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The Public Values Failures of Climate Science in the US

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Abstract This paper examines the broad social purpose of US climate science, which has benefitted from a public investment of more than $30 billion over the last 20 years. A public values analysis identifies five core public values that underpin the interagency program. Drawing from interviews, meeting observations, and document analysis, I examine the decision processes and institutional structures that lead to the implementation of climate science policy, and identify a variety of public values failures accommodated by this system. In contrast to other cases which find market values frameworks (the "profit as progress" assumption) at the root of public values failures, this case shows how "science values" ("knowledge as progress") may serve as an inadequate or inappropriate basis for achieving broader public values. For both institutions and individual decision makers, the logic linking science to societal benefit is generally incomplete, incoherent, and tends to conflate intrinsic and instrumental values. I argue that to be successful with respect to its motivating public values, the US climate science enterprise must avoid the assumption that any advance in knowledge is inherently good, and offer a clearer account of the kinds of research and knowledge advance likely to generate desirable social outcomes.

Keywords Public values · Climate science · Science policy · Global change · Research policy

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Introduction

In the United States, a large "global change research" community investigates climate change through research on the complex interrelations of natural processes, as well the role of humans in impacting and reacting to these forces. Atmospheric scientists, hydrologists, ecologists, paleobiologists, oceanographers, agronomists, statisticians, epidemiologists, glaciologists, and many others seek resources from US climate science funding. They launch hundred million dollar satellites, which orbit the Earth looking back at us. They assemble massive numerical models to run on the world's largest computers. They send research vessels throughout the world's oceans, and construct elaborate facilities to run experiments measuring ecological change.

Climate science[1] engages a wide range of disciplines and institutions: thirteen federal agencies fund work in this area. But this structural complexity exists under a single mission, vision, and framework set out in law by the Global Change Research Act of 1990 (PL101-606 1990), and maintained through an interagency coordination process. Since that time, more then $30 billion have gone to global change research.

A recent National Research Council (NRC) evaluation of US climate science found that, while the Program has significantly advanced understanding of climate change, "progress in synthesizing research results or supporting decision making and risk management has been inadequate" (NRC 2007, p. 3). This observation highlights an important fact: the Global Change Research Act (GCRA), like most science policies, has a broader purpose—it constructs an aspirational link between science and some form of social progress.

The GCRA stipulates funding for research in order to "produce information readily usable by policymakers." Nearly two decades later, the NRC finds that the great volume of knowledge resulting from global change research has failed to fulfill this mandate. In fact, from the very beginning, outside evaluators have highlighted the failure of the interagency program to make significant progress on this task (Pielke 2000a; NRC 2005, 2007; Byerly Jr 1989). In this paper, I use a Public Value Mapping (Bozeman and Sarewitz 2011, this issue), to investigate the link between climate science and the broader social purpose of climate science policies to show how this has happened.

I assess the fulfillment of public values by examining policies, institutions, and the mental models of individual decision makers associated with US climate science. As individuals and institutions coordinate, manage, and make specific choices about how to spend money on climate science, what drives their decisions? Do the incentives embedded in the system uphold the public values that motivate funding for climate science in the first place? Although the importance of such questions was highlighted in this very journal by Stephen Toulmin in 1964 (see also Kitcher 2003; Bozeman and Sarewitz 2011, this issue), to this day they seldom receive adequate attention as the nation's R&D system expands.

[1] As is common in many policy documents related to federal climate research, I use "climate science" and "global change research" interchangeably.

I begin by briefly outlining the Public Value Mapping framework.[2] I then identify and describe the key public values that emerge from program documents, external documents such as National Research Council (NRC) reports, and interviews I conducted with more than 50 program officials who work for science agencies and participate in interagency climate science activities. A juxtaposition of these values with the dynamics of decision making and management within the climate science program provides the basis for a public values failure assessment. This assessment reveals widespread and ill-founded assumptions about the connections between knowledge advancement and difficult social problems like climate change, and provides important insight, both for climate science, and for science policy in general.

Public Values Analysis

Bozeman (2007, p. 13) defines the public values of a society as:

> those providing a normative consensus about (a) the rights, benefits, and prerogatives to which citizens should (and should not) be entitled; (b) the obligations of citizens to society, the state and one another; and (c) the principles on which governments and policies should be based.

The term "normative consensus" does not imply universal agreement. It simply means that public values are widely recognized across a given society, and can serve as a basis for collective action. Public values also do not prescribe specific policy action. Thus, broad agreement on particular public values such as air quality, public health, or human dignity (in other words, agreement that these are good, desirable things), by no means precludes deep conflict over the way in which they might be achieved, or over their importance relative to one another. Public values *failures* occur when "neither the market nor the public sector provides goods and services required to achieve public values" (Bozeman 2007, p. 16).

Public values analyses are motivated by the conclusion that the economic outcome of a policy (e.g. profit, efficiency, growth of industry, GDP) is not *necessarily* an appropriate indicator of whether that policy is successful. For example, if a clean energy policy gives a substantial financial boost to corn farmers selling their crops for biofuel, we may reserve judgment as to whether the policy has succeeded in reducing emissions of pollutants as originally intended.

One can apply this argument to public investments in science as well. Bozeman and Sarewitz (2005) argue against the common assumption that market success (or failure) correlates directly with public values success (or failure) when it comes to the funding of research and development. Medical research provides a particularly compelling example: massive investments by the US government have fueled major advances in medicine, around which an enormous industry has grown. Yet health in the US remains mediocre in comparison to other developed nations even while its

[2] See Bozeman and Sarewitz (2011, this issue) for a more detailed account of Public Value Mapping in science policy.

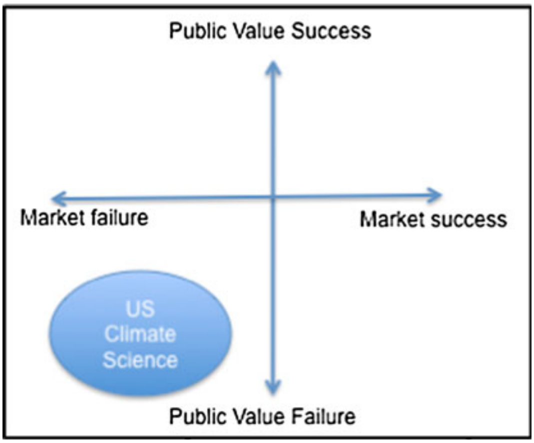


Figure 1 Climate science in the context of public values and market values

costs continue to skyrocket: market success; public failure (Gaughan 2002; Gawande 2009; Slade 2011, this issue).

Following this logic, one may view climate science as a market failure (funding is provided through the public sector), and, in light of critiques by the NRC mentioned above, as a public values failure. The grid in Figure 1 illustrates this.

Useful information, though important and prominent, is not the only public value associated with the climate science enterprise. In the next section, I present a list of five prominent public values that underpin US climate science, and discuss each of these values in the context of individual decision making and institutional structures. The last two decades have seen considerable continuity in the general purpose of coordinating climate science among agencies, even if the language used to express that purpose and the means of achieving it have evolved. So far, under the Obama Administration, the US Climate Change Science Program (CCSP, as it was known under the Bush Administration) remains largely intact, except that it has reverted to its pre-Bush-Administration name of "Global Change Research Program." For the sake of consistency, I will use CCSP as a reference to the federal interagency program in general.

Public Values in Interagency Climate Science

A variety of sources can provide information about public values, including public law, a government's founding documents, the results of surveys and public polls, or the missions and visions of public institutions.[3] Such sources often articulate aspirations that link, through some internal logic, particular activities (such as scientific research) to the achievement of positive outcomes for society. Claims of social benefit might be utterly political and insincere, advanced merely for personal gain, or preservation of the status quo. This should not discourage their use as expressions of public value. Sincere or not, if offered as a policy goal, they may

[3] See Bozeman (2007) and Bozeman and Sarewitz (2011, this issue) for more on this.

justifiably be used in evaluating the outcomes of that policy. Revealing divergences in public values and actual intent is precisely the point of Public Value Mapping.

The list in Table 1 focuses on the most commonly expressed, broadly agreed-upon principles and goals of the program drawn from a variety of documents. It is not hierarchical, and there is no clear consensus on how the values relate to one another, or should be balanced.

In discussing each of these values, I reference the concepts of instrumental and intrinsic values. Bozeman (2007) describes intrinsic values as representing a desired end state, while an instrumental value is adopted as a means to achieving an intrinsic value. The distinction between these two types of values is not always clear, and some public values may be framed as one or the other. Indeed, as I argue later, in some cases this malleability can be at the heart of public value failure.

The example statements in Table 1 demonstrate the consistency with which these values have been expressed in the years since the passage of the GCRA in 1990. Below I discuss each public value in more detail, drawing on interviews and official documents.

Value 1: Useful Information

In 1979, Lindblom and Cohen observed that the complexities of the lay community are perhaps as great or greater than the complexities associated with knowledge production. A variety of more recent studies examining how lay communities make use of climate information have born this out. Such studies highlight the importance of the social, physical, institutional, and political context of decision makers, and generally refute the common assumption that more information necessarily leads to better decision making or increased information use (e.g. Lach, Ingram, and Rayner 2005; Lach, Rayner, and Ingram 2005; Rayner, Lach, and Ingram 2005; Lahsen and Nobre 2007; Logar and Conant 2007; McNie 2007; Sarewitz and Pielke 2007; Pielke 1995). Scientific programs aimed at generating immediately useful knowledge must take this reality into account, and involve potential knowledge users throughout the research process (Cash, Borck, and Patt 2006; Jacobs, Garfin, and Lenart 2005; Meinke et al. 2006; Nelson, Howden, and Smith 2008).

To develop useful information is the most obvious, prominent, and challenging intrinsic public value of interagency climate science, and it has become a subject of study for social scientists focused on climate issues (c.f. Pielke 2000a; Agrawala, Broad, and Guston 2001; Cash, Borck, and Patt 2006; NRC 2007; Sarewitz and Pielke 2007; Jacobs, Garfin, and Lenart 2005; Pielke 2000a; NRC 2009). In thinking about CCSP's relationship to the challenge of developing useful information, one may ask: (1.) what users are targeted and why; (2.) how is useful information defined; and (3.) how could one guide or structure a research program to be responsive to questions one and two? In the case of the US climate science, the answers to these questions are not straightforward.

Who is Targeted?

Early discussions and wording of the GCRA (PL101-606 1990) seem to indicate that the Program should generate information useful specifically to decision makers

Table 1 Statements associated with public values underlying interagency climate science

1. Useful information

- "interagency climate science should 'produce information readily usable by policymakers'" (PL101-606).
- CCSP vision: A nation and the global community, empowered with the science based knowledge to manage the risks and opportunities of change in the climate and related environmental systems (CCSP 2003, 2008).
- CCSP mission: Facilitate the creation and application of knowledge of the Earth's global environment through research, observations, decision support, and communication (CCSP 2003, 2008).

2. High quality science

- "Development of effective policies to abate, mitigate, and cope with global change will rely on greatly improved scientific understanding of global environmental processes and on our ability to distinguish human-induced from natural global change" (PL101-606).
- "[The Strategic Plan] reflects a commitment by its authors to high-quality science, which requires openness to review and criticism by the wider scientific community" (CCSP 2003, p. 1).
- "CCSP remains committed to basic, ongoing research to understand climate processes and the forcing factors that cause changes in climate and related systems" (CCSP "Revised Science Plan" [2008, p. ii]).
- "It is therefore essential for society to be equipped with the best possible knowledge of climate variability and change so that we may exercise responsible stewardship for the environment, lessen the potential for negative climate impacts, and take advantage of opportunities where they exist" (Our Changing Planet [OCP 2008]).

3. Coordination and collaboration

- "Although significant Federal global change research efforts are underway, an effective Federal research program will require efficient interagency coordination, and coordination with the research activities of State, private, and international entities" (PL101-606).
- "CCSP adds value to federal agency efforts in climate change research and related activities by providing a structure and coordination mechanism that leverages individual agency efforts through increased cooperation, collaboration, and the joint development of research priorities" (CCSP 2008, p. ii).

4. Transparency and communication

- "The purpose of the [interagency] Office shall be to disseminate to foreign governments, businesses, and institutions, as well as the citizens of foreign countries, scientific research information available in the United States which would be useful in preventing, mitigating, or adapting to the effects of global change" (PL101-606).
- "CCSP has a major responsibility to communicate with interested partners in the United States and throughout the world, and to learn from these partners on a continuing basis" (CCSP 2003, p. 7).
- "CCSP undertakes the significant responsibility of enhancing the quality of discussion by stressing openness and transparency in its findings and reports" (CCSP 2003, p. 7).

5. Stakeholder participation and support

- "[The Program] shall consult with actual and potential users of the results of the Program to ensure that such results are useful in developing national and international policy responses to global change" (PL101-606).
- "The program will improve approaches for sustained interactions with stakeholders that consider needs for information from a 'user perspective'" (CCSP 2003, p. 7).
- "Programs must respond to needs for scientific information and enhance informed discussion by all relevant stakeholders" (CCSP 2003, p. 8).

in Congress (Pielke 2000a, b). The CCSP has adopted a much wider view of the potential users who should benefit from the results of climate science. The CCSP Strategic Plan and subsequent documentation tend to identify three categories of decisions that the Program will inform: Policy Decisions, Adaptive Management Decisions, and decisions related to the evolution of the science research agenda (see CCSP 2003, p. 112). However, the Program does not describe a plan for delivering useful information to these groups.

What is Useful Information?

CCSP's definition of "useful" is not always clear, but the Program aims to do more than produce information that is merely *relevant* to decision making issues. The Strategic Plan (CCSP 2003, p. 2) defines decision support resources as:

> The set of observations, analyses, interdisciplinary research products, communication mechanisms, and operational services that provide timely and useful information to address questions confronting policymakers, resource managers, and other users.

Consistent with the findings and recommendations of those who have worked in this area (e.g. Cash, Borck, and Patt 2006; Jacobs, Garfin, and Lenart 2005; Meinke et al. 2006), this definition implies a proactive stance, responsive to the needs and limitations of those served by the Program.

In general, ideas about what it takes to produce useful information in scientific research have evolved since the first decade of the Program, when a major focus was the reduction of uncertainty. Many have pointed out that most decisions do not (indeed, they cannot) rely upon the eradication of uncertainty (Pielke 1995); that scientific uncertainty can be a political tool used to win additional funds for science, or to delay a decision indefinitely (Shackley and Wynne 1996); and that a great deal of our uncertainty about the behavior of the climate and related systems is irreducible (Dessai and Hulme 2004). Reduction of uncertainty offers neither a sensible metric by which to judge progress in climate science, nor a reasonable surrogate for the goal of generating useful information (NRC 2005).

Consistent with this view, very few of those I interviewed saw reduction of uncertainty as a crucial goal for climate science. Instead, they described uncertainty as a matter of appropriate characterization, communication, and management. Despite this evolved notion of uncertainty, predictive capability is almost universally viewed as essential to generating useful climate science. As one official said, "how else will you know how high to build the sea wall?" Many take it for granted that deterministic predictive capability should be the main goal of climate science, because they truly believe that this is the kind of information necessary to deal with climate change effectively. In other words, these individuals presume a causal connection between a particular kind of knowledge advance (improved predictions) and the fulfillment of public values.[4]

[4] The questions of where the "prediction imperative" in climate science has come from, and why it is so dominant a force in shaping the research agenda, are important and interesting, but require more space than I have here. Maricle (2011, this issue) discusses these issues in a case study examining hazards research (earthquake and hurricane prediction).

The few program managers and agency officials I interviewed who rejected this mainstream view of prediction did so based on practical experience working with decision makers in various contexts. They described situations in which deterministic predictions were found to be unnecessary in helping communities, resource managers, local governments, and others to increase their resilience or better understand their options in the face of environmental change. These individuals do not view predictive models as totally irrelevant, but neither do they view them as "obligatory passage points" (Latour 1987 cited in Shackley and Wynne 1995) for making climate science useful.

How Is the CCSP Managing Research Agendas to Produce Useful Information?

Many CCSP documents focus on the need for useful information, but usually without any discussion of how specifically the research agenda needs to change in order to support that goal. Both the CCSP and the NRC, in their analyses and recommendations for climate science, tend to ignore the organizational and institutional components of science funding (i.e. the question of *how* to influence the direction of research and the composition of research portfolios). Simply identifying the gaps in knowledge or practice does not explain how to fill them using existing or new structures to advance desired public values.

One exception to this is the example of social science or "human dimensions" research, which is often cited as a crucial but under-represented and under-supported area. The example of human dimensions research and its relative presence in the interagency program over the last two decades illustrates a general inability or unwillingness on the part of CCSP to exert control over the makeup of the climate science portfolio.

In 1990, the NRC called human dimensions the most critically underfunded element of the USGCRP, a sentiment it has repeatedly echoed in the intervening 18 years (c.f. NRC 1990, 1992, 1999, 2001, 2005, 2007, 2009).[5] A 1992 report recommended that annual funding for this area of research be increased to $40–50 million, an amount that would have represented about 4–5% of the overall program at the time. In 2007, the NRC (2007, p. 4) found that "the level of investment ($25 million to $30 million) remains substantially lower than the level of investment in the other research elements, and funding is atomized across many agency programs." This represents about 1.5% of the total budget.

As I discuss in a later section (see "Values in the Structure and Implementation…"), the CCSP does not have a coherent or realistic approach to determining a research portfolio that will fulfill its mandate to develop useful information. Yet, even in cases where a clear need for change has long been asserted by outside evaluators, as in this example of human dimensions research, the CCSP and participating agencies have not implemented change in this direction.

[5] It is worth noting that many of these NRC reports were commissioned by the GCRP or CCSP for the specific purpose of providing guidance on these issues.

Value 2: High Quality Science

The need to maintain a thriving and robust scientific enterprise is emphasized throughout CCSP documentation, as well as by individuals involved with the Program.[6] On its face, such an assertion seems both obvious and uncontroversial: it is, after all, a *science* program. But in the context of interagency climate science a focus on maintaining high quality science is a political act which sends clear signals about the priorities of the Program, and the mental model that informs its behavior.

Sometimes high quality science functions as an instrumental value—a necessary element in achieving Program's underpinning goals and public values. For example, the CCSP Revised Research Plan (2008, p. 10) states that "substantive progress in CCSP Strategic Goals 1 through 3 is a required component of progress in many areas associated with Goals 4 and 5…" (see goals in Table 3). This claim reflects a common but false assumption (discussed further in a later section) that advances in fundamental understanding necessarily *precede* work on applied problems.

In other cases (and sometimes in reaction to such criticisms), high quality research is expressed as an intrinsic public value. Many believe that maintaining capacity in the core areas of research that have contributed to interagency climate science in recent decades is an important goal in and of itself. One program manager linked the fundamental work her scientists are doing to the idea of a "strong America." Another manager felt that shifting to a more applied focus denigrates the enterprise as a whole, making it less attractive to future scholars. Many view science as an independent, curiosity driven activity, in which the research proceeds in a bottom-up fashion. Though these individuals may understand the political or practical necessity striving toward useful information, they view this as a compromise which cuts against the intrinsic value of basic science—against the science values that underpin much of their decision making.

Whether functioning as an intrinsic or instrumental value, high quality science is a political tool. In many instances, a reference to the maintenance of high quality science does not just mean ensuring rigorous research; it implies a commitment to what has come before. It is a signal to those with a vested interest in climate science that there is still a place for them in the evolving program.

Value 3: Coordination and Collaboration

The need to coordinate and collaborate across agencies, programs, and disciplines relates strongly to the idea of an efficient government. It also comports with the notion of the "super discipline" of Earth System Science, which strives to fully integrate human and natural systems to generate comprehensive understanding of global processes (Lovbrand, Stripple, and Wiman 2009). Even without the formal structure of the CCSP, coordination across agencies would be a common occurrence, as indeed it was prior to 1990.

[6] The CCSP does not offer a clear definition of "high quality science," though the examples in Table 1 do give some indication of what the term implies. This trope may function as a subtle, perhaps unconscious acknowledgement of the highly politicized nature of climate change debates, in which authority and expertise are routinely contested based on scientific credentials.

Successful collaboration also emerged as a strongly held value among those I interviewed. When asked to describe a project which they had found personally rewarding, almost every person told a story in which they viewed the building of relationships across boundaries as one of the positive outcomes. Every story had a collaborative component.

Coordination and collaboration represent the biggest source of positive sentiment regarding the CCSP. Most interviewees agreed that CCSP, in convening interagency groups at various levels of government, serves a useful purpose in building a network of climate science managers and encouraging collaboration. Even among those whose general opinions of the CCSP are strongly negative—for example, because it distracts from important scientific work, or is cumbersome and ineffectual—this function of the Program was commonly seen as valuable, and perhaps the sole reason that they continued to participate.

Value 4: Transparency and Communication

As is evident from the examples in Table 1, this value is related to ensuring high quality science, but also functions as a public value instrumental in making science useful and realizing its benefits. These two conceptions emerged in interviews as well. It is widely accepted in the CCSP that making the processes and results of science open and available will enhance the quality of the scientific enterprise. It follows, then, that any research program (or any effort to coordinate and advance research) should strive toward openness and transparency simply as a matter of ensuring the health of the scientific enterprise.

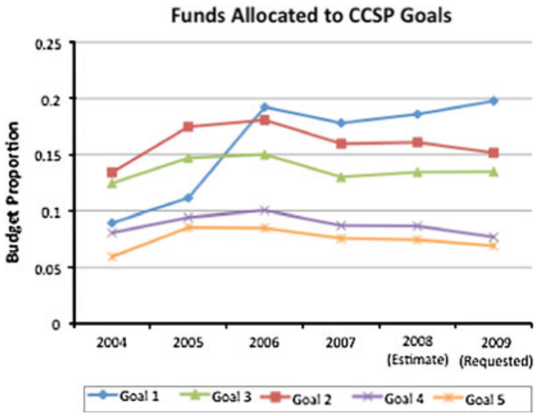
But many also describe openness as an essential part of achieving the broader aims of the CCSP. The 2003 Strategic Plan devotes a chapter to this goal, and the interagency coordination office devotes a considerable amount of time and resources to publicizing and explaining the synthesis and assessment reports it releases. Public events organized by CCSP at scientific meetings and other venues often combine an element of stakeholder feedback with a communications component in which staff explain what CCSP does in the broader landscape of climate science funding agencies.

Reporting progress to Congress is another important part of the communications effort. Almost every year since the passage of the Global Change Research Act the interagency coordinating office has submitted an "Our Changing Planet" (OCP) report to Congress.[7] In general, the document provides research highlights from the previous year, a sampling of plans for the coming year, and budget tables documenting resources allocated to climate science from each participating agency.

The budget tables in OCP demonstrate the ambiguity of the CCSP's role in advancing federal climate science. With no consistency across agency budget reporting, and no direct link between agency activities and CCSP priorities, it is virtually impossible to track changes in climate science over time within the framework of values and priorities established by the CCSP. Beginning with its FY2006 report, the CCSP began to group agency budget allocations under particular

[7] To access these reports, visit http://www.usgcrp.gov/usgcrp/Library/default.htm#ocp.

Figure 2 Research funding allocated to CCSP goals as a proportion of the overall CCSP budget. The goals are listed in Table 3. Note that the overall budget includes both research and observations, which is why the five goals do not add up to 100%



CCSP goals.[8] This affords one snapshot of how the Program has prioritized its funds over the last five years (Figure 2), but the ambiguity of the goals (discussed further below), subverts any attempt to monitor via budgets changes in priorities for US climate science.

Value 5: Stakeholder Participation and Support

The term "stakeholder," along with variants involving communities and users, is one of the most important buzzwords in interagency climate science. These concepts appear in all but one of the 16 chapters in the CCSP Strategic Plan,[9] and are similarly pervasive in the more recent "Revised Research Plan" (CCSP 2008). However, involving stakeholders in the processes associated with research and research policy requires managing, incentivizing, and carrying out research in different ways (e.g. Jacobs, Garfin, and Lenart 2005; Cash and Buizer 2005).

The CCSP is pulled in many different directions with respect to who it is serving, and how it aims to interact with a wide variety of groups, both within the scientific community, and the broader public. Given the Program's limited resources, and limited role in establishing research programs, it is not clear how the CCSP can systematically: (1.) identify appropriate groups that should be involved; (2.) work to understand the decision making needs and other challenges faced by those groups; (3.) reconcile those needs with climate research agenda; and (4.) help to translate research results into usable forms for appropriate groups. Yet, all of these functions are stated or at least implied by the CCSP.

The CCSP lacks the resources for a sustained effort to work with all of the groups of stakeholders that might make use of climate science knowledge. However, as a prominent public face of climate science in the US tasked with meeting the requirements of the GCRA, politically the CCSP must be seen as ensuring that this

8 However, the allocation of research to particular goals was done by the agencies, so the process is "black-boxed" and most likely based on inconsistent decision criteria.

9 The chapter on Observing and Monitoring the Climate System does not mention stakeholders but does mention decision support. It mentions users in reference to the science community.

is happening. One program manager told me, “I don’t think the funding has been adequate in the program for that kind of work, but yet the program has been sold on that.”

Another program manager involved in administering basic science activities conjectured:

> “I would guess that CCSP has not had any successes at any of that – the notion of helping the decision makers and policy people do things. As an organization, it’s just muddied the waters. It has not clarified anything.”

In addition to its derision, the quotation is noteworthy for the subject’s distance and unfamiliarity with such issues. Though he makes science policy decisions in his capacity as a manager, the Program’s success in leveraging that very process to achieve social benefit is of little concern to him. There is wide agreement among those I interviewed and outside evaluators (NRC 2007, p. 3) that the CCSP as an institution, and climate science in general, have not fulfilled this public value.

The scientific community’s role as a stakeholder in agency funding programs further complicates matters. Scientists have traditionally had the loudest voices in the debate over what should be funded and how. As one program manager explained:

> “I think of [scientists] as stakeholders, because if I step back, and look at the way they interact with the CCSP, they have all the characteristics of stakeholders. They’re fully vested. They have needs. They have very strong ideas about where the science needs to go.”

Many of the program managers I interviewed rely on the scientific community to guide them, whether through informal networks of colleagues, scientific advisory boards, peer review panels, or conversations at the many science meetings they attend. This kind of proximity with the scientific community is obviously a crucial element of effective science management. Yet, such interactions tend to reinforce the status quo and work against prioritization based on criteria related to public values other than those internal to the science itself. As one program manager noted, “the scientists, who are CCSP’s traditional major stakeholder group, are watching to make sure that you’re not selling them down the river.”

This dynamic raises questions about whether a manager is working to support a discipline for the sake of itself, or trying to fund the work most likely to support outcomes consistent with the public values of the Program. Undoubtedly the solution to such a conflict would be different for each agency, and in all cases it would involve striking an appropriate balance. However, in the current system, tensions between discipline-driven science and needs-driven science are rarely acknowledged.

Some programs or agencies within the departments that participate in the CCSP, such as Interior, Commerce, Agriculture, Defense, and Transportation, have extensive capacity and experience with decision support in very well-defined communities. These elements of the federal government could themselves be seen as stakeholders for US global change research. They could use the interagency process as a forum to argue for the climate science information needs of their respective stakeholders. But federal programs with decision support capacity (but which do not fund research) are generally absent from the decision making processes of the CCSP, which explicitly involves programs focused on basic science.[10] One program manager noted that, "if the mission is to empower decision makers, then decision making agencies… should definitely be at the table. Some of them are, but they have really small [climate science] budgets."

Public Values Failure in Interagency Climate Science

Having identified and described a set of public values underpinning US climate science, we can now look more closely at the ways in which the system is failing to deliver them. I draw on Bozeman's "public values failure criteria," (2007, p. 16; see also Bozeman and Sarewitz 2011, this issue), as a starting point for diagnosing public values failures. In Table 2, I list public values failure criteria from Bozeman that apply to this case, as well as two additional entries, "Public Values Displacement" and "Inadequate or Inappropriate Institutions," which I have added as a result of the public values inventory described above. The right-hand column in the table gives examples and explanations of how each criterion applies to US climate science. It is important to note that a wide variety of sources (such as program manager perspectives, public law, and budget reports), have contributed to this assessment of public values failure, each providing a different perspective.

Table 2 demonstrates the complexity of the interagency climate science landscape, and the variety of points at which the system lacks the structural and conceptual elements needed to link climate science more concretely to public values. The public value failures listed in Table 2 are not inevitable. Rather the CCSP strategy, framework, and processes *accommodate* them. This identification of public values failures serves as a critique of the general framework linking knowledge production to societal benefit, not a predictive or deterministic account. For example, in applying the "Inadequate Institutions" criterion, we find that managers are not incentivized to pursue CCSP goals within their own programs. However, this does not prevent a dedicated individual from doing so, or from directing his or her staff of program managers to do so. Interagency climate science is a product of both individuals and organizations; of institutional incentives conditioning behavior, and leadership that challenges and reshapes existing rules. The following section explores these dynamics in greater depth.

Values in the Structure and Implementation of US Climate Science

The most recent strategic plan published by the CCSP (CCSP 2003) provides a useful entry point for understanding the way in which assumptions linking

[10] There are a few exceptions to this. NOAA and EPA both have small programs with decision support elements, and those program managers participate in the CCSP. Other departments with decision support capacity (such as Transportation, Interior, and Agriculture) do participate in the CCSP, but through their science programs, rather than their decision support programs.

Table 2 Public Values Failure (PV) Criteria, and Potential Public Values Failures of Interagency Climate Science (adapted from Bozeman 2007)

PV Failure Criterion	Definition	Explanation/Examples of the Potential Failure in Climate Science
Mechanisms for values articulation and aggregation	Political processes and social cohesion should be sufficient to ensure effective communication and processing of public values.	• CCSP criteria for prioritization are too broad and vague to provide real guidance. No connection between science priorities and desired outcomes or public values. • Agency priorities trump interagency (CCSP) priorities. • Stakeholders too widely or ambiguously defined for meaningful, sustained interaction.
Imperfect public information	Similar to the market failure criterion, public values may be thwarted when transparency is insufficient to permit citizens to make informed judgments.	• Budget reporting inconsistent across agencies and generally opaque; detailed information not readily available.
Distribution of benefits	Public commodities and services should, ceteris paribus, be freely and equitably distributed. When "equity goods" have been captured by individuals or groups, "benefit hoarding" occurs in violation of public value.	• Particular kinds of climate science (particularly related to prediction) dominate the budget. Human dimensions research has not grown, despite recognized need.
Provider availability	When there is a legitimated recognition about the necessity of providing scarce goods and services, providers need to be available. When a vital good or service is not provided because of the unavailability of providers or because providers prefer to ignore public value goods, there is a public values failure due to unavailable providers.	• Priorities tend to favor natural science over social science, and science-driven research over needs-oriented research despite recognized need.
**Implausible and/or incomplete value chains	Pursuit of a proximate goal with ambiguous or unrealistic link to public values.	• Managers may assume that supporting the needs of the scientific community will achieve broader public values. • Managers judge program success based on scientific outputs, and not the impact or use of those products. • Five overarching goals of CCSP strategic plan assumed to lead to specified public value, but the link is neither explained, nor backed by an organizational structure that can establish that connection.

Table 2 continued

PV Failure Criterion	Definition	Explanation/Examples of the Potential Failure in Climate Science
**Inadequate or Inappropriate Institutions	The structure or culture of an institution disincentivizes the achievement of its motivating public values.	• Inadequate resources for decision support and communications (approaches 3 and 4). • Incentive structures built into science management emphasize science values. • Managers not incentivized to work toward interagency goals in building their programs.

Criteria marked with ** have been added as a result of this case study

knowledge advance to public values can influence the decision making and overall structure of US climate science policy. Table 3 lists the main elements included in the Strategic Plan. Its basic structure prescribes four different "approaches" to be used in pursuit of five goals, which ostensibly support the mission and vision of the program, evincing the following structure:

$$\text{approaches} \rightarrow \text{goals} \rightarrow \text{mission} \rightarrow \text{vision}$$

But the Plan does *not* describe how achievement of the goals (which all relate to advancement of knowledge) would actually support the mission and vision (which relate to the beneficial use of knowledge). Indeed each of the links in the structure is implicit, and taken for granted.

The two elements of the Plan that indicate something beyond supporting research and expanding knowledge are the third and fourth "approaches": Decision Support, and Communications. Decision support and communications, in turn, may be crucial to the mission and vision of CCSP, but they are not necessary for achieving the five over-arching goals of the Strategic Plan, which are research goals. Many involved with CCSP view goals one, two, and three as pertaining to "basic science" activities, with goals four and five constituting the more applied, or "decision support" work. But in reality, all five of the goals are flexible and overlapping, and all are concerned with expanding knowledge, not with developing capacity to apply it.[11] Thus, efforts to achieve identified goals (i.e. via research) can ignore completely the broader values that motivate global change research (i.e. supporting decision making to reduce negative social outcomes), even as they are consistent with the logic expressed in the Plan.

Another important element of the Plan is its list of "Criteria for Prioritization" (CCSP 2003, p. 8): scientific or technical quality; relevance to reducing uncertainties and improving decision support tools in priority areas; track record of consistently good past performance and identified metrics for evaluating future progress; and cost and value. It would be difficult for any single research effort to

[11] There is an important distinction to be made here: research on how to apply climate science effectively, though quite necessary, does not in and of itself generate sustained capacity in that regard.

Table 3 Major components of the CCSP Strategic Plan (2003)

Vision

A nation and the global community, empowered with the science based knowledge to manage the risks and opportunities of change in the climate and related environmental systems.

Mission

Facilitate the creation and application of knowledge of the Earth's global environment through *research*, *observations*, *decision support*, and *communication*.

Approaches	Goals	Research Areas
1. Scientific *Research*: Plan, sponsor, and conduct research on changes in climate and related systems. 2. *Observations*: Enhance observations and data management systems to generate a comprehensive set of variables needed for climate-related research. 3. *Decision Support*: Develop improved science-based resources to aid in decision making. 4. *Communications*: Communicate results to domestic and international scientific stakeholders, stressing openness and transparency.	1. Improve knowledge of the Earth's past and present climate and environment, including its natural variability and improve understanding of the causes of observed variability and change. 2. Improve quantification of the forces bringing about changes in the Earth's climate and related systems. 3. Reduce uncertainty in projections of how the Earth's climate and related systems may change in the future. 4. Understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes. 5. Explore the uses and identify the limits of evolving knowledge to manage risks and opportunities related to climate variability and change.	Atmospheric Composition Climate Variability and Change Water Cycle Land-Use/Land-Cover Change Carbon Cycle Ecosystems Human Contributions and Responses to Environmental Change

satisfy all of these criteria, but the list is broad enough that anything currently underway at participating agencies will probably satisfy at least one or two. Thus, instead of providing concrete direction for those wishing to make funding decisions with CCSP priorities in mind, the Plan offers complete flexibility within the normal limits of science funding.

The Strategic Plan designates "Interagency Working Groups" (IWGs) in key research areas, with members drawn from across participating federal agencies. As program managers with budget authority within their own agencies,[12] IWG members are in an ideal position to translate the goals of interagency climate science into requests for proposals, funding decisions, and the general management of climate science.

[12] The Strategic Plan specifies that IWG participants should have budget authority within their own agencies. In practice this is not always the case. One IWG co-chair complained to me that he was the only person in the group with budget authority, making it quite difficult from them to implement new priorities, even if they wanted to.

However, the circularity of this arrangement (specifying priorities that they themselves will carry out and subsequently report on) combined with a lack of authority and resources on the part of the CCSP, leaves little incentive for program managers to initiate anything beyond, or at odds with, the expectations of their home agencies. Thus, if asked to specify a priority relevant to CCSP goals for the coming year, the easiest answer for an IWG member would be whatever he or she had planned to fund anyway.

As one program manager put it:

> "We get asked every year how much money are we spending on ________, so, I'll come back and say, well, do you want a large number or small? Because I can go through my proposals and there's some of them that have some relevance … so do you want me to say "half of that's _______ money?" If you want me to, sure, fine, I don't care. If you want to say 'none of it,' that's ok, too" (blanks inserted to preserve anonymity).

This account highlights structural issues and incentives that tend to discourage interagency climate science from moving in new directions, creating considerable inertia in the research portfolio.

Observers and participants in the CCSP, including the NRC on multiple occasions (2005, 2007, 2009), and many of the people I interviewed, have pointed out that the interagency process has very little authority when it comes to influencing the research agenda for climate science. In that sense, it promises more than it can deliver (as the example of budgets for human dimensions research demonstrates). Even so, it is not at all clear what the CCSP is *trying* to deliver. In other words, the CCSP has not offered a clear account of what kinds of scientific advance would help to satisfy the public values that motivate the program to begin with. Under the current structure, any good science is good enough. This logic works because of the influence of intrinsic values related to the conduct of science itself, what I term "science values."

Science Values and Public Values

Whereas other cases have revealed the pitfalls of the "profit as progress" assumption (see Bozeman 2007; other articles in this issue), the systemic problems in US climate science stem from an equally problematic "knowledge as progress" assumption. Indeed, much of science policy is based on this rationale analogous to, but entirely separate from, the market failure model.[13] In this section, I describe a "science values" framework, which often motivates science policies and their implementation, and which helps to explain the public values failures described above. I then show how science values have led to the current structure of interagency climate science.

[13] Richard Nelson's (1959) account of basic science as a public good may describe an economic incentive for basic research investments in a general sense, but specific decisions to invest in, for example, biology, geology, or sociology may have a variety of drivers far removed from the logic of market failure.

The Linear Model

The "linear model of science" (Pielke and Byerly 1998) is a simplistic conception of scientific and technical advance that nonetheless remains an influential driver of science policy. According to the linear model, innovation happens in the following way: *basic* or fundamental research contributes to a general pool of knowledge; that pool of knowledge provides a resource for engineers or other innovators, who then *apply* it to create products that increase productivity, drive economic growth, enhance military power, and otherwise enrich lives and benefit society. This model assumes that advances in knowledge are by and large beneficial to society, and that the benefits are both automatic and unpredictable. It also assumes a unidirectional flow of knowledge that privileges basic research above applied as the originator of all scientific benefit (Stokes 1997).

Sarewitz (1996, p. 10) documents the implications of the linear model in a description of the myths that form a basis for science policy in the US, the first three of which are particularly relevant here:

1. The myth of infinite benefit: More science and more technology will lead to more public good.
2. The myth of unfettered research: Any scientifically reasonable line of research into fundamental natural processes is as likely to yield societal benefit as any other.
3. The myth of accountability: Peer review, reproducibility of results, and other controls on the quality of scientific research embody the principal ethical responsibilities of the research system.

These assumptions about the nature of scientific progress have shaped, over many decades, what Shackley and Wynne (1995, p. 113) call "the tacit commitments and assumptions which underpin a prevailing common culture of science and policy."

The most important elements of the linear model as it relates to the fulfillment of public values are the assumptions of automatic benefit and unpredictability. Taken together, the three myths suggest that more basic research is an unquestionably, if unpredictably, good thing. Few would deny that public investments in basic science have the potential to bring great benefit to society, often in unpredictable ways. However, these assumptions–when driving policy decisions–can compromise public values. For example, the unpredictability of outcomes renders nonsensical any attempt at reasoned choice among scientific activities. As Michael Polanyi (1962, p. 62) wrote, "you can kill or mutilate the advance of science, you cannot shape it," and the sentiment remains strong to this day. It emerges, for example, in outrage over attempts to limit certain areas of science (e.g. stem cell research).

But the history of government-driven innovation in the US shows that we can make sensible decisions about research investments in order to address particular problems. We would not, for example, fund seismologists in the hope that their work might one day lead to an AIDS vaccine, and it is not only reasonable to expect that we might make even finer grained choices with some success (see Kitcher 2003; Toulmin 1964), but historically clear that this has been the case (e.g. Greenberg 1967; Kevles 1977; Brooks 1995). Furthermore, reasoned attempts to direct research toward the solution of particular problems compromise neither the quality of research, nor its potential to yield unexpected breakthroughs.

Debate over how science should be funded, governed, and evaluated has a long history in the US (c.f. Guston 1994; Greenberg 2001; Toulmin 1964; Polanyi 1962; Jasanoff 1990) and continues to spark controversy as issues such as stem cell research, climate change, and nanotechnology capture the public eye. The appropriate technology movement (e.g. Winner 1986), the rise of the Congressional Office of Technology Assessment (Bimber 1996), passage of the Government Performance and Results Act (GPRA) (e.g. Cozzens 1995), and calls by President George W. Bush's Science Advisor for a new research program on the Science of Science and Innovation Policy (Marburger 2005) are all examples of a trend toward increased expectations of accountability in science since the 1970s (Cozzens 1999; Guston 2000).

Beyond the problem of choosing among potential lines of research, the linear model also creates problems for the assessment of that choice. If the benefits of science are at once automatic yet unpredictable, then public investments in science need not be evaluated beyond the general expectation that they meet the requirements of "good" science in the sense of academic rigor and allegiance to the ideals of objectivity and independence. This syllogism raises a crucial concern regarding science and public values: under the linear model, it is not *economic* productivity that serves as a surrogate for social benefit, but *scientific* productivity. In other words, knowledge equals progress.

There are two problems with this logical step. First, it is obvious that not all advances in knowledge are inherently good (Kitcher 2003). Indeed, judging the "goodness" of knowledge is impossible without consideration of the use of that knowledge—its function in a broader context (Bozeman and Rogers 2002). Second, if we accept the advancement of knowledge as an index to progress, then a complex *social* problem with many political and social facets, such as climate change or disease, is easily reduced to a *science funding* problem, wherein the solution is simply to fund more research, with little concern for the broader social context (Sarewitz 2004; Sarewitz et al. 2004). Put differently, linear model thinking ignores the fact that, even if a particular advance in knowledge can be said to be "good," beneficial use of that knowledge is not guaranteed.

The linear model and its accompanying science policy myths add context to claims by mainstream institutions such as the NRC that US climate science has greatly advanced knowledge while failing to achieve its broader purpose. Yet, it also helps clarify why appropriate solutions are rarely articulated or adopted. These very institutions exist to embody and protect science values as *intrinsic* public values. Figure 3 illustrates this problem by replacing the "market" axis of the grid in Figure 1 with an axis representing "science values." The right side of this axis indicates a decision making environment in which "knowledge advance" is taken as a reasonable and appropriate equivalent for public values. The left side indicates an approach to science policy that acknowledges the contingent and contextual aspects of scientific advance.

As with market values in Figure 1, the key point of Figure 3 is that science values may or may not be consistent with the public values that motivate a policy or

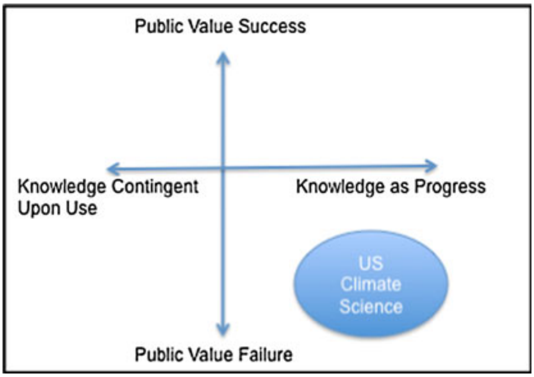


Figure 3 Climate science in the context of public values and science values

program. The outcome depends a great deal upon how different values are prioritized, and on how institutions and individuals contribute to the implementation of science policies. Examining how different sets of values impact policy implementation helps to reveal why public values failures occur.

Recommendations

There is no simple hierarchy of values within US climate science, and the relationships among values are complex, but the preceding analysis leads to two general observations. First, although decision making based on science values often seems to subvert public values, there are also many points of compatibility. Public values 3 and 4 (coordination and collaboration; transparency and communication) are also important *science* values. And high quality science (value 2) is necessary (though not sufficient) for developing useful information. Moreover, given the logical incoherence of the CCSP structure itself, there can be no way to connect the program's public values to its organization. In other words, CCSP reflects incoherence both in its organizing structure and in the relations among its public values. More careful thinking about how the program's public values can relate to one another could provide a valuable framework for reconsidering program structure.

The role of high quality science leads to the second point about value chains and public failures: high quality science and useful information are compatible as values; it is the flexibility and ambiguity of their relationship that leads to public values failure. When functioning as an intrinsic value, high quality science reinforces the linear model and subverts public values because advancement of knowledge serves as an end, rather than a means (i.e. an instrumental value). The interagency program should adopt language and institutional processes promoting high quality science that *also* contributes useful information. Without a structure that clearly identifies high quality science as a necessary (though not sufficient) step in generating useful information, potential for public values failure will remain.

Strengthening and clarifying value chains is a matter of individual leadership, and institutional change. As long as program managers continue to view the public failures of CCSP as unrelated to their own work (as in a quotation offered previously), they may continue to operate under linear model assumptions, and on-the-ground implementation of science policies will remain divorced from public values. Any changes in this direction are likely to result from leadership at multiple levels, both within science agencies, and in those parts of government charged with oversight of the interagency program (e.g. Congress, the interagency coordination office, and the President's Office of Science and Technology Policy).

The ambiguity and weakness of CCSP's value chains contribute to public values failure, but they are an advantage to the organization in other ways. To survive politically, CCSP needs to be able to show progress over time, despite a lack of control over the activities it must report on. Put in this light, the Program's goals (see Table 3) are quite convenient. They are a general prediction of what the collective agencies will accomplish over time as they pursue *science values*, rather than a reflection of what needs to be done to achieve *public value*s. The CCSP should pursue public values by setting goals for *science policy* (e.g. measures such as budget allocation, breadth and depth of decision support activities, or the generation of useful information), rather than goals for science. However, given CCSP's limited authority and resources, such goals might be unachievable, and thus politically untenable. Seen in this light, public values serve the Program as political cover, rather than as a firm basis for guiding both policy and practice.

It is not clear that the US currently has the institutional capacity to achieve the public values promised from climate science. Probably no one knows exactly how an effective program should be structured. However, it is fairly clear that the current system has proven inadequate in several important ways. This failure can be attributed, in large part, to the prevailing assumption that "knowledge equals progress"—that any advance in understanding justifies the initial investment of research dollars. This is analogous to other public values analyses which trace the implications of the assumption, "economic growth (or efficiency) equals social progress." Both cases may lead to or mask public failure.

To enhance the achievement of public values, the CCSP and its successors need to reject science values assumptions and instead ask what *kinds* of knowledge would lead to desired progress toward public values? What kinds of institutions are needed to facilitate that progress? CCSP must strengthen its value chains and make them more explicit. Even more crucially, it should differentiate its own priorities from those of participating agencies, and draw a distinction between goals that merely support science, and goals that *connect* science to public values.

In its 2003 Strategic Plan (see Table 3), the Program tried to fit the whole of US climate science into a single, unified framework, which resulted in an incoherent internal logic. Instead, the CCSP should identify the concrete areas of climate science in which it can make progress toward its own public values-based goals, and focus on those. This would mean thinking small. For example, CCSP could set a goal of incentivizing and supporting program managers who fund research that responds to stakeholder needs. This might mean providing additional funding for programs that qualify; convening workshops in which managers learn about ways of incorporating public values into their program solicitations, evaluations of proposals and progress reports; and lobbying agencies and the Office of Management and Budget to give additional recognition to such programs in the course of assessment and evaluation. This would not amount to a complete overhaul of the climate science enterprise, but it could have a visible impact in an important, but neglected area, and create conditions for further evolution away from science policy based on the linear model.

The CCSP might take on the role of a boundary organization specializing in communicating between normally disparate policy and disciplinary worlds (e.g. Guston 2001), with a goal of strengthening the connections between science programs and regulatory or service programs that have particular information needs. With this approach, the CCSP could begin with federal agencies and programs that already have representation in various CCSP committees, such as the Environmental Protection Agency, the Department of Transportation, or the Forest Service, and work to ensure that the relevant *research* programs become more responsive to their needs. Such an effort, if successful, could grow to include state and local groups as well.

Either one of the two suggestions above would allow incremental progress in addressing some of the public value failures of US climate science over the last two decades. A key aspect of both examples is an approach grounded in public values—and the relations among such values—as a basis for planning, action, and assessment. At present, such values tend to serve simply as political cover for business as usual.

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