JUNE 2010

FOUR POLICY PRINCIPLES FOR ENERGY INNOVATION & CLIMATE CHANGE: A SYNTHESIS

Executive Summary

There is now little doubt that reducing global carbon dioxide emissions to address climate change at a societally acceptable cost will require substantial innovation in energy systems and technologies over the coming decades. We do not appear to be on that innovation path, however. ››

CLEAN AIR TASK FORCE

Consortium for Science, Policy and Outcomes at Arizona State University

ASU

>> Over the last two years, several independent teams have sifted through history, experience and best practices on technology and energy innovation to suggest how we might get on that path. The teams include researchers organized by the Massachusetts Institute of Technology, Harvard University, Georgetown University, the National Bureau of Economic Research, the Brookings Institution, the National Endowment for Science, Technology and the Arts, the National Commission on Energy Policy, Arizona State University's Consortium for Science, Policy and Outcomes, the Clean Air Task Force, and Clean Air-Cool Planet. >>

Despite the independence of the teams, collectively they display substantial convergence on four basic policy design principles, summarized, explained and illustrated further in this report:

Principle #1: Recognize that innovation policy is more than R&D policy: Innovation occurs through a complex set of interactions, most of which occur in the private sector. The best way to sustain innovation is to have technologies deployed in the field, where engineers and scientists can then begin to optimize existing technologies and work to improve them. A focus on R&D investment and policy is important, but only touches on a small part of the broader energy innovation system. Accordingly, successful policy will:

- Align R and D with deployment actions; and
- Focus on key non-technical barriers to deployment that technologies will face as they enter the market.

Principle #2: Pursue multiple innovation pathways. Just as no one technology will be able to solve the energy-climate problem, no one institution is capable of solving it either. A diverse ensemble of technologies should be pursued, recognizing that successful innovation is never certain and there will always be successes and failures. A successful innovation system will encourage technologies that will mature at a variety of short- to long-term timeframes: near-term, readily available technologies should not overwhelm and crowd-out potential new technologies. Some successful examples of government sponsored innovation, including information technology, aircraft, and to an extent agricultural technology, reflect competition among a variety of government programs. Successful policy will:

- Encourage intra-governmental competition, complementing the role of the Department of Energy in basic research with the competencies of other agencies in research, technology scale-up and deployment such as Department of Defense, the National Aeronautics and Space Administration, and National Science Foundation.
- Catalyze linkages between government, academia and the private sector, at multiple geographical scales.

Principle #3: Recognize CO_2 reduction as a public good, and pursue energy innovation through a public works model. The market currently does not price the negative societal effects of climate change into the costs of carbon-intensive technologies, which means that some needed technologies that are not cost competitive may not develop in the current system. Recognizing greenhouse gas (GHG) reduction as a public good makes the government the customer, just as it is for pandemic flu vaccines, flood control dams, or aircraft carriers. This perspective suggests new approaches for supporting energy innovation and GHG management, including the following:

- Stimulate demand using public procurement and regulatory mechanisms (including performance standards and carbon pricing) to encourage private sector innovation. In particular, direct government procurement is one of the most powerful ways that the Federal government has stimulated demand for innovation in past technological revolutions. Certain agencies, such as the Department of Defense, have uniquely powerful purchasing capabilities due to their large size. In addition, direct technology-forcing regulatory mandates such as coal plant carbon performance standards are likely to move innovation in a shorter time scale.

- Support late-stage development and demonstration projects, which are typically too risky for private corporations to undertake, through financing and incentives.

Principle #4: Encourage collaboration on energy innovation with rapidly industrializing countries. While there may be political opposition to collaborating with countries like China and India, significant action on climate change may be impossible without them. Simply transferring technologies from developed countries to industrializing countries does not accelerate innovation. Industrializing economies need to develop their own innovation capacity and can best benefit from incremental improvements made in their industrial processes. Increased international collaboration may accelerate innovation, and as a result the United States can benefit from increased innovation capacities that exist in other countries.

Much work lies ahead to apply these principles to create specific innovation initiatives to meet the technology challenge posed by climate change. But the conclusions of the independent teams summarized in this report will provide policymakers with a useful head start.

ACKNOWLEDGMENT

WE WOULD LIKE TO THANK THE FOLLOWING PEOPLE FOR INPUT AND FEEDBACK ON THE CREATION OF THESE PRINCIPLES.

John Alic
Independent Researcher

Laura Diaz Anadon and Venkatesh Narayanamurti
Energy Research, Development, Demonstration and Deployment Project, Harvard University

Rebecca Henderson
Harvard University

Richard Lester
Industrial Performance Center, Massachusetts Institute of Technology

Sasha Mackler and Nate Gorence
National Committee on Energy Policy, Bipartisan Policy Center

Richard Nelson
Columbia University

Charles Weiss
George Washington University

None of these reviewers should be seen as explicitly endorsing this report.

FOUR POLICY PRINCIPLES FOR ENERGY INNOVATION & CLIMATE CHANGE: A SYNTHESIS

INTRODUCTION

There is now little doubt that reducing global carbon dioxide emissions to address climate change at a societally acceptable cost will require substantial innovation in energy systems and technologies over the coming decades. We do not appear to be on that innovation path, however. This report summarizes and synthesizes the findings of several recent studies that examine how we might get there.

Energy innovation to reduce climate change requires much more than research and development. Innovation is a complex process, involving many actors but primarily centered in the private sector, and it comes most frequently from incremental learning that happens when technology is deployed in the field. In established technological fields, innovation occurs naturally, with private industry evaluating and implementing new techniques and learning from the experience for business reasons. But with low carbon energy technologies, the absence of incentives and limited market opportunities for some technologies have kept private industry from innovating at a fast rate (with some exceptions, as for solar photovoltaics, where government subsidies have boosted rates of innovation). As a result, it is likely that the government has an important role to play in encouraging energy innovation beyond conventional R&D funding, most especially through procurement and well-managed demonstration projects, and by encouraging competition between government programs and institutions.

Table 1: Matrix of policy principles supported by each report/group. "Not applicable" (na) suggests that the report's focus was not relevant to the principle. A blank space implies that the concept could be relevant, but that it was not discussed.		Government should...									
Institution or Group Name	Reports	1. Recognize that innovation policy is more than R&D policy	a) Align front-end R&D with deployment programs	b) Focus on both policy and technical challenges in going to market	2. Pursue multiple innovation pathways	a) Encourage competition within government	b) Catalyze linkages between government, academics and the private sector	3. Recognize CO_2 reduction as a public good, embrace a public works model	a) Stimulate demand using regulatory mechanisms and public procurement	b) Support late stage development and demonstration projects	4. Encourage collaboration on energy innovation with developing countries
Industrial Peformance Center	America's Energy Problem (and How to Fix it)	X	X	X	X	X	X	X	X	X	X
Weiss and Bonvillian	Structuring an Energy Technology Revolution	X	X	X	X	X	X	X	X	X	X
CSPO/CATF	Innovation Policy for Climate Change	X		X	X	X	X	X	X	X	
Mowery, Nelson and Martin	Technology Policy and Global Warming: why new policy models are needed	X		X	X	X	X		X	X	X
Clean Air Task Force	RD&D 'road maps' for critical carbon capture and geologic sequestration	X	X	X	X	X	X			X	
Harvard ERD3	Various Publications	X	X	X	X	X	X	X		X	X
NBER	Presentations from the Henderson and Newell meeting	X		X	X	X	X	X	X	X	na
Energy Discovery-Innovation Institutes	ESII- a step toward America's energy sustainability	X	X	na	X	na	X	na	na	X	na
Climate Policy Center	An energy transformed: the future advanced research projects agency - R&D pathways to a low-carbon future	X	X	na	X	na	X	na	na	X	na

The rate of progress toward reduced greenhouse gas emissions from global energy production depends significantly on innovation policies. The small community of academics and policy makers who work in the general domain of innovation policy well understand the importance and complexity of appropriate energy innovation policies, but the perspective of this community has largely been absent from national and international policy and climate discussions. Motivated by this idea vacuum, ten groups (listed in the text box below) have independently undertaken studies aimed at elucidating policy principles and recommendations for catalyzing energy technology innovation. In October 2009, the Consortium for Science, Policy and Outcomes and the Clean Air Task Force (CSPO/CATF) convened representatives of most of these groups to discuss their findings, and in December 2009, CSPO/CATF obtained funding from the Doris Duke Charitable Foundation to write a synthesis report examining key and common insights on energy innovation from these various groups. Thus, we begin by examining and synthesizing the established insights and best practices from these activities. Then, given the broad agreement that exists on the basic principles of innovation policy, we discuss their application to the potential role of the Department of Defense in supporting procurement and demonstration projects.

REPORTS USED IN THE SYNTHESIS

Extended summaries are included in the Supporting Document, available at: [http://www.cspo.org/projects/eisbu/SynthesisSupport.pdf].

America's Energy Problem (and How to Fix it), by Richard Lester, from the Massachusetts Institute of Technology (MIT) and its Industrial Performance Center. This report examines the magnitude of the energy-climate challenge and the current context surrounding energy innovation while advocating for a better "system of innovation institutions." Funded by the Doris Duke Charitable Foundation (DDCF). 2009.

Structuring an Energy Technology Revolution, by Charles Weiss and William Bonvillian. Written by experts on innovation policy, this book presents a framework for innovation policy, seeking to create appropriate policies for different technologies and to overcome institutional hurdles. (MIT Press). 2009

Innovation Policy for Climate Change, by Arizona State University's Consortium for Science, Policy and Outcomes and the Clean Air Task Force (CSPO/CATF). This report relied on expert analysis from three workshops for obstacles to innovation for three different energy technologies. Provides a framework for improving Federal energy innovation policy. Funded by the National Commission on Energy Policy and led by Dan Sarewitz and Armond Cohen. 2009

"Technology Policy and Global Warming," by David Mowery, Richard Nelson and Ben Martin. This overview paper examines the best historical analogies for energy innovation. Examines key historical episodes of innovation in the US and UK, including agriculture and information technology. Funded by the National Endowment for Science, Technology and the Arts (NESTA). 2009.

An Energy Future Transformed, by Xan Alexander. From the Climate Policy Center of Clean Air Cool Planet. This report provides recommendations and an analytical framework for the new Advanced Research Projects Agency for Energy (ARPA-E). The author is a former manager in the Defense ARPA and provides a one year operating plan for ARPA-E. Funded by DDCF. 2009.

Coal without Carbon, by the Clean Air Task Force (CATF). Used groups of expert authors to develop research, development and demonstration road maps for critical clean coal and geologic sequestration technologies. Introduces the idea of a First Project Demonstration Fund to support demonstration projects. Supported by DDCF and led by Joe Chaisson. 2009.

Energy Discovery-Innovation Institutes, by J. Duderstadt et al. From the Metropolitan Policy Program at the Brookings Institution. This report advocates creating regionally focused innovation hubs to connect academic and federal researchers with private industry, oriented around on particular innovation tracks. Congress has since funded three energy hubs, following the EDII concept. 2009.

Clean Energy Technology Pathways, by the National Commission on Energy Policy (NCEP), which is part of the Bipartisan Policy Center. Using a system-level framework, this report draws on models of future energy technology 'mixes' and the effect that each technology will have on the others. Examines cross-cutting challenges to energy technology development. 2009.

Various publications by the Energy Research, Development, Demonstration and Deployment (ERD3) Policy Project, which is part of the Energy Technology Innovation Program at Harvard University. These reports make recommendations on the energy innovation policy and for management of innovation institutions. Funded by DDCF and led by Venkatesh Narayanamurti, Laura Diaz Anadon, and Matthew Bunn. 2009-2010.

Accelerating Energy Innovation, by researchers from the National Bureau of Economic Research (NBER). These publications examine the history of innovation in the life science, chemistry, agriculture, and information technology industries, examining insights for accelerating innovation in energy technologies. They will be part of a book edited by Rebecca Henderson and Richard Newell.

KEY PRINCIPLES OF INNOVATION

An analysis of the collected reports indicates ten main energy innovation policy principles, which have been divided here into four unifying themes. While they have different emphases and starting points, the various reports examined here all agree on the basic principles that underlie the overall innovation system[1]. Table 1 indicates which principles appear in which reports.

TO ENCOURAGE ENERGY INNOVATION, THE GOVERNMENT SHOULD:

1. Recognize that innovation policy is more than R&D policy: innovation occurs through a complex set of interactions, most of which occur in the private sector. The best way to sustain innovation is to have technologies deployed in the field, where engineers and scientists can then begin to optimize existing technologies and work to improve them. A focus on policy for research can be useful, but only touches on a small part of the broader energy innovation system.

a) **Align front-end R&D with Deployment programs.** Following (1), it is clear that deployment programs can be essential. However, a lack of coordination between research, development and demonstration programs (RD&D) and deployment programs can hinder the effectiveness of both. The Harvard ERD3 group, and several other reports, discuss the importance of connecting the work of research agencies with applied programs.

b) **Focus on both policy and technical challenges that technologies will face, especially as they enter the market.** Many of the challenges to innovation are non-technical in origin, and result from existing competition and entrenched political interests. When a new technology enters the marketplace, it is especially vulnerable to competition against established energy technologies. This problem should be examined early in the technology development process. Technologies should be evaluated based upon the businesses and markets that might produce and employ them, and potential political resistance that they might encounter. Investigating these non-technical issues early is important, and will allow development of technology policies that cater to the context of particular technologies.

2. Pursue multiple innovation pathways. Just as no one technology will be able to solve the energy-climate problem, no one institution is capable of solving it either. A diverse ensemble of technologies should be pursued, recognizing that successful innovation is never certain and there will always be successes and failures. A successful innovation system will encourage technologies that will mature at a variety of short- to long-term timeframes: near-term, readily available technologies should not overwhelm and crowd-out potential new technologies. Further, Richard Lester of MIT also argues for a diverse "system of innovation institutions," with different institutions having their own specializations.

a) Encourage intra-governmental competition. The Department of Energy has historically been focused toward basic research, and is not optimally equipped to work on more applied development projects. Encouraging multiple federal agencies, such as Department of Defense, the National Aeronautics and Space Administration, and National Science Foundation to take a greater part in energy innovation can create competition that can help each agency better support innovation. Some successful examples of government sponsored innovation, including information technology, aircraft, and to an extent agricultural technology, reflect competition among a variety of government programs.

b) Catalyze linkages between government, academia and the private sector, at multiple geographical scales. Encouraging use-oriented research is a complex problem, and one way to do it is by linking public and private researchers at particular geographic scales, as is suggested by the Brookings Institution report. Their report focuses on innovation in metropolitan areas, as opposed to emphasizing national and international scales. These proposed innovation hubs would focus on solving problems that are relevant for that particular region, which provides a framework and context that can encourage innovation. Within an individual innovation institute, the Harvard ERD3 reports reviewed principles for managing innovation, one of which involves balancing competition and collaboration amongst these different sectors.

3. Recognize CO_2 reduction as a public good, and pursue energy innovation through a public works model. The market currently does not price the negative societal effects of climate change into the costs of carbon-intensive technologies, which means that some needed technologies that are not cost competitive may not develop in the current system. Recognizing greenhouse gas (GHG) reduction as a public good makes the government the customer, just as it is for pandemic flu vaccines, flood control dams, or aircraft carriers. This perspective suggests new approaches and rationales for supporting energy innovation and GHG management. As with other public works projects, some tasks might be delegated to state and local authorities, which already collect trash, maintain water and

[1] Some of the reports have different goals. The Brookings Institution's **Energy Discovery-Innovation Institutes** and the Clean Air Cool Planet **An Energy Future Transformed** reports focus exclusivelyon advice for particular innovation organizations, and the Clean Air Task Force **Coal Without Carbon** report focuses entirely on recommendations for coal technologies. These reports articulate fewer general principles because of their focus on specific recommendations.

sewer systems, and attempt to safeguard urban air quality. The following two principles are important in their own right, but they also represent two ways to pursue energy innovation as a public works project.

a) **Stimulate demand using public procurement and regulatory mechanisms (including performance standards and carbon pricing) to encourage private sector innovation.** Without a reliable demand for new energy technologies, firms will not aggressively pursue energy technology innovation. In the United States, most attempts to create demand for low-carbon energy technologies have focused on establishment of a carbon cap or price. While this approach will push some innovation in the long run, carbon prices are likely to be low and unstable for an extended period, weakening their power. By contrast, direct government procurement is one of the most powerful ways that the Federal government has stimulated demand for innovation in past technological revolutions. Certain agencies, such as the Department of Defense, have uniquely powerful purchasing capabilities due to their large size. Procurement can be used to drive performance standards, and shows private industry that there will be a growing and sustained market, which in turn stimulates competition and innovation. In addition, direct technology-forcing regulatory mandates such as coal plant carbon performance standards are likely to move innovation in a shorter time scale.

b) **Support late-stage development and demonstration projects.** Some energy technologies can be well understood in the laboratory, but demonstrating technologies at a large commercial scale can reveal and create new, unforeseen problems. Successful demonstrations reduce uncertainty in a new technology, which can enable adequate technologies to develop and receive more investment. However, economic and structural biases often make it too risky for private corporations to undertake some demonstration projects, which prevents innovation. Government should help provide financing and incentives to encourage these demonstration projects. Finding the right mechanism and balance of funding with private industry is critical, and various authors have discussed creating a publicly-funded Energy Technology Corporation that would invest in new demonstration projects.

4. **Encourage collaboration on energy innovation with rapidly industrializing countries.** While there may be political opposition to collaborating with countries like China and India, significant action on climate change may be impossible without them. Literature on innovation in rapidly industrializing countries like China and India shows that simply transferring technologies from developed countries to industrializing countries does not accelerate innovation. Industrializing economies need to develop their own innovation capacity and can best benefit from incremental improvements made in their industrial processes. Increased international collaboration may accelerate innovation, and as a result the United States can benefit from increased innovation capacities that exist in other countries.

MOVING FORWARD: THE DEPARTMENT OF DEFENSE, PROCUREMENT AND DEMONSTRATIONS

The reports synthesized here examine innovation from a variety of different perspectives, which underscores the significance of the general agreement on the key principles. Acknowledging the general lack of prominence of these ideas in public discussions, and the potential value of making these principles more comprehensible through concrete examples, the following discussion shows how the principles might be developed and applied to make specific recommendations, with a focus on the Department of Defense and its potential expanded role in energy innovation.

DEMONSTRATION AND DIFFUSION SITE FOR BUILDING EFFICIENCY INNOVATION

Buildings account for 40 percent of U.S. energy consumption and represent a near-term cost effective opportunity to reduce U.S. energy consumption and lower CO_2 emissions. Yet technology innovations that can contribute to significantly improved building efficiency and increased use of renewable energy are hampered by the great diversity and decentralization of the building sector, and the resulting complexity of coordinating demonstration, commercialization, and diffusion of the necessary technologies (including lighting, HVAC, and other electric power technologies). The long life of most buildings (average of 40 years or more) and their energy systems, and the lag in payback from investments in more energy efficient retrofits, contributes to slow innovation, slow adoption of new technologies, and low investment in innovation.

A major challenge for building efficiency innovation is the demonstration of new technological systems, and transition from demonstration to diffusion. Absolute costs are not the major bottleneck because enhanced energy systems increase construction, renovation, and maintenance costs only marginally relative to total costs and can yield life cycle cost savings under all future energy cost projections. Rather it is the uncertainty in the costs and performance of new technologies which acts as a barrier to wide spread implementation.

How can the Federal government accelerate innovation in this sector? The U.S. Department of Defense (DoD) offers a truly unique opportunity for accelerating innovation in building efficiency. Key attributes include: 1) a massive built infrastructure including more than 300,000 buildings in the US containing

2.2 **billion** square feet; 2) significant internal technical capabilities for carrying out and assessing technical demonstration projects, and for ensuring transparency of results; 3) significant internal technical capacities for constructing, maintaining, and improving built infrastructure; 4) significant ability to attract private sector collaboration and stimulate competition, and to hold private sector technology providers accountable for delivering promised technological performance; and 5) crucially, a unique capacity within the Federal government for management integration, both across facilities, and across management functions (demonstration, procurement, facilities construction and management, etc.).

This latter attribute means that DoD programs can integrate research, demonstration, commercialization, and diffusion/adoption of new building efficiency technologies to an extent far beyond that of the private sector or other federal agencies.

As one example of these synergies, General Electric and DoD are partnering in a smart microgrid demonstration project on the nation's largest Marine Corps Base, Twentynine Palms Base in California. The cost to DoD for this project is only $2 million.

An annual investment of approximately $100 million over a period of five years could fund a diversity of demonstration projects on key technologies for improving energy efficiency, increasing the use of renewable energy and distributed energy sources on DoD facilities. Multiple site demonstrations should include;

- Smart Micro grid technologies
- New distributed energy resources
- Next generation energy storage systems
- Whole building optimal control systems
- Real time predictive control systems
- New design and retrofit tools to radically reduce energy needs
- Environmentally clean waste to energy approaches
- Building integrated PV systems and other solar technologies
- Advanced design technologies from passive lighting and ventilation to new energy efficient building materials

Demonstrations should be closely linked to planning, procurement, and management processes for DoD facilities, so that cost and performance advantages of new technologies are clear to those responsible for DoD infrastructure and the private sector. Performance improvements can be mandated in DoD facilities management plans. Ramp-up of DoD's capacity to be a smart and major customer for building energy technologies are likely to stimulate private sector investment and competition—and performance improvements—much more rapidly than regulatory mandates for the private sector.

PROCUREMENT AND SMALL MODULAR NUCLEAR REACTORS

Government purchase of new technologies is a powerful way to accelerate innovation through increased demand (Principle 3a). We explore how this principle can be applied by considering how the DoD could purchase new nuclear reactor designs to meet electric power needs for DoD bases and operations.

Small modular nuclear power reactors (SMRs), which generate less than 300 MW of power (as compared to more typical reactors built in the 1000 MW range) are often listed as a potentially transformative energy technology. While typical traditional large-scale nuclear power plants can cost five to eight billion dollars, smaller nuclear reactors could be developed at smaller scale, thus not presenting a "bet the company" financial risk. SMRs could potentially be mass manufactured as standardized modules and then delivered to sites, which could significantly reduce costs per unit of installed capacity as compared to today's large scale conventional reactor designs.

Table 2: Partial list of proposed small nuclear reactor designs, adapted from the Nuclear Regulatory Commission website.

Reactor Name	Company	Example Innovation	(years) Refuel time	(MWt) Thermal Output	(MWe) Power Output
NuScale	NuScale Power, Inc.	Smaller next generation utility reactor with modular fabrication	2	150	45
International Reactor Innovative and Secure (IRIS)	Westinghouse	Smaller next generation utility reactor with modular fabrication	3-3.5	1000	335
Pebble Bed Modular Reactor (PBMR)	PBMR, Ltd	Pebble bed fuel; high-temperature helium coolant	online	400	165
Super-Safe Small and Simple	Toshiba Corp.	High-energy neutron reactor with sodium coolant	30	30	10
Hyperion Power Module	Hyperion Power Generation Inc.	High-energy neutron reactor with lead-bismuth coolant	7-10	70	25
Power Reactor Innovative Small Module (PRISM)	GE-Hitachi Nuclear	High-energy neutron reactor with sodium coolant	1-2	840	311
mPower	Babcock and Wilcox	Smaller next generation utility reactor with modular fabrication	5	400	125

It is likely that some advanced reactors designs – including molten salt reactors and reactors utilizing thorium fuels – could be developed as SMRs. Each of these designs offers some combination of inherently safe operation, very little nuclear proliferation risk, relatively small nuclear waste management needs, very abundant domestic fuel resources, and high power densities – all of which are desirable attributes for significant expansion of nuclear energy.

Currently, several corporations have been developing small nuclear reactors. Table 2 lists several of these companies and their reactor power capacities, as well as an indication of the other types of reactor innovations that are being incorporated into the designs. Some of these technologies depend on the well-established light water reactor, while others use higher energy neutrons, coolants capable of higher temperature operation, and other innovative approaches. Some of these companies, such as NuScale, intend to be able to connect as many as 24 different nuclear modules together to form one larger nuclear power plant. In addition to the different power ranges described in Table 2, these reactors vary greatly in size, some being only 3 to 6 feet on each side, while the NuScale reactor is 60 feet long and 14 feet in diameter. Further, many of these reactors produce significant amounts of high-temperature heat, which can be harnessed for process heating, gas turbine generators, and other operations.

One major obstacle is to rapid commercialization and development are prolonged multi-year licensing times with the Nuclear Regulatory Commission. Currently, the NRC will not consider a reactor for licensing unless there is a power utility already prepared to purchase the device. Recent Senate legislation introduced by Senator Jeff Bingaman (D-NM) has pushed for DOE support in bringing down reactor costs and in helping to license and certify two reactor designs with the NRC. Some additional opportunities to facilitate the NRC licensing process for innovative small modular reactors would be to fund NRC to conduct participatory research to get ahead of potential license applications (this might require ~$100million/year) and potentially revise the current requirement that licensing fees cover nearly all NRC licensing review costs.

One option for accelerating SMR development and commercialization, would be for DOD to establish SMR procurement specifications (to include cost) and agree to purchase a sufficient amount of SMR's to underwrite private sector SMR development. Of note here may be that DARPA recently (3/30/10) issued a **"Request for Information (RFI) on Deployable Reactor Technologies for Generating Power and Logistic Fuels"**[2] that specifies may features that would be highly desirable in an advanced commercial SMR. While other specifications including coproduction of mobility fuel are different than those of a commercial SMR power reactor, it is likely that a core reactor design meeting the DARPA inquiry specifications would be adaptable to commercial applications. While nuclear reactors purchased and used by DOD are potentially exempt from many NRC licensing requirements[3], any reactor design resulting from a DOD procurement contract would need to proceed through NRC licensing before it could be commercially offered. Successful use of procured SMR's for DOD purposes could provide the knowledge and operational experience needed to aid NRC licensing and it might be possible for the SMR contractor to begin licensing at some point in the SMR development process[4].

Potential purchase of small modular nuclear reactors would be a powerful but proven way in which government procurement of new energy technologies could encourage innovation. Public procurement of other renewable energy technologies could be similarly important.

[2] https://www.fbo.gov/index?s=opportunity&mode=form&id=d0792af88a6a4484b3aa9d0dfeaaf553&tab=core&_cview=0

[3] The current updated and amended form of the 1954 Atomic Energy Act provides explicit permission for Department of Defense to use unlicensed nuclear reactors if directed to do so by the president. While there may be other relevant laws, it seems at least plausible that DOD could have legal authority to utilize non-NRC approved nuclear reactors.

According to Section 91 of the 1954 Atomic Energy Act, *"The President from time to time may direct the Commission…to authorize the Department of Defense to manufacture, produce, or acquire any atomic weapon or utilization facility for military purposes"* (Section 91 of the 1954 Atomic Energy Act). Approval of a utilization facility for defense use would imply the ability to create and use a nuclear reactor for energy generation (see definition below).

Section 110 of the Act explicitly states an exclusion to the reactor licensing process for DOD use, stating *"Nothing in this chapter shall be deemed…to require a license for the manufacture, production, or acquisition by the Department of Defense of any utilization facility authorized pursuant to section 91."*

Definition: *"The term "utilization facility" means (1) any equipment or device, except an atomic weapon, determined by rule of the Commission to be capable of making use of special nuclear material in such quantity as to be of significance to the common defense and security, or in such manner as to affect the health and safety of the public, or peculiarly adapted for making use of atomic energy in such quantity as to be of significance to the common defense and security, or in such manner as to affect the health and safety of the public"*

Link to the act: [http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0980/ml022200075-vol1.pdf#pagemode=bookmarks&page=14]

[4] NRC licensing may not be the only problem facing a new reactor. SMR technologies that require applications of materials that have not yet been certified by ASME face another constraint to rapid development and deployment, as this process may require 10-20 years of application in a relevant chemical, pressure and radiation environment.

CONCLUSION

Few would dispute that we need substantial innovation to meet the technology challenges posed by climate change; one can barely pick up a newspaper or magazine that does not make that point. However, most of the discussion in the United States has focused on the need to cap or price carbon, or on calls for "more research and development," such as increasing the budget of the Department of Energy. The multiple teams whose work is summarized here significantly deepen the discussion. They point to the need to go beyond research and development, to take a more ambitious "public works" approach to the problem as we have in other areas of national interest, to multiply the government capabilities brought to bear, and to successfully link US innovation efforts to those of developing countries, where we have much to gain as well as sell.

Much work lies ahead to apply these four broad principles to create specific innovation initiatives to meet the climate technology challenge. But the conclusions of the independent teams summarized in this report provide policymakers with a foundation for moving forward. ››

SPONSORS OF THIS REPORT

The Consortium for Science, Policy and Outcomes at Arizona State University creates knowledge and methods, 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.

The Clean Air Task Force is a nonprofit organization dedicated to reducing atmospheric pollution through research, advocacy, and private sector collaboration.

CSPO and CATF wish to acknowledge the work of Zachary Pirtle, principal compiler of this report.

Finally, CSPO and CATF gratefully acknowledge the support of the Doris Duke Charitable Foundation for this report.

Clean Air Task Force
18 Tremont Street
Boston, MA 02108
617-624-0234
www.catf.us

Consortium for Science, Policy and Outcomes
at Arizona State University

Consortium for Science, Policy and Outcomes
Arizona State University
1701 K Street, NW
Washington, DC 20006
202-446-0397
www.cspo.org