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Reconciling the supply of scientific information with user demands: an analysis of the problem and review of the literature

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ABSTRACT

Policy makers around the world are calling for the production and diffusion of more useful information for environmental decision-making. Ideally, useful information expands alternatives, clarifies choice and enables policy makers to achieve desired outcomes. Decision makers, however, often lack the useful information needed for good decision-making. By concentrating efforts on increasing the supply of scientific information, scientists may not be producing information considered relevant and useful by decision makers, and may simply be producing too much of the wrong kind of information. Users may have specific information needs that go unmet, or may not be aware of the existence of potentially useful information. This paper defines the practical problem of reconciling the supply of scientific information with users' demands so that scientists produce information that decision makers need and use in policy decisions. Literature from a variety of disciplines and topics is reviewed to: explain the goals of reconciling the supply and demand of scientific information; define what constitutes useful information; explore lessons learned from experience and describe the characteristics and conditioning factors that shaped those experiences; and identify various alternative strategies and processes that forge stronger science policy linkages. The paper concludes with recommendations for future research.

Introduction

Policy makers from around the world are calling for the production and diffusion of more 'useful' information for decision makers, albeit for a variety of reasons. Some of the organizations making such calls include the United States (U.S.) Federal government, U.S. National Oceanic and Atmospheric Administration, U.S. Global Change Research Program, The World Bank, the U.S. National Research Council, and others (CSHR, 2002; Ehlers, 1998; IBRD, 1999; Mayden, 2002; NRC, 1999b; US CCSP, 2002). Useful scientific information, by definition, improves environmental decision-making by expanding alternatives, clarifying choice and enabling decision makers to achieve desired outcomes.

In responding to calls for more useful information, however, many decision makers focus narrowly on increasing the supply of scientific information, funding more research that can lack any correlation to the information needs of decision makers (Lahsen and Nobre, 2007; Sarewitz and Pielke, 2007). Consequently, decision makers often lack the 'useful' information they need for good decision-making, or as the National Research Council explains, "when science is gathered to inform environmental decisions, it is often not the right science" (NRC, 2005, p. 26). By concentrating efforts on increasing the supply of

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Table 1 – Literature by topical areas

Climate change	Agrawala et al. (2001), Cash and Buizer (2005), Dilling (2007), Hartmann et al. (2002), Jagtap et al. (2002), Jasanoff and Wynne (1998), Jones et al. (1999), Lahsen and Nobre (2007), Lemos (2003), Lövbrand (2006), Miller (2001b), NRC (1999b, 2001), Niederberger (2005), Pielke (1997) and Wolfe et al. (2001)
Agriculture	Carberry et al. (2002), Cash and Moser (2000), Cash et al. (2002), Gadgil et al. (2002), Korfmacher and Koontz (2003), Logar and Conant (2007) and Siepen and Westrup (2002)
Rural and sustainable development, sustainability science	Adomakai and Sheate (2004), Clark and Dickson (2003), Cash et al. (2003), Lebel et al. (2004) and McCool and Stankey (2004)
Water quality and watershed management	Burroughs (1999), Callahan et al. (1999), Cash (2000), Edgar et al. (2001), Johnson et al. (2002), Koontz (2003), Koontz and Johnson (2004) and Leach et al. (2002)
Health and bioethics	Garland (1999), Keating (2001) and Kelly (2003)
Ecosystem and natural resource management	Berry et al. (1998), Clark et al. (1998), Guldin (2003), Guldin et al. (2003a), Holling et al. (1998), Johnson et al. (2003), Keen (1997), Lee (1993), Mills and Clark (2001), Reid (2004), Robertson and Hull (2001), Schusler et al. (2003), Smythe et al. (1996), Steelman and Ascher (1997) and Szaro et al. (1998)
Coastal and marine issues	Bray et al. (1997), Burger et al. (2001), Hernandez and Kempton (2003), Kaplan and McCay (2004), Stead et al. (2002) and Thia-Eng (1997)
Knowledge production and management, science policy and policy process	Bocking (2004), Cummings (2003), Goma et al. (2001), Gwin (2003), Holman and Dutton (1978), Jasanoff (1989), Miller (2001a), Neilson (2001) and Steel et al. (2005)
Other topical areas	Brown (2003), Cash et al. (2006), Guston (2001), Jacobs (2002), Joyce (2003), Robertson and Hull (2003), Sapsed and Salter (2004), Sarewitz (2004), Sarewitz et al. (2000), Sclove et al. (1998), Smith and Kelly (2003) and Wolfe et al. (1997)

scientific information, scientists may not be producing information considered relevant and useful by decision makers, and may simply be producing too much of the wrong kind of information (Cash et al., 2003). Users may have specific information needs that go unmet, or they may not be aware of the existence of potentially useful information (NRC, 1999c; Stone et al., 2001[1]). In order to better serve decision makers, the connections or linkages between both the supply of, and demand for, scientific information need to be enhanced so that scientists produce information that is both needed and used by decision makers in their policy decisions.

The concept of reconciling supply of scientific information with users' demands (RSD) is utilized in this paper as a heuristic, a way of understanding, conceptualizing, and evaluating an idealized relationship between the production of scientific information, and of its use by decision makers. Sarewitz and Pielke (2007), describe the RSD concept – one borrowed from economics – to illustrate two concepts about science policy. First, science policy decisions ''determine the composition and size of research portfolios which 'supply' scientific results. People in various institutions and social settings who look to scientific information as an input to their decisions constitute a 'demand' function for scientific results''. Second, as in economics, the relationship between supply and demand is ''closely interrelated'', characterized by communication and politically mediated feedback undertaken in the context of a dynamic decision-making context. The concept of RSD is contrary to the view that scientific research, in order to best serve societal needs, should be a process that is independent from application. Rather, decisions about science should be, and often are, based upon a dynamic process of interactions with users of information. Although borrowed from the field of economics, the RSD concept does not suggest a process of information flow that is linear, mechanistic, or intrinsically rational.[2] Nor does it imply that RSD is simply about the transactional 'event' of reconciliation. RSD, as used in questions of science policy, is about process, facilitating our exploration and assessment of the question: are we doing the 'right' science to better respond to society's needs?

The purpose of this paper is to analyze the practical *challenge* of 'reconciling the supply and demand' of scientific information between scientists and decision makers. Additionally, it seeks to describe the *decision process* through which strategies and opportunities are identified and utilized in order to facilitate the production of more useful information for environmentally-related decision-making. The literature relating to reconciling the supply and demand of scientific information and the production of useful information, discussed explicitly or, more often implicitly, is wide-ranging and multidisciplinary. The material covers not only a variety of topical areas such as climate change or resource management, but is also multidisciplinary, including such fields as geology and decision science (see Table 1[3]). Yet, there remains to date no explicit and comprehensive analysis of the *problem* of linking science to decision-making.[4]

Utilizing a problem-oriented approach offers several advantages. First, by focusing on understanding the problem, rather than pursuing a theoretical inquiry, one recognizes the highly contextual and pragmatic nature of reconciling the supply and demand of scientific information and that ''no

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[1] Stone et al. would describe this as a ''public goods problem, where there is an inadequate supply of policy relevant research'' or as a ''lack of access to research, data and analysis for both researchers and policy makers'' (2001, p. 3).

[2] See Friedman (1953) for description of 'Positive Economics'.

[3] This table is meant to be representative and not comprehensive. Note also that much of the focus on the literature in this article focuses on issues from the north and does not adequately capture the depth and breadth of literature addressing issues from the south. Such omission is due to the fact that the author's primary area of research is science policy in the U.S. and not international policy.

[4] Some related work, however, includes research by Cash and Clark (2001), Cash et al. (2002), Guston (2001), Guston et al. (2000) and Jacobs (2002).

single explanation can be expected to cover every case'' (Menand, 1997, p. 351[5]). For this reason, this exploration of the literature focuses more on specific cases, topics, and experiences rather than on purely theoretical treatments. Second, using a problem-oriented approach requires that one clarify the current state of affairs and the desired goals (of producing useful information for decision makers) and to identify the discrepancies between the two (Clark, 2002). Understanding the ''the scope of the problem and its varying contours of complexity and tractability'' enables one to identify ''workable solutions'' (2002, p. 85–86), or in this paper, alternative strategies for reconciling supply and demand of scientific information for decision makers. A problem-oriented focus, therefore, is a useful first step in the direction of practical action. One caveat in using this approach, however, is a necessary tradeoff between the breadth of inquiry, which is consistent with a problem-oriented approach of this nature, versus the depth of analysis, which represents the approach taken in much of the literature reviewed for this paper.

Before proceeding, it is important to establish some working definitions, particularly regarding the differentiation of policy and politics. While policy refers to a decision with a commitment to a particular course of action, politics describes who gets what, when and how (Birkland, 2001; Lasswell, 1971). For the purposes of this paper, the phrases policy maker and decision maker are thus interchangeable. A decision maker is any individual or group with the capacity to commit to a particular course of action. Stakeholders are individuals or groups with a vested interest in the outcome of a decision and can include just about anyone, e.g., scientists, citizens, farmers, resource managers, business, politicians, and the like. The phrase, 'reconciling supply and demand of scientific information' will be used frequently in this paper, yet other expressions describe related phenomena of linking science and knowledge to decision-making (cf. Cash and Buizer, 2005; Cash et al., 2003; Sarewitz and Pielke, 2007). Reconciling supply and demand could also be thought of as a subset of the rather ''broad and ambiguous'' phrase of integrated research, in that some of the thematic categories, recently explored by van Kerkhoff (2005), describe some of the goals of reconciling supply and demand of scientific information.[6] These research areas all describe a growing area of research that seeks to describe and resolve the problem of using information to improve decision-making processes and outcomes. Finally, while there is a growing literature about what constitutes knowledge and expertise, the term 'science' for the purposes of this paper refers to knowledge created as part of formal, western-oriented research programs. The focus on science in this context does not suggest agreement with the notion of scientific determinism or scientific management. Rather, science contributes to decisions, informing problems based on its unique perspectives, skills and products.

This paper proceeds in five parts. It begins with an explanation of the goal of reconciling the supply and demand of scientific information and of creating effective linkages between science and decision makers. Thus, Part I defines 'useful information'. Part II, 'lessons of experience', explores the historical trends, the circumstances and conditions that shape the trends, and the momentum for change in the status quo. Part III identifies various alternative strategies and processes that forge stronger science policy linkages. Part IV explores the literature in terms of how functional decisions are made in the decision process. The paper concludes, in Part V, with an analysis of the literature and offers suggestions for future research.

1. Part I: The goal—production of useful information for decision makers

In order for information to be considered 'useful', it must satisfy various value demands of the decision makers in which 'values' consist of a desired situation, object or condition that transpires through interactions between people (Clark, 2002; Lasswell, 1971). In this context, therefore, value demands for useful information fall into three broad categories: salience, credibility, and legitimacy (Cash and Buizer, 2005; Cash and Clark, 2001; Cash et al., 2002, 2003; Guston, 2001). Although there are many different approaches to classifying value demands, this taxonomy tends to be the most comprehensive, in that it includes concepts of scientific information utility characterized by a variety of researchers in many fields (Cash and Buizer, 2005; Clark, 2002; Clark and Dickson, 2003; Jacobs, 2002; Jones et al., 1999; Keating, 2001; Smith and Kelly, 2003).[7] Haas (2004, p. 573) describes 'usable' information as not only having a ''substantive core'' (in which information must be useful to policy makers), but also a ''procedural dimension that provides a mechanism for transmitting knowledge from the scientific community to the policy world and provides for agency when theorizing about broader patterns of social learning, policy-making, and international relations''. Useful information, therefore, can be thought of not only as content, but also as the product of an effective process.

Useful information must be salient and relevant to the specific context in which it will be used. In other words, it must be context-sensitive, thus responding to the specific

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[5] Menand makes this point in describing pragmatism, which is an ''account of the way people think-the way they come up with ideas, form beliefs, and reach decisions. What makes us decide to do one thing when we might do another thing instead? The question seems unanswerable, since life presents us with many types of choices, and no single explanation can be expected to cover every case.

[6] van Kerkhoff identifies 12 distinct uses of the term integration, and two of these types are consistent with our view of reconciling supply and demand. ''They are integration across: research and application activities such as policy implementation, product development and marketing. [And integration across] sectors, such as academia, industry and government'' (2005 p. 458). Realistically, however, the production of useful information for decision making may require integration across many of the areas described by van Kerkhoff, such as disciplines, research issues, and the like in order to produce useful information.

[7] Jones et al., identified four necessary conditions for integrating scientific information with policy-making, including: ''(1) Research results must be relevant to currently pending decisions; (2) research results must be compatible with existing policy-making processes and models; (3) research results must be accessible to the appropriate policy makers; (4) policy makers must be receptive to the research results'' (1999, p. 583).

information demands of the decision makers (Agrawala et al., 2001; Burger et al., 2001; Guston et al., 2000; Jacobs, 2002; NRC, 1999b; Siepen and Westrup, 2002). Salient information considers ecological, temporal, spatial, and administrative scales (Bray et al., 1997; Cash and Moser, 2000; Cash et al., 2003) and timeliness (Jacobs, 2002). For example, policy makers in a small town are unlikely to find global climate models relevant to their decision-making needs because of the mismatch of the scale of information. Another example of scale mismatch relates to timeliness. Information that takes two years to produce is not going to be useful to a decision maker who needs to make a decision next month. Salient information also considers regulatory and legal constraints; the values and beliefs of stakeholders (Lasswell, 1971); the political landscape; and how the information is communicated and presented, among other considerations (Buizer et al., 2000; Keating, 2001; Robertson and Hull, 2003). Jones et al. (1999), also suggest the information must take into account existing policy and decision-making processes. Production of salient, and thus relevant, information increases the likelihood that future decisions will be embraced (Deelstra et al., 2003).

Second, useful information must also be credible and dependable in that it is perceived by the users to be accurate, valid, and of high quality (Cash and Buizer, 2005; Jacobs, 2002; Lasswell and McDougal, 1992; Miller, 2001a). While peer review is often considered the sine qua non of credible information, other approaches also satisfy the credibility criterion, for example, government sponsored-research, industry sponsored-research and collaborative projects between several actors, and the like.

Third, useful information must be legitimate in that those who produce it are perceived to be free from political suasion or bias and that ‘‘the system has the interests of the user in mind’’ (Bottcher, 2003; Cash and Buizer, 2005, p. 8).[8] Other characteristics of legitimacy includes transparency, in that the information was produced and/or transmitted in a way that was open and observable, and that the relationship between producer and user of the information is characterized by mutual trust and respect (Deelstra et al., 2003). Another way of thinking about legitimacy is in terms of social capital: those qualities that define successful relationships and social organization, such as mutual trust, credibility, common rules, norms, reciprocity, and mutual respect to name a few (Cash, 2000; Edgar et al., 2001; Guston et al., 2000; Pretty, 2003; Putnam, 1993; Smith and Kelly, 2003). Many researchers identify aspects of social capital as a prerequisite for using information in decision-making (Jagtap et al., 2002; Miller, 2001a; Sclove et al., 1998; Smith and Kelly, 2003).

Those value demands that constitute useful information, that is, saliency, credibility, and legitimacy, must be taken into equal consideration and be balanced in a dynamic tension. Too much focus on one value category, say legitimacy, may undermine the quality of another value demand (Cash and Buizer, 2005). Finally, the ultimate metric for what constitutes useful information is whether the information is actually used to improve decision-making by expanding alternatives, affecting choice and enabling decision makers to achieve their desired outcomes, such as environmental sustainability, adaptability to climate variability, or more generally, the common interest.

2. Part II: The lessons of experience

Understanding the full scope of a problem requires that we explore its historical context, identifying the lessons learned from past experience, the circumstances and conditions that shape the trends, and momentum for change. This process of inquiry enables one to better assess the full scope of the efforts undertaken to solve the problem, and the likelihood of future success given the status quo (Clark, 2002). As Rayner and Malone (1998a, p. xiv) explain, ‘‘Any attempt to change the course upon which human society appears to be embarked requires not only new choices about future actions, but also understanding of past choices—the existing social commitments that have set the work on its present course. The possibility, indeed the inevitability, of choice lies at the core of the climate change issue’’. The next section begins with a review of past experiences and historical trends, then explores the various factors that influenced, shaped and conditioned these trends, and concludes with an exploration of future projections, given the status quo.

2.1. *Historical trends*

The problem’s historical trends spans four areas. The first trend, which was discussed briefly earlier in the paper, is that many national and international agencies are calling for the production and dissemination of more useful information, such as The World Bank, National Research Council, and the U.S. Congress to name but a few (CSHR, 2002; IBRD, 1999; NRC, 1999b). Other trends include: increasing levels of stakeholder participation in decision-making processes; the creation of new institutions that research how information is used in decision-making; and the development of institutions that serve to bridge the gap between science and decision makers as a way of reconciling supply and demand of science for decision-making.

Public participation in policy decisions has increased in two ways: in contributing to policy decisions in which science plays a contributing role (e.g., natural resource management), and in decisions *about* scientific research priorities and agendas. In shorthand, one can think of this as public participation with ‘science for policy’, and in ‘policy for science’ (Brooks, 1964). First, research across many environmental issue areas indicates that stakeholder participation in policy decisions, or ‘collaborative decision-making’, has increased significantly, from the international arena, to local issues (Beierle and Cayford, 2002; Chopyak and Levesque, 2002; Leach et al., 2005[9]). Indeed, the

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[8] Bottcher describes this as ‘‘lack of bias’’.

[9] Leach et al. write: ‘‘Contemporary debates about the changing relationships between science, public knowledge and different forms of expertise raise prospects for new forms of public engagement, whether in setting agendas for, conducting or applying the results of science and technology development. In recent years, there has been an explosion of participatory, deliberative and inclusionary approaches to decision-making about scientific and technological issues in the context of risk, and many claims have been made about the need for, and ways to, ‘democratize science’ and promote citizen involvement with it’’ (2005, p. 21).

public's expectation for such participation is also growing (Welp, 2001), and some researchers even suggest that public participation in environmental decision-making is now a routine feature (Beierle and Cayford, 2002; Hjortsø, 2004; Wolfe et al., 2001). Global organizations such as the World Bank[10], the World Health Organization[11], and the Food and Agricultural Organization[12] have recognized the need to increase the integration of civil society[13] into policy processes aimed at reducing poverty and hunger and improving the health of people around the globe.

Public participation in decisions *about* science and technology policy is also a growing trend and "is having an impact on science and technology policy funding" (Chopyak and Levesque, 2002, p. 163). Some of the federal agencies here in the United States that have recognized the need for new ways of making decisions about science that includes input and participation from stakeholders include the Centers for Disease Control[14]; The National Institutes of Health[15]; National Institutes of Environmental Health Sciences[16] (NIEHS); and the U.S. Department of Agriculture[17]. For example, the NIEHS sponsors a 'Public Participatory-Research' program in which citizens provide input into research priorities.[18] The Loka Institute, a not-for-profit organization established in 1987, works to "to ensure that democracy works through public engagement and participation at all levels and in all matters relating to science & technology and development" and seeks "to make science & technology and development responsive to the needs of people from all segments of society" (Loka Institute, 2006). The Loka Institute also provides "processes, protocols and best practices for democratic decision-making in organizations, community projects, and policy-making". The public has other means of shaping science (and technology) policies, albeit on more local levels, include science shops[19] (Fischer et al., 2003; Gladwin et al., 2002; Gnaiger and Martin, 2001; Mulder et al., 2001[20]; Sclove et al., 1998), community-based initiatives and management (Brunner et al., 2002; Campbell and Vainio-Mattila, 2003), consultative panels (Smith and Kelly, 2003), participatory action research (French and Bell, 1999), civic science (Bäckstrand, 2003, 2004; Clark and Illman, 2001), and a variety of participatory research mechanisms (Berardi, 2002; Borchers and Kusel, 2002; Breu and Peppard, 2003; Fischer et al., 2003; Goma et al., 2001; Kaplan and McCay, 2004; Martin and Sherington, 1997), just to name a few.

Numerous centers and institutes have also sprung up in the past two decades to facilitate the enhancement, and thus improvement, of connections between science and society. At a governmental level, many nations have revamped their science policy bureaucracies in response to a variety of factors, including, for example, globalization, the public's increasing scrutiny of scientific credibility, and concerns over transparency (Smith and Kelly, 2003). For example, Denmark established its Ministry for Research and Information Technology in 1993 "to more effectively use research and science to meet economic and social goals" in a more globalized world (Smith and Kelly, 2003, p. 348). A key strategy was to improve coordination "across the different arms of the Government, between Ministries, and at Cabinet level." In addition, in 1993, Norway created a Research Council that performs a variety of activities, from setting research priorities to advising the government. According to Smith and Kelly (2003, p. 348), "This amalgam of responsibilities places particular importance on the Council as a 'meeting place' which bridges the gap between researchers and research users". Australia has also followed suit with the creation of the Prime Minister's Science, Engineering and Innovation Council, which seeks "a fundamental change to ensure that the scientific basis for planning and policy advice is robust and that research resources are better aligned to meeting policy needs" (2003, p. 346). Great Britain recently codified the best practices of using scientific information in a guideline called 'The Use of Scientific Advice in Policy Making'[21] (Smith and Kelly, 2003). While each country responded in different ways to these concerns, two themes

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[10] http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/CSO/0,,contentMDK:20092185~menuPK:220422~pagePK:220503~piP~pagePK:220503~piPK:220476~theSitePK:228717,00.html.

[11] http://www.who.int/civilsociety/en/.

[12] http://www.fao.org/tc/NGO/index_en.asp.

[13] According to the Center for Civil Society at the London School of Economics, "Civil society refers to the arena of uncoerced collective action around shared interests, purposes and values. In theory, its institutional forms are distinct from those of the state, family and market, though in practice, the boundaries between state, civil society, family and market are often complex, blurred and negotiated. Civil society commonly embraces a diversity of spaces, actors and institutional forms, varying in their degree of formality, autonomy and power. Civil societies are often populated by organisations such as registered charities, development non-governmental organisations, community groups, women's organisations, faith-based organisations, professional associations, trades unions, self-help groups, social movements, business associations, coalitions and advocacy group" (LSE, 2004).

[14] The CDC solicited public comments on a recent Midcourse Review of its Healthy People 2010 program (Healthy People, 2005).

[15] Responding to a National Research Council Report ("Science Opportunities and Public Needs: Improving Priority Setting and Public Input at the National Institutes of Health" 1998. Committee on the NIH Research Priority-Setting Process, Institute of Medicine. National Academies Press, 136 pgs.), the NIH created the Director's Council of Public Representatives whose mission is to provide "advice and recommendations to, and consults with, the Director, National Institutes of Health (NIH), regarding matters related to medical research, NIH policies and programs, and public participation in agency activities" (NIH, 2006a). The NIH also offers other limited opportunities for public involvement (NIH, 2006b).

[16] For example, the NIEHS recently sought input from the public during its strategic planning process. Read the press release here: http://www.niehs.nih.gov/oc/news/plan2006.htm. Or view the survey: http://www.niehs.nih.gov/external/plan2006/home.htm.

[17] For example, the USDA's Cooperative State Research, Education, and Extension Service (CSREES, 2006).

[18] http://www.niehs.nih.gov/oc/news/plan2006.htm.

[19] As defined by the Loka Institute: "Science shops are offices set up in universities where community interests request and propose research. They are a low cost method of conducting new research for communities, as well as coordinating and reporting on existing research on science and technology issues" (Loka Institute, 2004).

[20] Mulder et al. explores both the successes and failures of starting new science shops.

[21] To view the report, see: http://www.ost.gov.uk/policy/advice/guidelines_2000/.

emerge as issues that the science policy restructuring sought to address: openness, and coordination and leadership (Smith and Kelly, 2003).

The private and educational sectors have created new organizations that serve to facilitate the transfer of information between science and society, act as facilitators in the process, and research science policy processes and decision-making. The Loka Institute, introduced earlier, is one such example that seeks to connect the public to decision-making about science and technology. Several research centers have also been created to understand and explore science and decision-making processes including the National Center for Environmental Decision Making Research (which is now defunct); the University of Colorado Center for Science and Technology Policy Research (where the author is employed); the Arizona State University Consortium for Science, Policy, and Outcomes; the National Oceanic and Atmospheric Administration's Regional Integrated Sciences and Assessments Program and many others. Despite some efforts in these areas to better connect science and decision-making, little is known about the effectiveness of these programs.

2.2. *Conditioning factors*

In the policy arena, one factor that has conditioned or influenced the historical trends relates to our de facto national science policy and its implications for science's implicit relationship with society. Another factor is that the public and others from the broader society outside of the scientific enterprise, oft excluded in policy decisions, now demand a greater role. A third factor is science itself—the process of scientific inquiry, the content of scientific information, and the culture of the scientific community. Finally, our understanding of 'knowledge systems' contributes to the problem of reconciling supply and demand of scientific information. Each conditioning factor will be addressed in the following subsections.

2.2.1. *Policy*

America's de facto science policy[22] can be traced back to Bush's (1945) essay, *Science: The Endless Frontier*, in which Bush described what he considered the ideal relationship, or 'social contract', between science and society (Byerly and Pielke, 1995). Scientific progress, Bush declared, was essential to national welfare, the fight against disease, national security, and economic well-being. In order for science to serve society, Bush argued that it was necessary to "remove the rigid controls" that had been in place during World War II, "and recover freedom of inquiry and that healthy competitive scientific spirit so necessary for expansion of the frontiers of scientific knowledge."[23] Only through unfettered research, would there be "a flow of new scientific knowledge to those who can apply it to practical problems in Government, in industry, or elsewhere".

The *Endless Frontier's* "flow" of knowledge is often analogized as a 'linear model' for the simple fact that knowledge, resources and scientific information flow just one way: from basic research to applied research and eventually to society (Pielke and Byerly, 1998). Once considered the key to our winning of the Cold War, the linear model is now considered outdated by many researchers (Byerly and Pielke, 1995; Crow, 2000; Gibbons, 1999; Guston, 1999; Guston and Keniston, 1994; Stokes, 1997). Indeed, many scientists still believe that their relationship with society is linear and only loosely connected (Brown, 2003), when in reality it is more dynamic (Agrawala et al., 2001; Byerly and Pielke, 1995). The linear model also oversimplifies, if not misrepresents, the complex and interconnected relationship between science and society (Agrawala et al., 2001; Pielke and Byerly, 1998); fails to adequately link society to science (Pielke, 1997); falls short on informing decision-making (Cash, 2001); and ignores important interactions across scales (Cash and Moser, 2000). Indeed, many researchers point to a science policy gap that artificially separates science from society, and vice versa, resulting in unnecessary obstacles to effectively linking science with society—a prerequisite for the production of useful information (Brown, 2003; Joyce, 2003; NRC, 1999b; Reid, 2004).

Major shortcomings of the linear model have led several researchers to call for new science policy models or relationships between science and society. These include, for example, Guston's (2000) "collaborative assurance"; Lubchenco's "new social contract for science" (1998); Gibbons' (1999) socially robust, transparent and participative approach; Gibbons et al.'s "Mode 2" science (1994), Gibbons, 2000); Nowotny et al.'s "socially robust knowledge" (2006); Nowotny et al., 2003[24]); Kitcher's "well-ordered science" (2001); Stokes' (1997) "use-inspired research" and Funtowicz and Ravetz's "post-normal science" (1995). Some researchers suggest the production and volume of scientific information has "outrun its effectiveness" for society (Brown in Pielke, 1997, p. 256). Producing more accurate information, such as climate predictions for climate policy, for example, will not necessarily inform what decisions must be made (Rayner and Malone, 1998b). Lubchenco (1998) argues that new research and management approaches must be adopted in order to adequately deal with today's complex, interdisciplinary problems. Still others suggest we approach understanding the linkages between science and decision-making more holistically, as a "knowledge-action system" (Cash and Buizer, 2005; or 'knowledge-action collaboratives' according to the NRC, 1999c). In recognizing the institutional challenges in adapting to new "knowledge-based realities", de la Mothe (2003, p. 205) suggests the need for greater attention to "institutional learning, networks and adaptation". Demeritt (2000, p. 324), commenting on the "emerging triple helix of intertwined university–state–industry relations", however, cautions against "Fetishizing the outcomes of research, in terms of new findings and results" that "generate immediate commercial and economic benefits and discounts other reasons for engaging in academic inquiry and conversation". Regardless of the concept or name used, most researchers of

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[22] The author's primary research area relates to U.S. science policy, thus the focus on science policy issues in the U.S. and the 'north'.

[23] For the complete report, see: http://www.nsf.gov/od/lpa/nsf50/vbush1945.htm#ch1.4.

[24] Gibbons, Scott and Nowotny are frequent collaborators in the area of Mode 2 science and 'socially robust knowledge'.

science and technology policy recognize the need for a new approach to science policy, an approach that recognizes, if not facilitates, stronger linkages between science and society in order for science to assist society in solving the pressing problems of today.

What can one expect in terms of future developments regarding our current state of science policy in the United States? At this time, there appears to be little momentum in either the legislative or executive branch of government for exploring any ''new social contract for science'' or for developing an official national science policy for that matter. The most serious effort to affect such change consisted of the report, ''Unlocking Our Future: Toward a New National Science Policy'' written by the House Committee on Science and chaired by Rep. Ehlers (1998). In fact, the report largely endorses the spirit of *Endless Frontier*, and suggests only minor alterations to our de facto national science policy. It is unlikely that any substantive changes to the national science policy will happen soon, lacking any discrete event that would otherwise propel the issue onto the national stage and into the nation's collective conscience (Downs, 1972).

2.2.2. *Civil society*

The second conditioning factor is that for years, civil society has been virtually ignored in policy processes. Frustrated by not having its voice heard, civil society now expects to participate in decision-making processes and wants its views and needs to be considered by science and politicians alike (Gnaiger and Martin, 2001; Stead et al., 2002[25]). The growing realization of the complexity of environmental problems and of man's role in shaping the global environment (e.g. Clark et al., 2004; NRC, 1999a,b) has heightened the awareness that scientific, social, economic, and political systems are linked (e.g., Brundtland, 1987). Additionally, societal values must, and do play a role in decision-making (Beierle, 2002; French and Geldermann, 2005; Lasswell, 1971). International conventions have contributed to this condition such as the Rio Declaration in 1992 that recognized the importance of public participation (Chuenpagdee et al., 2004); The United Nations Agenda 21 established in 1994; and the Åarhus Convention in 1998 that called for greater public involvement in water management issues (Welp, 2001).

A large literature has sought to explore broad trends in civil society that helps to explain how these changes are important in the context of science policies. Civil Society's call for participation in science policy processes is likely to increase in the years ahead (Smith and Kelly, 2003). Examples of the public's increasing level of participation are also evident in issues of resource management, community-based initiatives and sustainable development, and for a variety of reasons. First, as Brunner wryly suggests, ''necessity is the mother of invention'', in other words, government gridlock and bureaucracy has prompted more citizens to get involved in policy processes (Brunner, 2002, p. 39). Second, the explosion of the telecommunication industry and the rise of the Internet have greatly enhanced the ability of civil society to gather and disseminate information relevant to its concerns, and to organize and advance its values both locally and transnationally (Keck and Sikkink, 1999). The media has also emerged as an important ally in sharing information through more widely received public outlets. Third, concerns over scientific accountability and integrity of peer review have spurred ''demands for greater public involvement in assessing the costs and benefits, as well as the risks and uncertainties of new technologies'' (Jasanoff, 2003, p. 236). Finally, the notion of including civil society in policy processes, once anathema to those in power, is now becoming recognized as an important step to take in order to identify the common good and increase civic capacity (Dryzek, 1997). Public participation can also foster public 'buy-in', increase the likelihood of adoption of the policy, and avoid protracted legal battles. Awareness of the need to at least consider civil society's views in policy-making, if not include them completely, can be seen in such disparate worlds as business (e.g. the rise of Corporate Social Responsibility principles and the Global Compact[26]), agricultural development, and urban planning.

2.2.3. *Science*

Third, major cultural differences also contribute to problems in connecting science to society. These cultural differences create barriers between science and society such that some describe them as two separate worlds or subcultures (Gallopín, 2004; Jones et al., 1999; Reid, 2004). This cultural gulf makes forming strong linkages between science and society difficult to accomplish (Cash et al., 2002; Jones et al., 1999; NRC, 1999b).[27]

The field of Science and Technology Studies (STS) has contributed significant scholarship to the question of what constitutes science, expertise, knowledge, and expert information. Once viewed as having essential qualities such as universalism, communism,[28] disinterestedness, and organized skepticism (Merton, 1973), researchers later viewed science as being subject to social construction and influence of individual beliefs and politics (Haraway, 1991; Latour, 1987; Latour and Woolgar, 1979). Today, many researchers in STS view scientific expertise as more contextual and contingent, expanding the idea of what constitutes expertise to include citizens who bring their own experience and local knowledge to the fold. Nevertheless, Leach et al. (2005) argue that many non-western views of knowledge, as seen in research in development studies, still do not fit with the

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[25] For example, with coastal resource management.

[26] For more information on The Global Compact: http://www.unglobalcompact.org/Portal/Default.asp. The involvement of nongovernmental and non-business organizations is addressed here: ''As equal partners and important stakeholders, civil society and other non-business organisations can participate through a number of Global Compact engagement mechanisms, including Policy Dialogues, Learning, Local Networks and Partnership Projects. In these areas, such organizations have a crucial role to play in helping to foster partnerships and produce substantive action . . .''

[27] For example with regard to climate change.

[28] In this context, communism refers to the ''extended sense of common ownership of goods . . .'' Also, ''The substantive findings of science are a product of social collaboration and are assigned to the community'' (Merton, 1973, p. 273).

prevailing view of 'expert knowledge' in the west and thus may not be considered legitimate. And even when scientists reach out for local knowledge, they may lack important skills needed for success. Song and M'Gonigle (2001, p. 986–987) explain, ''Working with local knowledge requires new skills, including diplomacy and negotiation and a willingness to engage the 'other' in a respectful manner over long periods of time''. Scientists, policy makers, and the public also suffer from what Garvin describes as 'epistemological differences' which, in her research on risk analysis, leads to challenges in producing useful information. She explains, ''If science is the search for facts and truth, then policy is the struggle over ideas. This reinforces the idea that science and policy are separate domains with distinct and very different forms of legitimization and, therefore, different ways of producing and defining usable knowledge'' (Garvin, 2001, p. 448).

STS literature describes the process of demarcating science as 'boundary work' in order to construct and manage the boundary between science and society (Gieryn, 1995, 1999). Boundaries are needed to not only demarcate science from society, and hence define expert knowledge, but the boundary also serves to protect science from politicization and facilitate the development of both credible and legitimate information. Challenges in producing useful information thus involve the question ''how does one manage the boundary'' in such a way to produce information that is salient, credible, and legitimate?

In addition to living in two different worlds, scientists and policy makers often lack an understanding of the other's knowledge systems, and the process of scientific inquiry largely shapes this phenomenon. Scientists tend to be trained in what are called 'hard systems' (van Rooyen, 1998[29]) and experimental methods. 'Soft systems', on the other hand, are characterized by group dynamics, relationships and participation. The cultural differences and problems are thus realized by the fact that few scientists are trained in 'soft systems' and lack the understanding necessary for successful and productive participation in group processes (van Rooyen, 1998). One cannot underestimate, however, the importance of soft systems, or 'social capital' (e.g. Putnam, 1993), including mutual trust and respect between scientists and decision makers (Edgar et al., 2001; Smith and Kelly, 2003) in order to ensure legitimacy of the scientific information.

The content of scientific information also shapes trends. First, while scientists work in a world of uncertainty (Pollack, 2003) and probabilities, decision makers do not, preferring instead 'answers' to problems rather than statistical analyses (Bradshaw and Borchers, 2000; Pielke, 1999). Uncertainty in scientific findings stems from a variety of sources, such as spatial and temporal sensitivity (Owens et al., 1997); the complexity and interdependence of Earth systems (Mitchell and Lankao, 2004); attempts at predicting the future (Sarewitz et al., 2000); measurement, sampling, or human errors; and others. Indeed, some uncertainty is ''insurmountable'', particularly given ''the complex socioecological systems involved in the Earth system'' (Gallopín, 2004, p. 376). Despite the fact that uncertainty is prevalent in scientific research, scientists have difficulty in translating the concept of uncertainty into terms that the public understands (Smith and Kelly, 2003). Bradshaw and Borchers (2000) attributes this difficulty to differences in ''distinct behaviors and attributes'' between science and government.

Second, the preponderance of scientific information currently produced for decision makers, for example, with the multi-billion climate research arena, focuses primarily on global climate change models and other global scale issues, thus paying scant attention to local scales. While large-scale models and the like are essential to our understanding of the climate change problem, ''such large, deterministic simulation models have their limitations'' (Shackley et al., 1998, p. 194–195). Climate research today rarely takes into account the specific needs of the decision makers, particularly with regard to spatial and temporal scales (Cash, 2000; Cash and Moser, 2000; Clark, 1987).

Third, cultural barriers exist within the scientific community itself. For example, obstacles exist in the scientific community to participating in policy-relevant research. Tenure, retention and promotion in the academy are based on research, publications, and the like, but not necessarily on producing useful, or policy-relevant information that can be used by decision makers to solve problems. As a result, scientists resist participating in such research (Stead et al., 2002[30]). For their part, policymakers are reluctant to use more participatory research approaches because of the increased costs and longer time required for such processes. The tenure, retention and promotion criteria also tend to favor traditionally disciplinary scholarship, eschewing multi and interdisciplinary efforts despite the fact that many of society's biggest problems tend to span the boundaries of multiple disciplines (e.g. global climate change, poverty, health).

With regard to projections in science, there appears to be some momentum – albeit minor – in the call for reform in the academy in order to address some of the factors that erect the cultural barriers. For example, some scholars call for the reform of the retention, tenure, and promotion system so that young scientists who focus on policy-relevant and problem-oriented research can be evaluated in parity with those who conduct just basic research. Calls for interdisciplinary research are also heard in academia, and even the National Science Foundation recognizes the need to train more interdisciplinary scholars (e.g. its Integrative Graduate Education and Research Traineeship program[31]). As Schein (1999) explains, however, culture runs deep, and those individuals who depend on their organization – or university's culture – for predictability and stability are likely to resist change. The science culture is no exception.

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[29] The descriptions of hard systems and soft systems, however, are commonly used in systems theory, systems thinking, or systems science research. For more information see Checkland and Scholes (1999).

[30] Stead et al. describe this phenomenon as seen in their research in aquaculture and integrated coastal zone management (2002).

[31] See: http://www.igert.org/ for more information.

2.2.4. Knowledge and decision systems

The last conditioning factor relates to the fact that we have little understanding of ‘knowledge and decision systems’ and lack a framework for understanding, researching and improving upon decision processes, particularly with regard to environmental decision-making. While it is recognized that information use and effectiveness depends on multiple factors ranging from how the information is distributed to decision makers’ modes of understanding (NRC, 1999b) and how the problem is framed (Tversky and Kahneman, 1982), rigorous and systematic scholarship in this area has not been adequately pursued (Cash et al., 2003). The National Research Council recently identified the need for more research in the social and behavioral sciences in order to improve environmental decision-making, including questions of governance, decision science research, green business decision-making, and decision-relevant science. Specifically, the NRC (2005, p. 18) recommends “that the federal government strengthen the scientific infrastructure for evidence-based environmental policy by pursuing a research strategy that emphasizes decision relevance”. In order to incorporate issues of uncertainty into more robust environmental policy-making, Bradshaw and Borchers (2000) call for the development of a “rigorous theoretic framework for robust policy”. Regarding public participation in climate issues, Wolfe et al. (2001) claims that public participation “remains an uncertain enterprise” and asks how the process can be improved. In a recent report, the NRC (2005) observes that social and behavioral sciences are often unappreciated in their contributions to better decisions and suggests the need for more robust research in a decision science approach.

Taken together, the current trends in policy, society, science and knowledge systems, as well as their conditioning factors, clarify the problem in reconciling the supply and demand of scientific information for policy: in other words, discrepancies exist between the desired goals of the production of ‘useful’ information and the status quo. Only specific interventions, implemented purposefully, can accomplish that. Part III will examine various alternatives and strategies for resolving the problem.

3. Part III: Alternatives and processes for improving

The process of characterizing a problem through the clarification of goals, description of trends, and analysis of conditioning factors culminates in the development of policy alternatives (Clark, 2002). Another way of thinking of alternatives is that they represent possible workable solutions and strategies that reconcile the discrepancies between the goals – in our case, useful information that is salient, credible and legitimate – and the status quo (Clark, 2002). What follows is a two-step process of discovering alternative strategies for reconciling the supply and demand of scientific information. The first part describes specific alternatives, or what needs to be done to ameliorate the problem. The second part explores various processes that facilitate the implementation of the alternatives.

3.1. Alternatives

By a wide margin, the most frequent exhortation by researchers is that scientists need to reach out and identify the specific needs of decision makers in order to produce more relevant information (Agrawala et al., 2001; NRC, 1999a,b, 2001[32,33]; Thia-Eng, 1997; Smythe et al., 1996). Some researchers suggest the need to “strengthen the demand side” (Cash et al., 2003, p. 8090) of science policy in order to give a voice to consumer demand. The NRC (1999b) articulates this need particularly for climate sciences while Agrawala et al. (2001) suggest the need to move away from “climate determinism”. After identifying users’ demands, scientists must then be responsive to the decision makers by conducting research targeted to users needs. (e.g. Agrawala et al., 2001; Burger et al., 2001; Keating, 2001; NRC, 1999b). Scientists also need to ensure that their research is sensitive to the scale of the problem and the scale of the research (Bray et al., 1997; Cash and Moser, 2000; Cash et al., 2003). For example, water resource managers on the Columbia River, for example, need scientific information geared toward their regional concerns, not global climate models (Callahan et al., 1999).

Many researchers call for the inclusion of stakeholders in the decision-making process[34], whether in issues of sustainability, or other resource management issues more generally (Johnson et al., 2002, e.g. watershed management; Johnson et al., 2003, e.g. agricultural and natural resource management; MacDonell et al., 2002; Rayner and Malone, 1998a; Robertson and Hull, 2003). Wagle (2000) argues that public participation is necessary to ensure a democratic process in policy-making. Some scientists and policy makers, however, are concerned over the quality of information produced when stakeholders participate in decision-making processes. Beierle and Cayford’s (2002) meta-analysis of 237 case-studies of stakeholder participation in environmental policy processes should put such concern to rest. Not only did they find that the quality of decisions was not compromised by the inclusion of stakeholders, but they also found that such participation had a positive influence on the outcome of decisions. Indeed, many researchers point to added benefits of including stakeholders in decision processes such as buy-in for the policy decision, the contribution of ‘local knowledge’ (Fischer, 2000), and improved cost effectiveness (Adomakai and Sheate, 2004).[35]

Another significant finding from the literature review is the need for improved relationships between scientists and decision makers by creating more “social capital”, namely trust, respect, and cooperation between stakeholders (Carberry et al., 2002; Guston et al., 2000; Pretty, 2003; Sclove et al., 1998. See also Miller, 2001a). Increasing the quality of a trusted

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[32] The NRC recognizes the importance of “developing information that will be considered useful and relevant by participants in environmental decisions” (1999, p. 357) but suggests that research is necessary in order to improve techniques.

[33] With regard to the future of climate modeling, this NRC report discusses the need to examine “present and future society needs for climate information” (2001, p. 74).

[34] This refers to stakeholder participation with ‘science for policy’, not necessarily in decisions about ‘policy for science’.

[35] Adomokai and Sheate researched environmental decision-making in the Niger Delta (2004).

relationship can produce more effective interactions between scientists and policy makers. Indeed, Misztal (1996) claims that the issue of trust is of considerable importance in modern society generally. With regard to resource management, Parkins and Mitchell (2005) suggest, however, that institutional trust, or trust in the process of participation, may even be more important than individual trust. According to Clark et al. (1998), another quality necessary for effective integration is that of leadership. Johnson et al. (2002) also identify the importance of ''individual and social learning'' in which scientists must willingly participate with other stakeholders. Tippett et al. (2005, p. 288), articulate the importance of social learning in river basin management. They claim, ''Encouraging social learning implies emphasis on the process of developing options and involving different stakeholders'' and relates to stakeholders ability to manage river basins effectively. A common thread through much of the literature is that the production and maintenance of social capital is a dynamic and time-intensive process.

Another alternative strategy necessary to achieve the stated goals is that scientists and decision makers need to actively manage the boundaries at the interface between the two cultures. The boundary between science and politics is viewed to be socially constructed (e.g. Gieryn, 1995, 1999; Jasanoff, 1989) and thus must be actively managed by scientists and policy makers alike to produce useful and relevant information for decision makers (Cash, 2001; Farrell et al., 2001; Guston, 2000).[36] Guston (1999, 2001) has argued that 'boundary management' actually increases the salience, credibility and legitimacy of the scientific information. Boundary management not only encourages a two-way flow of information between science and decision makers but also enables communication to flow both directions across scales (Cash and Moser, 2000). Boundary management also constitutes what Guston (2000) calls a new social contract for science, one that is based on 'collaborative assurances' rather than on the linear model of science policy as described by Vannevar Bush. Boundary management also decreases the likelihood that science will become politicized and in turn, deters the 'scientization' of policy, politics, and decision-making.

Several researchers argue that the linkages that connect scientists and policy makers need to be strengthened. The call for 'stronger linkages' and 'bridging the gap' appear to be rallying calls for many researchers focusing on different aspects of environmental problems (Brown, 2003; Lomas, 2000; Mitchell and Lankao, 2004; NRC, 1999b; Stone et al., 2001). Others describe the linkages in more nuanced terms suggesting that stronger linkages result from collaborative efforts between scientists and decision makers. Mills and Clark (2001) argue that clear guidelines and ground rules for interactions can enhance linkages between science and policy. Lemos and Morehouse (2005, p. 61) describe a model of science policy co-production in which the concept of ''*iterativity*'' (italics in original) is central. In this context, iterativity ''emphasizes the need for assessment models to build effective internal and external networks, including the capability to sustain ongoing flows of information and participation between science and decision makers from the public, non-governmental, and private sectors''. Despite such calls for bridging the gap between science and policy, however, there is little consensus on how best to accomplish this (Cash and Buizer, 2005; Smith and Kelly, 2003).[37]

The call for improving communication is ubiquitous in science policy, in that when problems exist between scientists and decision makers, many researchers identify some failure in communication as the source of the problem. Siepen and Westrup identify ''ineffective communication'' as a barrier between ''research and on-ground management'' in the arena of vegetation and land management (2002, p. 171).[38] In the context of climate forecasts for water resource management, Callahan et al. (1999) specifically identify the need to increase communication between the producers of climate forecasts and forecast users. Some researchers specifically target the concept of scientific uncertainty as one area that needs to be redefined and explicated more accurately within the context of the particular problem at hand (Bradshaw and Borchers, 2000; Kinzig and Starrett, 2003; Sarewitz et al., 2000). In other words, scientists need to describe accurately the inherent uncertainty in their data. Other researchers call for improved translation of scientific information into a more common language that is more easily understood by decision makers (Schiller et al., 2001).[39] Siepen and Westrup (2002) suggest that scientists need to develop a wider range of communication skills in general.

Some researchers also suggest that scientists and researchers need to develop a new way of thinking about science policy issues. In other words, scientists and researchers need to develop a 'theoretic-framework' for enhancing linkages between science and decision makers (Cash and Moser, 2000; NRC, 1999a; Smith and Kelly, 2003). Such a framework would not only provide useful guidance in future policy processes, but also provides a baseline from which to analyze, understand, and improve future science policy processes. Johnson et al. (2002, p. 512) describe a 'social learning process' in which scientists learn alongside stakeholders and recognize that their own participation and presence in the process will affect the outcome of the entire system.

3.2. *Process*

The literature describes a variety of processes and techniques for linking science to decision makers more effectively, or

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[36] Farrell et al., in their research on environmental assessment processes, discuss the importance that ''each group [scientists and decision makers] maintain its self-identity and protect its sources of legitimacy and credibility, so boundaries are commonly negotiated, articulated and maintained by assessment participants'' (2001, p. 318).

[37] Cash and Buizer make this point in the context of seasonal to interannual forecasting.

[38] Siepen and Westrup (2002) provide a detailed exploration of the various communication methods and criteria for successful communication of scientific information for natural resource management.

[39] For example, ecological indicators.

'how' to implement the alternatives and mitigate the problem. Many processes share similar approaches and dozens of processes have been identified in literature from across multiple disciplines. Listed below, however, are a summary of processes and techniques discussed most frequently in the science policy literature including the use of participatory processes, boundary organizations, adaptive management, science shops, consensus conferences, and other approaches.

3.2.1. *Various participatory approaches*

The term 'participatory processes', and many of its related expressions, describe a range of techniques used in decision-making (e.g. Jason et al., 2004), although Dryzek (1990, p. 97) defines participatory processes as allowing "for pooling of information . . . for the progressive integration of knowledge as it becomes available". van den Hove (2000, p. 463) explains that by utilizing participatory processes, "a more comprehensive understanding of the issues can be reached that includes different perspectives of a scientific, social, cultural and ethical nature". The NRC (1999b) claims that participatory methods produce credible outcomes that are more likely to produce positive behavioral changes in the persons who are involved in the process. Rowe and Frewer (2005, p. 252–253), however, argue that key concepts of public participation "are not generally well defined", and that "some researchers might disagree with the scope of activities implicitly or explicitly included within the concept by others". To some, participation could include the public's passive receipt of information, or at another extreme, the lay public's complete involvement in decision-making. For these reasons, Rowe and Frewer suggest adopting the phrase *public engagement* in lieu of *public participation*.

The range of power sharing between scientists and stakeholders, the flow of communication, the scale of the problem, and the degree of participation by stakeholders varies widely among the disparate participatory processes. Blumenthal and Jannink (2000, p. 1) suggest adopting a framework based on five criteria for comparing collaborative management methods, including: "participation, institutional analysis, simplification of the natural resource, spatial scale, and stages in the process of natural resource management". In their effort to develop a typology of public engagement mechanisms, Rowe and Frewer (2005) find that most mechanisms fall into one of three types based on how communication flows between society and sponsor, or in this paper's context, society and science. Information can flow from sponsor to public (public communication); from public to sponsor (public consultation); and between sponsor and public (public participation). Reconciling the supply of and demand for scientific information suggests that the ideal type of communication would be that which flows *between* sponsor and the public in order to produce information that salient, credible and legitimate.

Researchers across many disciplines and topic areas have described various processes for involving the public, and at times the list of alternatives seems inexhaustible. Rowe and Frewer (2005, p. 256) identified over 100 different public engagement mechanisms[40] and proclaimed "there are undoubtedly more". While the alternatives are too numerous to mention here, I have identified several that strive to achieve the goals of more effective science policy linkages. Examples include community-based initiatives (Brunner et al., 2002); Community Research (Stead et al., 2002);[41] Deliberative Polling; Citizen Juries; Stakeholder Dialogues; Scenario Workshops; Consultative Panels (Smith and Kelly, 2003); Participatory Planning Processes (Forester, 1999); Participatory Development (Campbell and Vainio-Mattila, 2003); Consensus Conferences (Chopyak and Levesque, 2002); Tribal Participatory Research (Fisher and Ball, 2003); civic science (Bäckstrand, 2003; Clark and Illman, 2001), community science (Carr, 2004), and others including Stakeholder Collaboration, Community Participatory Research, Co-Research, Feminist Research Methods, Integrated Resource Management, Collaborative Decision Making, and the like.

Another way to approach and think about participation that also recognizes the need to manage the boundary between science and society is that of public ecology, which exists "at the interface of science and policy" (Robertson and Hull, 2003, p. 300). Public ecology is similar to adaptive management (see below) in that it recognizes that scientific information is not "perfect or complete". Rather, public ecology "requires that science be produced in collaboration with a wide variety of stakeholders in order to construct a body of knowledge that will reflect the pluralist and pragmatic context of its use (decision context) while continuing to maintain the rigor and accountability that earns scientific knowledge its privileged status in contemporary society" (2003, p. 400). Luke (2003, p. 25) explains that public ecology responds to the need to "focus on hybridities of Nature/Society at sites which intermix the natural and the social". The process of public ecology requires stakeholder participation and deliberative, democratic and open processes of decision-making, thus increasing the salience and legitimacy of information. As a "philosophy and practice", public ecology contains six attributes: it is evaluative, adaptive, contextual, multiscalar, integrative and accessible (Robertson and Hull, 2001, p. 970). While we understand much about the philosophy, less is known about the practice of public ecology, suggesting the need for additional research in this area.

3.2.2. *Adaptive management*

This process is based on the notion that policies are just experiments and that the outcomes of the experiments constitute opportunities for learning and improving the subsequent decisions (Holling, 1978; Lee, 1993, 1999). Adaptive management is iterative and step-wise in its approach to decision-making. As working hypotheses, policies are not permanent features but rather represent opportunities for learning and adapting the policies to new information. Lee (1993, p. 9) explains: "Linking science and human purpose, adaptive management serves as a compass for us to use in searching for a sustainable future". Given that some irreducible uncertainties will persist with Earth system science, adaptive management offers flexibility in managing such complex and dynamic systems (Gallopín, 2004). Examples of adaptive management include the Northwest Power Planning

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[40] With a bias on U.S. and UK mechanisms.

[41] Stead et al. (2002) explore community research in the context of inter coastal zone management.

Council's Columbia Basin Program[42] and the Plum Creek Timber Company conservation plan (Lee, 1993, 1999). The NRC (1999c) supports the use of adaptive management concepts and practices, and this approach is now used in a variety of natural resource management activities around the world.

3.2.3. *Science shops and community-based research (CBR)*

Science shops and CBR emerged in Europe as a way to provide private citizens, non-governmental organizations, and other small to medium organizations with access to scientific information, technological advice, and research at relatively low costs (Fischer et al., 2003). Research is available across a wide variety of disciplines and most science shops operate out of universities. In this process, the research produced is in direct response to the needs of civil society (Gnaiger and Martin, 2001). Underlying issues in the development of science shops include issues of social justice and democracy. The shops exist in varying degrees of size, with various levels of management linkages and financial support to and from universities, and various degrees of success. Science shops are found in many countries, although most are found in Europe (Fischer et al., 2003).

3.2.4. *Boundary organizations*

One alternative process that has emerged over the past decade or so is the use of 'boundary organizations'. These organizations can utilize the various alternatives described in the first section, but also specifically addresses concerns over boundary management raised by the STS community. Boundary organizations act as intermediaries between scientists who produce information, and decision makers who use the information. These organizations operate in a dynamic environment, essentially "straddl[ing] the shifting divide between politics and science. They draw their incentives from and produce outputs for principals in both domains, and they internalize the provisional and ambiguous character of the distinctions between these domains" (Guston et al., 2000, p. 1).

An important distinction of boundary organizations from other processes described in this paper is their explicit recognition of the boundary between science and society, and the acknowledgement of the cultural barriers erected by science. Rather than attempting to dismantle them, they focus their efforts on three management functions: translating information, mediating actively across both sides of the boundary, and communicating effectively to all groups of stakeholders. Boundary organizations attempt to strengthen linkages between science and policy by facilitating a two-way flow of information. As Agrawala et al. (2001), describe the process with regard to climate information, it is an "end to end" system: from climate scientists to consumers and back again, thus enabling decision makers to clarify their information needs. Boundary organizations produce boundary objects, such as reports, conferences and the like. Another important quality is that boundary organizations are accountable to both sides of the boundary in order to ensure their role as an honest broker and the production of information perceived to be legitimate. Cash et al., argue that the ultimate goal of boundary organizations is to produce useful and relevant information that decision makers can use (Cash, 2000; Cash et al., 2003).

Examples of Boundary Organizations include the Cooperative State Research, Education, and Extension Services provided through the U.S. Department of Agriculture; the Pacific El Niño Southern Oscillation (ENSO) Application Center; the Consultative Group of International Agricultural Research (CGIAR), and U.S. Sea Grant Colleges (Cash and Moser, 2000). Other boundary organizations include The Health Effects Institute (Keating, 2001); the Subsidiary Body for Science and Technology Advice (Miller, 2001a); the International Research Institute (Agrawala et al., 2001); the Institute for Applied Systems Analysis; the Advisory Body on Climate Change Research and Policy (Niederberger, 2005); NOAA's Regional Integrated Sciences and Assessments Program; the Convention on Long-Range Trans-Boundary Air Pollution (e.g. Cash et al., 2003); and various agricultural extension groups in Australia (Carr and Wilkinson, 2005).

Given a variety of processes available to facilitate the reconciliation of supply and demand, how does one know which process is the 'right' one to utilize? Answering this question requires a balancing act of sorts. From a macro perspective, we know, generally speaking, that the aforementioned alternatives and processes are useful in a wide variety of contexts. But as we move to the micro level, it becomes apparent that some alternatives work better than others and that close attention must be paid to the particular characteristics of each problem. Indeed, more than one process can be used simultaneously and what works over time may also change given the dynamic environment at the science policy interface. Attempting to prescribe some idealized mix of alternatives would be counterproductive and contrary to the notion of contextuality and contingency in knowledge production as discussed earlier. As Forester (1984, p. 30) explains[43], "If practical strategies are context dependent and contexts in practice vary widely, always changing, then rational action and decision-making will fail in a technical search for a one-best-recipe. Instead of recipes, repertoires of strategies are called for—and should be investigated in diverse decision-making situations".

Research at the Health Effects Institute, a so called boundary organization, suggest that another important factor in its success in producing useful information rests with its director, whose leadership was identified as essential to the organization's success. As Keating notes, "Astute and respected individual leadership is essential to the success of efforts that attempt to bring multiple stakeholders to the table, to push the limits of consensus, and to forge credible knowledge" (citing Keating and Farrell, 1999; Keating, 2001, p. 424). Balancing the selection of processes and approaches that reflect the needs of a particular context underscores not only the importance of leadership, but the importance of understanding how decisions are made *about* the selection of approaches. Ultimately, however, the appropriateness of any alternative rests with its ability to produce useful information, that is, information that is salient, credible and legitimate.

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[42] According to Lee, this program was the first in the United States to utilize an adaptive management approach in 1984.

[43] Forester makes this point in discussing public policy in general.

As explained earlier, utilizing a problem-oriented approach enables us to discern the full scope of the problem and the challenges in reconciling the supply and demand of scientific information. Part I described the goal of producing useful information and defined what that means. Part II clearly established the problem, clarifying the discrepancies that persist between the production of useful information and the status quo. Part III presented a variety of alternatives and process that prove to be effective various contexts for reconciling the supply and demand of scientific information for decision-making. This brings us back to our question, are we doing the 'right' science to better respond to society's needs? The results from this analysis of the problem indicate that we have more work to do in order to achieve the goals of providing useful information for decision makers. In order to move toward a solution and ''close in on problem solving'', however, one must explore, describe and understand how communities make decisions (Clark, 2002).

4. Part IV: The decision process

How do organizations and groups, which need useful information, make decisions about selecting and implementing the various alternatives and processes described in Part III? Effecting change by utilizing the various alternatives and processes requires that the 'right' decisions be made. According to Clark (2002, p. 76), ''the decision process is the very heart of policy making'', and one needs to recognize that countless small decisions are made in the context of larger policy decisions. Understanding how a problem gets evaluated and resolved through the decision process helps to illuminate important aspects of the problem's context and also serves to identify ways in which decision-making, and thus policy-making, can be improved in order to produce workable solutions to the problem. In so doing, one can develop a better understanding of how, when, why and where to implement alternatives and whom is responsible for doing so.

Decision-making has been studied widely in a variety of fields, including economics, psychology, political science, and policy. Research on decision-making has also varied greatly in terms of scale, from human cognition, judgment, and choice, to group and organization decision processes. Additionally, researchers have explored decision-making from the practical, in terms of analytic method, to the theoretical level (Allison and Zelikow, 1999; Bardach, 2000; French and Geldermann, 2005; Friedman, 1953; Goldstein and Hogarth, 1997; Hammond, 1996; Lal et al., 2001; Lindblom, 1950; March, 1994; Shepsle and Bonchek, 1997; Simon, 1983; Slovic et al., 1999; The Social Learning Group, 2001; Tversky and Kahneman, 1982).

Many researchers who study decision-making, however, have rejected the notion that it is an inherently rational, context independent, or sequential process and suggest that limitations exist in attempting to utilize theories for predictive purposes. Human cognition and decision-making is only 'boundedly rational' (Simon, 1983), and the policy process more incremental, gradual, and more of a ''muddling through'' (Lindblom, 1979). Nevertheless, theories, and frameworks, can be useful for decision makers to ''simplify their worlds, to suggest what is most important to attend to, what can safely and decently be neglected'' (Forester, 1984, p. 30). Recognizing that there are both limitations and opportunities in utilizing theories to explore decision-making, I have opted to use a framework described by Lasswell (1971) (Lasswell and McDougal, 1992). Although criticized as being too linear as a ''stages heuristic'' (e.g., Sabatier, 1999), the framework actually favors a more holistic approach to analyzing decisions, recognizing that ''in any policy-making process there will be elements of rationality and irrationality, comprehensiveness and parochialism'' (Clark, 2002), and thus fits well with the contextual nature of this problem analysis.

According to Lasswell (1971), every decision process consists of seven phases that together consist of the pre-decision (gathering intelligence, promoting alternatives), decision (prescribing the solution, and its implementation and application), and post-decision (terminating the decision and evaluating it) (Lasswell and McDougal, 1992). By using the seven phases as a framework of analysis, one can better identify specific functions of decision-making, who is involved in making decisions, whether ''they are being performed well'', and how each decision function can be improved (Clark, 2002, p. 83). As explained above, however, the actual decision-making process is not linear or sequential, but rather, this framework invites exploration and analysis of decision-making, not unlike how a map provides one with the 'lay of the land'. In the section below, I list each decision phase and a functional question that best describes what 'gets done' in that particular phase, and evaluate the current literature based on how well it addresses these questions.

4.1. *Intelligence phase*

How are decisions made regarding the type and quantity of scientific information that is needed and gathered by decision makers? Researchers have identified various process for determining what scientific information is needed, including Agrawala et al. (2001), Cash and Moser (2000), Jones et al. (1999) and Wolfe et al. (2001), and others. For example, Wolfe et al. (2001) describes the use of regional workshops that were held to identify community concerns and issues relating to the national assessment of impacts to climate change. At the Health Effects Institute, Keating describes a 'program development stage' in which researchers solicit input from sponsors in order to prioritize research needs. An ad hoc committee of researchers eventually selects which research projects to fund. Other techniques include the use of town meetings (O'Fallon and Dearry, 2002; O'Fallon et al., 2003[44]), questionnaires and surveys (Bärlund and Carter, 2002[45]), and still others suggest using multiple criteria to evaluate the

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[44] O'Fallon et al., explain: ''To achieve broad public input and to foster community-university partnerships, the National Institute of Environmental Health Science supports various workshops, roundtables, and advisory groups. In particular, the NIEHS finds Town Meetings to be a successful model for brining academic researchers together with community residents, state and local departments of health, and community-based organizations to foster greater awareness of community needs, public health needs, and environmental health science research'' (2003, p. 1855).

[45] The surveys were designed to elicit users needs regarding global change scenarios in Finland.

relevance, compatibility, and access to information (Jones et al., 1999).

4.2. *Promotion phase*

How is the scientific information culled, prioritized, and packaged for presentation to the decision makers, and what are the bases for such decisions? The promotional function, which has been well articulated from a sociological perspective by Jasanoff and Wynne (1998), Kuhn (1962), and Merton (1973), is not as well understood from the perspective of a decision-making process. Researchers have suggested some processes of promotion, however, including project review (Keating, 2001); scientific peer review (Guldin, 2003; Guldin et al., 2003a); and improving science translation (Cash and Moser, 2000). Jones et al. (1999) suggest that scientists need to determine the receptability of the information. As mentioned earlier in this paper, several authors have identified the need for scientists to translate and communicate their information more effectively, but the literature in this area is insufficient to describe how this process unfolds with regard to decision-making.

The U.S. Forest Service has developed a process called *Science Consistency Reviews* (SCR) that answer the question: ‘‘Is the analysis or decision document consistent with best available science?’’ (Guldin, 2003; Guldin et al., 2003a; Shaw et al., 2000). The SCR examines the content and rigor of the science, the applicability of the science to the decision process and whether the relevance of the science is considered. It also determines whether the science has been reasonably interpreted, accurately described, and whether risks and uncertainty are adequately described. The process is conducted by a group of stakeholders consisting mostly of scientists both internal and external to the process and shows promise of success.

4.3. *Prescription phase*

Ultimately, some scientific information gets used by decision makers while other information does not: how are these decisions made? Korfmacher and Koontz (2003), in describing the decision process of farmland preservation task forces, suggests that the prior experiences of decision makers and extent of information use in those prior decisions influences how decisions are made about what science to use. Strong structures, goals, processes, and prior experience suggest that decision makers would be more likely to incorporate scientific information into future decisions. They also noted, however, that the collaborative decision-making groups obtained and used information in a variety of ways. More theoretical analyses exist regarding how decisions are made regarding the use of information, such as the Maximization Postulate, Expected Utility Theory, Prospect Theory, Social Amplification Theory, and Arena Theory. Literature in these areas, however, was not reviewed, but these topics could provide some insight into the prescription function at a future point in time.

4.4. *Implementation and application phases*

What is the process for agreeing to or disputing how the information will be used? Only a few researchers suggested methods for disputing how information would be used. Mills and Clark (2001) suggested developing guidelines to identify and clarify power relationships such as who has final authority in decisions. They also called for dealing with disputes immediately and directly. Doble (1996) calls for a framework that ‘‘outlines choices and tradeoffs’’ that the public can use in making these decisions (in Smith and Kelly, 2003).

4.5. *Termination phase*

How is it decided that information is no longer needed or useful? Nothing in the literature I read suggested any mechanisms or processes for deciding when information was no longer useful. One exception to this is Adaptive Management, however, which involves some aspects of the termination function, but fits better in the evaluation function that I describe below.

4.6. *Evaluation phase*

How is it determined that the information used was effective and useful in meeting the objectives of the decision makers? Literature across many disciplines and topic areas address the issue of programmatic evaluation (e.g. Johnson et al., 2003; Leach et al., 2002; Rowe and Frewer, 2004; Rowe et al., 2004).[46,47,48,49] With regard to the evaluation of the decision itself, the NRC (2005, p. 30) suggests that internal criteria are necessary for evaluation rather than relying solely on the outcomes of the decisions. They claim, ‘‘defining decision quality for practical environmental decisions has not received the level of research attention it deserves’’.

Despite such work on evaluating outcomes and decisions, less is known about evaluating the value of scientific information in a decision process. We have more information describing the *criteria* of success (Beierle and Cayford, 2002; Shaw et al., 1997) than we do about the *process* of evaluation (Wolfe et al., 2001). Shaw et al. (1997, p. 5) suggest using criteria such as determining the consistency of the decision against available information; whether all relevant information was considered; whether the science was understood and interpreted correctly; and whether risks were adequately addressed. Other authors declare that evaluation needs to be built into the process at the beginning, such is in community or co-learning models (Siepen and Westrup, 2002), while others suggest that evaluating predictions is difficult to perform (Pielke and Conant, 2003). Jones et al. (1999) suggest using integrated assessments for evaluating the effectiveness and usefulness of climate change research for decision-making. On the other hand, others suggest using ‘‘expost satisficing[50]’’ (Deelstra et al., 2003, p. 521) or ‘‘expost

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[46] Regarding user participation in agricultural and natural resource management research.

[47] Regarding stakeholder partnerships in watershed management.

[48] Regarding public engagement mechanisms.

[49] Regarding the evaluation of a deliberative conference.

[50] Ex post satisficing means, ‘‘the extent to which involved actors are satisfied with the result of the policy-process. This satisfaction may be determined by a (neutral) ex post evaluation of the perceptions of actors’’ (Deelstra et al., 2003, p. 521).

evaluation'' (Herrick and Sarewitz, 2000) as approaches to evaluations in assessment processes.

Holling (1978) and Lee (1993) describe a process for evaluating the usefulness of information through Adaptive Management. Policy decisions are viewed as hypotheses that are built on scientific information and predictions. The outcomes of the decisions are then measured against the predictions and then assessed. The evaluation of scientific information is not direct, however, but rather it is indirect, in that the effectiveness and usefulness of the information is evaluated in the context of how successful the previous management decisions were. Nevertheless, evaluation of the decisions can then inform new directions in future research and new policy decisions.

5. Part V: Conclusion and discussion

This problem analysis provides information in a variety of areas regarding reconciling the supply and demand of scientific information for decision-making. The goals of producing useful scientific information suggest that useful information must be salient, credible, and legitimate and that the production of useful scientific information is about process, and not just product. Users' information needs must be identified and research must be targeted to those needs. Creating and maintaining social capital and fostering mutually respectful relationships are also important processes necessary for forging stronger linkages between science and decision makers. Although there are countless journal articles calling for the production of more scientific information, such data were omitted from this problem analysis. The issue under consideration in this paper involves the optimization and reconciliation of the supply and demand of scientific information, and not necessarily the need for more information, yet more information may be desirable at times. Nevertheless, some researchers argue, ''that we could be using existing knowledge better'' (Edgar et al., 2001, p. 190[51]; NRC, 1999b).

Several historical trends inform the problem of reconciling the supply and demand of scientific information for policy. First, governments, agencies, non-profit organizations, and research centers have proliferated in order to understand and apply science policy for better outcomes. These trends occur internationally as well as locally. Despite such promise, however, momentum is not as strong as it may seem. For example, the National Center for Environmental Decision Making Research existed for just a few years and closed its doors before the end of its full funding cycle.

Review of the literature provided ample description of the circumstances that condition the problem. Several forces are converging and influencing how science and society relate to each other in decision-making processes. Not only is civil society demanding a larger role in decision-making (both in policy decisions and in decisions about science), but increased public scrutiny and what some see as a 'failure' of the linear model of science policy have provoked many to call for a new social contract for science and for new ways of thinking about these issues. Simultaneously, our awareness of the complexity and interconnectedness of environmental problems is prompting calls for more integrated science policy that includes a broader range of stakeholders.

The literature describes a wide variety of alternatives to our current and dominant approach to reconciling supply and demand. These alternatives vary in terms of scale (national or international versus local applications), power sharing (in terms of stakeholder involvement and participation), and process (creating a boundary organization or using participatory methods within existing frameworks). Of these alternatives and processes, however, only two consider the importance of actively managing the boundary between science and society: boundary organizations and public ecology, although the literature about boundary organizations is significantly greater than that in public ecology. In order to solve the problem of providing the 'right information' for decision makers, and select the 'best' repertoire of alternatives to facilitate that process, we must be able to describe and understand how decisions are made. In this respect, the literature left many questions and issues about decision-making unanswered.

Given the outcome of the problem analysis, what is next? The most glaring omission in our knowledge of this problem relates to the practical decision functions in real-world settings. That is, there is much to learn about how decisions are made regarding what information is needed (intelligence phase), how it gets packaged and presented (promotion phase), how it gets selected (prescription, implementation and application phases), determining when it is no longer useful (termination phase), and how the information is evaluated (evaluation phase). As Jacobs et al. (2005, p. 9) explain, ''Gaining insight into how decisions are made, then, can be considered an important part of scientist–stakeholder interactions''. Additionally, we know little about how responsibility is allocated and who is responsible and accountable for such decisions. Research on decision-making processes in business organizations exists, yet we know very little about the science policy decision process. Perhaps knowledge from the business and management fields can help inform the problem of decision-making to reconcile supply and demand of scientific information, but this approach has yet to be undertaken. Additional research on environmental decision-making more generally would also help inform this problem. The National Research Council recently suggested supporting ''a program of research in the decision sciences addressed to improving the analytical tools and deliberative processes necessary for good environmental decision making'' (NRC, 2005, p. 2).

Second, given the importance of the science policy linkages, relationships, group dynamics, trust, and social capital, it is essential that we develop a more robust

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[51] Edgar et al. explain: ''Conventional wisdom has it that we already have enough science to address the problems causing degradation of our environment, including rivers. This is not true. However, it is the case that we could be using existing knowledge better and that we could be doing more to learn the lessons from the huge sums being spent on river restoration and management'' (2001, p. 190).

understanding of experience and practical experiments regarding how relationships are constructed and managed across the science–society boundary. How can relationships centered on trust and respect be maintained without compromising the credibility of the science or that of the decision-making body? How are some organizations or groups more successful at building social capital than others? In other words, how is the production of social capital developed and maintained?

Third, context – the importance of temporal, spatial, political, scientific and cultural factors – plays a significant role in the relative success or failure in the production of useful information for decision makers. Given that 'one size does not fit all', how does one know what approach to take in reconciling supply and demand? What strategies should one employ, with whom, and how? Are there steps to take or questions to ask that enables some actors to be more flexible and responsive to the needs of a particular context, and if so, what are they? Although we have a basic understanding of how many of the various alternatives presented herein function, such as participatory methods, we lack a coherent understanding of how these alternatives relate to the problem at hand, and the decisions regarding which alternative to use in what context.

Fourth, boundary organizations show promise in facilitating the reconciliation of the supply and demand of scientific information. Not only does boundary work encompass many other alternatives and processes mentioned herein, but boundary work recognizes explicitly the importance of actively managing the science–society boundary, an issue not well addressed by the other approaches discussed. Management of the boundary mitigates the chances that the science becomes politicized or the decision becoming 'scientized'. Yet, research to date has fallen short on what it means to 'manage the boundary'. Future research is needed to understand how to create, manage, and replicate boundary organizations, particularly with regard to institutional characteristics, management of group dynamics, description of culture, and organization dynamics. How do these organizations function and what kind of management approach works best? Key 'boundary spanning individuals' appear to play an important role in boundary work, yet we know very little about these individuals, how they do the work they do, and how to foster such attributes in others, if it is possible to do so. With regard to the primary functions of boundary organizations, namely communicating, mediating, and translating, we have much to learn regarding the decisions that are made about these functions and how boundary organizations perform them. Perhaps the most important question regarding boundary organizations is: do they work? More evaluative research is needed on boundary organizations.

Fifth, we know from other researchers that decisions about science research priorities ultimately shapes the information that is available to decision makers (Sarewitz and Pielke, 2007). Lahsen and Nobre (2007), showed how the lack of a research plan focusing on the production of useful information relevant to land-use changes in the Amazon left the Large-scale Biosphere Atmosphere Experiment research agenda as "an unfinished project". With regard to carbon-cycle science, Dilling (2007) suggests that, "Without a change in fundamental attitude towards empowering the use of information as a central goal for research programs aimed at serving society needs, the supply of information is not likely to become significantly more usable". Despite such importance, the literature was virtually silent on the issue of decisions about scientific research agendas. How then, do program managers and research funding organizations make decisions about research priorities? What are their information needs for 'useful' information that would improve decisions about scientific research aimed at producing policy-relevant information? We know very little about science policy decision-making and need to address this gap in our understanding of science policy.

Finally, research is necessary to explore the most fundamental question of this problem of reconciling supply and demand of scientific information for decision-making: can it be done? Is it possible to solve this problem? Can the theories and concepts about linking science to society for the production of more useful information, and hence, better decisions, be converted into operational tools? While I have elected to use the concept of RSD to explore the problem presented in this paper, questions remain about its validity as a tool for analysis. Does the RSD model provide an adequate framework for analyzing the problem and what can we learn by using it in our own research? While its simplicity provides value as a heuristic, the question remains, is it too simplistic? Or, is it adequately robust as a tool for analysis? While the research in this paper has focused more on the supply side, in part due to this researcher's focus on science policy and decisions about research agendas, more research is also needed to explore and understand the dynamics of the demand side. Ultimately, those of us studying the role of science in decision-making, and decision-making about science, must become more reflexive in our analyses. We face our own challenge in the reconciliation of the supply of and demand for information. What seems abundantly clear is that we know enough to get to work.

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