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Accelerating Technological Advance for Climate Change: Lessons from Sixty Years of U.S. Innovation Policy

Testimony before the U.S. Senate Committee on Energy and Natural Resources

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

John Alic
Independent Consultant

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Abstract

Limiting the concentration of greenhouse gases in the atmosphere is largely a problem of technological innovation. Appropriate energy-climate innovation policies will be necessary to accelerate rates of performance improvement and cost reductions for energy technologies. Such policies should be guided by four general principles:

1. To improve government performance, and expand innovation options and pathways, Congress and the administration should foster competition within government.

2. To advance GHG-reducing technologies that lack a market rationale, government should selectively pursue energy-climate innovation using a public works model.

3. To stimulate commercialization, policy makers must recognize the crucial role of demonstration projects in energy-climate innovation, especially for technologies with potential applications in the electric utility industry.

4. To catalyze and accelerate innovation, government should become a major consumer of innovative energy technology products and systems.

Mr. Chairman and members of the Committee, thank you for inviting our testimony. My name is John Alic. Now an independent scholar, I worked for more than fifteen years at the Office of Technology Assessment. The first author of this statement, Daniel Sarewitz is a former House Science Committee staff member and now professor of science and society at Arizona State University and co-director of the Consortium for Science, Policy and Outcomes, which he helped to found in 1999. Dr. Sarewitz's research focuses on how science and technology policies can help to achieve important societal goals, with a particular focus on problems of uncertainty in policy making, and the role of technology in meeting human needs.

Our statement draws and expands on a recently released study "Innovation Policy for Climate Change" (available at: http://www.cspo.org/projects/eisbu/), which was carried out jointly by the Consortium for Science, Policy and Outcomes, and the Clean Air Task Force, and funded by the National Commission on Energy Policy.

In my remarks today I would like to make a few very important points about how to think through the greenhouse gas problem. The first, quite simply, is that limiting the concentration of greenhouse gases (GHGs) in the atmosphere is largely a problem of technological innovation. If this nation, and the world, decides that it is necessary to transform the global energy system to radically reduce GHG emissions, that means embarking on a path of profound technological transformation. It follows that effective innovation policies will be the necessary complement to whatever other options Congress may choose to pursue in grappling with the immensely difficult challenge of climate change, all the more so in that fossil fuel prices are likely to remain low relative to other sources of energy over the next decade or more, and markets for some of the key technologies that will be necessary do not yet exist.

The second point, again a simple one, is just to emphasize that for the past century and more the United States has led the world in innovation. If we decide to turn this unmatched capacity to the climate change problem, we know, in principle, what to do and how to do it. What is daunting is the scale and scope of the problem. But it is not without precedent. After World War II, the U.S. government put in place a suite of policies aimed at stimulating innovation that helped make possible our Cold War victory and fueled continued economic growth and job creation. We know what works, based on our experience. Yet so far we are not sufficiently applying what we know about innovation to address energy technologies and climate change.

Let me then briefly review our Cold War innovation policies, which took on their fundamental shape at the time of the Korean War, for which the United States was woefully unprepared. Over the next several years, technological innovation became a central pillar in our larger Cold War strategy. In the technological response that took shape, intense competition among and within the military services combined with greatly increased budgets for R&D and procurement in a long-running search for "force multipliers" to offset the numerical advantages of the Soviet Union and its allies, especially in Europe. The Department of Defense (DoD) paid the bills, which were large and carried charges for much waste and duplication but also brought forth a flood of innovations from the defense and aerospace industries and virtually created the digital electronics industry and the fields of computer science and materials science.

High-tech military advances created by Cold War innovation policies included nuclear submarines in the 1950s, intelligence satellites in the 1960s, precision-guided missiles in the 1970s, and stealth aircraft in the 1980s.[1] Advances in military technology during the Cold War also spawned civilian applications, innovations and industries that fueled economic growth and created the high technology infrastructure that we depend on today, from our communications systems to our aviation network.

The nation's Cold War commitment to technological innovation was neither justified nor rationalized by market logic. We committed ourselves to a path of technological innovation in pursuit of a public good—national defense—and that commitment created powerful incentives for market actors to produce improved technologies for both military and civilian applications.[2] Table 1 sets the Cold War innovation system alongside an approach to innovation appropriate to the scale and scope of global climate change and the restructuring of the nation's energy system.

Table 1. Innovation Systems Compared.

	Cold War Innovation System (ca. 1950-1990)	***Energy-Climate Innovation System (Prospective)***
Basic Problem	Offset numerical advantages of Soviet Union and Warsaw Pact through technologically superior military systems and equipment.	Mitigate climate change caused by carbon dioxide and other greenhouse gases through decarbonized energy technologies, greater energy conversion efficiency and energy conservation.
Primary Sub-Problems	Find acceptable balance between conventional and nuclear forces. Restrain the "military-industrial complex" through high-level civilian oversight and effective management of budgetary politics and process.	Speed diffusion of both new and existing low-carbon technologies in face of massive sunk costs in the existing "energy system." Defuse politically powerful geographic and sectoral interests (e.g., coal and coal states) that threaten capture of policy process.
Guiding Principles	National security is a public good, the responsibility of government. The Soviet Union is the primary threat; for purposes of military technological innovation, all other threats can be considered (perhaps incorrectly, in retrospect) as lesser included cases.	Mitigation of climate change through control of greenhouse gases is a public good, the responsibility of government. CO_2 released in burning fossil fuels, especially coal for generating electricity, is the highest priority target.
Subsidiary (Design) Principles	Support a wide range of technologies and system concepts, accepting overlap and duplication caused by intra- and inter-service rivalry. Rely on private firms for system design and development based on new technology flowing from R&D also conducted primarily in the private sector. In the absence of market forces, rely on military professionals to select systems likely to prove effective in blunting a Soviet invasion of Western Europe.	Support a portfolio of technologies through a portfolio of policies tailored to fostering innovation in each. Create competition elsewhere in government for the Energy Department and its laboratories to discipline decision-making and boost organizational effectiveness. Build durable ties between federal agencies and private firms to encourage the latter to assign their best engineers, scientists and managers to energy-climate projects. Rely to the extent possible on market feedback to guide technical improvements and reductions in costs.

As just one example, consider the evolution of the jet engine and gas turbine. Early jets were in one respect greatly inferior to the piston engines they replaced. They burned much more fuel, limiting combat radius for fighters to little more than 100 miles, a severe handicap in Korea. Defense agencies funded

[1] John A. Alic, *Trillions for Military Technology: How the Pentagon Innovates and Why It Costs So Much* (New York: Palgrave Macmillan, 2007).
[2] John A. Alic, Lewis M. Branscomb, Harvey Brooks, Ashton B. Carter, and Gerald L. Epstein, *Beyond Spinoff: Military and Commercial Technologies in a Changing World* (Boston: Harvard Business School Press, 1992).

much jet propulsion R&D, while procurement contracts created potent incentives for private sector innovation, the more so once commercial sales began. After all, airlines, too, place a very high value on fuel efficiency, which affects their operating costs and profit margins directly. Feedback from operating experience in military and civilian applications led to continual technical improvements. Gains in fuel efficiency were such that by the mid-1980s, electric utilities began buying gas turbines to meet peak power demand. And while early jet engines needed to be overhauled every 100 hours or so, in commercial service today they remain “on wing” for 30,000 hours or more.

The jet engine story illustrates four key points for energy innovation policy:

First, promising technologies rarely make economic sense early in their evolution. They are pursued because they can do something different or better than existing technologies, or at least they hold that promise. When government is responsible for providing a public good like national defense—or public health—it may choose to pursue technologies (digital computation, genome mapping) based on their *potential* for providing that good, rather than on strict considerations of cost. The very process of applying technologies to the solution of societal problems may then lead to accelerated innovation, improved performance, reduced costs, creation of new markets and generation of new wealth.

Second, design and development is the core technical activity of innovation, and that capability resides mostly in private firms. Innovation does not proceed from basic science to applied to development and diffusion; rather it is a complex, incremental, iterative process of learning over time, much of this learning occurring through the real-world use and continued improvement of technologies based on producer and customer experience. Although most of this activity takes place in the private sector, government policies are immensely important for the overall enterprise. Congress well appreciates the significance of publicly-funded *research*, but research is only one component of effective government innovation policies. We have a portfolio of policy tools to draw from in encouraging and accelerating innovation, and different combinations of tools may be appropriate depending on the technology and on market conditions. The tools include procurement, tax credits and subsidies to producers and users, loan guarantees, patents, demonstration projects, technical standards, distribution of information, provision of technical support to firms, and education of consumers.

Third, government can be a crucial and demanding early-adopting customer, initiating the continuous incremental innovations that unfold over time to transform radical new technologies into everyday products and systems, such as the Internet. As firms scale up to meet government demand, they attract new, non-government customers and investors, and benefit from expanding sources of feedback, which speeds learning and fosters additional innovation. In the Cold War, the promise of future procurement contracts motivated defense firms to build up their innovative capacity, beginning by hiring the best engineers and scientists they could find, so as to be able to design and develop the complex technical systems sought by the armed services and intelligence agencies. And as we saw with the jet engine, procurement may also drive performance improvements that benefit civilian applications. The demonstration effect of government purchases can itself be a powerful stimulus for market development, as in the early years of microelectronics and computing.

Fourth, competition among government agencies, like competition among firms in market economies, is a powerful stimulus to innovation. Competition among the military services was a key part of the Cold War innovation story. Deprived of fixed-wing combat planes after the Air Force became independent, the Army innovated in helicopters, which grew more versatile as their gas turbine engines became more powerful. Innovation is inherently uncertain, competition breeds diversity, and diversity in energy-climate technologies promises more and better options for pursuing effective and efficient carbon-free pathways.

Competition among agencies also increases incentives for risk-taking and provides benchmarks for performance and accountability, again like competition among firms.

Of course, looking back at technological successes can mislead us. In 1940 no one knew if the jet engine would be a boom or a bust. Innovation is a highly complex and uncertain process, and with successes come failures. Uncertainties attach not only to technical performance (such as rates of improvement over time), but costs, compatibility with other technologies embedded in the economy, the outcomes of competition among technologies with similar applications, and acceptance by customers and society at large. The gas turbine never made it into passenger cars or highway trucks, despite much R&D and some prototypes. Video phones flopped when introduced in the 1960s, while mobile telephony from the beginning expanded at rates beyond all expectations. For nuclear power, bust followed initial boom. (Our report "Innovation Policy for Climate Change" explores the reasons).

The uncertainties inherent in technological innovation have crucial implications for policy. Government must of course invest robustly in research to sow seeds for future innovations, and there is no question that we have been under-investing for decades in energy-related R&D. But breakthroughs cannot be predicted. Indeed, they may even go unrecognized until some time after commercialization (as happened with the microprocessor). Policymakers, moreover, have few tools to use in search of breakthroughs, primarily basic research funding and intellectual property protection.

Pathways from breakthrough to adoption tend to be circuitous and subject to blockage, perhaps temporary but sometimes permanent. More research may overcome the obstacles, but no one can know (as for fusion energy). Consider high-temperature superconductivity, a breakthrough discovery in 1986 that seemed to promise virtually 100 percent efficient transmission of electrical power. At the time, one of us (Alic) directed an entire study by the Office of Technology Assessment at the request of this committee (and others). More than twenty years have now passed without significant applications. Innovation policies that presume technological breakthroughs will achieve particular goals, especially in the near-to-medium term, are unrealistic and irresponsible.

If the technological capacity to achieve GHG reductions needs to advance significantly in the coming decade or two, then energy-climate innovation policies will have to accelerate rates of performance improvement and cost reductions for existing technologies. While breakthroughs are unpredictable and sporadic, once in use many technologies undergo continual incremental improvements that lead to large gains over time.

Incremental innovation depends much less on major conceptual advances in science than on learning through experience, supported by research—basic or applied—aimed at market expansion, cost reduction, or focused on particular problems encountered by users. Over time, incremental innovations can add up to enormous gains, as we see in domains as disparate as agricultural productivity (which has risen by about 1.5 percent per year for the past 50 years) and the reliability of nuclear power plants (which reached 90 percent only in the early 2000s, after some forty years of experience). (Moore's law, which predicts a doubling of computer power every 18+ months, is the best-known example of incremental gains, but digital electronics is atypical; given physical limits on energy efficiency, there can be no Moore's law for energy-climate technologies.)

Incremental gains may themselves lead to radical innovation. That is part of the jet engine/gas turbine story, for which the first patent was issued in 1872. The first working turbines followed three decades later. Another three decades passed before demonstration of jet engines that were "good enough" for aircraft.

In looking back at technological success stories, we sometimes forget that different technologies at different stages of evolutionary development responded to different policies. Effective technology and innovation policies make use of tools appropriate to the task at hand. For example, the unprecedented productivity increases in U.S. agriculture during the first half of the twentieth century were driven in part by research, but also by federal-state extension programs that diffused new knowledge and methods to small farmers, many of them initially resistant to “scientific agriculture.” Yet nothing similar has been tried for other sectors and technologies, with the notable exception of manufacturing extension partnerships created under the 1988 Omnibus Trade and Competitiveness Act. Agricultural extension succeeded by showing farmers how to improve yields and productivity. New energy technologies have been slow to diffuse because of generally weak market pull, in part a result of historically subsidized energy supplies, yet the lesson from agriculture—that teaching and demonstration can accelerate the diffusion of innovations—has not yet been taken to heart.

With the observations above in mind, let me now turn to some specifics for how government can boost energy-climate innovation capacity. The Obama administration has begun by channeling more than $6 billion in stimulus funds (under the American Recovery and Reinvestment Act of 2009) to the nondefense R&D programs of the Department of Energy (DOE). These appropriations, to be spent during fiscal years 2009 and 2010, represent a 50 percent increase of DOE’s energy R&D over the two-year period. That’s a good start. But, as I have tried to make clear, R&D is only one indicator of innovative capacity, and sometimes it is overemphasized. If such investments are not accompanied by a comprehensive and systemic approach to energy innovation policy, they could generate impressive scientific results without making much difference, or could potentially allow others in the world energy technology market to capture the benefits.

The most important lesson for energy-climate innovation from our comparison with the Cold War innovation system is this: government, in addition to paying for basic and applied research, has many tools for accelerating and guiding technology development. Procurement will often be the most potent of these. If private sector innovators and entrepreneurs see government purchases as a meaningful market, they will design and develop products and services accordingly, tapping internal funds along with whatever R&D contracts they may win from DOE or other agencies.

In turn, government R&D investments are most valuable for innovation in the near-to-medium term when they respond to problems identified by private sector innovators. By the 1950s, the U.S. military had come to accept its dependence on private industry, and had broken free of its earlier dependence on internal arsenals and supply bureaus. As firms began to uncover and define technical problems, DoD sponsored research aimed at overcoming them. This was the story for the development of more powerful and efficient jet engines and fly-by-wire control systems, reliable light-weight materials with reproducible properties, and digital hardware and software for signal processing at real-time speeds. Priorities for DoD-sponsored research, that is, reflected needs revealed in the course of engineering design and development in the private sector. DoD learned to cooperate with defense firms (and universities) in providing “just-in-time” research, as well as in advancing the knowledge base—and training the technical workforce—that underpinned new systems and equipment.

Today, while about four-fifths of DoD R&D funds support work conducted by private firms (even though the services have many R&D laboratories of their own), some three-quarters of DOE R&D funds (including those for defense programs) go to the agency’s own laboratories (although some of the money passes through to firms and universities).[3] So long as government is not a customer for energy-climate technologies, DOE cannot, realistically, be expected to forge consistently close connections with the broad communities of firms and industries working to commercialize advanced energy-climate technologies. Yet without those connections, the type of innovation-accelerating system that the United States built during the Cold War may remain beyond reach. Should, on the other hand, the U.S. government decide to treat GHG reduction as a public good, and purchase goods and services with that as its direct objective, doing so in economically significant quantities (for example, by purchasing CO_2 itself, for sequestration; by buying and operating, or contracting for the operation of, direct air capture equipment; and by "greening" the federal government's enormous infrastructure), it will bring DOE closer to the market and pull innovative firms closer to government. Government purchasing power will boost U.S. energy-climate innovation capacity, and policymakers will be better positioned to learn what else is needed to foster the sort of innovations necessary for large-scale decarbonization of the energy system. (Table 2 expands on the principles we have been discussing.)

Table 2. Principles for Energy-Climate Innovation Strategy.

Principle	**Rationale**
Recognize decarbonization of the energy system as a *public good* akin to national defense, provision of clean water and sewage treatment, and protection from natural disasters.	In providing public goods in the absence of viable markets, the U.S. government has often spurred technological innovation, notably in military and intelligence technologies during the Cold War and in public health.
Encourage *interagency competition*, within limits, among government bodies charged with responding to climate change and fostering energy-climate innovation.	Innovation occurs in response to "environmental pressures" such as those created by market forces and public policies (e.g., regulation). And just as market competition encourages innovation by business firms, competition within government encourages innovation by agencies. Although too much competition within government leads to wasteful overlap and duplication of effort, DOE's monopoly over energy has not been conducive to either technological advance or policy development.
Tailor innovation policies to particular technologies and suites of technologies.	The U.S. government can call on many well-proven policy tools in addition to R&D for stimulating innovation. By most accounts, for example, procurement of integrated circuits for military and space systems had more impact on early innovations in microelectronics than government R&D, while DoD's insistence on non-proprietary technologies had powerful long-term effects on computing and computer networks.
Rely on private firms for innovation.	Government has been a "smart customer" for military technological innovations, outlining requirements and offering incentives in the form of possible future contracts for design, testing and production of defense and intelligence systems. For energy, the U.S. government has relied too heavily on the DOE laboratory system, which has some excellent research capabilities, many of them closer to pure science than to practical energy technologies, but has not had strong and stable incentives to develop and maintain effective working relationships with innovative firms.
Seek international agreements and arrangements conducive to *indigenous innovation in developing economies* such as China and India.	Many countries will have to take action if greenhouse gas emissions are to be controlled. Among the most powerful incentives for action is the prospect of home-grown innovations that can become a source of business profits, jobs and exports. Viewing other countries primarily as passive recipients of "technology transfers," or as export markets for U.S.-based firms, would slow worldwide technological advance and hinder adoption of GHG-reducing innovations.

[3] *Science and Engineering Indicators 2008*, Vol. 2 (Arlington, VA: National Science Board/National Science Foundation, 2008), Appendix table 4-30, p. A4-53.

Let me close by offering the following recommendations. They are intentionally general, but not vague: they can be understood as criteria for both designing and assessing energy innovation policies.

1. **To improve government performance, and expand innovation options and pathways, Congress and the administration should foster competition within government.** Competition breeds innovation. That is true in economic markets and it holds for government too. Inter-agency competition has been an effective force in innovation across such diverse technologies as jet engines, genome mapping and satellites. Insufficient competitive forces exist for energy-climate technologies. While ARPA-E provides a new capability within DOE that could productively boost intra-agency competition, appropriate expertise and experience also exist in many parts of the public sector, including the DoD, the Environmental Protection Agency and state and local governments. As just one example, DoD's huge infrastructure offers a potential test-bed for a wide variety of advanced energy technologies that no other public agency or private sector entity could replicate.

2. **To advance GHG-reducing technologies that lack a market rationale, government should selectively pursue energy-climate innovation using a public works model.** There is no customer for innovations such as post-combustion capture of power plant CO_2 and air capture of CO_2. (Indeed, no more than about two dozen people worldwide appear to be working on air capture at all—an unacceptably small number by any standard.) Recognition of GHG reduction as a public good redefines government as a customer, just as it is for, say, pandemic flu vaccines, flood control dams or aircraft carriers. This perspective points to new approaches for creating energy-climate infrastructure, in support of innovation and GHG management. Some tasks might be delegated to state and local authorities, which already collect trash, maintain water and sewer systems, and attempt to safeguard urban air quality. The federal government currently budgets over $60 billion annually for infrastructure investments, and state and local governments spend about three times as much.[4] Policymakers could approach GHG control as a similar form of infrastructure investment. Indeed, many of the energy expenditures in the American Recovery and Reinvestment Act could be viewed as a down payment on such an approach.

3. **To stimulate commercialization, policy makers must recognize the crucial role of demonstration projects in energy-climate innovation, especially for technologies with potential applications in the electric utility industry.** Demonstrations in energy may have a poor reputation, but government-sponsored demonstration programs have a long-established place of importance in U.S. technology and innovation policy. In aviation, DoD and other federal agencies funded many demonstrations of unproven technologies, including the famous series of X-planes. In microelectronics and computing, government acted as a "lead customer," demonstrating what these then-new technologies could do, for all to see. The primary purpose of demonstration projects is to reduce technical and cost uncertainties, which means the private sector should be chiefly responsible for managing them. So long as government provides financial support, it should also see that results are disseminated openly, so that all parties can take advantage. Well-planned and conducted programs could push forward technologies such as CO_2 capture from power plants. While, for example, the DOE has supported exploratory R&D on advanced coal-burning power generation for several decades, it has only recently begun to address the issues raised by capturing CO_2 from the nation's *existing* coal-fired power plants, which produce over one-third of U.S. CO_2 emissions. We have emphasized the uncertainty of innovation, and no one can know whether a new generation of those advanced coal-burning plants will ever be built. On the other hand, technologies do exist for capturing CO_2 from a substantial portion of the 1500 or so coal-burning plants operating today, and they have not even been evaluated at full scale.

4. **To catalyze and accelerate innovation, government should become a major consumer of innovative energy technology products and systems.** The many billions of dollars DoD spends each year on procurement has been an enormously powerful influence on innovation. In contrast, the U.S.

[4] *Issues and Options in Infrastructure Investment* (Washington, DC: Congressional Budget Office, May 2008), Table 1, p. 4.

government has not systematically or strategically used its purchasing power to foster energy-related innovations. Yet each year, federal, state and local governments spend large sums on goods and services with implications for GHG release and climate change, including office buildings, motor vehicles and transit systems. Government can be a smart and demanding customer for the best energy-climate innovations, helping to demonstrate new approaches, create early markets, drive competition among firms, and foster confidence in advanced technologies, including those that are not yet price-competitive. The President's October 5 Executive Order establishing sustainability goals for Federal agencies is an excellent first step in this direction.

The private sector will be the main source of energy innovation, as it is for other areas of technology. That is where the knowledge and experience lie. So far, of course, the incentives have been lacking. But it will take more than a price on carbon, or regulatory inducements. Government must build stronger bridges to industry and become a smarter customer, just as DoD has often been a smart customer with deep pockets for military innovation. By treating climate mitigation as a public good and GHG reduction as a public works endeavor, analogous to public health and safety, vaccine stockpiles, dikes, levees, weather forecasts, and national defense, the United States can begin to show other countries how to build energy-climate technologies into the fabric of their innovation systems and their societies.

The nation's energy system—and the world's—is extraordinarily complex. Rapid technological transformation of such systems to achieve meaningful reductions in greenhouse gas emissions over the next twenty to thirty years is an enormous task, without precedent and hard even to comprehend—and much more complex than other environmental problems of recent decades. In seeking to understand how such a goal might be pursued, we have offered lessons from the nation's Cold War innovation experience. Whether the climate threat merits a response of this magnitude is of course something that Congress will continue to deliberate upon. Our goal in this statement has been simply to show that the experience of the United States provides essential yet thus-far neglected lessons for accelerating innovation in support of long-term national goals.

About the Authors

Daniel Sarewitz's 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 improved real-world practice? From 1989 to 1993, Sarewitz worked on R&D policy issues as a staff member in the U.S. House of Representatives, and principal speech writer for Committee Chairman George E. Brown, Jr. He received a doctorate in geological sciences from Cornell University in 1986. He now directs CSPO's office in Washington, D.C., and focuses his efforts on a range of activities to increase CSPO's impact on federal science and technology policy processes. Sarewitz also holds a professorship in ASU's School of Life Sciences and School of Sustainability.

John Alic writes and consults on policy issues related to technology and science. As a staff member at the Congressional Office of Technology Assessment from 1979 to 1995, he directed studies on international competitiveness and technology policy. Alic is the author or co-author of several books and over 100 papers, articles, case studies and book chapters. A graduate of Cornell, Stanford and the University of Maryland, he has taught at several universities.

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.