CSPO Report # 10-04

CONSORTIUM FOR SCIENCE, POLICY & OUTCOMES
AT ARIZONA STATE UNIVERSITY

Advancing the Science of Science and Innovation Policy

Testimony before the U.S. House of Representatives
Committee on Science and Technology
Subcommittee on Research and Science Education

Daniel Sarewitz, PhD
Professor of Science and Society, School of Life Sciences at Arizona State University
Co-Director, Consortium for Science, Policy and Outcomes at ASU

September 23, 2010

Abstract

With shrinking discretionary budgets, vibrant global economic competitors, and a daunting array of challenges to our well-being, the nation needs effective tools for making better decisions about how to design, assess and set priorities for our science and innovation enterprise. With a modest budget and small staff, SciSIP is working to mobilize a diffuse community of researchers to focus on the complex problem of wringing the most out of our public investment in science and innovation. Outputs are not outcomes, and SciSIP must focus on outcomes. Outputs are immediate products of R&D, like publications, patents, and PhDs. Outcomes are what most people care about, and they include not just economic growth, but also secure and affordable food and energy supplies, high quality public health, a clean environment, expanding job opportunities, and a strong national defense. Research on outcomes-based science and innovation policies, and the *use* of such research by decision makers, should not be treated as separate processes. NSF's great strength in supporting bottom-up inquiry on fundamental problems is also a weakness when there is an urgent need for new knowledge. First, NSF could sponsor one or more large centers for SciSIP research, education and outreach, with a core requirement to build strong and ongoing collaborations between researchers and science policy decision makers. Second, NSF could work with mission-oriented R&D agencies to integrate SciSIP activities into a range of existing, outcome-oriented programs. Third, NSF could require *all* of its center-scale awardees to be designed from the outset to include integrated SciSIP components. Through such approaches, SciSIP could enhance its capacity to generate usable knowledge for the near- to medium-term, and help accelerate a convergence between science and innovation policy research, and policy decisions across a range of R&D outcome priorities.

Mr. Chairman, Members of the Committee, thank you for inviting me to testify today. My name is Daniel Sarewitz, and I am co-founder and co-director of the Consortium for Science, Policy and Outcomes at Arizona State University, as well as Professor of Science and Society at ASU. My formal training was in geosciences, but for more than 20 years I have worked in science and technology policy, first as a AAAS Congressional Science Fellow and then a staffer on this Committee, working for Chairman George E. Brown, Jr., and more recently as an academic, at Columbia University and now at ASU. So I'm very pleased to return to the place that launched me on a new and incredibly interesting and exciting career path and intellectual journey, and honored that you have asked for my input to the Committee's deliberations on the status of the science of science and innovation policy.

Introduction: Input-Output Science and Innovation Policy

Most people agree that government support of research and development is an essential foundation of today's complex, knowledge-based, high technology society. Yet the problem of how to make the most out of the nation's investment in R&D remains amazingly poorly understood. This problem has been actively debated in Congress since World War II. In the interim the annual public investment in R&D has grown from a few tens of millions of dollars to about 140 billion dollars. Yet, throughout this period of remarkable growth—and, I should say, remarkable bipartisan support for such growth, exemplified by this Committee—the basic principles, terms of debate, and policy tools for guiding investment and measuring its effects have changed remarkably little.

For more than sixty years, the core of science policy has been the belief that more money for R&D translates into more benefits for the nation. Science policy has, above all else, been science budget policy. The capacity of the nation to solve problems related to science and technology has been measured by the incremental growth of the R&D budget. The idea that the size of the R&D budget is a measure of the social value of science and technology remains the bedrock of science policy.

Three other powerful beliefs have dominated science policy decision making. The first is that research becomes valuable for society as part of a linear progression starting with basic discovery and leading to application, either in the form of technological innovation, or information to inform decision making. The second, related belief is that there is a clear distinction between research activities aimed at creating new knowledge, and research aimed at applying that knowledge to solving problems. The third belief is that scientific excellence, as defined and assessed by scientists themselves, typically through the peer review process, is the best measure of the potential value of science for society.

The result of these beliefs has been a national R&D enterprise that is largely understood and discussed in terms of simple inputs—how much money is being spent on which type of science?—and simple outputs—how much scientific knowledge is being produced? That this simple input-output way of understanding science and technology policy led to the world's largest and most productive R&D enterprise is, however, much more of a happy historical accident than an endorsement of this way of looking at R&D policy.

Coming out of World War II, the U.S. simply had no serious scientific or economic competitors, so we had a huge head start that only began to be seriously eroded in the 1980s. Moreover, the U.S. R&D enterprise as a whole was—and still is—so much bigger than that of any other nation that simply as a function of scale it could—and still does—outperform everyone else. An additional crucial point is that by far the dominant player in translating the public R&D investment into tangible societal outcomes was the Department of Defense. The core of DOD's approach was the cultivation of very powerful linkages between high-tech private sector firms, research universities, and the DoD itself, an arrangement that was responsible for creating most of the important technological systems that undergird our society and our economy today.

I present this thumbnail sketch to explain how we have arrived at the situation in which we find ourselves today. The limits of the post-War input-output approach, as I have said, became increasingly clear starting in the 1980s, with the rise of serious economic and technological competitors, especially in east Asia; with the end of the Cold War, and the decline of DoD's catalytic role in civilian technological innovation; and with the increasing awareness of an array of social challenges that seemed to demand scientific and technological solutions—from cancer and emerging infectious diseases to energy security and environmental quality. Yet if one looks at the endless series of reports over the past decades sounding the alarm bells about the nation's science and technology enterprise, one finds the problem still discussed predominantly in terms of the same old input-output measures: how much are we spending, how many scientists are we producing, how many publications or patents are issued, and how do these input-output numbers compare to our economic competitors?

The problem with the input-output model is that it can't tell us very much about what actually matters: how the size, organization, and productivity of the R&D enterprise itself relates to the achievement of the societal outcomes that we desire and expect. Because pretty much everyone assumed that these outcomes flowed automatically from the R&D enterprise, as long as it was big and scientifically productive, there seemed to be no reason to worry about how the enterprise worked. These assumptions put a damper on research, as well as debate, about the complex relations between scientific advance, technological innovation, and the well-being of society. Why try to understand these issues if the only thing that really mattered was the size of the budget?

But in an era of constrained resources and mounting challenges to our well-being, the limits of the input-output approach have become impossible to ignore. We cannot ignore them because we need to make difficult choices about how to allocate scarce resources. We also cannot ignore them because we are faced with strong prima fascia evidence that the input-output approach is leading to significant science and innovation policy failures. For example, the National Institutes of Health's forty year War on Cancer has yielded remarkable new scientific knowledge, yet remarkably modest public health benefits for the tens of billions spent. The devastation of New Orleans by Hurricane Katrina occurred despite the existence of comprehensive scientific knowledge about the inevitability and precise consequences of such an event. Thirty years of energy R&D has left the nation no less vulnerable to energy-based security, economic, and environmental threats than it was when the Department of Energy was created. These are not input-output problems, but they are science and innovation policy problems.

In 1992, this Committee issued a brief "Chairman's Report" entitled the "Report of the Task Force on the Health of Research," which pointed at the need to re-think basic assumptions about science and innovation policy. (As a Committee staffer at the time, I was privileged to be one of the members of that Task Force.) While there certainly were, at that time, small pockets of academic scholarship on the links between science policy and societal outcomes, and while some federal S&T programs had of course had great success in achieving the outcomes that the public expected from them, the fact is that there existed in the United States at the end of the 20th century an extraordinarily modest capacity to develop knowledge, tools, and human resources that would allow the nation to improve its capacity to turn progress in S&T into progress toward desired societal outcomes.

A turning point in achieving high level attention and action came in 2005, when President Bush's science advisor, John Marburger, speaking at the Science and Technology Policy Colloquium of the American Association for the Advancement of Science, declared that "The nascent field of the social science of science policy needs to grow up, and quickly." His point was that the nation could no longer afford to set policy for one of it's most important areas of public investment on the basis of simplistic ideas that had arisen in a very different world, half-a-century ago. The National Science Foundation responded to the urgency of Dr. Marburger's call by creating the Science of Science and Innovation Policy (SciSIP) program.

<u>Committee Question 1. (A) Please provide an overview of the research activities of the Consortium for Science, Policy, and Outcomes. (B) How are you facilitating interdisciplinary collaborations within the Consortium? (C) What new and continuing areas of research in the science of science and innovation policy (SciSIP) could significantly improve our ability to design effective programs and better target federal research investments? (D) What are the most promising research opportunities and what are the biggest research gaps?</u>

Background to CSPO:

The Consortium for Science, Policy, and Outcomes (CSPO) was conceived in 1997 during discussions between myself and Michael M. Crow, who was then Executive Vice Provost at Columbia University, and formally launched in 1999. The decision to create CSPO was made for much the same reasons that SciSIP was created: despite the overwhelming importance of science and technology in our society, policy makers and scholars almost completely lacked the knowledge and tools necessary to make informed and effective decisions. CSPO was founded as one small effort to begin to reverse this lack of capacity.

When Michael Crow became President of Arizona State University he asked me to move to ASU as well, and gave me the opportunity to help transform CSPO from a small research and policy center to a broader consortium with expanded ambition and reach. Today this consortium operates at three organizational levels: First, there is a core group of fifty or so faculty, researchers, students, and staff who work directly in CSPO, mostly in Arizona but with several of us located here in Washington, DC. Second, there is a significantly expanded group of collaborators throughout ASU as a whole, ranging from many of the university's top scientists and engineers, to faculty and students in ASU's programs on public policy, law, business, architecture and design, communications, journalism and even the arts. Third, we have deep and persistent collaborations with researchers and students at other universities in the U.S. and around the world. Virtually all of our major research thrusts are carried out in collaboration with individuals or groups at other universities, and CSPO hosts an continual stream of visiting scholars and students, many from foreign universities and research institutions, for periods of up to two years.

In briefly describing CSPO's major research activities, I want to emphasize a point that should be obvious but is often lost in discussions of the Science of Science and Innovation Policy. Public support for science and innovation is justified for a wide range of reasons, many of which are non-economic. For example, we count on science to provide a safe, abundant, and tasty food supply for a growing population; ensure the protection of our natural environment and the provision of reliable and affordable energy; protect and improve our health; help ensure national security; and create new and challenging work opportunities. The reason I belabor this obvious point is that in fact we are particularly empty-handed when it comes to understanding how best to design and assess S&T policies aimed at advancing these non-economic outcomes. This is the arena where CSPO focuses most of its efforts.

CSPO is engaged in a wide range of research activities that seek to advance knowledge, real-world practice, and human resources in this broad domain of science and innovation policy for social outcomes.

And I want to gratefully acknowledge the National Science Foundation's generosity in providing peer-reviewed grant support for many of our most important and I would say high-risk, high-pay-off ideas, through a variety of its programs, including SciSIP.

At the core of all of our research is a commitment to looking at S&T activities as part of larger social systems. Trying to understand and assess the outcomes of science and innovation by studying and measuring research and development activities alone is like analyzing a family's home life by studying lumber mills and brick kilns. What makes a given line of research valuable for society? Of course the science itself must be of high quality, just like a fine home needs to be constructed of quality materials. But for investments in science and innovation to support desired social outcomes, many other elements will come into play: the ways that scientists choose projects; the culture and organization of research institutions; public-private interactions; economic incentives and regulatory structures; public preferences and behavioral norms—all this and more make up the process by which knowledge, innovation, and social benefit are connected.

<u>1. (A) Please provide an overview of the research activities of the Consortium for Science, Policy, and Outcomes.</u>

With this background, let me outline some of our efforts, in four areas of direct relevance to the science of science and innovation policy.

(1) CSPO's flagship research program is our Center for Nanotechnology in Society (CNS), an NSF Nano-scale Science and Engineering Center which has just been renewed for a second and final five-year grant period, under the directorship of CSPO co-director Professor David Guston. CNS takes a systems view of technological innovation to ask: what are the factors that may influence whether an emerging domain of technology, in this case nanotechnology, is able to move toward areas of social need and desired outcomes? CNS involves multiple universities and researchers from multiple disciplines bringing numerous specialties to bear on what we call "real-time technology assessment," or a capacity to understand linkages between new knowledge, emerging innovations, and societal outcomes—as they are unfolding.

Among the many specific research activities encompassed by CNS are relatively traditional tools for assessing scientific productivity such as citation and patent analysis, as well as proven methods for tracking public opinions and preferences. But we also bring social scientists together with nanoscale scientists and engineers to reflect on the choices available to them for advancing nanotechnology, and to develop and discuss future scenarios of nanotechnology-enabled society. We cultivate ongoing discussions with the public about potential benefits, problems, and dilemmas of nanotechnology. We bring graduate students working on nanotechnology into discussions of science policy and social outcomes. We work with science and technology museums to create programs and exhibits that go beyond technical explanations to help people understand the ways that nanotechnology and society influence each other.

In total, what we are trying to create with CNS is a test-bed for developing a more holistic understanding of science, innovation, and social outcomes, where the choices made about science, innovation, and their application in society are brought out in the open and discussed even at the earliest stages of the innovation process, to bring into better alignment the directions of science and innovation, and the aspirations and needs of society. I also hope it is clear from this brief description that standard categories of "basic research," "applied research," "education," and "outreach" are not pursued separately, but are part of an integrated approach at CNS.

I want to emphasize three elements of U.S. science policy that made this research program possible. First was the explicit desire of this Committee and the Congress in general, as expressed in the 21st Century Nanotechnology Research and Development Act of 2003, to ensure that nanotechnology advanced along with a capacity to understand unfolding social implications. Second was the complementary recognition by the National Nanotechnology Initiative, under Mihail Roco's early leadership, and the National Science Foundation, that understanding the social aspects of nanotechnology should be an important aspect of the overall nanotech research agenda. And third was ASU itself, a university that has made huge strides in reducing the barriers to true interdisciplinary collaboration, and that is simultaneously committed to connecting the work of its faculty and students to the needs of society.

(2) A second project I want to mention is Science Policy Assessment and Research on Climate (SPARC), funded through NSF's Decision Making Under Uncertainty program. SPARC is a collaboration with the Center for Science and Technology Policy Research at the University of Colorado, and we are finishing the project up after a five-year funding period. SPARC explores a question that lies at the heart of science and innovation policy: what makes the results of a scientific research project useful, and usable? While the broad context for this project was the nation's considerable investment in research related to climate, our research looked at science policy decision making aimed at many different problems, including water management, weather and natural hazards, nanotechnology, technological standards, agriculture, and ecology.

SPARC results reinforce a major point: science policies tend to be more successful when they are carried out through institutional arrangements that allow scientists and decision makers to understand each other's needs and capabilities. Fostering close, ongoing, trusting relations between those who produce new knowledge and those who might benefit from it seems to be an essential attribute of science policies that lead to new knowledge quickly moving into society for public benefit. Drawing on the lessons of this major project, we produced a short handbook for science policy decision makers, called "Usable Science." We released this report last April at a meeting here in DC that attracted about 100 participants, many from federal agencies. The handbook is available at: http://cstpr.colorado.edu/sparc/outreach/sparc_handbook/ .

(3) A third project, called Public Value Mapping, or PVM, has been supported by the SciSIP program, as well as the V. Kann Rasmussen Foundation and the Rockefeller Foundation. The idea behind PVM draws on my previous point that most publicly funded S&T activities aim to advance a variety of social outcomes, not just economic ones. PVM finds that these desired social outcomes—what we call "public values"—are clearly expressed at many levels across the science and innovation policy endeavor—in legislation and laws; in the strategic plans and budget documents of R&D agencies; in the websites and press releases of individual R&D programs and even projects.

Because public values are harder to characterize, measure, and assess than economic values, they are often given short shrift both in debates about science and innovation policies, and in research to evaluate the outcomes of such policies. Yet a key concept for PVM is that the public values associated with science and innovation policies may conflict with one another, and with economic values. For example, a new medical technology may create profit for a corporation and benefit from those who have access to the technology, even as it contributes to health care outcome disparities and over-diagnosis and unnecessary treatment. PVM seeks to unravel and clarify such complexities, in order to help view and assess the full range of social outcomes tied to science and innovation policies.

In brief, our research aims first to identify public values across a particular area of science and innovation policy. We then analyze how various value statements actually relate to each other (for example, are they complementary or contradictory?) and assess whether the research activities are in fact organized in ways that may allow them to achieve those values. Our work is still preliminary. During three years of NSF-supported research, we have completed a set of detailed case studies, looking at S&T policy issues such as technology transfer, nanotechnology for cancer treatment, and environmental chemistry. One intriguing, but still quite preliminary, result of our work is that we think we can say something about the potential for a major research program to achieve desired social outcomes based in part on how public values are articulated across the program's various levels and components. For example, our study of natural hazards research at the U.S. Geological Survey shows a strong coherence among public values expressed by scientists, the agency, legislative mandates, and various stakeholders, whereas our analysis of Federal climate change research shows considerable diversity and even conflict among values within and across these various levels of activity. We are now working to test the hypothesis that the relations among public values may in fact be predictive of a program's performance. If this turns out to hold up after further research, it could offer a powerful tool for assessing the capabilities of science and innovation policies.

(4) As one final example, I want to mention CSPO's growing work on energy technology innovation. This is a cross-cutting theme that works its way into a number of our research projects, but I think it helps to communicate our overall approach. Consider, for example, solar energy technologies, which may have particular potential to serve energy needs in a desert state like Arizona. Yet to understand the potential for solar energy R&D to contribute to Arizona energy needs, one also needs to understand issues of regulatory incentive, land use, water access and availability, public lands management, agricultural policies, transmission corridors, military bases, Indian reservations, even immigration. Each of these variables may play a crucial role in determining the outcomes of solar energy science and innovation policies—and policies that do not attend to these variables run the risk of failing to achieve their desired social outcomes, regardless of levels of funding or scientific productivity.

<u>1. (B) How are you facilitating interdisciplinary collaborations within the Consortium?</u>

CSPO facilitates interdisciplinary collaboration in three main ways. First, we organize our activities around problems, not around disciplines, and then we bring into our research teams the expertise that we need to help us understand what's going on and how to make progress.

Second, as an administrative matter, CSPO is located in ASU's College of Liberal Arts and Sciences, so it does not have a disciplinary affiliation. Our core faculty members have advanced degrees in fields ranging from earth sciences and electrical engineering to political science and philosophy. Core faculty are jointly appointed between CSPO and a variety of academic units, including the Schools of Life Sciences; Government, Politics, and Global Studies; Human Evolution and Social Change; Geographical Sciences and Urban Planning; Sustainability; Communications; and Social Transformation. If these don't sound like familiar names for traditional academic disciplines, that's because ASU itself has moved to reorganize standard departments into interdisciplinary units in order to bring appropriate intellectual force to bear on complex problems.

Third, we have worked hard to cultivate long-term collaborations with natural scientists and engineers across the university, many of whom are affiliate faculty members at CSPO. We work with these colleagues to design new educational and research projects and programs that return value both to CSPO and to our science and engineering partners. These activities create familiarity and trust that allow us to engage in higher-stakes collaborations. For example, many of the major science-and-engineering grant proposals submitted by ASU to funding agencies now include an integrated set of activities aimed at understanding and enhancing societal outcomes. We have even been funded by NSF, partly with the support of the SciSIP program, to study the impacts of natural science-social science collaborations in labs at ASU and around the world.

1. (C) What new and continuing areas of research in the science of science and innovation policy (SciSIP) could significantly improve our ability to design effective programs and better target federal research investments? (D) What are the most promising research opportunities and what are the biggest research gaps?

CSPO faculty members have been brainstorming over the past few weeks to develop a short list of “foundational/transformative” research challenges in response to a call for ideas issued by NSF’s directorate for Social, Behavioral, and Economic Sciences. Given CSPO’s orientation, our ideas, not surprisingly, are directly relevant to the SciSIP program.

1. Science and innovation policies often aim to help transform existing technological systems to achieve particular societal outcomes: for example, to move the nation’s energy system toward a more economically, environmentally, and geopolitically secure technology base; or to move the nation’s health care system to achieve better health outcomes at lower cost. New scientific and technological advance are obviously going to be key drivers of such transitions. Yet modern societies have very little understanding of how to catalyze and steer these sorts of complex system changes, and well-intentioned efforts can often lead to unanticipated consequences whose benefits are very difficult to assess, as we have seen, for example, in efforts to advance alternative biofuels. **A key SciSIP research priority should be to gain fundamental understanding about the drivers and dynamics of transitions in complex socio-technical systems.**

2. Science and innovation policies are, in one sense, a bet on the future: that a certain type of knowledge or technology will prove useful or valuable. Yet the future of social and technological change is impossible to predict in detail. To try to deal with this unpredictability, a relatively small number of forward-thinking companies, academic units, and non-profit organizations employ a variety of techniques and tools that can allow them to better visualize, understand, and discuss a range of alternative possible futures. Such activities can inform decision making by helping to make clear the broad array and potential implications of scientific, technical, and social options and pathways available for addressing social challenges. **SciSIP should support the study and assessment of existing tools, and the development and testing of a range of new tools, to bring future-visioning techniques to bear on science and innovation policy making processes.**

3. **In general, SciSIP should emphasize support for research and education programs that foster integration between natural sciences and engineering, and social sciences.** Such integration can help to ensure that science and engineering activities are conceived and carried out with a realistic understanding of the social context in which knowledge and innovation are pursued and applied. In turn, social scientists will gain a deeper, and earlier, understanding of the potential futures that cutting edge R&D programs are making possible. The result should be a growing capacity to design and conduct science and innovation activities that are better able to contribute to desired social outcomes.

4. **SciSIP should consider supporting the development of a set of case studies to identify and characterize the key attributes of S&T institutions and programs that strongly link science and innovation activities to desired social outcomes.** Case studies should range across the S&T enterprise, sampling a variety of sectors, scales, structures, and desired outcomes. Such a program

would need to be coordinated to ensure comparability between the methods and organization of the cases. Its institutional and programmatic focus would make it distinct from, and complementary with, the STAR METRICS approach that NSF and sister agencies are already taking. This case-based effort should focus on the development of a set of key organizational principles that science and innovation policy makers can use to guide investment strategies and priorities.

<u>Committee Question 2: Is the Federal Government, specifically the National Science Foundation, playing an effective role in fostering SciSIP research and the development of a community of practice in SciSIP? What recommendations, if any, do you have for the National Science Foundation's SciSIP program?</u>

Overall, I believe that NSF is doing a good job in building the SciSIP program and community. But this is a very difficult task. The community of researchers working in the SciSIP domain is rather small and very diffuse. In fact, it does not really identify itself as a single community, but rather as several independent communities, for example, innovation economics, science and public policy, and science and technology studies. So there's simply not a lot of capacity yet in this domain, and what capacity there is needs to be better integrated. Moreover, most of the quantitative data available for analysis of science and innovation policy is input-output data—budget levels, numbers of scientists and graduate students, publication numbers, patents, and citations, and so on. Such data can be subjected to highly sophisticated data mining and analysis techniques using ever-improved software packages designed for this purpose, so it is very attractive to researchers. But this kind of input-output data can offer only an incomplete and in many ways distorted view of the societal value of the S&T enterprise, a view that does not allow us to escape the simplistic beliefs of the past.

Now it's clear that those running the SciSIP program understand these problems. They brought together a good cross section of the community to help plan the program in the spring and summer of 2005; they have sought to attract grant applications from a wide array of researchers; they have organized or otherwise supported events to bring together SciSIP researchers to build a sense of integrated community; they have provided grant support to a diverse set of research approaches and problems; and they are working through the STAR METRICS program to try to build better quantitative data sets that can assist certain types of analytical work. All this is very positive.

To some extent, however, NSF's institutional strength is also a weakness here. The agency prides itself on its bottom-up approach to setting its research agendas. While the SciSIP program does reflect a top-down decision to create a new program area, in part as a response to concerns repeatedly expressed by then-Presidential science advisor Marburger, the shape and direction of SciSIP has significantly been dictated by the existing research community. Much of that community continues to work within the input-output model of science and innovation policy, due, as I've said, to existing data sources and tools. For similar reasons of measurement ease, the community also tends to focus on economic outcomes to the significant exclusion of the much broader range of societal outcomes that the nation seeks to derive from its S&T investment. Because researchers and peer reviewers are drawn from the same general communities, such tendencies can be difficult to escape.

A range of tools are potentially available for building the community and its coherence, and driving the intellectual agenda away from an input-output framework, and toward a systems-oriented, outcomes-focused approach. Not all of these tools require new money. SciSIP should use program guidelines and requirements to transform and build the research community; indeed, this year's program announcement is notable for its openness to a wide range of approaches to SciSIP research. **SciSIP could also consider using some of its budget to support training grants, similar in spirit, if not in scale, to NSF's successful IGERT (Integrated Graduate Research and Traineeship) program, as a way to**

more quickly build up capacity. However, if the Committee, and NSF, believe that the science and innovation policy research community needs to be significantly larger and more coherent, this will probably require more resources. To reinforce my position throughout this testimony (also see my comments on "dissemination, " below), any claim to a bigger budget must be matched by programmatic design elements to help ensure that knowledge created by SciSIP is both usable and used. **This would likely require a commitment to fund integrated Science and Technology Center-type science and innovation policy research organizations that can create and support ongoing interaction between SciSIP researchers and policy makers,** perhaps analogous to NOAA's Regional Integrated Science and Assessment program.

<u>Committee Question 3. Please describe the education and outreach activities of the Consortium for Science, Policy, and Outcomes.</u>

CSPO sponsors a wide variety of education and outreach activities, ranging from formal degree programs and intensive, short-term training activities, to public outreach events and products targeted at science and innovation policy makers.

1. Graduate Degree Programs

The ASU Professional Science Masters in Science and Technology Policy was initiated in 2009. It provides professional education for students seeking advanced public, non-profit, or private sector careers in science and technology policy and related fields in the United States or abroad. Students learn essential skills, knowledge, and methods for analyzing innovation, expertise, and large-scale technological systems. Particular emphasis is placed on the political and societal contexts and impacts of science and technology policy. The program is a one-year, 30-credit cohort-based program designed to attract students of the highest caliber in their early to mid-careers. Key learning outcomes of the program include:

- Understanding of the theoretical foundations of the interactions among science, technology, and society.
- Understanding of US and, where appropriate to a student's career interests, international science and technology policies and the policy processes that generate them.
- Analysis of knowledge systems supporting policy decisions.
- Analysis of the social and policy dimensions and implications of large-scale technological systems.
- Analysis of scientific and technological innovation systems.
- Skills in collaborative, team-based analysis of science and technology policy problems.
- Skills in effective professional communication.

Ph.D. Program in the Human and Social Dimensions (HSD) of Science and Technology. Here CSPO collaborates with ASU's Center for Biology and Society and Center for Law, Science, and Technology to offer a highly interdisciplinary and integrative program of advanced study. We aim at training scholars and practitioners to understand and inform the conceptual and philosophical foundations of scientific research; to analyze and assess the increasingly powerful roles of science and technology as agents of change in society and the economy; and to challenge universities to become leaders in fostering the new science and technology policies necessary to meet the problems and opportunities of the 21st century.

The HSD curriculum is flexible, combining a strong, integrated, first-year experience, with substantial freedom for students, in conjunction with their advisors, to design carefully crafted programs of study relevant to their own areas of interest and expertise. The curriculum trains researchers with the necessary skills and preparation to analyze three key aspects of the study of the human and social dimensions of science and technology: 1) the historical, philosophical, and conceptual foundations of science and technology; 2) the social and institutional foundations of scientific research and technological systems; and 3) the political, ethical, and policy foundations of science and technology.

Research projects of current HSD students supported by CSPO include:

- Social and ethical challenges of smart grid development
- Leadership training in graduate science and engineering education
- Comparative analysis of interdisciplinary research fields in the US and China
- The emergence and stabilization of legal regimes in online communities
- The role of non-governmental organizations in energy siting decisions in the United States
- Public values and public engagement in energy policy in the United States
- The organization and management of international scientific assessment processes
- Connecting knowledge to decision making in water policy
- information technology in learning & inequality

2. Non-Degree Programs and Training

Ph.D. plus. This integrative, non-degree program offers advanced graduate students in science and engineering the chance to consider how their research relates to the world of science policy and the relationship between science, technology and societal outcomes. Science and engineering students work with a CSPO faculty member to write an additional chapter of their dissertation that explores the social implications, political context, or ethical concerns of their work. The Ph.D. plus process is informal, and is arranged by discussions between the student, her or his dissertation advisor, and the CSPO advisor. Most Ph.D. plus students take one or more classes offered by CSPO faculty; attend seminars and other activities sponsored by CSPO; and in general interact closely with the CSPO community for an academic year or more.

In the annual *DC Summer Disorientation*, cohorts of about 15 science and engineering graduate students spend two weeks in Washington, DC interacting with the government officials, lobbyists, staffers, regulators, journalists, academics, museum curators, and others who fund, regulate, shape, critique, and study science and technology. Students participate in interactive role-playing experiences where they may testify at mock Congressional hearings; work under tight deadlines to write briefing papers for senior officials; or write op-ed pieces for a demanding editor. The goal is to help future scientists develop an understanding of the political and social context of their research. CSPO has recently expanded this program and now accepts graduate students from outside of ASU.

The Next Generation of Science and Technology Policy Leaders. Here we are seeking to catalyze a community of early-career science policy scholars who can span the terrains of intellectual inquiry and real-world practice, communicate effectively to general audiences, and contribute to effective decision making on key issues of science, technology, and society. We organized a national competition to select a dozen early-career science policy researchers and practitioners (5 years or less since Ph.D). This “Next Gen” group prepared draft papers, and each scholar was then paired with an early career “communicator” (typically a writer working through new media). The scholar and the communicator collaborated to craft a compelling, non-scholarly description of the scholar’s work—something that would appeal to a general audience. Next Gen scholars also led a roundtable discussion where each presented her/his research to a group of about 40 people at a major CSPO-sponsored conference, to allow the scholars to hone the more technical aspects and presentation of their work, and to interact intensively with an engaged audience. Next Gen scholars are now working on two versions of their research papers, one for a policy-making audience, and one for an academic audience. This project was supported by grants from NSF's programs on Science, Technology, and Society, and Informal Science Education.

3. Outreach

CSPO views outreach as an integral part of its operations at all levels—not as a separate, add-on, or late-stage activity. As described above, our research and education programs often involve policy makers, members of the public, and scientists and engineers, and so also serve an outreach function by creating and strengthening links and communication between CSPO scholars and these other groups. Indeed, in many cases it is difficult to know where research ends and outreach begins. For example, much of our work on energy innovation policy is presented to policy makers and the media in briefings and policy reports at the same time as it is written up for academic audiences (see: http://www.cspo.org/projects/eisbu/). Similarly, SPARC involved numerous workshops that brought scientists and science policy makers together in a way that enhanced both communication and learning.

The integration of outreach and education is apparent in CSPO's growing collaboration with science museums and science centers. We view these collaborations as ways of reaching wider audiences and increasing the ability of our graduate students—social scientists as well as natural scientists and engineers—to communicate to broader audiences. Our Center for Nanotechnology in Society has fostered a national strategic partnership with the NSF-funded Nano-Scale Informal Science Education Network to develop programs and exhibition materials and plans that incorporate societal interests and outcomes in communicating about emerging technologies. CSPO opens science communication opportunities for scientists and engineers through its monthly Science Café series with the Arizona Science Center and incorporates museum-floor experience into its integrated training of doctoral scientists and engineers. CSPO is also working with the Museum of Science, Boston and the National Academy of Engineering to plan a national educational campaign to focus on climate change and engineered systems, to prepare the next generation of engineers, citizens, and leaders to meet the challenge of adapting the nation's technological infrastructure to climate change.

Overall, we are continually engaged in a wide variety of efforts to make our ideas accessible to the public and policy makers, through informal and formal meetings and briefings in the Phoenix area and in Washington, DC; through "handbooks" for decision makers; through ongoing contact with the media; as well as by writing op-eds and articles for non-technical magazines, websites, and blogs. We have just received a small supplement to our SciSIP grant on Public Value Mapping to produce engaging, instructional web-based videos for science policy practitioners. New outreach products and activities are promoted via CSPO's monthly electronic newsletter, which goes to over 3000 people in academia, government, and industry. In all, I think it is fair to say that CSPO views outreach, education, and research as equally necessary foundations for pursuing its mission.

<u>Committee Question 4. How can the dissemination of SciSIP research findings be improved so that policymakers are better informed of the current state of research? Are there best practices that can be implemented by the Federal government and/or the research community to improve the incorporation of science and technology policy research into the decision making process?</u>

SciSIP program officers, in collaboration with their grantees, with organizations like the American Association for the Advancement of Science, and with other federal agencies, has made an impressive effort to ensure that research results are made available to science and innovation policy makers, through the SciSIP website and listserve, and through a variety of workshops, including one to be held this coming December.

SciSIP and NSF more broadly face something of a dilemma here, however. As I'm sure the Committee well appreciates, academic researchers are generally not rewarded for communicating their work to policy makers, or even for making the results of their work comprehensible to non-experts. I'm extraordinarily fortunate to work at a university where this is not the case. Moreover, given the fundamental nature of much of the research supported by SciSIP, the extent to which project results can translate into results immediately useful to decision makers may be highly variable. At the same time, it's fair to say that science and innovation policy decision makers may not always be either receptive to, or able to act on, the results of research conducted under SciSIP.

In line with many of the comments I've already made, and consistent with research done by CSPO and many other groups, the best way to further improve the value of SciSIP research for decision makers would be to increase the level of interaction between the researchers and decision makers. This point should not be interpreted as a criticism of the current SciSIP program, which as far as I can tell is effectively pushing the boundaries of typical NSF practice, and working at the limits of its human and fiscal resources, to try to maximize dissemination.

Yet ensuring that researchers are providing knowledge that decision makers can actually use is not only a matter of "dissemination," it is also structural. For SciSIP results to be both usable and used, researchers and decision makers must each come to understand the needs, capabilities, and languages of the other—a process that we have termed, in our SPARC project, "reconciling the supply and demand of research." Such a reconciliation takes time and ongoing interaction. It can certainly be pursued along multiple paths—through joint committees, workshops, personnel exchanges, interviews and surveys, and so on—but the key is ongoing and meaningful interaction leading to mutual understanding. An NSF research program, even one advanced with the creativity and vigor that characterizes SciSIP, is unlikely to be able, by itself, to provide the sort of institutional infrastructure that leads to the production of consistently usable knowledge. The idea of integrated SciSIP centers, previously mentioned, could be one way to create a greater capacity to move ideas into use. Federal agencies and programs that sponsor mission-oriented research, and that have a proven record of producing usable knowledge, might also be able to play a role here to help achieve the necessary integration.

<u>Committee Question 5: What are the fundamental skills and content knowledge needed by SciSIP researchers and practitioners? What are the backgrounds of students pursuing graduate degrees in science and technology policy, and what career paths are sought by these graduates? Is the National Science Foundation playing an effective role in fostering the development of science and technology policy degree programs at U.S. universities? If not, what recommendations, if any, do you have for NSF and/or the universities with such programs?</u>

As I've suggested, the domain of SciSIP research and practice cannot and should not be defined by any particular set of skills or area of knowledge. In fact, given the complexity and diversity of the challenges facing SciSIP policy makers, it will be important to keep the field as open and flexible as possible, where the necessary skills and knowledge are determined based on the problem at hand, and on the evolution of the field itself, rather than some arbitrary boundary. I've already mentioned the varied backgrounds of CSPO's core faculty group, and our graduate students are if anything even more diverse, coming to us with degrees in business, information systems, science and technology studies, astrophysics, political science, law, English, public policy, library and information science, philosophy, physics, biology, environmental science, geology, anthropology, sociology, and industrial management.

Graduate training in science and technology policy is also diverse, occurring in many different types of programs, with many institutional and administrative arrangements, in many U.S. universities. There is no standard-model science and technology policy graduate degree, and given the complexity of the field perhaps that is just as well, but it does create challenges in terms of attracting resources, creating an identity, and setting priorities. Similarly, while many career paths are open to those who have advanced training and degrees in science and technology policy, there is no formula for how to build or advance a career in this field, as there is in, say, law, medicine, or engineering. In CSPO's brief experience with graduate education, we do see our students and post-docs progressing on traditional academic paths, but they are also going into the private sector, working at nongovernmental organizations, and taking up positions in government agencies and think tanks. I also want to emphasize the importance that we place on "continuing education" via our professional Masters program, which we hope will reach mid-career professionals already working in areas related to science and technology policy, and equip them with tools to do their jobs more effectively, or to move into more complex jobs, in the public, private, and nongovernmental sectors.

As I discussed in my response to Question 2, NSF's SciSIP program, as well as its Science, Technology, and Society Program, are working hard to build a sense of community and identity among science and technology policy researchers, and to provide support for research across a broad domain of problems and applications. However, as discussed at length by about 75 members of the community at this summer's Gordon Conference on Science and Technology Policy, the traditional academic structure of universities remains a considerable obstacle to building long-term capacity in the field, and most science and technology policy programs exist in the margins and spaces of standard disciplinary schools and departments. I am fortunate enough to work at a university whose leadership has a strong commitment to cultivating interdisciplinary, problem-based research that can link knowledge creation to solutions for complex societal problems. Yet even at ASU the long-term future of science and technology policy research probably depends on finding a way to more closely knit CSPO into the fabric of the formal academic units on campus.

One conclusion here is that NSF's ability to foster the development of the field of science and technology policy is partly dependent on incentivizing universities to recognize SciSIP as a field worth cultivating. While the SciSIP program is certainly of a scale sufficient to mobilize and motivate individual researchers working on science and innovation policy, it is probably not big enough to get the attention of university administrators. I have already emphasized the potential value of applying an integrated Science and Technology Center model to building the SciSIP community and moving its research results into use. An NSF commitment to supporting one or more such centers would also send a strong signal to university leaders that the science of science and innovation policy is a national priority, deserving of strong focused effort and investment from our universities.

About the Author

Daniel Sarewitz is Professor of Science and Society, and co-director and co-founder of the Consortium for Science, Policy and Outcomes (CSPO), at Arizona State University (http://www.cspo.org). His work focuses on revealing the connections between science policy decisions, scientific research and social outcomes. How does the distribution of the social benefits of science relate to the way that we organize scientific inquiry? What accounts for the highly uneven advance of know-how related to solving human problems? How do the interactions between scientific uncertainty and human values influence decision making? How does technological innovation influence politics? And how can improved insight into such questions contribute to real-world practice? He is the author of *Frontiers of Illusion: Science, Technology, and the Politics of Progress* (Temple, 1996), an exploration of the public myths that underlie decisions about science and technology; the co-editor of three other books; and the author of many articles about the interactions of science, technology, and society. In addition to scholarly journals his work has appeared in *The Atlantic Monthly*, *The New Republic*, and many newspapers; from December 2009 until September 2010 he wrote a monthly column on science policy for the journal *Nature*. His work has also received featured coverage on NPR's Morning Edition, in the *New York Times* and the *Chronicle of Higher Education*. From 1989-1993 he worked on R&D policy issues for the U.S. House of Representatives, first as a AAAS Fellow in the office of Congressman George E. Brown, Jr., and then as a staffer on the Committee on Science, Space, and Technology. He received a Ph.D. in Geological Sciences from Cornell University in 1986. He now directs the Washington, DC, office of CSPO, and focuses his efforts on a range of activities to increase CSPO's impact on federal science and technology policy processes. His new book, *The Techno-Human Condition* (co-authored with Braden Allenby; MIT Press) will be published in March 2011.

About CSPO

The Consortium for Science, Policy and Outcomes at Arizona State University is an interdisciplinary intellectual network aimed at enhancing the contribution of science and technology to society's pursuit of equality, justice, freedom and overall quality of life. CSPO creates knowledge and methods, educates students, cultivates public discourse and fosters policies to help decision makers and institutions grapple with the immense power and importance of science and technology as society charts a course for the future. CSPO's unique and productive synthesis of theoretical, empirical and problem-oriented research and tool development is driven by three guiding ideas: desired outcomes can drive science; the value in society of new knowledge is determined by how it is used, and by whom; and the definition of the problem helps determine the relevance of the research. CSPO believes that politics and the ideas, institutions and the people behind them – and not science alone – determine the outcomes of science and technology in society. In this view, science policy is vastly more complex – as well as more interesting and malleable – than merely setting a budget for scientific research and development.