ELSEVIER

Research Policy 26 (1997) 157–168

research policy

Policy for science for policy: A commentary on Lambright on ozone depletion and acid rain

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Received 12 February 1997

Abstract

Scientists face increasing pressure to demonstrate how their work contributes to societal objectives. Likewise, policy makers proposing environmental policies are often asked to provide the scientific basis on which their proposals are based. These twin pressures are forcing a closer connection between science and policy. In our view, policy-for-science-for-policy is a recursive process of defining societal goals, using those goals to identify questions to be addressed by science, then relating the findings of science back to the original goals, and if necessary, revisiting the goals themselves. Any policy analysis that focuses solely on policy-for-science or on science-for-policy tells only part of the story. To illustrate the need for and utility of a more integrative framework we critique a recent study of science and policy in the case stratospheric ozone depletion provided by W.H. Lambright in the September 1995 issue of *Research Policy* and in the process offer an alternative analysis. We find that the primary lesson of the ozone experience, supported in the case of acid rain, lies not in the conduct of research by government agencies or in the efforts of research managers to provide entrepreneurial leadership, but in the establishment of a healthy policy process —a policy-for-science-for-policy— that connected scientists and decision makers in pursuit of a common goal. © 1997 Elsevier Science B.V.

Keywords: Ozone depletion; Acid rain; Policy relevance; Policy-for-science-for-policy

1. Introduction

There is growing concern with the need to better integrate science and decision making. Scientists face increasing pressure to demonstrate how their work contributes to societal objectives. Likewise, policy makers proposing environmental policies are often asked to provide the scientific basis on which their proposals are based. These twin pressures are forcing a closer connection between science and policy. Much of our understanding of the science-policy connection has been shaped by a distinction between 'policy for science' and 'science for policy' (Brooks, 1964). The former refers to issues of resource allocation, peer review, etc. within science, while the latter refers to the production of useful knowledge to contribute to decision making. These frameworks are frequently used in both a practical and an analytical sense to describe the linkage between science and policy.

We contend that rather than differentiating between these concepts, the relationship of science and policy can better be understood through their integra-

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PII S0048-7333(97)00020-6

tion —policy-for-science-for-policy— described by Cowling (1992, p. 113) as "a prescribed set of policy-relevant issues which are written down in a coherent set of policy-oriented questions." In our view, policy-for-science-for-policy is a recursive process of defining societal goals, using those goals to identify questions to be addressed by science, then relating the findings of science back to the original goals, and if necessary, revisiting the goals themselves. [1] Any policy analysis that focuses solely on policy-for-science or on science-for-policy tells only part of the story. Such partial approaches are likely to be incomplete in the sense that they miss the *inter*relation of science and policy. As Brunner (1991, p. 66) has stated, "Most *preventable* errors of policy analysis stem from the analyst's perspective: As the analyst simplifies a problem to make it tractable for analysis and action, some important part of the relevant context is misconstrued or overlooked altogether" (emphasis in original).

To illustrate the need for and utility of a more integrative framework we critique a recent study of science and policy in the case stratospheric ozone depletion provided by W.H. Lambright in the September 1995 issue of *Research Policy* and in the process offer an alternative analysis. We argue that Lambright's article overlooks important parts of the context of the relation of ozone science and policy. Focusing primarily on science for policy, the article presents a number of lessons for relating science and policy based on an identification of the National Aeronautics and Space Administration (NASA) as the "principal institutional actor constructing the network of scientists and users in the ozone case" (Lambright, 1995, p. 749). NASA in the 1970s adopted a strategy, according to the article, "For making science relevant to policy: and that as a result of this strategy, NASA successfully built a network for accomplishing research, and transferring it to policy users in a way that proved quite satisfactory for most parties" (Lambright, 1995, p. 759).

While Lambright's article focuses our attention on an important topic, it suffers from several important errors of fact and interpretation (discussed in the pages that follow) that limit that particular case study's value for contributing to our understanding of how to better relate science and policy. More importantly, the article tells only part of the story. Focusing on the role of a single actor, NASA, its emphasis is on science for policy. The article asserts that NASA, through entrepreneurial leadership, managed the ozone issue in a manner that effectively connected science to decision making. The article neglects policy for science and thus misses the broader context in which NASA was operating and the role of other participants. Consequently, the article misses one of the most important lessons of the ozone case.

This paper suggests an alternative interpretation of the significance of the case of ozone depletion using Lambright's article as a foil, pointing out its errors of fact and interpretation. We also revisit the case of acid rain, which Lambright's article compares briefly to the case of ozone and, in our view, incorrectly. Like Lambright, we find that "ozone depletion is an example of relatively effective policy-relevant science" (p. 758). However, we find that the primary lesson of the ozone experience, supported in the case of acid rain, lies not in the conduct of research by government agencies or in the efforts of research managers to provide entrepreneurial leadership, but in the establishment of a healthy policy process that connected scientists and decision makers in pursuit of a common goal. [2] In the mid-1970s the U.S. Congress created such a process for the ozone issue that contributed significantly a decade later to the systematic and effective use of science in domestic and international ozone decision making. In other words, it established a policy-for-science-for-policy under which scientists and policy makers worked together to address the societal problem of ozone depletion.

[1] Of course, not all scientific research is supported with the goal of contributing to policy formulation. Science is sometimes supported to advance knowledge. Our focus in this paper is on science supported as a direct contributor to policy.

[2] We view a healthy policy process as one that effectively organizes the interactions of multiple participants to clarify and secure common interests. Thanks to Ronald Brunner for this clarification. See Brunner (1991).

2. Policy-for-science-for-policy in the case of stratospheric ozone depletion

In contrast to Lambright's assertion that in 1974 and 1975 "as environmentalists called for action, policy makers were uncertain how to respond" (Lambright, 1995, p. 750), the U.S. Congress reacted quickly and effectively to the ozone threat, in spite of substantial scientific uncertainties. According to a primary participant at the time, "Within less than a year of its reported discovery, the fluorocarbon-ozone problem received attention by high levels of government before it could be smothered by bureaucratic deliberation. A vehicle was developed within government for interested and knowledgeable scientists to be involved in the decision process" (Bastian, 1982, p. 164). The vehicle referred to was federal coordination of the ozone issue through legislation and interagency cooperation, in other words the development of a policy-for-science-for-policy.

In June 1974 M. Molina and S. Rowland published their seminal work on ozone depletion in *Nature* (Molina and Rowland, 1974). Congress acted on the issue almost immediately: the House Interstate and Foreign Commerce Committee held hearings in December 1974 and March 1975; The Senate Committee on Aeronautical and Space Sciences held Hearings in January and September 1975; and the House Science and Technology Committee held hearings in May and July 1975. The executive branch acted quickly as well: in January 1975 the Council on Environmental Quality and the Federal Council on Science and Technology —two White House committees— together created an interagency task force on Inadvertent Modification of the Stratosphere (IMOS) to report on the 'fluorocarbon-ozone question' (IMOS, 1975, iii). In its report, produced six months later and distributed to each member of Congress, the IMOS task force concluded that "fluorocarbon releases to the environment are a legitimate cause for concern... If the National Academy of Sciences confirms the current task force assessment, it is recommended that the Federal regulatory agencies initiate rulemaking procedures for implementing regulations to restrict fluorocarbon use" (IMOS, 1975, p. 5). Yet, at the time a significant obstacle existed to the promulgation of any regulation in that "in early 1975 no one was certain what agencies could regulate fluorocarbons under which legislation; the authorities appeared to be both overlapping and incomplete" (Bastian, 1982, p. 173).

In overcoming this obstacle, a 'vehicle' for linking science and policy was created. A policy-for-science-for-policy was formulated and applied in three overlapping phases: clarification of roles and responsibilities, legislation of authority and control, and invocation of the policy.

2.1. Clarification

At the request of the IMOS task force the Justice Department sought to clarify legal authority for chlorofluorocarbon regulation based on existing legislation. In a June 1975 letter to IMOS from Wallace H. Johnson, assistant attorney general, the Justice Department reported that EPA could regulate aerosol-related pesticide products; FDA could regulate aerosol-related foods, drugs, and cosmetics, and the Consumer Product Safety Commission could regulate all other aerosol-related consumer products as well as home and school refrigeration and air conditioning (IMOS, 1975, pp. 101–109). However, it was determined that no agency has jurisdiction over aerosol-related commercial and industrial uses or aerosols used by the automotive industry. The Justice Department report was key in identifying what decisions could and could not be made based on existing legislation, and thus clarified what actions needed to be taken to establish a process that would allow decisions to be made about chlorofluorocarbons.

2.2. Legislation

Congress introduced several bills during 1975 in response to the ozone issue. One, "The Upper Atmospheric Research and Monitoring Act of 1975" is presumably the one referred to by Lambright (Lambright, 1995, p. 750) as giving NASA authority to conduct research, technology development, and monitoring of the upper atmosphere. The bill became law (P.L. 94–39) on June 19, 1975 as an amendment to NASA's organic act, whereby it added upper atmospheric research to the NASA mission (NASA, 1978). The law, as Lambright notes, provided for "a long-term R and D effort... [with] research [to be] relatively basic, generally performed by academic

scientists'' (Lambright, 1995, p. 750). The law *did not* provide explicitly for a connection of science to policy.

A close look at the legislative history of the ozone issue suggests that this interpretation of the role that NASA was expected to play in the formulation of the ozone policy process is flawed in two important respects. First, it overemphasizes the role of NASA as a producer of science for domestic policy. The reality is somewhat more complex: NASA was one of a suite of agencies that was given responsibility to conduct ozone depletion research. Other agencies were also provided with a research mandate, notably the Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA). Second, Lambright's interpretation largely overlooks the significance of other more important legislation that was also introduced in 1975; legislation that was important because it created a 'vehicle' to connect science and policy.

Congress proposed two bills in 1975 to establish a process for research to contribute to decision making. These bills would later be adopted in law as the Clean Air Act Amendments of 1977. Lambright notes that Congress amended the Clean Air Act in 1977 because it ''wanted answers'' (Lambright, 1995, p. 750). Congress not only expressed a desire for answers in the Clean Air Act Amendments but established a process to get those answers and translate them into policy action. In the Act, Congress established a criterion for assessing whether or not action would be necessary. One of the most important lessons for our understanding of the connections of science and policy from the case of ozone depletion lies with the language of the Clean Air Act Amendments of 1977. The production of information usable by policy makers depends more on the establishment of a healthy *process* than on the support any particular body of research (cf. Pielke, 1994).

The ozone language in the Clean Air Act Amendments of 1977 was actually introduced in 1975 as H.R. 3118, ''The Ozone Protection Act of 1975'' (HCST, 1975, p. 13). The ozone provision of the Amendments were needed because ''the 1970 version [of the Clean Air Act] would have been a legal nightmare to utilize for controlling this type of pollutant'' (Bastian, 1982, p. 175). As passed by the House of Representatives in 1975 the bill provided a clear and unambiguous link between ongoing research and policy action. The bill stated that the Administrator of EPA ''shall propose regulations for the control of any substance, practice, process, or activity (or any combination thereof) which may reasonably be anticipated to affect the stratosphere, especially the ozone in the stratosphere, if he finds that such effect on the stratosphere may reasonably be anticipated to endanger public health or welfare'' (HCST, 1975, p. 24). [3] Meanwhile, the Senate passed similar legislation (Congressional Quarterly, 1976). The legislation also provided for the possibility of Congressional disapproval of any promulgated regulations. Congress, in the bill, made clear that the research to be conducted by NASA and the other agencies would play a role in policy development. The House Science and Technology Committee (HCST, 1975, p. 15) observed that it

> anticipates that NASA will play a major role. They have now taken major responsibility for research leading to instrument and platform development for upper atmospheric monitoring. It is assumed however, that routine monitoring will continue to be done by NOAA after techniques are developed, and that research on health and welfare effects and research needed for regulatory purposes will be under the lead of EPA. Of course, EPA should take advantage of any appropriate facilities or competencies in any government agency.

The legislation was not signed into law until two years later, August 7, 1977 (P.L. 95–95). [4] Nevertheless, the language requiring EPA to regulate ozone under the condition of endangered public heath or welfare remained intact.

In October 1976, as the Clean Air Act Amendments were slowly moving to law, Congress passed

[3] The final language of Sec. 157(b) of the Clean Air Act Amendments adopted in 1977 (P.L. 95–95) is substantially similar to that first introduced in 1975: The EPA administrator must regulate ''for the control of any substance, practice, process, or activity (or any combination thereof) which in his judgement may reasonably be anticipated to affect the stratosphere, especially ozone in the stratosphere, if such effect in the stratosphere may reasonably be anticipated to endanger public health or welfare.''

[4] The 1975 bills died in conference due to provisions unrelated to stratospheric ozone depletion. Similar legislation was introduced in subsequent years.

the Toxic Substances Control Act (TSCA, P.L. 94–469). According to Wirth et al. (1982, p. 218) this act began "regulatory action by the U.S. government on chlorofluorocarbons." Regulatory action was divided into two phases by a working group established by the TSCA, where phase one would consider the regulation of 'nonessential uses' of chlorofluorocarbons (i.e., uses for which there were substitutes) and phase two would consider what was expected to be the more difficult challenge of the regulation of essential uses (Wirth et al., 1982). The TSCA covered only nonessential uses for which regulations were developed and implemented in December 1978, i.e., the 'aerosol ban' (cf. Morrissette, 1989). [5] Regulation of essential uses would have to wait for the broader authority provided by the Clean Air Act Amendments.

2.3. Invocation

The ozone policy-for-science-for-policy —as expressed in the TSCA and Clean Air Act Amendments— was the U.S. component of broader international action on ozone. Lambright's article largely ignores this larger context. As ozone moved from a matter of national regulation to international diplomacy it was the existence of the ozone policy-for-science-for-policy established over 1975–1977 that ensured U.S. participation in international negotiations and led to the mature relation of ozone science and policy that we observe today.

By the late 1970s, in addition to Canada, Norway, Sweden, Denmark, and Germany, a number of international organizations had begun to take seriously the issue of chlorofluorocarbons (Bastian, 1982). [6] The United Nations Environment Programme (UNEP), World Meteorological Organization, Organization for Economic Cooperation and Development, and the European Economic Commission were among the international organizations that expressed concern (Morrissette, 1989). In response to their concerns and supported by national activities of regulation and research, these organizations began to formulate an international response. In 1977, UNEP held a meeting that resulted in the creation of a World Plan of Action for the Ozone Layer to coordinate research. In 1981, UNEP formed a working group to draft a Global Framework Convention for the Protection of the Ozone Layer. Four years later this would become the Vienna Convention for the Protection of the Ozone Layer. Two years later, in 1987, the vague commitments of the Vienna Convention were replaced by stringent regulations of chlorofluorocarbons in the Montreal Protocol on Substances that Deplete the Ozone Layer (Morrissette, 1989). How did the United States go from regulation of only nonessential uses to participation in a global regulatory accord?

According to Lambright (1995) U.S. participation in the international process was encouraged by 'user pull' of the international community. [7] It is certainly likely that the concern of the international community added support to those encouraging U.S. participation in the international negotiations. However, the pull of the international community is not sufficient to explain U.S. participation and the international community pulled for at least several years before the U.S. became an active participant (Parson, 1993). [8] It was the ozone policy-for-science-for-policy established through the Clean Air Act Amendments of 1977 that provided the legal mechanism to ensure that the U.S. would promulgate domestic regulations and participate in the international negotiations. This assertion is supported by a law suit brought by the National Resources Defense

[5] In addition, certain aspects of the phase one regulations were covered by the Food, Drug, and Cosmetic Act. The regulatory process is described in detail in Wirth et al. (1982).

[6] Great Britain and France were more cautious about the issue (Morrissette, 1989).

[7] Lambright's article is somewhat unclear and very brief on this point. We interpret the use of the phrase 'user pull' to mean that the international community's interest in negotiations was a primary cause of the eventual U.S. commitment to action.

[8] There is also the issue of how hard the international community was actually pulling in the years leading to the Vienna Convention. According to Peter Usher, of the United Nations Environmental Programme, the period leading to the Vienna Convention in 1985 did not proceed with the intensity and urgency that characterized the period leading to the Montreal Protocol in 1987 (interview with authors, 1 May 1996). Thus, some other factor must be responsible for the emergence of U.S. interest in international action with respect to the ozone layer.

Council (NRDC) against EPA in 1984 and its subsequent settlement. It was a push rather than a pull that reengaged EPA and the U.S. as active participants in the ozone issue.

In October, 1980 EPA released an Advanced Notice of Proposed Rulemaking (ANPR) in which the Administrator acknowledged the danger of chlorofluorocarbons and called for an immediate freeze on production (45 FR 66726, Oct. 7, 1980). [9] The ANPR, issued in the last days of the Carter administration, was one of a suite of actions called the 'midnight regulations' because of their proximity to the November election (Cagin and Dray, 1993, p. 243). Less than a month later Ronald Reagan was elected to office. He installed Anne Gorsuch, who was cool to further regulations of chlorofluorocarbons, as director of EPA. During this period the science of ozone depletion was in many ways still uncertain, yet was certain enough that the previous EPA administrator had seen fit to propose in the ANPR further regulations of essential uses of chlorofluorocarbons.

Scientific uncertainty led some to reconsider the policy-for-science-for-policy. In Congress Representative Thomas H. Luken (D-OH) and Senator Lloyd Bentsen (D-TX) sought to again amend the Clean Air Act with respect to ozone depletion and in the process remove the criterion for action, i.e., "The EPA administrator shall regulate if..." (Dickson, 1981). They wanted EPA to focus solely on research *without* any criteria for action in the law (Roan, 1989). In short, they wanted to remove the legal basis for chlorofluorocarbon regulation. Those who wished to modify the 1977 law received a 'giant gift-wrapped present' in the form of a 1982 National Academy of Sciences study that suggested that the ozone depletion threat was somewhat less than was previously thought (Cagin and Dray, 1993, p. 249). However, efforts within Congress led by Senator Robert Stafford (D-VT) stopped the attempts to again amend the Clean Air Act, meaning that the policy-for-science-for-policy remained intact (Roan, 1989). [10]

Although the Clean Air Act Amendments remained on the books, EPA under Gorsuch still wished to avoid promulgating any new regulations with respect to the ozone because of the Reagan Administration's reticence to regulatory action. For about three years this strategy was successful (from Gorsuch's perspective). In March, 1983 the EPA directorship changed hands from Ann Gorsuch to William Ruckelshaus, but the agency's position with respect to the 1980 ANPR did not change. A process of change in the EPA position began in May 1983 when the Natural Resources Defense Council filed with EPA a letter providing a sixty-day notice of its intention to sue the agency because, "We believe that the Agency is legally obligated to take some regulatory action on the basis of the scientific conclusions stated in the ANPR... EPA is obligated by Section 157 of the Clean Air Act." [11] Both NRDC and EPA had experience with such 'citizen lawsuits' that were included as a provision in the original Clean Air Act of 1970 (Waxman, 1991). By invoking the policy-for-science-for-policy NRDC took a chance that EPA would try to remove the basis for the lawsuit.

Within EPA an effort did begin to rescind the 1980 ANPR, most likely as a consequence of the threatened lawsuit. However, a number of scientists with EPA were opposed to making an argument that CFCs would not endanger public health or welfare and thus resisted the effort to overturn the ANPR (Cagin and Dray, 1993). Furthermore, had EPA actually rescinded the ANPR that decision would have been judicially reviewable requiring scientific evidence that chlorofluorocarbons would *not* endanger public health or welfare. [12] This meant that EPA would have to face the provisions of the 1977 law whether they followed the 1980 ANPR or not. In this instance scientific uncertainty meant that the 1977 law could not be easily overturned. In September 1983 amid internal reorganization of EPA offices responsible for the ozone issue, the agency dropped

[9] Cagin and Dray (1993, pp. 243–261) is a well documented history of this period.

[10] The Clean Air Act was not amended during the Reagan Administration.

[11] Quote from letter from Alan Miller, NRDC to W. Ruckelshaus, EPA, 31 May, 1983, excerpted in Cagin and Dray (1993, pp. 254–255).

[12] Thanks to David Doninger for this observation.

consideration of reversing the ANPR. NRDC was encouraged by this action. However, NRDC remained concerned about possible EPA or Congressional efforts to rescind the basis for the lawsuit and did not file it at this time.

By August 1984 EPA had taken little action with respect to chlorofluorocarbon regulations. NRDC again notified EPA of its intention to file suit, which was eventually filed in November 1984 (NRDC v. EPA, District of Columbia District Court, No. 84-3587). [13] EPA Administrator Ruckelshaus resigned in January 1985 and was replaced by Lee Thomas. After reviewing the issue immediately upon assuming the office, Thomas agreed to the possibility of an out-of-court settlement with NRDC. Negotiations between EPA and NRDC resulted in a settlement in December 1985. As a result of the settlement, EPA agreed to conduct further research on regulatory aspects of ozone depletion, reestablish inter-agency coordination, hold a series of assessment workshops, participate in international workshops, and importantly, provide support for the Vienna Convention (Lobos, 1987). The provisions of the settlement later proved important in moving the international process forward (Doniger, 1988).

Lambright's article overlooks the NRDC lawsuit and thus incorrectly attributes the reappearance of EPA as an actor in the ozone issue to the discovery of the 'ozone hole.' In May 1985, Joe Farman, a British researcher, published an article in *Nature* in which he reported a 40% decrease in stratospheric ozone over Antarctica the previous October (Farman et al., 1985). This article prompted a great deal of additional research as well as a sense of public urgency on the problem of ozone depletion. Recall, however, that NRDC's lawsuit was filed in November 1984 and that Thomas had agreed to negotiate an out of court settlement in early 1985, *before* Farman's paper was published. Furthermore, in its December 1987 (EPA, 1987) proposed rule to meet the requirements of the Montreal Protocol, the EPA refers to continuing scientific uncertainty about the cause of the ozone hole and asserts, "*The Agency has de facto assumed that the ozone hole is not related to CFCs and halons*" (40 FR 82 – 52 FR 47489 December 14, 1987, emphasis added). Lambright, by focusing only on a narrow part of the ozone story, missed this important piece of the puzzle.

The threat of and actual filing of the NRDC lawsuit were an invocation of the ozone policy established 1975–1977. It is uncertain what would have happened in the absence of the legal mandate that required EPA to regulate if chlorofluorocarbons were determined to be harmful to human life. However, it is plausible that the Reagan Administration would have been able to continue to thwart efforts to ensure U.S. participation in international negotiations under the claim that science was incomplete and uncertain. The 1977 law provided a standard or level of certainty for action that was met in 1980. Additional research did not prove chlorofluorocarbons to be safe by 1984 and EPA was consequently forced by the citizen lawsuit to take action.

In the early 1980s, it was the policy-for-science-for-policy that ensured that research findings would lead to sensible action. If more political support had existed for Senator Bentsen's and Congressman Luken's proposals, Congress could have overturned the 1977 Clean Air Act Amendments or the EPA could have pursued its efforts to rescind the 1980 ANPR. However, in the absence of such political will, the 1977 law set a standard that proved difficult to change in light of continuing scientific uncertainty. A healthy policy process made this possible.

3. The case of ozone depletion as a mature science / policy relationship

With the discovery of the ozone hole in 1985 and the adoption of the Montreal Protocol in 1987 the relation of science and decision making on the ozone issue took on a more mature status. In this respect it is a somewhat different sort of issue than it was in the 1970s and early 1980s. In the 1970s and early 1980s the primary issue was whether or not to act. The ozone policy-for-science-for-policy provided clear guidance on this issue for the U.S. and was finally resolved with a decision to act, first in 1978 with the aerosol ban and then later in 1985 with the

[13] See also Cagin and Dray (1993, pp. 280–281) for discussion.

provisions of the settlement of the NRDC lawsuit. In the latter half of the 1980s, beginning with the adoption of the Montreal Protocol up to the current time the primary issue has been: given that we are going to act, what actions ought to be taken (cf. U.S. Senate, 1988).

Lambright's assessment is on more solid ground in his discussions of the relation of science and policy in the second, mature phase of the ozone issue. During this phase, policy makers have had specific technical questions that were amenable to scientific assessment and targeted scientific efforts such as Antarctic and Arctic ozone expeditions (Usher, 1996). In this context, Lambright's article provides several valuable lessons about the importance of assessment, coupling of information users and producers, and communication have the most validity. [14] However, these lessons do not apply equally to the immature phase of the ozone issue, particularly the relation of science and decision making in the United States, and presumably will also not apply to immature, domestic phases of other contexts where science is expected to contribute usable information to the policy process.

4. The case of acid rain: a second look

Lambright's article contrasts the case of stratospheric ozone depletion with that of acid rain research in the 1980s arguing that the "principal difference between acid rain and ozone depletion lay with the management of these two programs." It is somewhat unclear what is meant by 'management' in this context. If it refers only to the actions of science administrators in the agencies with responsibility for program implementation (as it does throughout the article) then we disagree. We find that the case of acid rain supports our claim for the vital importance of a healthy policy process to connect science with decision making. While, arguably, a policy-for-science-for-policy was created at the outset of the acid rain issue, unlike what happened in the case of ozone, this process was largely ignored by managers, researchers, and users alike. A review of the history of the National Acid Precipitation Assessment Program supports this assertion.

4.1. National Acid Precipitation Assessment Program: 1980–1990

Acid deposition, commonly called acid rain, was a matter of public concern in the northeastern U.S. at the end of the 1970s. In response to these concerns, President Jimmy Carter agreed to the Acid Precipitation Act of 1980. [15] The act originated in a proposal put together at the request of the White House Council on Environmental Quality in 1978. In August 1979 President Carter called for a long-term acid precipitation research program (ORB, 1991). Among other provisions, the Acid Precipitation Act of 1980 called for the identification of the causes and sources of acid precipitation, an assessment of the effects of acid precipitation, and for actions to be taken in response to the harmful effects of acid precipitation (P.L. 96-294). The law created the National Acid Precipitation Assessment Program (NAPAP) to be implemented over ten years by an Interagency Task Force on Acid Precipitation. At enactment, NAPAP consisted of ten task groups, each under the leadership of a different federal agency. Most of the task groups focused on the science of acid rain, but one of these task groups was called "Assessments and Policy Analysis," and was created to "communicate scientific and other information in ways that allow comparison of policy choices" (OTA, 1993, p. 141). The assessment task group was, arguably, the 'vehicle' through which science would be connected to the needs of decision makers. Together, these actions in support of P.L. 96-294 form a policy-for-science-for-policy on the issue of acid rain.

Almost immediately, the Program began to neglect its assessment functions as called for in the Acid Precipitation Act. Early on the Assessments Task Group began to develop "integrated assessment methodologies and to perform multiple assessments throughout the program to ensure policy rele-

[14] NASA played an important role in helping to resolve many technical issues.

[15] The Acid Precipitation Act was Title VII of the Energy Security Act of 1980, Public Law 96-294.

vance'' (OTA, 1993, p. 141). [16] The first assessment was due in 1985, with a second and third due in 1987 and 1989. However, the first assessment was delayed when a new director of NAPAP changed the program's focus from policy and economic assessments to natural science research (Roberts, 1987). The Assessments Task Group was disbanded and the program stopped funding integrated assessment modeling to spend ''limited funding on other research'' (OTA, 1993, p. 141).

The first assessment was finally released in 1987 and was roundly criticized (Roberts 1987; Shabecoff, 1987). While the scientific content of the assessment was widely judged ''first rate,'' criticism focused on what information was emphasized in the executive summary, and what was left out (Roberts, 1987). The first director of NAPAP cited the delay in the first assessment as the key to the program's loss of credibility in the policy process. He wrote to *Science* magazine that NAPAP could have been in sync with the legislative process if the 1985 interim assessment had been released as planned. Instead, the momentum developed during the first 5 years was lost when leadership and consensus-building were replaced with autocratic management. The resulting lack of participation in the assessment process eroded NAPAP's technical and political credibility (Bernabo, 1991, p. 1475).

The second and third planned assessments were never produced, and when NAPAP did produce another assessment it was, in the words of one congressional staffer, ''totally irrelevant'' to the Clean Air Act Amendments of 1990 (Roberts, 1991, p. 1302). [17] According to a former NOAA administrator the final assessment was delayed largely for political reasons: ''The NAPAP report did not buttress all parts of the Bush administration's program; thus, the administration did not display enthusiasm for timely publication'' (Knauss, 1994). And unlike the case of ozone depletion there was not a citizen lawsuit filed to force compliance with the original NAPAP legislation. Consequently, the final NAPAP assessment was not published in time for consideration in debate over the Clean Air Act Amendments, hence NAPAP influenced the policy process only indirectly and unsystematically (Bernabo, 1993).

EPA anticipated the program's performance shortfall and established in 1989 a NAPAP Oversight Review Board (ORB) to evaluate the program (ORB, 1991). The report of the oversight review board was the first of what several observers have called a ''cottage industry of retrospective studies'' of NAPAP (Herrick and Jamieson, 1995, p. 106). Apart from minor quibbling about the effects of NAPAP on the policy process these critiques are in general agreement that NAPAP was to deliver scientific information in order to clarify policy alternatives but largely fell short of delivering on that mandate (cf. Cowling, 1992).

4.2. Lessons of NAPAP

NAPAP did not follow its policy-for-science-for-policy nor was its policy-for-science-for-policy invoked by interested parties. The Program thus produced much science but lacked a means to effectively connect that science with decision making: Science in this case complicated rather than facilitated policy development. Early on, NAPAP received high marks for its organizational and scientific capabilities. However, its failure to facilitate decision making damaged its scientific credibility, and hence its contribution to the policy process (Bernabo, 1991; Knauss, 1994). The ORB (1991, p. 27) concluded that

somewhere along the way the assessment focus articulated earlier was lost and priorities appeared to be set by scientific and technical rather than assessment need. Important assessment questions, such as the implications of the timing of controls on social, economic, and ecological parameters, were not given

[16] According to OTA (1993, p. 141), ''Assessment and policy analysis research develops and uses quantitative methods to organize and communicate scientific and other information in ways that allow comparison of policy choices. These methods include decision analysis, benefit-cost analysis, risk analysis, and technology assessments.''

[17] It is misleading to say that NAPAP was ''irrelevant.'' It is more accurate to say that NAPAP did not systematically and effectively produce information that was usable in the Clean Air Act Amendment process of 1990. NAPAP did produce information that has proved ''relevant'' to a number of policy issues. See Cowling (1992), Bernabo (1993).

enough attention. Little information on such matters was available when it came time for decisions to be made.

The information that was made available was technical and not framed by a broader context.

According to Herrick and Jamieson (1995, p. 107) NAPAP produced detailed scientific findings that were of little use to the nonspecialist. Hence, the range of raw research findings "allowed policy advocates to pick and choose among NAPAP's reported findings, emphasizing facts or uncertainties supporting a particular position and de-emphasizing others." NAPAP failed "to characterize acid rain as a problem, non-problem, or something in between" (ibid.). The Chair of the ORB agreed, and concluded that "to be useful to decision makers, scientific findings must be accompanied by a reasonable assessment, a process that evaluates a problem in a way that helps policy makers and the public weigh options" (Russell, 1993, p. 56). The ORB concluded that "NAPAP's enabling legislation (1980) and the Amendments of 1990 both enjoin NAPAP to provide information on economic and social implications of alternative policies, but this topic received comparatively little attention." Also, "The assessment function appears to have received tardy and inadequate attention and insufficient funding —certainly less than ten percent of the total by NAPAP's counting— and the result was that NAPAP did not completely fulfill its promise in this regard" (ORB, 1991, p. 14). In short, by ignoring or avoiding its assessment mandate NAPAP was limited in its contributions to policy making in spite of its broad and detailed scientific research (cf. Lackey and Blair, 1996). The problem was not poor management alone, as suggested by Lambright's article. Poor management compounded the broader failure of the program and its overseers to invoke the acid rain policy-for-science-for-policy. The failure to invoke the policy-for-science-for-policy was a factor that allowed poor management to persist.

The ORB found that NAPAP understood poorly the relationship of science and policy making. One lesson of the ORB study was to "understand the role of science and how to use it." The ORB concluded that "programs such as NAPAP have a large science component but they are not science programs per se. They are designed to aid in the formation of public policy. Doing good science contributes to this end; it is not the end in itself..." (ORB, 1991, pp. 28–29, emphasis in original). Perhaps the most important lesson of NAPAP is that the establishment of a process to connect science and decision making is a necessary but not sufficient condition for successful linkage of science and policy. An explanation for the different outcomes on ozone depletion and acid rain is that the process —the science-for-policy-for-science— was invoked and followed in the former case but ignored and avoided in the latter.

5. Conclusion

The primary lesson of the ozone case for the relation of science and policy in the context of the United States is the importance of establishing, following, and respecting a process that provided a vehicle to link the results of research with action. A policy-for-science-for-policy was created shortly after concern was raised about the possibility of deleterious effects of chlorofluorocarbons on stratospheric ozone (and thus on people and the environment) and this process was followed throughout. The process created conditions that broke the gridlock over the ozone issue when it became highly political under the Reagan Administration. By way of contrast, the case of acid rain is notable in that its process for connecting research with policy was not followed. As suggested by Lambright (1995), NASA, and science more broadly, did play a significant role in the development of policy responses to ozone depletion. Yet so also did the development of effective substitutes, the relatively simple social structure of chlorofluorocarbon economics (i.e., only several large producers), effective coordination among parties, and the dedicated efforts of researchers, research managers, nongovernmental organizations, federal agencies, elected and appointed officials, and members of the public (Haas, 1991).

We find one of the most important, but overlooked explanations for understanding the development of ozone depletion response policies to be the development by Congress and the Executive of a plan of research among the agencies and the estab-

lishment of a criterion for regulatory action in the Clean Air Act Amendments of 1977. The 1977 law also helped set the stage for U.S. participation in the global ozone accords. The ozone policy-for-science-for-policy set the context within which national and to a lesser degree international activity takes place. It embedded policy making and scientific research in an interrelated process, and this process was respected. As suggested by the case of acid rain, a policy-for-science-for-policy is a necessary but not sufficient condition for effectively linking science and policy.

The role of the ozone policy-for-science-for-policy in facilitating national and international action has thus far been largely overlooked by policy analysts in favor of piecemeal explanations. A topic for future research is the existence of a policy-for-science-for-policy on the problem of climate change. It is unclear whether such a framework exists in the U.S. or at the international level. If it does exist, what is its significance? Has it been invoked? If a climate change policy-for-science-for-policy does not exist, why not? An analysis of the climate change issue using an integrative framework of the science-policy relation may help us to better understand obstacles to connecting science and policy in this area.

Acknowledgements

The authors would like to gratefully acknowledge helpful comments and discussions during the preparation of this manuscript from Ronald Brunner, Radford Byerly, Michael Coffee, David Doninger, Quindi Franco, Dale Jamieson, F. Sherwood Roland, Susan Solomon, Nina Tannenwald, and Peter Usher. Of course all responsibility for errors of fact or misinterpretation lies solely with the authors. The National Center for Atmospheric Research is sponsored by the National Science Foundation.

References

Bastian, C.L., 1982. The formulation of federal policy. In: Bower, F.A., Ward, R.B. (Eds.), Stratospheric Ozone and Man, vol. II. CRC Press, Boca Raton, FL, Chapter 8.

Bernabo, C., 1993. Statement before the House Committee on Science, Space and Technology, Hearing on Global Change Research Science and Policy, 103-60, pp. 33–55.

Bernabo, C., 1991. Letter. Science 251, 1475.

Brooks, H., 1964. The scientific advisor. In: Gilpin, R., Wright, C. (Eds.), Scientists and National Policy-Making. Columbia University Press, New York, pp. 73–96.

Brunner, R.D., 1991. The policy movement as a policy problem. Policy Sci. 24, 65–98.

Cagin, S., Dray, P., 1993. Between Earth and Sky. Pantheon Books, New York.

Congressional Quarterly Almanac, 1976. Clean air amendments die at session's close. Congressional Quarterly, Washington, DC, pp. 128–132.

Cowling, E.B., 1992. The performance and legacy of NAPAP. Ecol. Appl. 2, 111–116.

Dickson, D., 1981. Congress faces decision on CFC, New ozone data from NASA. Nature 293 (3), 3–4.

Doniger, D.D., 1988. Politics of the ozone layer. Issues Sci. Technol., Spring, 86–92.

EPA (U.S. Environmental Protection Agency), 1987. Proposed rule on protection of the stratospheric ozone 40 FR 82 – 52 FR 47489; December 14, 1987. Reprinted in BNA Int. Environ. Reporter Curr. Rep. 11 (1), 62.

Farman, J.C., Gardiner, B.G., Shanklin, J.D., 1985. Large losses of total ozone in Antarctica reveal seasonal ClOx/NOx interaction. Nature 315, 207–210.

Haas, P.M., 1991. Policy responses to stratospheric ozone depletion. Global Environ. Change 2, 224–234.

Herrick, C., Jamieson, D., 1995. The social construction of acid rain: Some implications for science/policy assessment. Global Environ. Change 5, 105–112.

HCST (House Committee on Science and Technology), 1975. Stratospheric Research and Protection Act of 1975, House of Representatives, 94th Congress, 1st Session, Report 94-575, Part 1.

IMOS (Inadvertent Modification of the Stratosphere Task Force), 1975. Fluorocarbons and the Environment, Report of Federal Task Force on IMOS. Council on Environmental Quality, Federal Council for Science and Technology, June.

Knauss, J.A., 1994. Assessment is a daunting environmental challenge. Forum Appl. Res. Public Policy 9, 143.

Lackey, R.T., Blair, R.L., 1996. Science, Policy, and Acid Rain: Lessons Learned, paper presented at the conference: Crossroads of Science and Policy: A Review of Bioregional Assessments, 6–8 November, 1995, Portland, OR.

Lambright, W.H., 1995. NASA, ozone, and policy-relevant science. Res. Policy 24, 747–760.

Lobos, M.S., 1987. Thinning air, better beware: Chlorofluorocarbons and the ozone layer. Dickinson J. Int. Law 6, 87–117.

Molina, M.J., Rowland, F.S., 1974. Stratospheric sink for chlorofluorocarbons: chlorine atom-catalysed destruction of ozone. Nature 249, 810.

Morrissette, P.M., 1989. The evolution of policy responses to stratospheric ozone depletion. Natur. Resour. J. 3, 793–820.

NASA (National Aeronautics and Space Administration), 1978. National Aeronautics and Space Act of 1958, as amended, and related legislation. Committee on Commerce, Science, and Transportation, US Senate, 95th Congress, 2nd Session.

ORB (Oversight Review Board), 1991. The Experience and Legacy

of NAPAP, Report to the Joint Chairs Council of the Interagency Task Force on Acidic Deposition, April. EPA, Washington, DC.

OTA (Office of Technology Assessment), 1993. Preparing for an Uncertain Climate — vols. I and II, OTA-O-568. US GPO, Washington, DC.

Parson, E.A., 1993. Protecting the ozone layer. In: Haas, P.M., et al. (Eds.), Institutions for the Earth: Sources of Effective International Environmental Protection. MIT Press, Cambridge, MA.

Pielke, R.A. Jr., 1994. Scientific information and global change policy making. Climatic Change 28, 315–319.

Roan, S., 1989. Ozone Crisis. Wiley, New York.

Roberts, L., 1991. Learning from an acid rain program. Science 251, 1302–1305.

Roberts, L., 1987. Federal report on acid rain draws criticism. Science 237, 1404–1406.

Russell, M., 1993. NAPAP: A lesson in science, policy. Forum Appl. Res. Public Policy 8, 55–60.

Shabecoff, P., 1987. Government acid rain report comes under sharp attack, New York Times, September 22, p. 19.

U.S. Senate, 1988. Ozone Protocol. Committee on Foreign Relations, pp. 100–114.

Usher, P., 1996. Interview with authors, 1 May.

Wirth, G.F., Brunner, P.W., Bishop, F.S., 1982. Regulatory actions. In: Bower, F.A., Ward, R.B. (Eds.), Stratospheric Ozone and Man, CRC Press, Boca Raton, FL, pp. 217–240.

Waxman, H.A., 1991. An overview of the Clean Air Act Amendments of 1990. Environ. Law 21, 1712–1824.