta, Interview with the author, January 4, 2011.

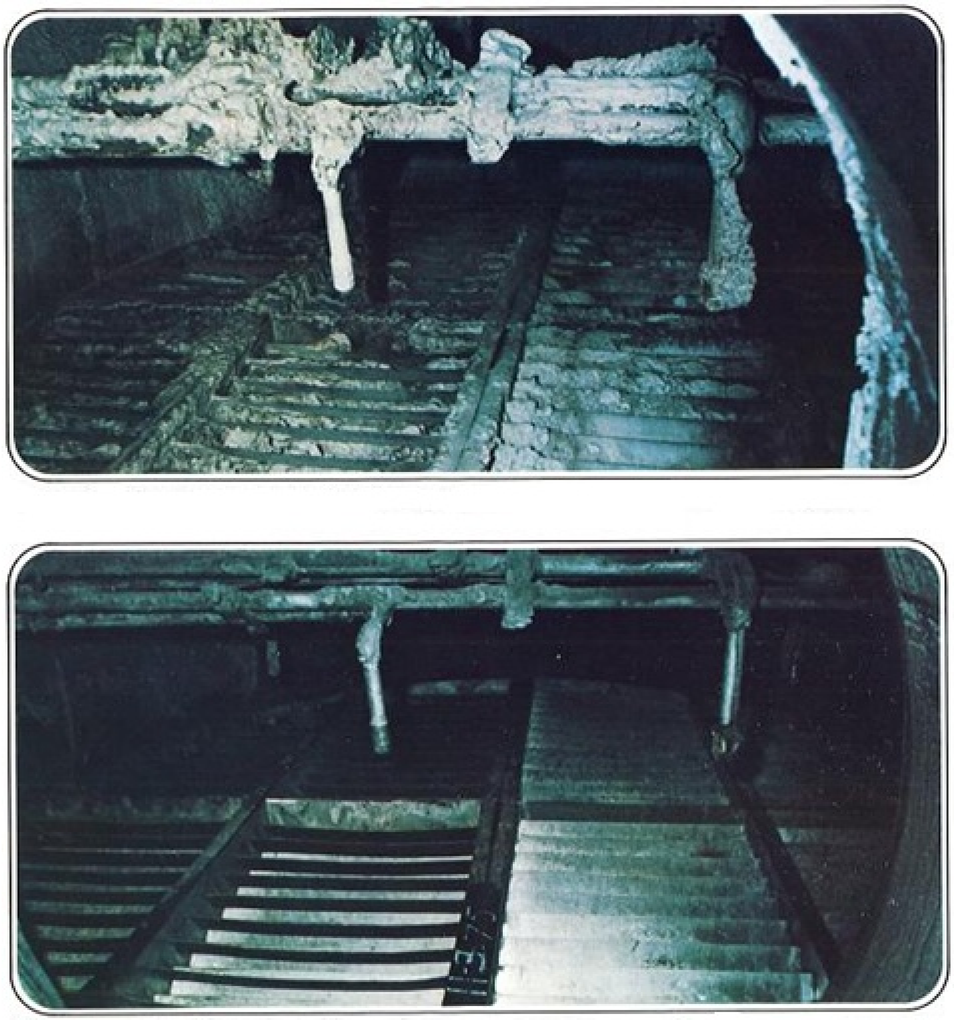

Fig. 5.2 Improvement in Scaling by Alkali Utilization on a Scrubber. *Source*: EPA, *Lime/ Limestone Wet-scrubbing Test Results at the EPA Alkali Scrubbing Test Facility* (Washington, DC: EPA, Office of Research and Development, Prototype Demonstration Facility, Technology Transfer, 1976) (Top: Scale formed on the top vanes of the mist eliminator; bottom: Scale problem eliminated by alkali utilization and washing with makeup water.)

5.2.3 Cooperating with the TVA and Separating Scaling and Plugging

The successful debut of scrubbers in the Quarles hearing represented an important turning point. Inside the EPA, the ball was now turned over to the CSL engineers from the OAQPS regulators. As the hearing coincided with the energy crisis of 1973, the federal government moved their focus toward the energy supply, which meant a shift back to coal from oil. The utilities continued to pursue lawsuits, but they slowly and more openly invested additional money and expertise into scrubbing research. All of these changes meant increasing funding and support for Princiotta and his colleagues. In this section, I focus on the details of the EPA's collaboration project with the Tennessee Valley Authority (TVA), a government-corporate power generator, and Bechtel Corporation, a private contractor. Facing inaction and resistance from utilities, the EPA generated new knowledge about scaling and plugging and demonstrated prototype-scale scrubbers at the collaboration project.

In the early 1970s, continuing their work at the new agency, engineers at the CSL invested their energy into two types of scrubbing: a throw-away process and a regenerable (recovery) process. Two branches of the CSL focused on each of the two, and they competed with each other to find better solutions to the SO_2 problem. The throw-away process removed SO_2 from the flue gas and disposed of it. On the other hand, the regenerable process was designed to retrieve sulfur or sulfuric acid out of the flue gas. The throw-away process was generally cheaper than the regenerable process, but sludge disposal posed potential environmental effects. The regenerable process was first considered to be more environmentally sound, but further research added more complexity. The market for sulfur and its compounds was already competitive. In addition, the electric utilities found not much incentive for using extra energy for the regeneration of sulfur. Sludge disposal was still cheap compared to other coal byproducts disposal and keeping the electricity rate down topped the priority list of the national agenda.[30] As a result, the regenerable process gradually lost its impetus and the throw-away process became the main focus of the CSL toward the end of the 1970s.[31]

Thus, the expansion of the throw-away process throughout the 1970s provided a crucial opportunity for Princiotta. When Sheldon Meyers, the CSL director, hired Princiotta in June 1971, Meyers assigned him to the throw-away process team.[32] The CSL had facilities spread out at three locations: the NERC building in RTP, and the Mutual building and its annex in Durham. Princiotta's team was at the annex with Meyers' office. His role in the team was limited at the beginning, compared to his experience in the public and private sectors, and he was expected to show his potential in his new position. The first project Princiotta undertook and executed successfully became a stepping stone for him to increase his role at the CSL.

NAPCA, the predecessor of the EPA in air pollution research, began a stationary air pollution abatement project in June 1968 with two cooperators.[33] The TVA provided the site and constructed and operated the units. Bechtel Corporation, an architecture and engineering firm from San Francisco, was the major contractor that directed the test. After the establishment of the EPA, CSL inherited this project.[34]

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[30] EPA, *Sulfur Oxide Throwaway Sludge Evaluation Panel (SOTSEP), Volume II: Final Report-Technical Discussion* (Research Triangle Park, NC: EPA, Office of Research and Development, National Environmental Research Center, Research Triangle Park, April 1975), 35-39; EPA, *Flue Gas Desulfurization: Answers to Basic Questions* (Research Triangle Park, NC, EPA, Office of Air and Waste Management, Office of Air Quality Planning and Standards, October 1973).

[31] Princiotta, Interview by the author, January 4, 2011.

[32] Princiotta, Email correspondence by the author, April 23, 2012.

[33] NAPCA, *Control Techniques for Sulfur Oxide Air Pollutants*.

[34] EPA, *Limestone Wet-scrubbing Test Results at the EPA Alkali Scrubbing Test Facility: First Progress Report* (Washington, DC: EPA, Office of Research and Development, Prototype Demonstration Facility,

In 1968 the project team began building three 10 megawatt scrubbers concurrently. They were the Marble-Bed Absorber, the Turbulent Contact Absorber (TCA), and the Venturi/ Spray Tower. The team chose these three candidates to minimize the total time required to prepare for a demonstration of scrubbing technology and to find the most successful technology out of the pool at the site. Each system was designed to treat approximately 10 megawatt equivalents of flue gas from the Shawnee boiler No. 10 (150 megawatt total). The 10 megawatt size was chosen for "minimum cost, consistent with the ability to extrapolate results to commercial scale." Boiler No. 10 burned a high-sulfur bituminous coal leading to SO_2 concentrations of 2300 to 3300 parts per million in the flue gas.[35]

Pursuing three scrubbing systems at the same time demanded a large budget and strong organizational support. This parallel strategy faced its first challenge as one prototype scrubber failed to be produced on schedule. Combustion Engineering's Marble-Bed Absorber was discontinued in July 1973.[36] Operating problems such as nozzle failure and subsequent plugging

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1974), 3. The location of the EPA-TVA-Bechtel collaboration project provides an interesting historical background to the EPA's pollution control activities for electric power generation, as well as a good summary of the Cold War, energy, and environmental history. The project site was at Shawnee on Ohio River, about 10 miles northwest of Paducah, Kentucky, where the TVA built plants powering a uranium enrichment process. Shawnee fossil-fuel power generation plants were built to support the "peace-time" nuclear energy generation program in the Cold War tradition. In addition, the EPA-TVA-Bechtel demonstration project added another layer of emissions control of fossil-fuel power generation in the "environmental decade." "DOE's Paducah Plant History"; "U.S. Army Corps of Engineers Louisville District's Kentucky Ordnance Works"; "Paducah Gaseous Diffusion Plant Timeline (1950-2008)."

[35] EPA, *First Progress Report*, 3-4.

[36] John E. Williams, *Summary of Operation and Testing at the Shawnee Prototype Lime/Limestone Test Facility* (Research Triangle Park, NC: EPA, Office of Research and Development, Industrial Environmental Research Laboratory, April 1977), 1.

of the bed were the main reasons for failure.[37] So it was important for Princiotta and other engineers that the two remaining scrubbers could generate diverse test data. Systems for the other two scrubbers were designed in such a way that the configuration of the scrubber internals and piping could easily be changed. The TCA, supplied by Universal Oil Products, used a fluidized bed of plastic spheres moving between retaining grids. Operating engineers were able to operate the TCA as a one-, two-, or three-bed unit. They could also dewater the spent solids by a clarifier alone or with a clarifier in combination with a filter or a centrifuge.

The Venturi, manufactured by Chemical Construction, absorbed particulate matter and sulfur components. To supplement Venturi's absorption capacity, engineers attached a spray tower that served to increase contact time.[38] For both the TCA and Venturi/Spray-tower systems, there was a central panel board that employed cutting-edge sensor and communication technology to monitor and control information. Central board operators used an electronic data acquisition system to record the operating data, and measured and controlled the gas flow rate by venture flow tubes and dampers on the induced-draft fans. They also employed photometric analyzers to measure the concentration of SO_2 in the inlet and outlet gas (fig. 5.3).

The most significant accomplishment of the original test program was, in fact, the recognition that scaling and plugging were "separate problems, each with separate and distinct

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[37] EPA, *Lime/ Limestone Wet-scrubbing Test Results*, *Second Progress Report* (Washington, DC: EPA, Office of Research and Development, Prototype Demonstration Facility, 1975), 4-5. However, this failure did not mean that Combustion Engineering stopped developing its scrubbers. Instead, it developed other commercial options.

[38] EPA, *Second Progress Report*, 4; EPA, *Lime/ Limestone Wet-scrubbing Test Results, Third Progress Report* (Washington, DC: EPA, Office of Research and Development, Prototype Demonstration Facility, 1976), 4-5.

solutions."[39] After identifying scaling and plugging as the two most nagging operational problems of the scrubbing process, team engineers devoted much of their early efforts into characterizing the problems and running experiments. To address the problem of scaling, they designed and executed experiments where they operated the scrubbers with changes in parameters like liquid-to-gas ratio, reaction tank residence time, pH, and percentage of solids in slurry. While changing liquid-to-gas ratio and pH proved to be effective, more effective control methods were washing mist eliminators with fresh make-up water once every 4-8 hours from the top and low pressure drop nozzles. However, finding operating parameters and designing washing techniques demanded more time than the original estimates.

[39] Williams, *Summary of Operation and Testing at the Shawnee Facility*, 5.

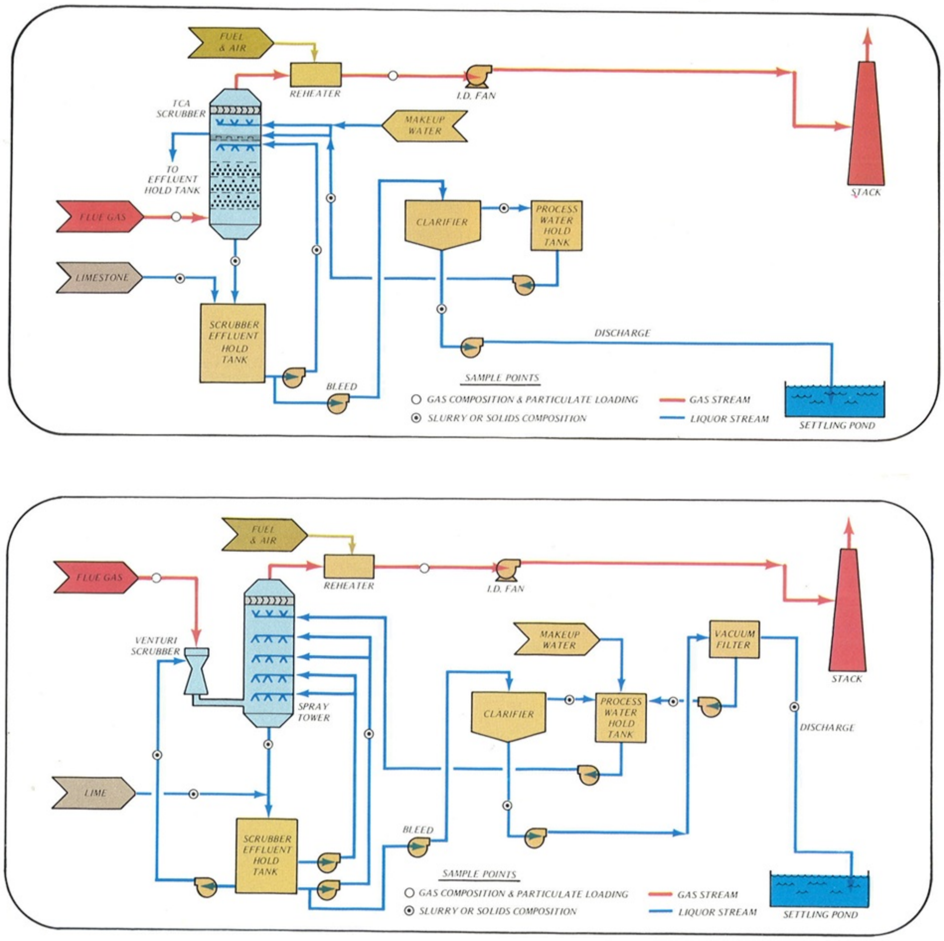

Fig. 5.3 Process Flow Diagrams of Two Scrubbers. *Source*: EPA, *Lime/ Limestone Wet-scrubbing Test Results at the EPA Alkali Scrubbing Test Facility* (Washington, DC: EPA, Office of Research and Development, Prototype Demonstration Facility, Technology Transfer, 1975) (Top: TCA Scrubber with limestone; bottom: Venturi/Spray Tower Scrubber with lime.)

Solutions to the plugging problem proved more difficult than scaling remedies. The use of a wash tray upstream of the mist eliminator was marginally successful. The wash tray enabled soft solid deposits to be transferred to an area where they could more easily be removed, but the process also reduced gas flow rates. Even though washing techniques were helpful enough to continue operation without shutting down the scrubbers for periodic cleaning, a successful control of soft solids deposit was not achieved in the first phase of the test program.[40]

After Princiotta found a need for additional development of lime/limestone wet-scrubbing technology, he established an advanced test program with internal and external support. Before the scheduled end date of the program's first phase, the Shawnee test program was expanded and the program's advanced phase began in 1974. While the test program achieved most of its original goals, Princiotta argued that he found additional research and demonstration needs in the areas of "sludge disposal, improved reliability, variable load operation, and improved process economics." In choosing these additional goals, Princiotta relied on comments from utilities and scrubber vendors and encouraging results from the RTP pilot plant.[41]

Princiotta emphasized a multi-step process to reach the final goal and spent enough time in each step to gain enough reliability to proceed to the next process. The program engineers first tested the scrubbing system with air and water to determine pressure drop model coefficients and to observe fluid hydrodynamics. Then they tested the system with sodium carbonate (Na_2CO_3) to determine gas-phase mass-transfer coefficients in mathematical models. Finally the team used these coefficients to predict the SO_2 removal rate.[42]

During the tests to improve the alkali utilization method, Princiotta's team found a correlation between alkali utilization and the accumulation of soft solids. Under a system operating above about 85 percent alkali utilization, the solids were easily removed "even with very infrequent (once per 8-hour shift) washing with fresh make-up water." This finding was important as it provided solutions to multiple problems at the same time. Improved alkali

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[40] Williams, *Summary of Operation and Testing at the Shawnee Facility*, 5.

[41] Ibid., 3-4.

[42] EPA, *Second Progress Report*, 8; EPA, *Third Progress Report*, 8.

utilization not only decreased plugging, but it reduced both the quantity of lime/limestone input and sludge output and thus enhanced the overall efficiency of the scrubbers system. Princiotta first found this at his preliminary test at the RTP pilot plant; he then confirmed this correlation at Shawnee and another TVA pilot plant.[43]

Successful demonstration of lime/limestone scrubbers at the Shawnee site answered most questions raised in the Quarles hearing. The scrubbers proved to be more reliable and efficient compared to other engineering alternatives like low-sulfur coal or coal cleaning, as the team engineers separated scaling and plugging and found answers for both by alkali utilization. The utility industry's concern about the high cost of scrubbers, compared to tall stacks or ICS, also decreased as alkali utilization required less lime/limestone and produced less sludge. One remaining problem was sludge. As more utilities used and were expected to use scrubbers, they would produce more sludge. The potential environmental effects of scrubbers could potentially undermine the EPA's overall efforts in environmental protection. In the worst scenario, scrubbers merely moved sulfur from coal and air into land and water. How did Princiotta and CSL answer this sludge question?

5.3 Control Technology for the Environment and Energy

Increased sludge production from scrubbers became a salient issue for the EPA, industry, and environmental organizations. Princiotta organized a panel of multimedia specialists, reemphasized the importance of throw-away scrubbers under the ongoing energy crisis, and addressed environmentalists' and industrialists' concerns about water and solid waste issues by promising further research as well as suggesting engineering alternatives such as a regenerable

[43] Williams, *Summary of Operation and Testing at the Shawnee Facility*, 6.

process and sludge-gypsum conversion. Through success in scrubber demonstration and multimedia panel leadership, Princiotta and CSL became the coordinator of a federal interagency program for energy and environmental research and development program. While the control technology approach expanded in the interagency program, proponents of the community health approach continued to raise their voices or they left the EPA to work for other government agencies, consulting firms, and universities.

5.3.1 Engineering Approaches to Sludge-generated Pollution

At the Quarles hearing, several technological options were discussed addressing the environmental concerns of sludge and its disposal. They included closed-loop operation, use of pond liners, and chemical treatment.[44] While vendors of these technologies projected optimistic estimates, the EPA witnesses expressed concerns about possible water or land contamination. As an alternative to the throw-away scrubbers, the EPA witnesses suggested regenerable scrubbers, which they considered to produce saleable products like sulfur or sulfuric acid.[45]

As a chief regulator and major researcher of pollution in all media, the EPA had the privilege to manage information about cutting-edge technology and to control the regulatory timeline in accordance with their other priorities. With the benefit of hindsight, as previously mentioned, the regenerable scrubbers did not prosper in part because of their higher price tags in an already competitive market for sulfur and its compounds. Princiotta and other CSL engineers estimated that the throw-away process scrubber would dominate the market for its edge in price

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[44] In a closed-loop operation, there is no discharge of liquid, but make-up water is added to compensate for water lost through evaporation or left with the purged solids.

[45] EPA, *Report of the Panel*, 51-53.

and reliability.[46] However, for the EPA witnesses at the Quarles hearing, the regenerable process was still a persuasive option to address the environmental concerns of sludge. The EPA used the "regenerable process" card to calm down the heightened worries about sludge and continued to pursue it as an alternate until the point when the throw-away process became more reliable and popular.

In addition to worried industry and state officials, the intended audience of the Quarles hearing included the Court. When the U.S. Court of Appeals for the District of Columbia remanded the NSPS on September 10, 1973, one of the allegations charged that the EPA's consideration of the sludge disposal problem was insufficient.[47] Responding to this Remand (40 FR 42045) on November 12, 1974, the EPA confirmed that permanent land disposal of raw sludge is environmentally unsound and definitely degrades large tracts of land.[48] Therefore, the EPA continued work on the chemical treatment of sludge, focusing on decreasing permeability and leachability of the wastes to reduce their solubility and the seepage of water. To improve ponding, underdrainage systems were proposed to facilitate quick settling and densification of the sludge and return all underdrainage to the scrubbing system.[49]

Scrubber-generated sludge was a new type of waste that needed definition for the purpose of regulation. State and local agencies had used existing standards and regulations to treat sludge. Solid waste disposal regulations were the most frequently used, as sludge was often transported

[46] EPA, *SOTSEP: Technical Discussion*, 12-13, 35-44.

[47] *Essex Chemical Corp. v. Ruckelshaus* 486 F.2d 427 (D.C. Cir. 1973).

[48] EPA, *Data Base for Standards Regulations Development for Land Disposal of Flue Gas Cleaning Sludges* (Cincinnati, OH: EPA, Office of Research and Development, Municipal Environmental Research Laboratory, December 1977), 13.

[49] EPA, *Disposal of By-products from Nonregenerable Flue Gas Desulfurization Systems* (Research Triangle Park, NC: EPA, Office of Research and Development, Industrial Environmental Research Laboratory, February 1979), 4-5, 35.

to the landfill. Several states also applied water regulations to sludge to address drinking water quality issues. While these regulations addressed concerns about water contamination, flooding, reclamation, and potential leachate generation, they could not cover the environmental effects of hazardous constituents of scrubber sludge. Therefore, some states like Kentucky and Kansas considered sludge as an extension of industrial and hazardous waste disposal regulation, which had generally been applied to discharges from mining and fertilizer production.[50]

Princiotta identified an opportunity where federal regulation was not yet present. By the time Princiotta found, but not yet confirmed, alkali utilization as a solution to plugging and sludge at Shawnee, sludge-generated waste management had become an important hurdle for proponents of scrubbers in the utilities industry and the government. Princiotta organized and chaired the Sulfur Oxide Throwaway Sludge Evaluation Panel (SOTSEP), EPA's multimedia evaluation panel on sludge. SOTSEP consisted of one staff member from the Office of Research and Development (ORD)'s Air Pollution Control Division, another from the Office of Air and Waste Management, and four CSL members including Princiotta. The mission of SOTSEP was "the evaluation of the environmental and economic factors associated with disposal or utilization of sludge from nonregenerable" scrubbing processes.[51] In executing their mission, SOTSEP panelists first explored the current status of other alternative control technologies: chemical and physical coal cleaning, coal gasification and liquefaction, and fluidized bed combustion. In its 1975 two-volume report, panelists argued that these alternatives were still emerging technologies

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[50] John P. Woodyard and Dallas E. Weaver, "The Regulation of Flue Gas Desulfurization Sludge Disposal: Present and Proposed Approaches," American Society of Civil Engineers, Joint Power Generation Conference (Long Beach, CA, September 20, 1977).

[51] EPA, *SOTSEP: Technical Discussion*, xiv.

and economically not competitive over the next ten years.[52] Then they argued that proper disposal of lime/limestone scrubber sludge would be important as they expected a potential high demand for scrubbing.

Four locations existed as options for sludge disposal—mines, oceans, ponds, and landfills. SOTSEP acknowledged potential water and land pollution with these four options and assured the skeptics that extensive research and development programs would resolve any issues.[53] Mine and ocean disposals existed as options but were not used extensively. With ponding, two environmental issues arose: water pollution from soluble materials in the waste and land-degradation from non-settling or physically unstable waste. For the landfill option, the sludge must be dewatered or chemically treated before being hauled to the site.

To approach water and solid waste pollution issues, Princiotta and SOTSEP panelists consulted with five other specialists and relied on established practices for waste of all kinds. Their strategy to analogize between new sludge pollution and existing pollutants gained meaningful but limited success. It provided answers to concerned pollution makers by estimating the size of land the scrubber sludge would cover and pointing out the similarities between scrubber sludge, municipal sewage, and conventional coal combustion products. It was also helpful for policy makers to understand the scope of the new pollution from sludge and to develop regulatory responses. This analogical approach, however, hid the fact that this new pollutant would be added to the existing stream of solid waste pollution (fig. 5.4).

The EPA's other card regarding the sludge issue was converting sludge (calcium sulfite) into another material, gypsum (calcium sulfate). Princiotta and CSL appropriated the idea of a regenerable process into the throwaway process and produced synthetic gypsum. Pushing back

[52] Ibid., 30-35.

[53] Ibid., 30-35.; EPA, *Sulfur Emission: Control Technology and Waste Management*, 15-24.

on the criticism of shifting pollutants among media, CSL advertised a novel method to produce saleable products. The forced oxidation method, which produces synthetic gypsum by forcing air into the slurry of calcium sulfite, obtained very high utilization (95 percent) in both lime and limestone systems.[54]

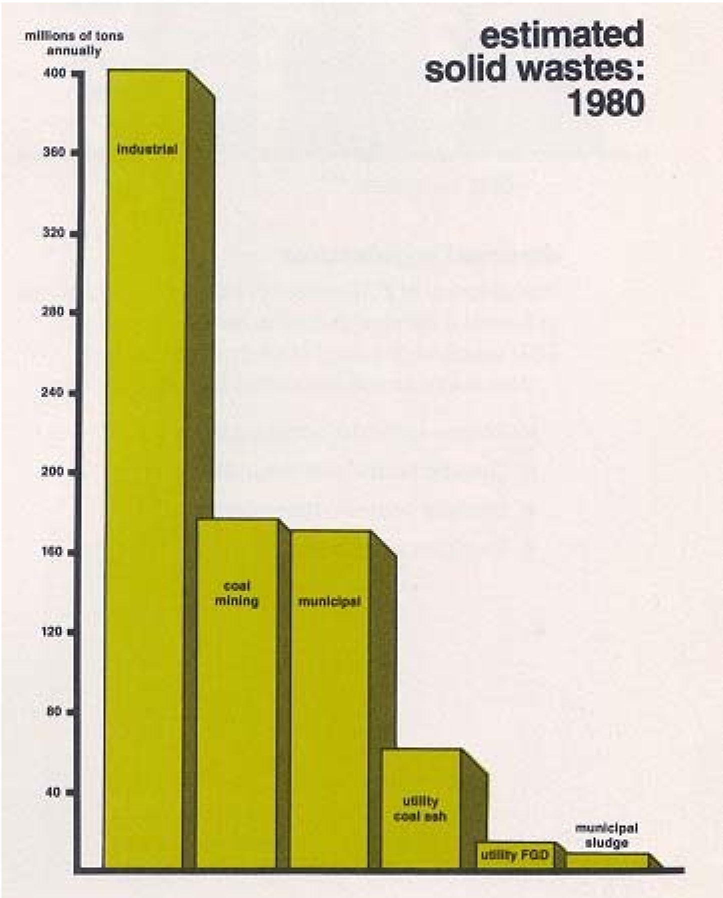

Fig. 5.4 Comparison of Scrubber Sludge with Other Solid Waste. *Source*: EPA, *Sulfur Emission: Control Technology & Waste Management* (Washington, DC: Office of Research and Development, Office of Energy, Minerals, and Industry, May 1979). Bar labeled “utility FGD,” second from right, means scrubber sludge.

[54] Williams, *Summary of Operation and Testing at the Shawnee Facility*, 8.

Obtaining saleable products out of the throw-away scrubber system was attractive to EPA engineers. In 1976, EPA's RTP laboratory engineers successfully produced gypsum at the 0.1 megawatt pilot plant. Based on this finding, Princiotta's team at Shawnee conducted forced oxidation testing in January 1977 for the scale-up. Synthetic gypsums were used as construction material, like drywall and plasterboard, or as an agricultural amendment.[55] Utilities also embraced forced oxidation as it reduced the amount of material to dispose of and generated extra profit by selling the final product. Perhaps gaining credibility from environmentally-concerned consumers was a more attractive reason why utilities hastily followed the EPA in producing gypsum out of sludge.

Despite efforts from government and private engineers to ensure the safety of synthetic gypsum, concerns about possible leaching still existed. EPA researchers found trace metals and other contaminants that might threaten human and environmental health. In cases where sludge was disposed at lined ponds or landfills, it would be possible for contaminants to reach crops, animals, and human beings through surface and ground water (fig. 5.5).

Princiotta and CSL engineers reached out of their comfort zone to address sludge-generated pollution and found their efforts rewarding. In order to define and establish pollution as an engineering problem, they first reviewed preexisting alternatives—low-sulfur coal, coal cleaning, and regenerable processes—and argued that all of them were still insufficient compared to scrubbers in both technical and economic terms. Depending on the readily available expertise on cross-media pollution at the EPA, Princiotta and SOTSEP panelists expanded the realm of engineering approaches to water contamination and land reclamation issues. Producing

[55] EPA, *Sulfur Emission: Control Technology and Waste Management*, 19-20; EPA, *Disposal of By-products from Nonregenerable Systems*, 6.

and marketing synthetic gypsum added additional credibility to scrubber protagonists as gypsum producers and sludge cleaners.

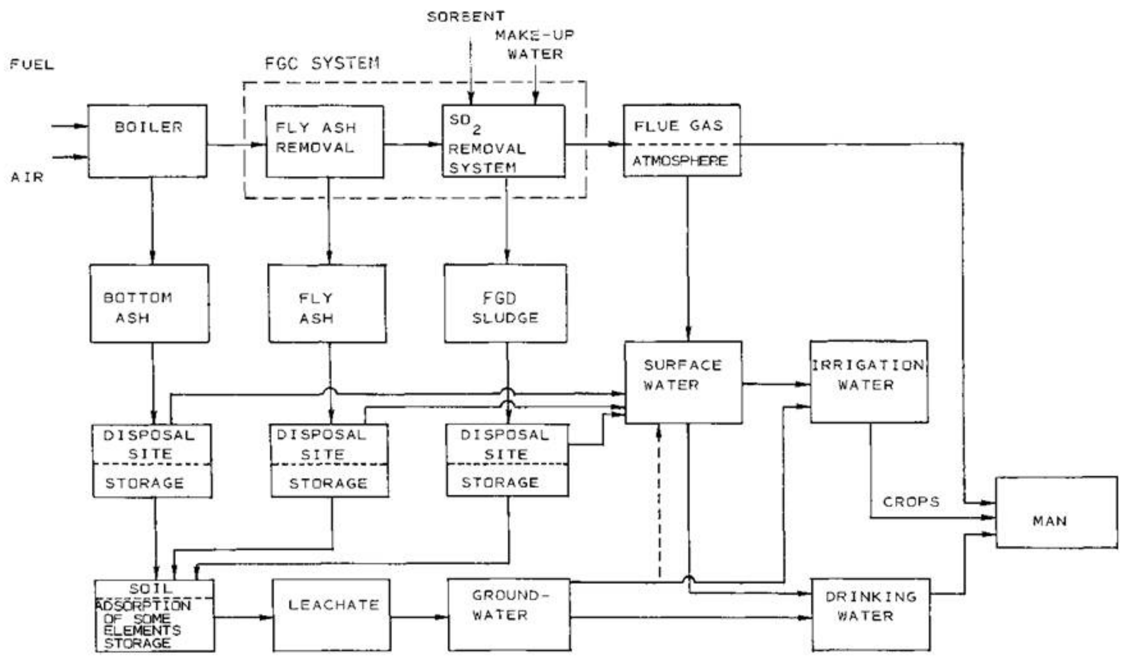

Fig. 5.5 Pathway Chart for Contaminants from Coal to Humans. *Source*: EPA, *Data Base for Standards Regulations Development for Land Disposal of Flue Gas Cleaning Sludges* (Cincinnati, OH: EPA, Municipal Environmental Research Laboratory, December 1977).

With the successful inclusion of sludge-generated water and land pollution into the scrubber research and demonstration program, Princiotta and CSL engineers provided a blueprint for cooperation between engineering and regulation functions in the agency. They introduced the new environmental knowledge of scaling and plugging into the making of a better engineering practice to reduce lime/limestone and sludge. As scrubbers became a de facto standard for SO_2 reduction, regulating stationary air pollution evolved into developing scrubbers and demonstrating their reliability. Therefore, reducing sludge's environmental effects became a critical passage that engineers, scientists, and regulators needed to traverse before they proceeded to their next problem. This collaborative project between engineering, science, and regulation was expanded and institutionalized outside the EPA into broader energy issues.

5.3.2 Control Technology at the Interagency Program

With growing concerns about dependence on foreign oil after the oil embargo, the call for new energy technologies became a national agenda, but the federal government was not ready to coherently tackle this challenge on energy policy. The Federal Nonnuclear Energy Research and Development Act of 1974 began with the following statement: "The urgency of the Nation's energy challenge will require commitments similar to those undertaken in the Manhattan and Apollo projects; it will require that the Nation undertake a research, development, and demonstration program in nonnuclear energy technologies … over the next decade." Legislators were also concerned about the nation "suffering from a shortage of environmentally acceptable forms of energy." Despite the fact that the Act supported the establishment of the Energy Research and Development Administration (ERDA) as the new control tower for energy policy, the competing interests from several government agencies generated grounds for policy negotiation. The Congressional statement also acknowledged "the existing technical and managerial expertise in the various energy fields within Federal agencies and particularly in the private sector."[56]

Frank Princiotta became an important actor for the research, development, and demonstration of control technologies for energy processes by participating in an interagency program. Influenced by the wake-up call of the Act, the White House established the "Federal

[56] Federal Nonnuclear Energy Research and Development Act of 1974, Public Law 93-577, 42 U.S. Code 5901; EPA, *The EPA Energy/Environmental Control Technology Program*, 4.

Interagency Energy/Environment R&D Program" based upon two nascent task forces for energy development and environmental protection.[57] Princiotta himself moved to Washington, DC, to head the new Energy Processes Division of the ORD in March 1975. Until he came back to head the Industrial Environmental Research Laboratory (IERL, successor of the CSL after July 1975) in October 1980, Princiotta was involved in the interagency program as one of the program coordinators in the Office of Energy, Minerals, and Industry (OEMI, 1976-1980). In 1980, the OEMI was reorganized with other offices and became part of the Office of Environmental Engineering and Technology (OEET).[58]

ERDA and the EPA were two big players in the design and execution of the interagency program and their roles in the program were defined by their missions and priorities. The program's overall coordination and planning was the responsibility of the EPA's OEMI; ERDA could not take on that overall role because it "cannot be expected to focus as intensely on the environmental aspects as it does on its primary energy development responsibilities."[59] The EPA's primary mission, however, was environmental protection, and "its objective in the energy area [was] to enable ERDA's efforts to progress as rapidly as possible while assuring that national environmental goals [were] maintained."[60] There were 15 other government agencies in the program, from the U.S. Forest Service and the Bureau of Mines to the National Aeronautics and Space Administration and the National Institute of Occupational Safety and Health.[61]

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[57] EPA, *Interagency Energy/Environment R&D Program*, 4.

[58] U.S. Congress. House, *Organization and Management of EPA's Office of Research and Development*, 94th Cong., 2nd sess., Washington, DC, 1976; EPA, *ORD '80: The Organization* (Washington, DC: EPA, June 1980).

[59] EPA, *Interagency Energy/Environment R&D Program*, 6.

[60] Ibid., 6.

[61] Ibid., 2-3.

From the session formats and main speakers of the 1977 Energy/Environment II conference, we can confirm this subtle balance of attention between energy and the environment. Out of eight session topics, three focused on energy, four focused on the environment, and the last one on the integration of the two.[62] John F. O'Leary, Deputy Secretary of the Department of Energy (DOE, successor of ERDA after 1977), opened up with introductory remarks and the EPA administrator Douglas M. Costle delivered a keynote address.

O'Leary's and Costle's speeches expressed the strong contrast between the DOE's and EPA's interests in the interagency program and their stances on the recent issues. O'Leary focused on the continuity of federal efforts in energy development, while Costle praised accomplishments from the new cooperation between federal executive units. O'Leary emphasized two previous R&D efforts aimed at future energy technology: the light water nuclear reactor and coal/ oil shale conversion. While O'Leary focused on the continuing innovation in energy research, Costle highlighted the energy initiatives that the EPA had been involved in since its establishment. Costle outlined a few projects where the EPA cooperated with the TVA, Bureau of Mines, U.S. Geological Survey, and National Bureau of Standards. The two senior officials from the DOE and EPA also showed differences in framing and addressing recent issues. O'Leary acknowledged concerns from the energy industry that federal efforts might cause competition among the coal, oil, natural, gas, and other industries. However, he argued that the urgency of the energy crisis justified efforts from all sectors, including the federal government, in investing, researching, and developing new energy technologies. Costle argued that he and

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[62] Energy topics were fuel processing, utility and industrial power, and extraction and beneficiation. Topics on the environment were health effects, atmospheric transport and fate, measurement and monitoring, and ecological effects. Integrated technology assessment was the topic where energy and environmental issues met.

President Jimmy Carter had recommended “tough but fair clean air standards for automotive emissions.” He then refuted automakers’ claims about price increases and fuel economy loss. While O’Leary’s points signified the DOE’s preemptive efforts to settle possible credibility and legitimacy questions about the role of the new department, Costle’s arguments dealt with the EPA’s ongoing fights with automakers on the proposed mobile air pollution standards.[63]

The establishment of the DOE did not solve the accountability question among federal engineers, scientists, and managers. While environmental protection minus energy development functioned as an organizing principle and ethos for the EPA, there still existed competing viewpoints within the agency itself. During the same conference, Stephen Gage, Acting Assistant Administrator of the Office of Research and Development, and Delbert Barth, Deputy Assistant Administrator of the Office of Health and Ecological Effects gave two overview talks, each on control technology and health effects. Gage’s talk on the first day focused more on the broader meaning of control technology to solve urgent energy issues, and Barth’s talk on the second day dealt more with the other half of the conference presentations, primarily those on health and environmental effects, for participants who might not be friendly to or familiar with the topics.[64]

Gage argued for the increased role of control technology in making the transition from coal and oil to other forms of energy, using the bridge metaphor. “We need the control technology bridge to give us time to develop the miracle technologies … such as fluidized-bed combustion in the mid-term and coal gasification, oil shale, solar, and nuclear fusion over a longer term.” He exemplified the broad range of the control technologies, from a piece of equipment to a system of pollution abatement: catalytic converters for auto emissions and smog,

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[63] Douglas M. Costle, “Keynote Address,” in *Energy/Environment II*, 37-40.

[64] Gage, “Control Technology,” 15-25; Barth, “Achieving Compatibility between Energy and Environmental Goals,” in *Energy/Environment II*, 27-31.

sewage treatment plans for sewage, land disposal sites for solid wastes, cleanup devices on local utilities' and industries' stacks, and discharge pipes for air and water pollutants. Gage assured the audience that the EPA was pursuing the best available technologies in order to control the environment as mandated and required by various laws and court decisions.[65]

Gage suggested two strategies to deal with the unclear future of the energy supply: necessity and possibility. He first acknowledged the ambivalent feelings on control technology's uncertain characteristics: "Do we really need them? Aren't there other ways of achieving the same objectives? Aren't there breakthroughs waiting just around the corner which will obviate the need for our control technologies?" His answer was straightforward: "Control technologies are our bridge, and our only bridge, into an uncertain future." He pointed to the necessity of control technology by emphasizing that there were no other options available at the moment. Gage's second strategy for publicizing control technology at the conference was touting its potential in remedying four main issues related to energy development: sulfur oxides, mining disruption, nitrogen oxides, and fine particles. The successful demonstration of two types of scrubbers, throwaway and regenerable, was a good example for Gage to persuade the audience about the near-term success of other control technologies that were still in their early stages.[66]

Opening the second day of the conference, Barth began his talk by establishing and defending the role of health and environmental effects research in the interagency program. He

[65] Gage, "Control Technology," 15-16. Gage used the terms control technology and environment control technology interchangeably. He even equated them with "technological fix," which he described as an esoteric term preferred in science policy circles. The omission of the term "environment" in front of control technology entails the shift in focus from environmental protection to the promotion of control technology. The framing of control technology as technological fix can also be read as another representation of this shift. At the same time, the idea of fixing the bigger system with a piece of control technology resonates with the ideology of technological change.

[66] Gage, "Control Technology," 16-17.

lauded the first day's conference presentations and praised the fact that 57 percent of the interagency program's R&D funding had been put to good use. Then he added that the health and environmental effects of energy development should be taken just as seriously. For this purpose, he did not fear to make a sound critique of the DOE's recent accomplishments. He pointed out the elephant in the room: "The good news is, we are getting a national energy policy. But there could also be some bad news. Since the energy policy means expanded coal use, some severe health and environmental impacts could result from that expanded use."[67] Barth then introduced the various research projects on human health effects, pollutants transport and fate, monitoring and control, and ecological effects.

After briefly establishing his office's position at the conference, Barth also underscored that he did not want the audience to believe that environmental researchers were antagonistic to the development of energy. Barth cited the confirmation hearing message of EPA Administrator Costle: "For too long, environmental concern has been portrayed as an obstacle to energy development. This Administration, in contrast, believes that environmental protection is not an obstacle but merely a necessary pre-condition for energy development."[68]

Barth's position and background might have enabled him to better point out the tensions between energy and the environment at the EPA and in the interagency program. His speech, however, did not change the trend toward the increasing use of the control technology approach. As long as he stayed under Gage, his former-colleague and now-supervisor, he had no more leeway than he had in terms of public speech in a conference. He probably knew that he could only speak to the extent that he actually did.

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[67] Barth, "Achieving Compatibility between Energy and Environmental Goals," 27-28.

[68] Ibid., 28-29.

Before long, with increasing tensions with Gage, Barth left the EPA.[69] Meanwhile, Princiotta and IERL had expanded their positions within the EPA and the interagency program, increasing their influence on this tension between "control technology" and "community health," and overshadowing the latter. However, the two approaches, which originated from the EPA's RTP laboratories, functioned as a productive tension at the federal level. President Carter established the Department of Energy in 1977. From the beginning of Fiscal Year 1979, the Department of Energy took over the coordination and planning function of the interagency program from the EPA.[70]

5.4 Conclusion: Expansion of a Control Technology Approach

Princiotta's successful demonstration of scrubbers in reducing stationary air pollution and the subsequent expansion of the control technology approach to energy issues marked important changes in air pollution regulation. Princiotta's and his colleagues' demonstration of scrubbers shows how engineering and regulation became co-produced. In the throw-away scrubbing technology team, Princiotta was able to collect and disseminate information on scrubber manufacturing and operation via government reports, hearings, and other technology transfer activities. In addition, he also generated new knowledge about their reliability and cost.

As scrubbers became a de facto standard for stationary air pollution, subsequent technology-based regulations reflected this change. Early ideas about the control and trading of emissions developed separately, as concepts such as bubbles, netting, offset, and banking were

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[69] Barth expressed his tension with and dissent from Gage in his interview. After leaving the EPA, he moved back to Las Vegas to become an adjunct professor at the University of Nevada at Las Vegas. Barth, Interview by the author, Feb. 10, 2011.

[70] EPA, *The EPA Energy/Environmental Control Technology Program*.

applied to new, modified, or existing sources of pollutants. After an initial period of confusion where environmental groups, industrialists, the Congress, and the Courts were engaged, these emission trading schemes became part of the regulatory engineering. As a result, the EPA allowed utility managers to redefine the meaning of “pollution source” by compiling multiple emission points into one big imaginary area. Companies in this big imaginary area could construct a new source of pollution (offset) or avoid administrative and technological requirements (netting) by reducing emissions from another source of pollution. They could also adjust the level of emissions reduction among individual points so they could reduce the required sum to the least cost (bubble) or reduce emissions more than required to earn emission reduction credits (banking), which could be applied later in the same area or be traded to other companies willing to purchase credits.[71] The success of scrubbers provided an important leverage for engineers and managers to open up new markets where industry found more incentives to meet the emission standards.

Princiotta’s approach to the environmental effects of scrubbers is another point worth mentioning. Instead of minimizing the scale of the problem, the EPA engineers acknowledged the problem and shared the most current information with industry. At the same time, they used it as a way to draw more funding to initiate new projects. So, was Princiotta successfully resolving stationary air pollution by converting it into other types of pollution and continuing to look for engineering solutions? Health researchers at the EPA’s ORD, who followed the “community health” approach in the federal energy/environment program, became marginalized by the expansion of the control technology approach.

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[71] Richard A. Liroff, *Reforming Air Pollution Regulation: The Toil and Trouble of EPA’s Bubble* (Washington, DC: The Conservation Foundation, 1986), 3-9.

Princiotta's demonstration of the scrubbers became a powerful tool in elevating the control technology approach in energy and environmental policy. The Control Systems Laboratory provided substantial support to the planning of new energy/environment R&D activities.

Chapter 6. Conclusion

"To what extent have we succeeded in protecting public health and the environment from the pollutants that are byproducts of our highly technological society? The following case histories ... illustrate that while science and technology do not yet have all the answers, workable pollution controls do exist and can make a difference when they are used."
"Toward a Cleaner Environment," *EPA Journal*, 1980[1]

In January 1980, the *EPA Journal* asked 34 Americans, including bureaucrats, environmentalists, farmers, industrialists, politicians, scientists, and union leaders how the coming decade would compare to the 1970s, "a decade of historic environmental achievement." The list of successes was long: "tremendous progress" in legislation, "the Stockholm Conference in 1972," a new generation of Americans keenly aware of limited resources, and the finding that "development and technology can co-exist with a clean environment." However, there remained numerous concerns: the high cost of environmental regulation, a continuing energy crisis, inflation, and a deregulation backlash. There thus was much to achieve in the 1980s: stronger law enforcement, the "clean-up of the workplace," "cleaner, safer, and renewable energy sources," and better representation of the poor, women, youth, workers, and retirees.[2]

The wide spectrum of interviewees' perspectives from praise to criticism reiterates the guiding questions of this dissertation. In what ways, I have asked, did the meaning of environmental protection change as a consequence of the EPA's emphasis on scientific research and technological development? How did the EPA manage competing goals for the improvement of public health, technological control of pollution, and energy and economic security in its

[1] "Toward a Cleaner Environment," *EPA Journal* 6, no. 1 (1980): 17.
[2] "The New Decade 1980s," *EPA Journal* 6, no. 1 (1980): 26-31.

capacity as a regulator for the environment? How were the careers and identities of EPA scientists and engineers shaped by becoming problem-solvers for environmental protection?

In my dissertation, I define regulatory engineering as an approach to socio-technical problems where engineering practices are incorporated into regulatory and organizational changes, which in turn influence technical knowledge and identity formation. Regulatory engineering emphasizes both the process and product of the coproduction of engineering practices, regulatory measures, and environmental policy. In the previous chapters, I demonstrated how the concept can be an effective tool to analyze significant changes and continuities of systems ideals in environmental management and to trace the amalgamation and early expansion of economic, energy, and environmental policy. I also provided the implications and limitations of singling out this concept under the influence of which we continued to live.

In this conclusion, I first examine how effective the EPA as an organization was in setting up and tackling environmental problems as a challenge to technopolitical systems. Then I trace the consequences of expansion of the control technology approach in federal environmental management through an integrative analysis of three case-studies—the Community Health and Environmental Surveillance System (CHESS), catalytic converters, and scrubbers. Specifically, I focus on the shifts in government research priority and the growing demands for effective regulation. Further attention will be given to the benefits of applying regulatory engineering, the primary conceptual tool of my dissertation, to the co-production of knowledge, identity, and institution in the context of environmental protection in the 1970s EPA and beyond. I conclude by arguing how the aspirations, struggles, and achievements of the EPA engineers, scientists, and regulators in its first decade sheds light on our ongoing efforts for a sustainable and improved environment, public health, technology, and society.

6.1 The Environmental Protection Agency as a Technopolitical Solution

In the early 1970s, President Nixon's tactical reorganization of the executive branch coincided with rising public awareness of environmental problems, resulting in the EPA as a new, independent agency focusing on regulation and research. While the EPA inherited much of the pollution control efforts from its predecessors and was assigned new roles under new legislation, it nevertheless faced epistemic and functional challenges; working through these challenges, its regulators and researchers gained authority and expertise. At the same time, the EPA's regulatory engineering enabled a broader epistemic shift beyond the EPA, where technology was redefined as a reliable solution, not the primary cause of pollution, and left behind an organizational legacy where energy and environmental research became closely coordinated in terms of budget and personnel.

In the late 1970s, the Carter administration's emphasis on energy policy and "regulatory reform," combined with concerns about inflation, gradually shrank the boundaries of EPA's regulatory actions.[3] Bureaucratic contention over environmental governance continued between the EPA, the Interior, Agriculture, and the new Department of Energy. The Reagan administration inherited Carter's emphasis on energy policy and boastfully expanded market-based approaches under the name of deregulation. Reagan's first EPA Administrator Ann Gorsuch accordingly reduced the agency's budget by 22 percent. The research budget portion of the Office of Research and Development (ORD) stayed the same at 26.5 percent between fiscal

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[3] Russell D. Motter, "Seeking Limits: The Passage of the National Energy Act as a Microcosm of the Carter Presidency," *The Presidency and Domestic Policies of Jimmy Carter*, edited by Herbert D. Rosenbaum and Alexej Ugrinsky, 571-594 (Westport, CT: Greenwood, 1994).

years 1980 and 1981.[4] In spite of clear progress in cleaning the nation's air, water, and land, the future of this young agency wasn't clear.

Let's come back to the first issue of the *EPA Journal* in the new decade in order to see how industrialists responded. They raised voices against environmental regulation at this policy transition while drawing on the terms of environmentalism such as health, balance, and cleanliness. Ford Motor Company's president Philip Caldwell expressed the prevailing rhetoric of industry when he claimed that "the task ahead is to maintain the country's economic health as we improve the environment." The Tennessee Valley Authority's chairman S. David Freeman called for "an optimum balance among public health needs, environmental considerations, energy objectives, and economic goals." The gas industry argued that natural gas was the cleanest major source of energy available.[5]

Meanwhile, to both represent and benefit from broadened public interests and support, advocacy and nonprofit groups for the environment became diversified. While traditional conservation-oriented organizations expanded their memberships, some radical groups emerged and other legal action-centered ones flourished. The National Wildlife Federation's executive vice president Thomas L. Kimball expressed his concerns about the foggy future. "Unless the Nation adopts a conservation ethic particularly in light of our expanding human population with its increasing needs, we are not optimistic about the state of the environment for the future." Friends of the Earth's David R. Brower, formerly of the Sierra Club, using his colleague Amory Lovins's concept of soft energy path, claimed the shift from fossil and nuclear fuels to energy efficiency and renewable energy would "enhance equity, create jobs, reduce the triple threats of

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[4] EPA, *Research Outlook 1980* (Washington, DC: EPA, Office of Research and Development, February 1980).

[5] "The New Decade 1980s." Caldwell at page 27, Freeman at 28, and gas industry voice at 31.

inflation, acid rain, and nuclear proliferation, and preserve irreplaceable resources inanimate and living." The Environmental Defense Fund's executive director Janet Welsh Brown criticized the growth of strip mining and synthetic fuel development but was more optimistic about the future than others. "[B]y the end of the 1980s, the rising public awareness of the environmental problems will reverse the rolled back standards and policies."[6]

In all of these domains, scientific research and technological innovation had become key agents of environmental harmony. David Rall of the National Institute of Environmental Health Sciences touted major environmental legislation as accomplishments of the 1970s and argued that scientific information necessary to most effectively use these laws would be critical for the environment in the 1980s and 1990s. Union Pacific CEO James Evans echoed this emphasis on science and efficiency but with a different flavor, arguing for incentive-based programs: "a critical reevaluation of existing and new regulations should emphasize the scientific and technical justification for each control strategy and explore cost-effective comparisons of alternative environmental programs." The Sierra Club's executive director Michael McCloskey argued that the increasing scarcity of oil might pressure the industry to resist installing pollution control devices" but hoped that "slower growth in pollution will offset growing resistance to pollution controls."[7]

What were the consequences of reframing environmental problems as policy questions for effective regulation, via new science and technology? The Office of Research and Development presents the best case to answer this question. First, toward the end of the 1970s, outside participation in planning and management of government environmental research had increased. Critique of EPA's research performance from academic and corporate peers during the

[6] "The New Decade 1980s." Kimball at page 31, Brower at 30, and Brown at 27.

[7] "The New Decade 1980s." Rall at page 31, Evans at 29, and McCloskey at 30.

CHESS controversy generated an opportunity for them to provide more input in design and evaluation of future research. Through participation in Congressional hearings and advisory committees, leading environmental scientists, engineers, and economists gained detailed knowledge about the EPA's research and regulation. The EPA administrator became legally obliged to annually report the next five-year research outlook to the Congress. With better knowledge about the working mechanism and future priorities of EPA research, academic and corporate researchers voiced their opinions and influenced the discussion process.[8]

Second, this proximity between government regulators, industrial researchers, and academics stimulated the growth of environmental science and engineering within the extended environmental management community. Federal support for academic and consulting research in environmental issues contributed to the establishment of specialized educational programs and numerous consulting firms that were often run by former government employees. With the influx of funding, a new or retrained workforce, and positive future prospects, the new field of environmental research continued to expand.[9]

Third, as a repercussion, the Office of Research and Development's researcher profile in the field became less conspicuous than its role as research manager. The number of permanent

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[8] About the role of the EPA's own Science Advisory Board as advisory panel for the EPA administrator on the EPA's major and potentially controversial research results, see section 3.3.1. For cases where the Congress requested the National Academy of Sciences to provide reports, see sections 3.3.1 and 4.2.2. On cases where academic and corporate researchers increasingly took on the role of consultants or peer reviewers in other EPA research projects, see sections 3.3.2, 4.3.4, and 5.2.3.

[9] In his book on the National Laboratories of the Department of Energy, historian Peter Westwick argued that the environmental research boom in the 1970s can be understood as efforts of the government laboratories to find new research areas when the physical sciences became less attractive for drawing funding. Peter J. Westwick, *The National Labs: Science in an American System, 1947-1974* (Cambridge, MA: Harvard University Press, 2003).

positions at the ORD decreased about 15 percent between fiscal years 1973 and 1978. The EPA's overall portion of federal research and development dollars slowly decreased from 1975's highest point of about 1.5 percent to less than 1 percent in 1978.[10] During the 1980s, public health researchers and environmentalists argued that the ORD became too focused on control technology development and research management rather than promoting basic science and public health research.[11]

6.2 Regulatory Engineering and the Rise of the Control Technology Approach

While the EPA became the federal government's control tower for regulation and research for environmental protection, there were competing approaches to the management of environmental problems. As technical knowledge and regulatory practices became convoluted, new approaches and identities formed and expanded beyond the EPA. In my dissertation, I conceptualize this as the fall of the community health approach and the rise of the control technology approach. In this section, I will contrast and reemphasize these two approaches by looking at the legal, regulatory, and technical changes in the late 1970s.

Two competing approaches coexisted in the Clean Air Act Amendments of 1970. Under the stringent deadlines imposed by legislators, EPA regulators set up the National Ambient Air Quality Standards (NAAQS) for six criteria pollutants by considering only the health effects of them. Senator Muskie and other environmentalist groups welcomed this clear exclusion of economic or technological considerations as a big step forward for the betterment of the

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[10] EPA, *Research Outlook 1978* (Washington, DC: EPA. Office of Research and Development, June 1978), 90-91.

[11] Bernard D. Goldstein, "EPA as a Public Health Agency," *Regulatory Toxicology and Pharmacology* 8, no. 3 (1988): 328-334.

environment. The 1970 Clean Air Act Amendments, however, also gave the EPA administrator the authority to set up New Source Performance Standards (NSPS) for new and renovated sources of air pollution. The EPA set up the NSPS considering technology, cost, and environmental factors. The NSPS for sulfur oxides, for example, was 1.2 pounds per MBtu, set as a 70 percent sulfur element reduction of eastern coal with the available technology.

In the Clean Air Act Amendments passed in 1977, in contrast, the control technology approach was more dominant. What were the economic and political backgrounds of this shift? How did the rise of the control technology approach benefit from and contribute to the new economic incentives approach in environmental regulation? To answer these questions, let's look at the details of the changes and continuities in environmental legislation and regulations in the late '70s with the background of technology development and economic difficulties.

The 1977 Amendments maintained the core of the 1970 Amendments but added new changes. Three major changes in the 1977 Amendments reflected the EPA's ongoing efforts to control air pollution and the resultant compromise in consideration of economy and energy issues. First, one motivation for the revision came from Congress's understanding that many areas of the country were not meeting NAAQS and were making little progress toward meeting them.[12] As a result, the time for attaining compliance with NAAQS for certain areas was extended. At the same time, new emission control requirements for nonattainment areas were added. Legislators used their own balance to retain legal authority but not lose their potential voting base.

Second, the 1977 Amendments codified the Prevention of Significant Deterioration program, the EPA's program that prevents the degradation of air quality in areas where NAAQS

[12] Clean Air Act Amendments of 1977, Public Law. No. 95-95, 91 Stat. 685.

attainment has been achieved. The program required a detailed preconstruction review for new and modified sources located in attainment areas so that already clean air in the areas would not degrade.[13]

Third, before 1977, the EPA did not generally allow the construction and modification of a facility in the non-attainment area. Managers of the electric utilities and industrial plants argued that environmental regulations deterred them from building new plants and modifying old plants and thus limited the growth of the area and the nation. Federal and state enforcement officers on the other hand, argued that strict regulations did not provide enough ways to penalize or incentivize diverse activities of potential polluters. Facing both criticisms, the EPA adopted several policy options that eventually opened up an era of new regulatory regime. The Clean Air Act Amendments of 1977 and the New Source Performance Standard of 1978 reflected the availability of scrubbers and their operation, and they introduced concepts like bubble, banking, and the offset of emissions to overcome the limitations of the preexisting command-and-control approach.

These economic incentive programs and the subsequent emission trading policy, reflecting new directions for energy and environmental policy under the Carter administration, became important bases for “regulatory reform.” The EPA’s new initiative became much more stabilized with the influx of new managers and economists such as Administrator Douglas Costle and his Assistant Administrator for Planning and Management, William Drayton. Both had experience in Connecticut’s state government instituting a program of “economic law enforcement,” where violators were charged for noncompliance “an amount just sufficient to

[13] Roy S. Belden, *Clean Air Act* (American Bar Association, 2001). Especially chapter 5 “New Source Review.”

make compliance as economically attractive as profitable commercial expenditures."[14]

The rise of the control technology approach in the EPA also contributed to the expansion of an economic incentives program in the federal government. Developing and using technologies to control emissions from pollution sources became increasingly important for the following reasons. First, the role of pollution control technology in engineering and regulatory practices at the EPA had shifted from support to criteria. Monitoring devices advanced faster than the bureaucratic capacity to administer monitoring activities across the country. The fast development of pollution monitoring technology coupled with increasing needs to control emissions from automobiles and smokestacks and culminated in the EPA's coordination of the Interagency Energy/Environment Research and Development Program. Once catalytic converters and scrubbers became important parts of regulatory engineering at the EPA, subsequent regulatory and research plans presumed the continued use of these control technologies and anticipated further development of advanced ones.

Second, the federal government promoted gradual reform over radical changes. Although the public image of technology in the 1960s and '70s was more about the production of new commodities, various technologies occupied correspondingly important roles in building the infrastructure for maintaining old rules and standards of the society.[15] Technical fixes for social and cultural problems were effective because those social and cultural problems were also problems of technology and engineering. Using control technologies for the betterment of the environment therefore became a good segue for bureaucrats to promote the environmental

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[14] Cook, *Bureaucratic Politics and Regulatory Reform*, 69. Original quote from page 2 of William Drayton, "Economic Law Enforcement," *Harvard Environmental Law Review* 4, no. 1 (1980): 1-40.

[15] David Edgerton, *The Shock of the Old: Technology and Global History Since 1900* (New York: Oxford University Press, 2007).

technology industry and tone down the uproaring voices of the environmentalists.

Third, after control technologies were introduced as pollution reduction tools, they became the basic interface for researchers and regulators to tackle environmental problems. Healthy criticism about the side effects of new devices became less common and internal debates on the balance between health/environmental effects research and control technology development were formally discouraged in the ORD. Instead, the side effects of pollution control technologies became another specialized territory for technology assessment where regulatory engineers were able to define problems, conduct research, test prototype devices, and suggest policy recommendations. Engineers and scientists who focused on newly created missions like controlling the sulfate emissions from catalytic converters and reducing scrubber sludge-related water and soil pollution became more dominant. Control technology that was embedded in a regulatory interface forestalled certain questions about how much technology would be helpful for dealing with environmental problems and what the EPA should do to deal with side effects of using new control technologies.

Fourth, the rise of technology as a solution to environmental problems also contributed to the growing dependence on energy policy. Among various types of environmental technologies, from the monitoring and abatement of pollution to the enhancement of the environment, particular technologies became more popular—namely, those that reduced pollution at the end of the pipeline rather than at the beginning. I describe this as the expansion of the "control technology" approach in air pollution management. Catalytic converters and scrubbers reduced automobile and smokestack emissions at the end of the gasoline/coal extraction-processing-transportation-combustion cycle. The success of certain technologies also limited the future trajectory of environmental regulation. Catalytic converters' successful application delayed other technical and behavioral changes such as reducing pollution when processing fuel and transportation control measures. Car inspection and maintenance programs were gradually introduced to enforce the appropriate use of catalytic converters and to reduce tailpipe emissions from old or heavy polluters by permits. The successful introduction of scrubbers also delayed the development of technology to reduce sulfur components. Going through two oil crises and economic ups and downs, environmental technologies became mandatory attachments to the energy supply for society's continuing growth. Figure 6.1 shows how the EPA conceptualized various emissions and other environmental problems to deal with relevant control technologies at each stage of extraction, processing/conversion, and generation.

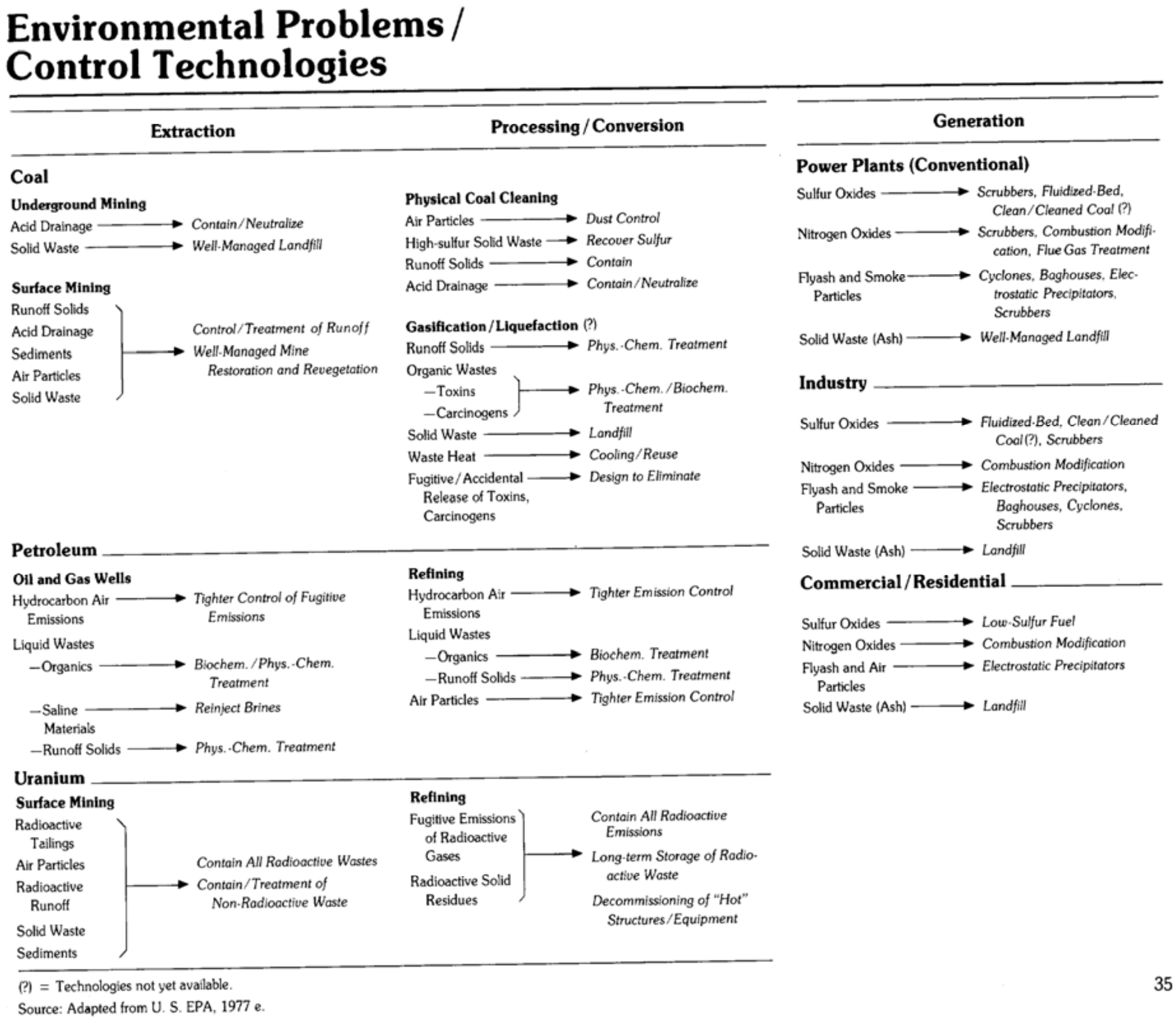

Fig. 6.1 Control Technologies for Energy Related Environmental Problems. *Source*: Department of Energy and EPA, *Energy/ Environment Fact Book* (Washington, DC: EPA, Office of Research and Development, Office of Energy, Minerals and Industry, March 1978), 35.

6.3 Technogovernance in the Age of Deregulation

Former EPA lawyer and manager Mark A. Greenwood claimed in his oral history interview with the Chemical Heritage Foundation that the integration of technology-based regulations and engineering practices began early in the EPA's establishment:

> This concept of using technology-based standards […] was an attempt back then to [move away from the more] intractable issues of big picture sustainability and environmental science, [which was less developed then,] to something that was very pragmatic. 'What can we get people to do today? Let's get them to put treatment systems in.' Okay. And so, you went immediately into those questions of what was viable, what was possible...it became an engineer's program. So, the EPA very much at the beginning was an engineer's program.[16]

Greenwood's claim that the EPA was an engineer's program was certainly informative for my research in its early stage, but it still might not be well received among many former EPA employees. The scientists and engineers I interviewed often pointed out that researchers and regulators were separated from each other and that senior leaders of the EPA lacked technical knowledge and did not appreciate their ways of thinking. These interviewers' observations reiterate their complaints toward managers who often had backgrounds in law or economics as well as management. In my research I was able to find increasing numbers of senior leaders who had scientific and engineering backgrounds toward the end of the 1970s. But more importantly, this collective memory informs us about the dominant ethos of the EPA researchers and provides a good chance to look at how exactly this ethos played out in the new agency that had desperately sought ambitious goals of research and regulation.[17]

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[16] Chemical Heritage Foundation, *The Toxic Substances Control Act: From the Perspective of Mark A. Greenwood*. Interview by Jody A. Roberts and Kavita D. Hardy at Ropes & Gray LLP, Washington, DC. 26 February 2010. Oral History Transcript # 0644. With Subsequent Corrections and Additions. (Philadelphia: Chemical Heritage Foundation, 2010). Brackets from original.

[17] This tension appears to have a long history since the beginning of the EPA. In the letters to editors section of the journal *Environmental Science and Technology*, William Ruckelshaus, the first EPA administrator, defended against editors that the EPA did have enough senior managers equipped with

I argue that EPA regulators and researchers often worked together and sometimes took over each other's burdens. In other words, environmental regulation and research were co-produced at the levels of knowledge and institution. The Office of Research and Development researchers, for example, not only executed their own long-term research projects, but also conducted monitoring and research to support enforcement actions and performed evaluation and assessment functions for regulatory missions of the EPA. Regulators and researchers at the Office of Mobile Source Air Pollution Control at Ann Arbor collaborated and competed with other researchers in Cincinnati and Research Triangle Park to understand emission characteristics of automobiles when catalytic converters were introduced. Regulators at the Office of Air Quality Planning and Standards communicated with fellow ORD researchers at Research Triangle Park to inform each other about current research and development activities inside the EPA and beyond, and sometimes inadvertently applied regulatory timelines to researchers to expedite research about specific pollutants.

What then were the consequences of the co-production of environmental research and regulation at the EPA? How did the EPA researchers and regulators respond when proponents of deregulation claimed that environmental regulation and supportive research were inefficient and therefore cumbersome to the economy and society? I would like to point out three findings from the emerging relationship between government and industry with the rise of the control technology approach from the 1980s on, which I call *technogovernance*. Technogovernance is a technoscientific and managerial form of governance where policy decisions about regulation and promotion are mediated by priorities of the regulator and the regulated.

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scientific knowledge and experience. William D. Ruckelshaus, "EPA Technical Views," *Environmental Science and Technology* 7, no. 2 (1973): 89-90; "Editorial," *Environmental Science and Technology* 6, no. 10 (1972): 861.

First, the policy framework of pollution and environmental protection has shifted from direct regulation to cooperative management. Renowned economist Robert M. Solow emphasized the "external effects" of pollution in front of fellow scientists and engineers in December 1970, arguing that "one person's use of a natural resource can inflict damage on other people who have no way of securing compensation, and who may not even know that they are being damaged."[18] Most conventional economists at the time, however, considered pollution happened outside of the market. The environment came into the economist's equation only when it was a reservoir of raw material or a landfill for waste disposal. The rising environmental movement of the 1960s certainly solved the awareness issue, but still economists like Solow were not satisfied with the "insufficient," "piecemeal," direct regulation and preferred disincentives like taxes or charges and incentives like subsidies.[19]

After multiple contentions about the health effects of automobile emissions and the introduction of catalytic converters, a new cooperative initiative emerged between the government and industry. In 1980 the Health Effects Institute (HEI) was created to provide "high-quality, impartial, and relevant science" by balanced funding of 50:50 from the EPA and

[18] Robert M. Solow, "The Economist's Approach to Pollution and Its Control," *Science* 173, No. 3996 (August 6, 1971): 498-503.

[19] Solow later served as advisor for a few studies about EPA research performance. U.S. National Research Council, *Perspectives on Technical Information for Environmental Protection*. A Report to the U.S. Environmental Protection Agency from the Commission on Natural Resources and the Steering Committee for Analytical Studies, National Research Council. Volume I of Analytical Studies for the U.S. Environmental Protection Agency (Washington, DC: National Academy of Sciences, 1977). To learn more about Solow's perspective on conventional economics, see Tiago Mata, "Migrations and Boundary Work: Harvard, Radical Economists, and the Committee on Political Discrimination," *Science in Context* 22, no. 1 (2009): 115-143.

automakers.[20] Michael Walsh, head of the Office of Mobile Sources Air Pollution Control, and Charles Powers, Cummins Engine Company's vice president, suggested a joint venture between the EPA and the auto industry to fund and publish research on the health effects of automotive pollutants. The result was a "boundary organization" between the government, industry, and scientific community, where its first board was composed of members representing the three sectors.[21] After a few tumbles in its first decade, the HEI became a reliable source of information on air pollution science.

John Bachmann, a former EPA regulator from the Office of Air Quality Planning and Standards (OAQPS), argued that the HEI produced relevant and trusted health effects research under the leadership of Daniel Greenbaum, a former regulator in the Massachusetts government. He also pointed out that one half of the EPA's funding share at the HEI came from the OAQPS and the other half came from the ORD.[22] How this type of technogovernance has influenced government or industrial research is still an open question.

Second, there has been growing awareness of economic incentives and willingness to connect them with technological innovation among policy makers and industrialists. Cooperative

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[20] Terry J. Keating, "Lessons from the Recent History of the Health Effects Institute," *Science, Technology, & Human Values* 26, no. 4 (2001): 409-430.

[21] Members were Archibald Cox, former Watergate special prosecutor; William O. Baker, president of Bell Laboratories; and Donald Kennedy, president of Stanford University. David Guston defines "boundary organization" as "institutions that straddle the apparent politics/science boundary and, in doing so, internalize the provisional and ambiguous character of that boundary." To know more about this concept, see David H. Guston, "Boundary Organization in Environmental Policy and Science: An Introduction," *Science, Technology, and Human Values* 26, no. 4 (2001): 399-408; David H. Guston, *Between Politics and Science: Assuring the Integrity and Productivity of Research* (New York: Cambridge University Press, 2000), 14-36.

[22] John Bachmann, Interview by the author, March 14, 2012.

management for environmental protection became popular among the EPA managers who preferred setting and enforcing performance-based standards. From the 1980s on, many proponents of the community health and command-and-control approaches to environmental governance argued that these approaches cannot address the remaining environmental problems "efficiently, effectively, equitably, and accountably."[23]

EPA's founding members opted for a command-and-control approach in regulatory compliance. Once the EPA set up environmental criteria and standards, the regulated, whether in public or private sectors, were supposed to take measures to meet them. Although specific methods to meet the standards were usually left up to the regulated, EPA regulators sometimes set standards and deadlines in a way that the regulated were forced to adopt certain types of technologies—even develop new ones. The EPA's initial organizational structure and common ethos also contributed to the command-and-control regulation enforcement. The Office of Enforcement and General Counsel recruited young, energetic lawyers who filed law suits against polluters and defended the agency from legal challenges. When health was pronounced the primary criterion to set up national standards for pollutants under the Clean Air Act and Clean Water Act, there was not much area for compromise or other considerations, for different technological options, or the related costs.

In the late 1970s and early 1980s, federal regulators argued for changes to the regulatory status quo in the name of regulatory reform and regulatory relief. In the realm of environmental regulation, concerns about efficiency came from the Office of Management and Budget. Based

[23] Robert F. Durant, Daniel J. Fiorino, and Rosemary O'Leary, eds., *Environmental Governance Reconsidered: Challenges, Choices, and Opportunities* (Cambridge, MA: MIT Press, 2004), 2; Arthur P. J. Mol, "The Environmental Transformation of the Modern Order," *Modernity and Technology*, edited by Thomas Misa, Philip Brey, and Andrew Feenberg, 303-325 (Cambridge, MA: MIT Press, 2003).

more on realpolitik than notions of public good, a new generation of regulators argued that new approaches should encourage more cooperative and cost-effective behaviors such as innovation and collaborative decision making.[24] Emission trading practices based on the availability of various scrubbing technologies became popular as they became a symbol of flexible regulatory practices.

Third, the expansion of regulatory engineering and technogovernance in the federal government accelerated the redefinition of the environment as the subject of control and management. How did the environment become fragmented into controllable units and what were the implications of this change? One of the reasons why environmental problems were new in the 1960s and ’70s was that they raised fundamental questions about the role of the government: If there is a crisis in maintaining the environment on which the modern state and government rely, what is the responsibility of the government and how far can it reach out to bring the balance back?

From the Progressive Era to the 1960s, the federal government employed diverse values such as health, safety, and conservation to deal with food, agriculture, and natural resources. The environmental issues centered on but were not entirely limited to human health, public safety, or resource depletion. There was a gradual change in people’s understanding of environmental problems during the 1970s. A growing emphasis on control of the environment by technological intervention made environmental problems appear more controllable and therefore tolerable to policymakers and industrialists than other contemporary issues.

Questions about fresh air and clean water were translated into problems of reducing specific pollutants in the containing media by certain percentages. Monitoring of pollutants in the

[24] Cook, *Bureaucratic Politics and Regulatory Reform*, 6-12; Durant et al., *Environmental Governance Reconsidered*, 3-9.

ambient air, once a cutting-edge technological puzzle, became a routine exercise of technical professionals. Instead of changing lifestyles and societal infrastructure to depend less on automobiles, electricity, and fossil fuels, more technologies were developed and applied to facilitate end-of-pipeline emission reduction and to move pollutants to other media.

We still live in the lasting legacy of regulatory engineering and technogovernance that originated in the 1970s. Despite the addition of new concepts including the risk paradigm and environmental justice, American environmental policymakers, regulators, and researchers continue to emphasize control technology, economic incentives, and cooperative management. Frank Princiotta and Research Triangle Park engineers continued developing control technologies for nitrogen oxides, radon, and chlorofluorocarbon, to deal with thorny environmental issues throughout the 1980s and ’90s: acid rain, cancer, and ozone depletion. Emission trading markets expanded from sulfur oxides to nitrogen oxides to tackle acid rain. While agreeing with and supporting conservative criticism on “excessive regulation,” American industry found the development of pollution control technology a part of new innovation. Since 1982, the electric utilities industry has been co-conveners with the EPA of the annual symposium on control technologies for stationary air pollutants. The Obama administration’s fuel efficiency standards of 54.5 mile per gallon by 2025 include plans to reduce greenhouse gas emissions by developing and introducing a wide range of technologies and incentives for natural gas, electric, hybrid, and fuel cell vehicles. American and foreign automakers took a major role in fleshing out this plan, contrasting a positive image against their financial crisis and government subsidies a few years ago.

The legacy of regulatory engineering and the control technology approach is also found beyond the EPA. Proponents of the community health approach, John Finklea and John Moran, moved to the National Institute for Occupational Safety and Health and set up criteria standards, designed surveillance networks, and again faced corporate resistance to occupational health and safety. The Food and Drug Administration, the oldest regulatory agency of the federal government, recently redefined its mission around the research and application of “regulatory science.” Other EPA alumni went to consulting and academic sectors. Stanley Greenfield and Eric Stork became consultants for industry and municipal and state governments. Delbert Barth and Carl M. Shy moved into academia to produce the next generation of regulatory professionals.

The EPA’s regulatory engineering practices centered on the development and application of end-of-pipeline control technologies to reduce major pollutants in the air. This historical choice was effective in improving air quality during the 1970s, but it also shaped subsequent trajectories in environmental regulation and research. Economic incentive programs and flexible regulations increased with the expansion of emission trading policy. Monitoring and research on the health and environmental effects of pollution took a supplementary role within the Office of Research and Development. New environmental challenges from climate change and nano-level products might require creative ideas and initiatives on a different scale. Reappraising the accomplishments and limitations of the EPA’s first ten years’ experience provides a good chance to understand the origins of the current technological and managerial approaches in environmental policy. It tells us how new forms of knowledge, institution, and identity for and about pollution and environmental protection emerged at the intersection of engineering and regulatory practices.

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Appendix A. Document Numbering Systems of the EPA

The EPA developed and implemented different document numbering systems to synthesize its research activities and facilitate dissemination of its publications within the EPA and beyond.

After July 1972, the Office of Research and Monitoring (ORM) abolished all existing numbering systems, such as the one used in the "water pollution control research series" and created its research reports series, initially in five categories which expanded to nine. They were R1 (Environmental Health Effects Research), R2 (Environmental Protection Technology), R3 (Ecological Research), R4 (Environmental Monitoring), R5 (Socioeconomic Environmental Studies), R6 (Scientific and Technical Assessment Reports, STAR), R7 (Interagency Energy/Environment Research and Development), R8 ("Special" Reports), and R9 (Miscellaneous Reports). For example, EPA-R2-72-066 denotes the sixty-sixth (066) environmental protection technology-type (R2) publication by the ORM published in 1972. It is noteworthy that the implementation of new research categories was justified as an effort to "foster technology transfer and a maximum interface in related fields."[1]

Instead of the character R, numbers associated with each NERC (650-Research Triangle Park; 660-Corvallis; 670-Cincinnati; 680-Las Vegas) have also been used. For example, EPA-650/2-75-010-b denotes volume 2 (lowercase expander b) of the tenth (010) environmental protection technology-type (2) publication by the NERC-Research Triangle Park (650) published in 1975. As the reorganization of the Office of Research and Development (ORD, successor of the ORM after July 1973) eliminated the National Environmental Research Center (NERC)

[1] EPA, *Bibliography of R&D Research Reports* (Washington, DC: EPA, Office of Research and Development, July 1973), 1.

structure and 15 individual laboratories reported directly to headquarters since June 1975, one number (600) began to represent all ORD reports. Likewise EPA-600/9-79-019 denotes the nineteenth (019) miscellaneous report (9) by the ORD (600) published in 1979.

Since 1991 the EPA has been using another system that is composed of three digit numbers that identify the organization responsible for producing the publication, an alpha descriptor of the document type, two digits of the calendar year in which the publication was produced, and the sequential number. For example, EPA-202-K-93-003 denotes the third (003) pamphlet/book type publication (K) from EPA History Program (202) in 1993 (93).