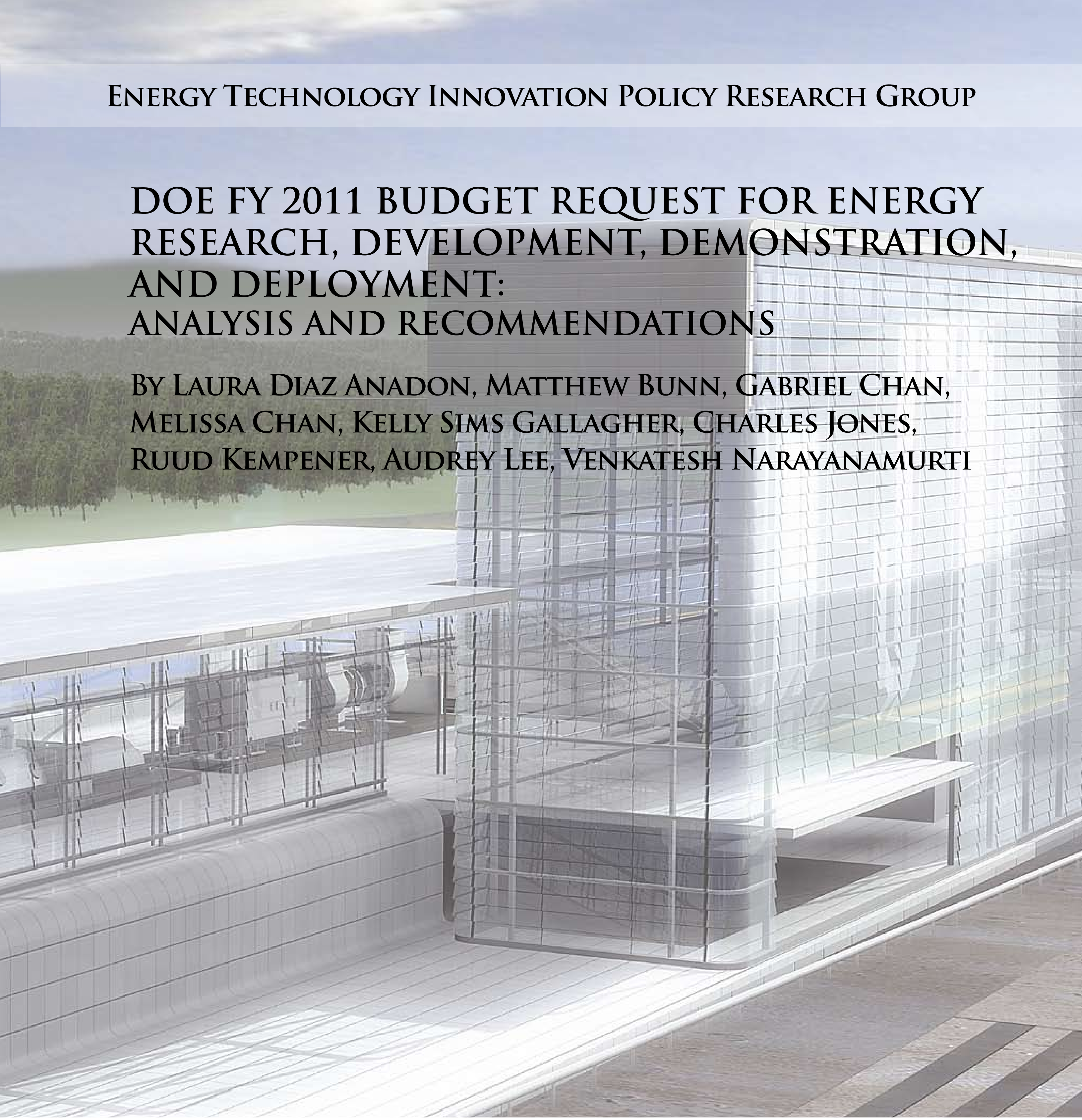


Energy Technology Innovation Policy Research Group

DOE FY 2011 Budget Request for Energy Research, Development, Demonstration, and Deployment:
Analysis and Recommendations

By Laura Diaz Anadon, Matthew Bunn, Gabriel Chan, Melissa Chan, Kelly Sims Gallagher, Charles Jones, Ruud Kempener, Audrey Lee, Venkatesh Narayanamurti

HARVARD Kennedy School
Belfer Center for Science and International Affairs

April 2010

ACKNOWLEDGMENTS

The authors are grateful to the Climate Change Initiative of the Doris Duke Charitable Foundation for supporting the work of the Energy Research, Development, Demonstration, and Deployment (ERD3) Policy Project and the Science Technology and Public Policy Program, both at the Belfer Center of Science and International Affairs of the Harvard Kennedy School.

The authors would also like to thank Neal Doyle and Patricia McLaughlin for their help with editing and formatting. All responsibility for any remaining errors or misjudgments remains with the authors.

CITATION INFORMATION

This paper may be cited as: Anadon, Laura Diaz, Matthew Bunn, Gabriel Chan, Melissa Chan, Kelly Sims Gallagher, Charles Jones, Ruud Kempener, Audrey Lee, and Venkatesh Narayanamurti. *DOE FY 2011 Budget Request for Energy Research, Development, Demonstration, and Deployment: Analysis and Recommendations.* Cambridge, Mass.: Report from the Energy Technology Innovation Policy research group, Belfer Center for Science and International Affairs, Harvard Kennedy School, April 2010.

Comments are welcome and may be directed to Laura Diaz Anadon at the Belfer Center, Harvard Kennedy School, Harvard University, 79 JFK Street, Cambridge, MA 02138.

Cover Image: Artist rendering of FutureGen plant to be built in Mattoon, IL. The project will employ coal gasification technology integrated with combined cycle electricity generation and the sequestration of carbon dioxide emissions.

Image Source: U.S. Department of Energy

Energy Technology Innovation Policy Research Group

DOE FY 2011 BUDGET REQUEST FOR ENERGY RESEARCH, DEVELOPMENT, DEMONSTRATION, AND DEPLOYMENT: ANALYSIS AND RECOMMENDATIONS

By Laura Diaz Anadon, Matthew Bunn, Gabriel Chan, Melissa Chan, Kelly Sims Gallagher, Charles Jones, Ruud Kempener, Audrey Lee, Venkatesh Narayanamurti

HARVARD Kennedy School
Belfer Center for Science and International Affairs

April 2010

TABLE OF CONTENTS

HIGHLIGHTS

In spite of the difficult fiscal situation, President Obama's FY 2011 budget request for energy research, development, and demonstration (RD&D) would increase funding for applied energy RD&D programs by 7% over the FY 2010 appropriation, to $3.9 billion. Most of the increase in the applied programs comes from the $300 million that would be allocated to ARPA-E. Funding for basic energy science research would increase by 12%, to $1.8 billion. Combining one-third of the funds provided by the American Recovery and Reinvestment Act of 2009 (ARRA) for basic energy sciences, energy RD&D programs, biological and environmental research, and energy technology deployment—roughly the amount expected to be spent during FY 2011—the FY 2011 request would result in total investments of over $17 billion, which exceeds President Obama's campaign promise to invest $15 billion a year for energy technology innovation. Once the ARRA funds are spent, however, it is unclear how current levels of investment in energy technology innovation will be maintained.

The modest 7% proposed increase in applied energy RD&D spending is certainly needed, but remains well short of the large and sustained investment likely to be required to transform U.S. and global energy use and production and to meet the climate, energy availability, and energy security demands of the twenty-first century. In real terms, the support for basic and applied energy RD&D would remain 30% below the 1978 level, the peak of government funding for energy RD&D in the United States. (See Figure 1).

The combination of support for ARPA-E with $107 million for the new Energy Innovation Hubs and continuing support of $140 million for the Energy Frontier Research Centers indicates that DOE and administration leaders are rightly taking a portfolio approach to the mechanisms used to fund energy RD&D. There is still an urgent need, however, for an improved institutional approach to managing large-scale demonstrations of new energy technologies; greater funding and strengthened coordination for international partnerships for energy technology innovation; and a more strategic approach to allocating and evaluating DOE's partnerships with the private sector. In addition, while the funds in ARRA would support several carbon capture and storage demonstration projects (which will hopefully be carried forward), additional funding for demonstrating this technology at scale in a range of different geologies and configurations is likely to be required.

The underlying data in the figures presented in this paper can be found in the database that accompanies this paper (Gallagher and Anadon 2010).[1] This database includes DOE funding for energy technology innovation from the creation of DOE in 1978 until today and is available at our website.

[1] Gallagher, K.S., Anadon, L.D. 2010. "DOE Budget Authority for Energy Research, Development, & Demonstration Database". March 20, 2010. Available at: http://belfercenter.ksg.harvard.edu/publication/20013/.

MECHANISMS FOR SUPPORTING ENERGY RD&D

The use of a "portfolio of mechanisms" to accelerate innovation is DOE's response to long-standing criticism that DOE's energy RD&D was not sufficiently efficient and innovative in developing and commercializing new energy technologies. But there is still more to be done to ensure that taxpayers get the maximum "bang for the buck" out of DOE's energy RD&D investments. (As the term is used here, "mechanisms" includes both ways of doing RD&D, such as laboratories and centers, and ways of channeling RD&D funding, such as cooperative agreements between DOE and private firms.) In DOE's vision, both new institutions and DOE's traditional energy RD&D funding offices have important roles to play.

ARPA-E

With a proposed budget of $300 million, the FY 2011 request would further consolidate the role of ARPA-E as one of the keystones of the U.S. government's energy innovation strategy, with a mission of funding high-risk, high-payoff projects "that no one else will fund"[2] to meet the climate challenge and improve energy security. ARPA-E was first funded with $400 million in the American Recovery and Reinvestment Act of 2009 (ARRA). As we discuss in our recent Policy Memo,[3] DOE should communicate aggressively to policymakers and the public that because of the high-risk nature of ARPA-E projects and the long time-frames of technology development, the early success rate of these efforts is not likely to be high. DOE and ARPA-E should develop a set of appropriate metrics to assess the quality of the organization, especially the technical excellence of the program officers responsible for the dispersal of the funds over a range of timeframes. Congress should give ARPA-E 5 to 10 years of strong, consistent funding to provide an appropriate chance to demonstrate its value. In order to ensure its nimbleness, ARPA-E must have the ability to make decisions free of traditional bureaucratic processes. It should be cognizant of innovation efforts in other parts of DOE, and at the same time it should be able to choose to pursue parallel paths of investigation, which would be healthy for innovation.

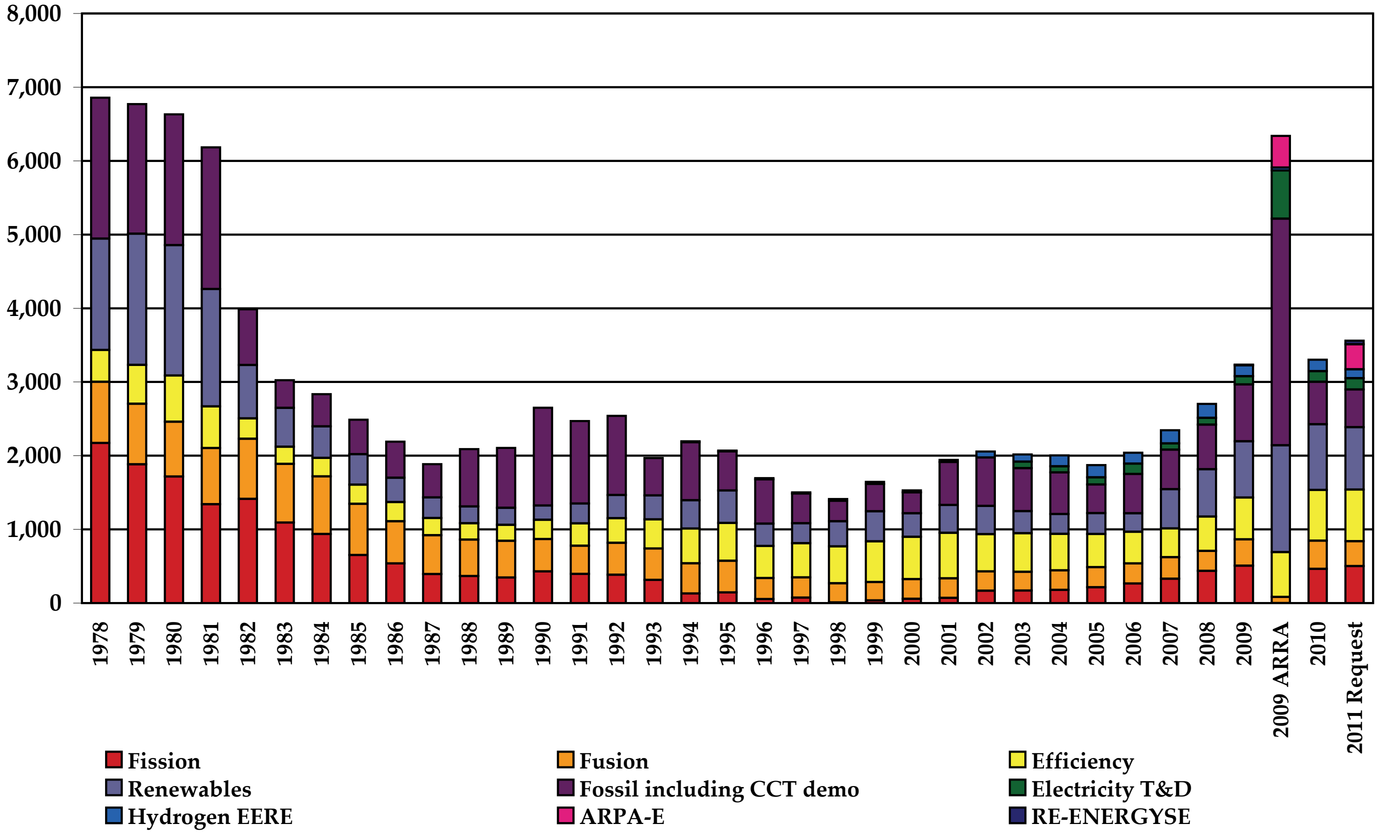
Energy Innovation Hubs

DOE's budget proposal would continue to support the concept of Energy Innovation Hubs, with $107 million. The FY 2011 request includes $24 million for each of the

[2] DOE. 2010. "Department of Energy – FY 2011 Budget Overview Rollout Presentation." February 1. Available at: http://energy.gov/media/Secretary_Chu_2011_Budget_rollout_presentation.pdf. Accessed on February 15, 2010.

[3] Anadon, L.D., Bunn, M., Jones, C., and Narayanamurti, V. 2010. "U.S. Public Energy Innovation Institutions and Mechanisms: Status & Deficiencies." Cambridge, Mass.: Policy Memo from the Science, Technology and Public Policy Program, Belfer Center for Science and International Affairs, Harvard Kennedy School, 14 January. Available at: http://belfercenter.ksg.harvard.edu/publication/19877/. Accessed on April 11, 2010.

Figure 1. Energy RD&D Funding by DOE Between 1978 and the FY 2011 Request*
(in millions 2005$)



* Figure 1 does not include funds for the EFRCs, Basic Energy Sciences, or the NSF. The nuclear fission figures do not include funding for nuclear facilities (e.g. Idaho facilities management, or radiological facilities management), because historically, a substantial fraction of this funding has gone to activities that were not directly related to RD&D on new nuclear energy technologies. The figure includes funds from ARRA.

three Hubs that received funding in FY 2010 (Energy Efficient Building Systems Design, Fuels from Sunlight, and Modeling and Simulation)—a $2 million increase per hub. In addition, the FY 2011 request includes $34 million to set up a new Hub under the Office of Science on "Batteries and Energy Storage." The Hubs have 5-year initial grant periods, which may be renewed for up to 10 years (a renewal after 10 years is expected to require even stronger justification). The longer funding time-horizons and the mission-oriented structure of the hubs could help break down the barriers between basic and applied research and lead to much-needed breakthroughs in areas such as energy storage. Overall, with appropriate management structures in place, the hub approach deserves support.

Energy Frontier Research Centers

The Energy Frontier Research Centers (EFRCs) initiative of the DOE Office of Science, which was created in FY 2009 and has made 46 awards to date, would receive $140 million in the proposed budget. The request proposes to use $40 million to increase the number of EFRCs. These centers have a greater focus than the hubs on fundamental research specifically related to key energy problems; whereas, the hubs aim to bridge the gap between basic and applied research, and are smaller in scale. The EFRCs' innovation model is based on enabling collaboration between different groups of researchers on cutting-edge research topics.

ARPA-E, the Hubs, and the EFRCs are designed to support different and necessary types of innovative activities. They all deserve funding support, but it is important that the activities they ultimately support reflect their different innovation models, and that they translate the information they generate to the private sector and other government organizations effectively.

Next Steps: The National Labs

These new energy RD&D mechanisms are important steps to strengthen U.S. energy innovation. Nevertheless, additional action is needed to strengthen U.S. energy innovation institutions—including additional in-depth analysis of the many institutions that now exist or are proposed, and how they can best work together.[4]

In particular, the nation needs a new approach to managing DOE's national labs. Over the past couple of decades there has been a progressive shift toward the national laboratories being managed by for-profit companies, as has occurred most recently at Los Alamos and Livermore. In addition, there has been an increasing emphasis on detailed direction from DOE headquarters. One of the implications of these shifts is that the labs have been increasingly focused on operational requirements in areas such as safety and security rules at the cost of a decreasing primacy of their technical mission. The government-owned contractor-operated (GOCO) system needs to be reinvigorated with more focused missions for each laboratory; the right laboratory leadership with sufficient authority to act; new steps to strengthen the culture of innovation; improved management structures, balancing freedom to innovate with accountability, including a rebalancing of what has sometimes proved to be excessive micromanagement from DOE headquarters; and stable funding allocated with sufficient flexibility to give laboratory management and researchers the ability to seize technological opportunities as they arise, while at the same time gathering information to learn and adapt.[5]

---

[4] Narayanamurti, V., Anadon, L.D., Sagar, A. 2009. "Transforming Energy Innovation." *Issues in Science and Technology* (Fall 2009): 57-64.
[5] *Id.*

Next Steps: Public-Private Partnerships

Cooperation with private firms is important to successful energy innovation. Public-private partnerships increase the funding available to projects, add expertise and other resources, and help bring technology into use. However, close partnerships between disparate organizations are difficult to manage and require major efforts focused on design and planning. While the current selection process may do an adequate job of selecting good proposals, it has not been deliberate about when to use 'real' partnerships (exemplified by cooperative agreements and CRADAs[6]) and when to use other more transactional mechanisms, such as simpler contracts and work-for-others agreements. Partnerships should fit into a strategy of distributing RD&D mechanisms in order to attract specific resources while expending the greatest effort only on the projects of highest importance.

To date, inconsistency of the public-private partnership effort at DOE across several dimensions, along with the lack of discussion about the use of partnerships, seems to indicate that partnerships and other support mechanisms are not being treated as a strategic element by DOE. An improved system of partnerships should include simple and consistent reporting and evaluation mechanisms, and routines for learning from past projects. Strategic decisions regarding partnerships must include the distribution of resources by technology, the types of overlapping interests to pursue and market failures to address, and the complementary abilities needed to achieve strategic goals.[7]

Next Steps: Managing Large-Scale Demonstrations

In several areas, government-funded, large-scale demonstrations of energy technologies are likely to be needed before these technologies can be taken up and widely deployed by the private sector. Five of the six CCS demonstration projects funded through the Recovery Act are still planned, the Next Generation Nuclear Plant project is ongoing, and large-scale demonstrations are likely to be needed in several other areas as well. To date, DOE has had a poor record of managing large-scale demonstration

[6] Cooperative research and development agreements (CRADAs) are technology transfer mechanisms funded by the non-government party and involving collaborative research and sharing the resulting intellectual property. Cooperative agreements are mechanisms to support and stimulate R&D by sharing costs and other resources for projects selected by competitive proposal [see DOE. 2007. "Report on Technology Transfer and Related Technology Partnering Activities at the National Laboratories and Other Facilities Fiscal Year 2006." Office of Policy and International Affairs. Washington D.C.: Department of Energy; DOE. 2009. "R&D support." Available at: http://www.doe.gov/r&dsupport.htm. Accessed on March 15, 2010; and Federal Laboratory Consortium. 2007. "Technology Transfer Mechanisms Used by Federal Agencies: A Quick Reference Guide" (Draft)]. Both CRADAs and cooperative agreements involve closer coordination between parties than grants or other "transactions," e.g. work-for-other agreements.

[7] Jones, C., Anadon, L.D. 2010. "Public-Private Partnerships for Energy Technology Innovation." *Global Energy Assessment*. Forthcoming. IIASA.

projects. Such efforts, designed to provide information the private sector can use to judge how technologies will work and how much they will cost under realistic commercial conditions, pose profoundly different management challenges than do projects at earlier, smaller-scale innovation stages. The United States needs a new institution for managing large-scale demonstration projects—possibly one separate from DOE, such as the government-owned energy technology demonstration company suggested by Ogden, Podesta, and Deutch.[8]

Next Steps: Balancing Stability and Flexibility in Strategy

DOE cannot set a particular strategy and consider it permanent. Programs must have a balance of stability and the flexibility needed to seize new opportunities, learn from experience, and adapt to changing conditions. DOE should establish targeted mechanisms that allow managers to learn from each project and institution and adjust the design of future projects and institutions to the technical and organizational lessons of the past. This will require a system of reporting the features, inputs, and results of each project, with the data broadly shared across DOE. Such a system must be simple to report and access, to avoid creating an additional burden on project participants, and should be separate from incentive or accountability systems so that lessons may be learned from unsuccessful projects without threat to project participants. At the same time, the distribution of effort across technology areas, time scales, risk profiles, and investment mechanisms should adjust to changing conditions in the state of technology, markets, environment, and economics. A transparent mechanism to assess conditions and adjust accordingly would reduce the uncertainty that occurs at each budget cycle while improving the fit between effort and need.

BUDGETS FOR BASIC AND APPLIED ENERGY RD&D

Beyond the funding for the EFRCs, the Hubs, and ARPA-E, the remaining $5.2 billion for basic and applied energy research will be spent through Basic Energy Sciences (BES) core research and through the applied DOE offices.

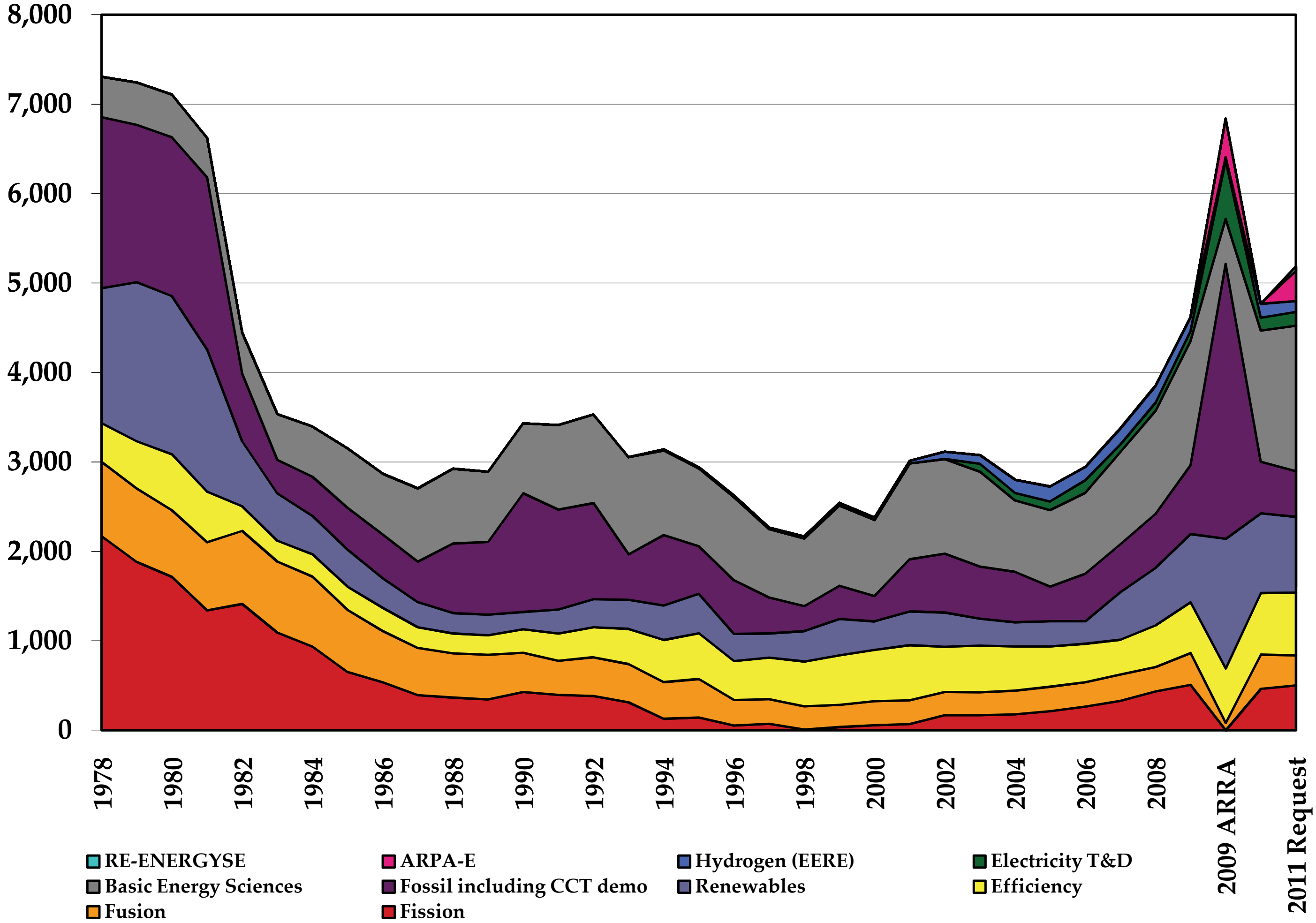
Basic Research

BES would receive $1.8 billion in the proposed budget, $200 million more than the FY 2010 appropriation. The recent increases bring the BES budget to a more appropriate level, on a path to double from the FY 2004 appropriation. This is a worthwhile investment, particularly given the importance of energy innovation in the U.S. economy. The BES program utilizes three main funding mechanisms, two of which were dis-

[8] Ogden, P., Podesta, J. & Deutch, J. 2008. "A New Strategy to Spur Energy Innovation." *Issues in Science and Technology* (Winter 2008).

Figure 2. Basic Energy Sciences (BES) and Applied Energy RD&D Funding by DOE Between 1978 and the FY 2011 Request*

(in millions 2005$)



* Figure 2 includes the BES program, which means that all funding for the Energy Innovation Hubs and the EFRCs is included. Again, the nuclear fission figures do not include funding for nuclear facilities (e.g. Idaho facilities management, or radiological facilities management), because historically, a substantial fraction of this funding has gone to activities that were not directly related to RD&D on new nuclear energy technologies. The figure includes funds from ARRA. Details on the BES program can be found on: http://www.cfo.doe.gov/budget/11budget/Content/Volume%204.pdf.

cussed above: EFRCs, the Energy Innovation Hubs, and the "core research" program. As shown in Figure 2, the basic energy research component of DOE has more than doubled (in real terms) from its 2004 level. In addition, funding for environmental and biological research (not included in Figure 2), would increase 3.8% from the FY 2010 appropriation, to $627 million.

Nuclear Fission and Fusion

For nuclear fission R&D, the Obama administration requested $566 million, a 9% increase over the FY 2010 appropriation.[9] The bulk of these funds would go to two programs: "Fuel Cycle R&D" ($201 million, formerly the Advanced Fuel Cycle Initiative), and "Reactor Concepts RD&D" ($195 million, formerly the Generation IV Nuclear Energy Systems project). With the termination of funding for licensing activities for the Yucca Mountain nuclear waste repository, the Fuel Cycle R&D program would explore a variety of possible approaches to managing spent fuel. The Reactor Concepts RD&D effort would continue work on the Next Generation Nuclear Plant (NGNP, a very high-temperature gas reactor) and other reactor concepts, while initiating a targeted program on small modular reactors.

The fusion program would receive $380 million, a 10% decrease from the FY 2010 appropriation, returning the fusion program to somewhat below its FY 2009 funding. Funding would continue to be a third higher than it was in FY 2008 and previous years, however.

Fossil Energy and Carbon Capture and Storage

With $404 million for fossil energy RD&D, the FY 2011 budget request would represent a 10% decrease from the FY 2010 appropriation, a 43% reduction from the FY 2009 appropriation, and a 21% decrease from the FY 2008 appropriation.[10] At the programmatic level, the 10% decrease from the 2010 appropriation to the 2011 budget request comes almost entirely through the lack of funding for the natural gas technologies program and the unconventional fossil energy technologies program.[11] The FY 2011 $404 million request for fossil energy RD&D is entirely through the coal program's fuels and power systems subprogram. And within the subprogram, the request allocates $261 million for fuel and power plant RD&D—which includes $55 million for advanced IGCC, $65 million for innovations for existing plants, and the remainder for programs on advanced turbines, fuels, fuel cells, and advanced research in materials, models, and controls—and $143 million for carbon sequestration RD&D.

While the FY 2011 request cuts non-coal RD&D programs, the funding for coal RD&D in the FY 2011 request relative to the FY 2010 budget appears unchanged. However, the coal program was bolstered by the approximately $2 billion in announced

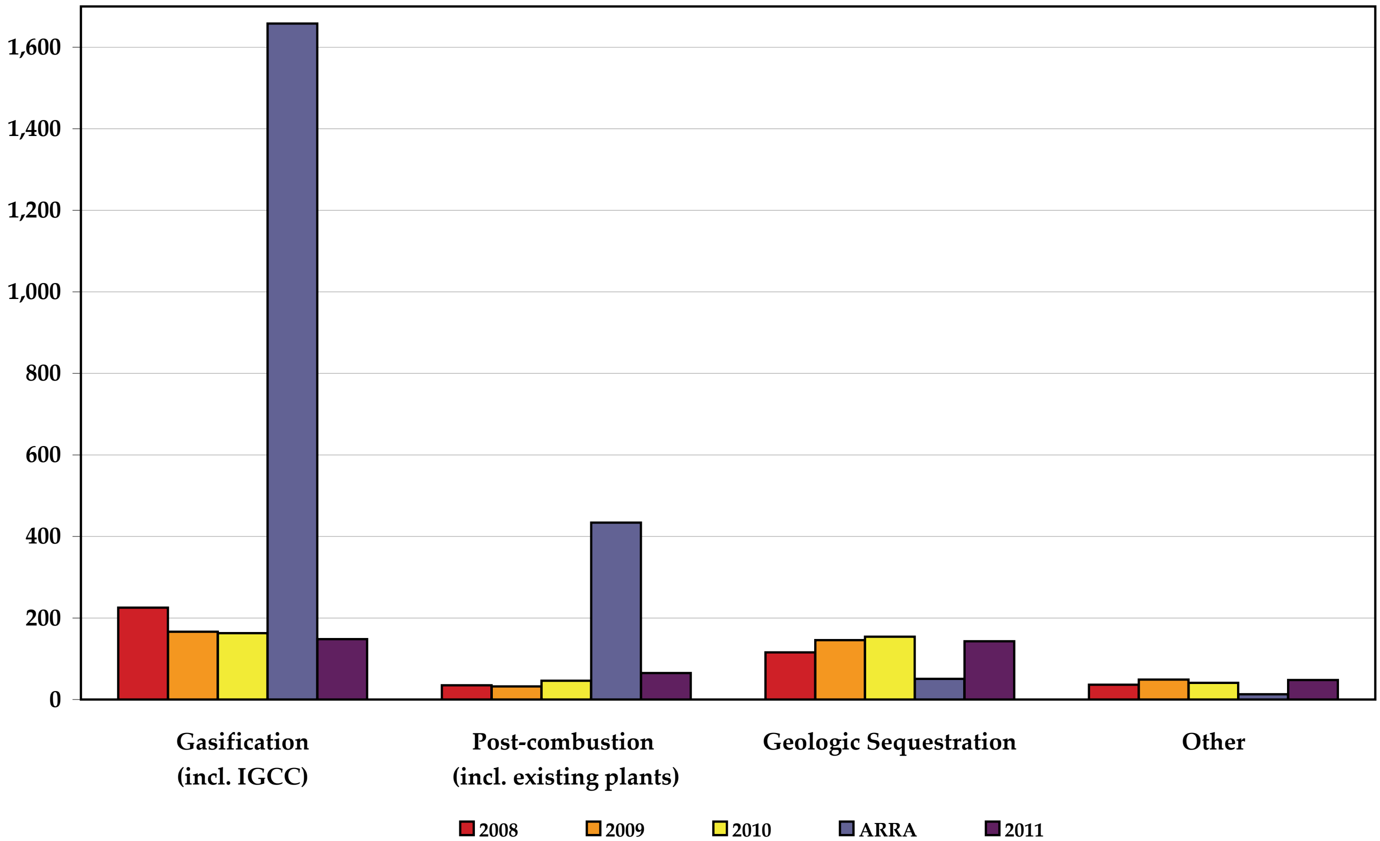
[9] This figure does not include nuclear facilities management, or nuclear energy programs pursued for purposes other than the production of commercial energy, such as naval reactors or the construction of a plutonium-uranium mixed oxide (MOX) fuel plant for disposition of excess weapons plutonium.

[10] The totals for fossil energy RD&D exclude congressionally-directed projects and non-RD&D expenses such as program direction, DOE facility upgrades, environmental restoration, student fellowships, and the like.

[11] The FY 2011 request would also not fund the coal and biomass to liquids program and the water management and fine particulate control for existing plants R&D program—both of which received funding in the FY 2010 appropriation.

Figure 3. Fossil Energy Research, Development, and Demonstration Related to Coal Power Generation with Carbon Capture and Sequestration Between 2008 and the FY 2011 Request*

(in millions 2005$)



* Figure 3 includes ARRA announcements, but excludes industrial CCS, which received $1.5 billion from ARRA.

funding for coal RD&D contained in ARRA, some of which will still be available to spend in FY 2011. Of the ARRA funds, $1 billion was allocated to FutureGen, over $800 million was awarded to four new demonstration projects under the extended third round of the Clean Coal Power Initiative (CCPI),[12] and $69 million was allocated

[12] The CCPI funds research and large-scale projects to improve the environmental challenges associated with coal-based power generation. Eight projects were selected under its first round solicitation in January 2003; two of these projects are in the operational phase, one was completed, and the remaining five were withdrawn or discontinued Under the second round of CCPI solicitations, four projects were selected in October 2004. Two of these projects are under development and will demonstrate advanced IGCC technology (without sequestration), one project in operation is demonstrating a neural-network control process for advanced multi-pollutant controls by means of plant optimization, and the fourth project was withdrawn (see: DOE. 2010. "Clean Coal Technology & The Clean Coal Power Initiative." April 6. Available at: http://www.fossil.energy.gov/programs/powersystems/cleancoal/. Accessed on April 11, 2010). Although $800 million from ARRA was awarded to the third round of CCPI (see: DOE. 2010. "Recovery and Reinvestment - Breakdown of Funding." Available at: http://www.energy.gov/recovery/breakdown.htm. Accessed on April 11, 2010), over $1.09 billion in CCPI Round III awards has been announced (see: DOE. 2010. "Fossil Energy. Recovery Act. Clean

for geologic carbon sequestration R&D and training. An additional $1.5 billion from ARRA was allocated for large-scale industrial CCS, including innovative concepts for beneficial uses of CO_2. The industrial CCS program is the largest Recovery Act program for the Office of Fossil Energy; however, only $94 million of the $1.5 billion (6%) has currently been awarded, let alone spent. This delay is partly attributable to the need to prepare an Environmental Impact Statement (EIS) under the National Environmental Policy Act (NEPA), which often takes two years, before large-scale industrial projects can be funded. Similarly, FutureGen and CCPI projects will likely face similarly lengthy NEPA review processes. The DOE should continue to work to streamline the NEPA review process to accelerate the realization of these projects.

Figure 3 shows the trend over the last four budget cycles (including ARRA) of RD&D funding for coal power generation, with CCS divided into RD&D allocated towards coal gasification, post-combustion capture, geologic sequestration, and other supporting technologies.

The funds for pre-combustion capture via coal gasification in both the FY 2011 budget request and ARRA are well over three times the funds for post-combustion CO_2 capture. Given the likely importance of developing technology to capture carbon from non-IGCC coal plants, Congress should consider providing additional funds for post-combustion CO_2 capture RD&D. Similarly, the FY 2011 budget proposes to decrease funding for geologic storage RD&D by 7% from FY 2010, even though, in contrast to capture technology, relatively few funds are available from ARRA for this work. Therefore, Congress should consider increasing funding for geologic storage RD&D as well.

Six large-scale CCS demonstration projects funded through the Recovery Act have been announced; in December 2009 one of them (Southern Company's post-combustion CCS retrofit demonstration on a 160 MW plant in Mobile, AL) was withdrawn. Of the remaining five projects, three will demonstrate Integrated Gasification Combined-Cycle (IGCC) technology, in which coal is converted to synthesis gases before it is burned to facilitate the removal of carbon dioxide,[13] and two will demonstrate post-combustion carbon capture, which could potentially be applied to coal plants with designs similar to those that are widely deployed today.[14] These projects will complement the two

Coal Power Initiative Round III." Available at: http://fossil.energy.gov/recovery/projects/ccpi.html. Accessed on April 11, 2010). Of the announced CCPI Round III funding, $796 million has obligated, as of March, 28 2010. (see: DOE. 2010. "DOE Recovery Act Funding." Available at: http://www.energy.gov/recovery. Accessed on April 11, 2010).

[13] The three IGCC plants announced as part of the Recovery Act are the FutureGen plant in Mattoon, IL, Summit Texas Clean Energy's Texas Clean Energy Project in Bainbridge Island, WA, and Hydrogen Energy International's Hydrogen Energy California Project in Kern County, CA.

[14] The two remaining post-combustion capture projects announced as part of the Recovery Act are American Electric Power Company's Mountaineer CO_2 Capture and Storage Demonstration in Columbus, OH, and Basin Electric Power Cooperative's Post Combustion CO_2 Capture project in Beulah, ND (see: DOE. (2009). "Recovery Act – Clean Coal Power Initiative Round III." Available at: http://fossil.energy.gov/recovery/projects/ccpi.html. Accessed on March 25, 2010.

IGCC demonstration projects selected in 2004 and funded through the second round of the CCPI (although the round-two CCPI projects do not capture CO_2). The CCS demonstration projects are structured as public-private partnerships with different levels of private sector cost-share. For example, FutureGen will have a private sector cost-share of 33% of a total cost of $1.5 billion,[15] and the extended third round CCPI demonstration projects (prior to the withdrawal of one of the projects) would have had a minimum 69% private sector cost-share of the over $3 billion total cost.[16] The large majority of funding for industrial CCS demonstration projects has not been awarded[17], and as a result we have little information regarding the details of the partnerships or mechanisms that will be set up to carry out this effort; however, DOE has a cost-share target of 50% for this program[18]. DOE should seek to identify the key lessons from its (admittedly short) FutureGen and CCPI experiences with demonstrations.

The Obama administration has devoted extensive high-level attention to the issues posed by the development, demonstration, and deployment of CCS technology. On February 3, 2010, the administration released a Presidential Memorandum creating an "Interagency Task Force on Carbon Capture and Storage." The Task Force is charged with recommending a "plan to overcome the barriers to the widespread, cost-effective deployment of CCS within 10 years, with a goal of bringing 5 to 10 commercial demonstration projects online by 2016."[19] This is an important new step and the task force could learn from previous projects and awards to ensure that public funds are used to generate information for the next generation of CCS facilities and for accelerating and improving the efficiency of the loan guarantee process. In addition, as discussed in more detail below, recent legislation has authorized substantial loan guarantees to support CCS projects.

---

[15] The exact private investment in FutureGen is estimated to be between $400-$600 million. The 33% private cost-share estimated above was calculated using an average value of $500 million.

[16] DOE. 2010. "Secretary Chu Announces $3 Billion Investment for Carbon Capture and Sequestration." DOE Office of Public Affairs. December 4, 2009. Available at: http://www.fossil.energy.gov/news/techlines/2009/09081-Secretary_Chu_Announces_CCS_Invest.html. Accessed on March 12, 2010.

[17] Of the $1.5 billion allocated to industrial CCS, only $21.6 million was awarded in the first of two award rounds. The $21.6 million award is being matched by an almost equal amount of private sector funding (the DOE cost share for the first round was 49%) (see: DOE. 2009. "Fossil Energy Techline - Secretary Chu Announces First Awards from $1.4 Billion for Industrial Carbon Capture and Storage Projects." DOE Office of Fossil Energy. October 2. Available at: http://fossil.energy.gov/news/techlines/2009/09072-DOE_Announces_Industrial_CCS.html. Accessed on March 28, 2010).

[18] The DOE announced its cost-share target for this program in the June 8, 2009 funding opportunity announcement: http://fossil.energy.gov/programs/sequestration/publications/arra/DE-FOA-0000015.pdf

[19] The White House. 2010. "Presidential Memorandum—A Comprehensive Federal Strategy on Carbon Capture and Storage." Office of the Press Secretary. February 3. Available at: http://www.whitehouse.gov/the-press-office/presidential-memorandum-a-comprehensive-federal-strategy-carbon-capture-and-storage. Accessed on March 4, 2010.

Renewable Energy

Excluding congressionally directed projects, which added up to around $240 million in FY 2010, the FY 2011 budget request would increase funding for renewable energy RD&D projects by 16% to $740 million (see Figure 4).[20]

The largest absolute increase over the FY 2010 appropriation would be directed to the solar program. It would receive a total of $302 million—a $55 million boost, largely directed to double funding for work on concentrating solar power. The proposed solar budget is 22% more than the FY 2010 appropriation, and a 75% increase over funding in FY 2009.

The largest relative increase from FY 2010 levels amongst renewables is for the wind program. Under the administration's proposal, wind would receive $122 million, a 53% funding increase over FY 2010, and 125% more than in FY 2009. This increase is largely due to a new focus on offshore wind technology, which would receive $49 million. In FY 2009 and FY 2010 this activity was included under the Low Wind Speed Technology category and added up to $5 million in FY 2010—meaning that the budget request represents a 10-fold increase. With other countries such as the United Kingdom—which sees the development of offshore wind as a "replacement" for its oil and gas industry (which is declining due to the depletion of the North Sea reservoirs)[21]—and Denmark[22] leading the world in the deployment offshore wind technologies, the United States is correctly increasing its attention to this option. Figure 4 shows that since the 2006 low point, support for renewable energy RD&D has tripled.

There has been a striking rise in congressionally directed projects in the area of renewable energy since FY 2008, which is the first year that included these projects in the budget justification documents. Although allocating congressionally directed projects reported under the Office of Energy Efficiency and Renewable Energy between renewable energy and energy efficiency is far from straightforward, there is clearly a growing trend in the area of renewable energy. The large portion of the budget that Congress earmarks for favored projects makes it more difficult for DOE to manage a program targeted toward the areas it has identified as the highest priorities.

---

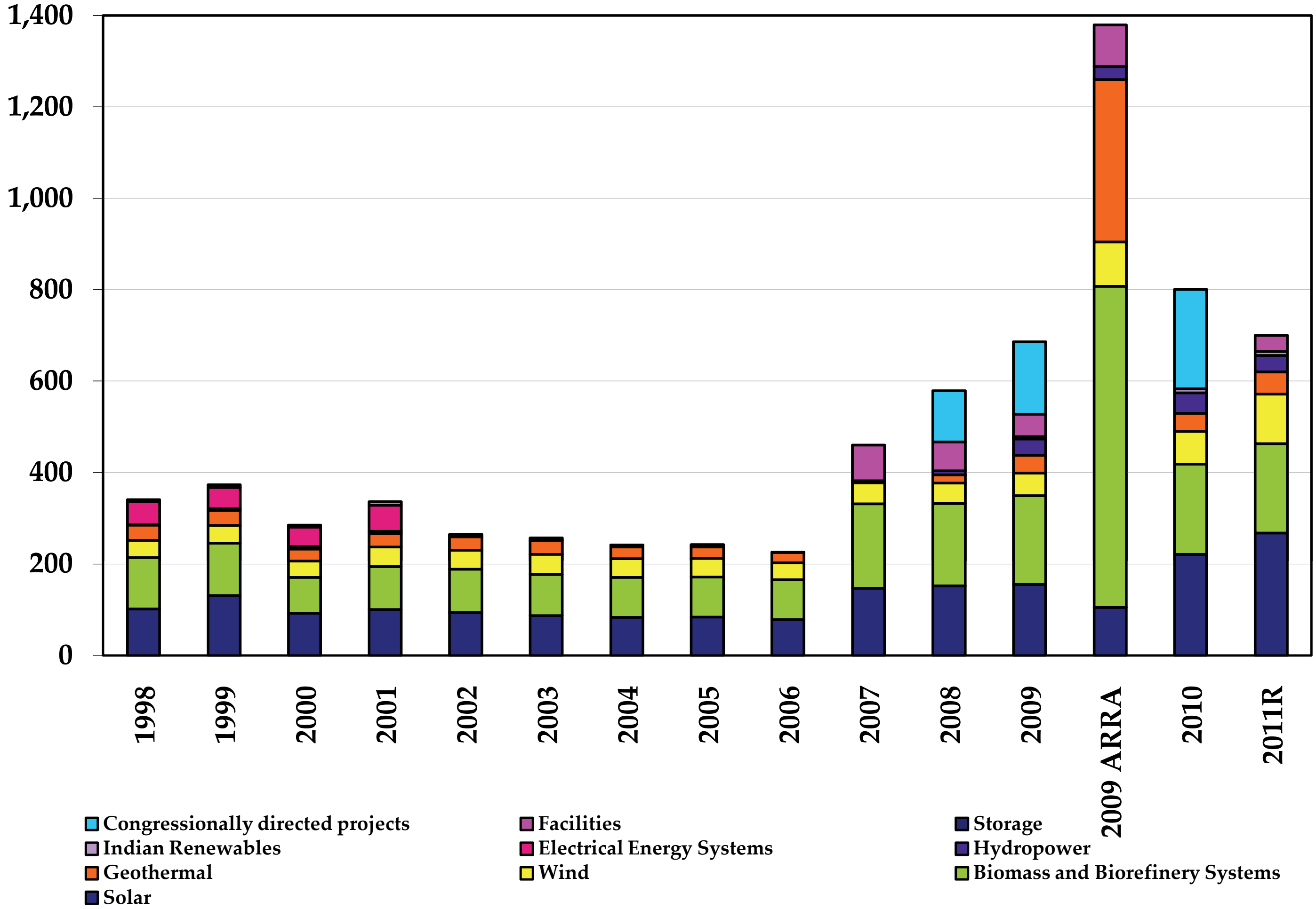
[20] These numbers exclude funding for "policy and management", which are included in the aggregate numbers of expenditures in Figures 1 and 2.

[21] U.K. Department of Energy & Climate Change. 2010. "Press Notice – Offshore Wind Expansion Biggest Expansion in the World." January 10. Available at: http://www.decc.gov.uk/en/content/cms/news/pn10_004/pn10_004.aspx . Accessed on February 28, 2010.

[22] Denmark's 91-turbine farm near Esbjerg—180 miles west of Copenhagen— with 209 MW of capacity is the world's largest offshore wind farm. Combined with the Horns Rev 1 farm it makes up 11% of total installed wind capacity in Denmark, which gets 20% of its total electricity from the wind. See: Zeller, T. 2009. "Bloomberg Eyes Danish Offshore Wind Farm and Sees New York's Future." *The New York Times.* December 14.

Figure 4. Breakdown of DOE Funding for Renewable Energy RD&D Programs Between 1998 and the 2011 Request*

(in millions 2005$)



* Figure 4 includes funding in the ARRA 2009, but excludes funding for program direction.

Energy Efficiency

Excluding congressionally directed projects and program direction, the FY 2011 budget request is $629 million, a 4% increase for the office's three energy efficiency programs—efficiency for vehicles, buildings, and industry. The growth of the building technologies program during Obama's tenure is dramatic. DOE has a dedicated Energy Innovation Hub to foster integrated basic and applied research and development on building technologies and the FY 2011 request of $231 million would more than double the size of the program from the FY 2008 appropriation ($107 million). Furthermore, as proposed, the vehicle technologies and industrial technologies programs would increase by 56% and 58%, respectively; the vehicle technologies program accounts for half of the proposed energy efficiency RD&D. (See Figure 5).

Electric Transmission and Distribution

The electric transmission and distribution (T&D) program would receive $173 million in the proposed budget, a 9% increase over the FY 2010 appropriation. This program has been a priority for the Obama administration; it has grown by 73% since FY 2008.

The smart grid R&D activity, which was created in FY 2010, would receive $39 million, $22 million more than in its first year. The $40 million proposed for RD&D on energy storage for stationary applications is almost a tripling over the FY 2010 appropriation.

Hydrogen

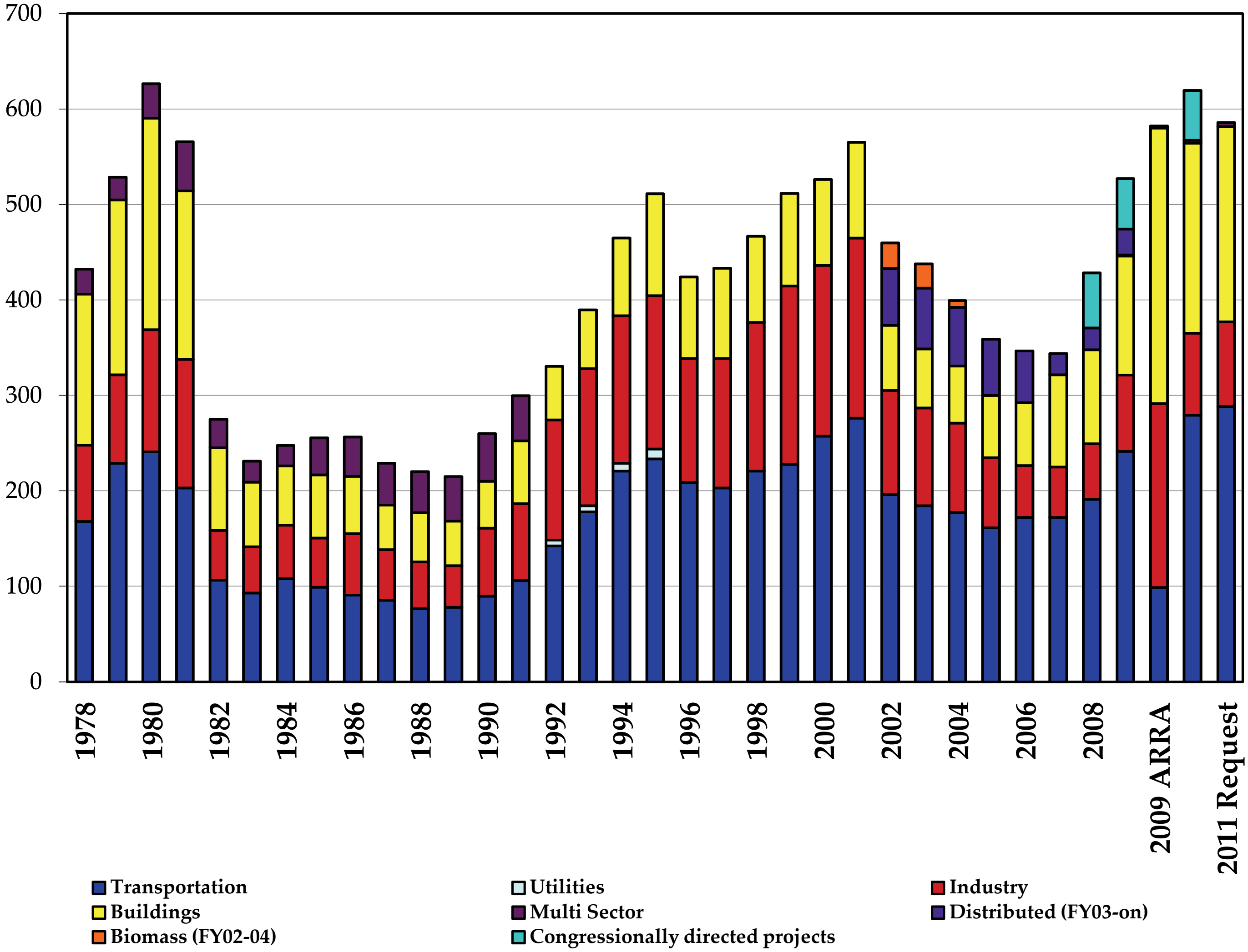
The Obama administration has been much less enthusiastic about hydrogen than the Bush administration, arguing that a variety of technical and market barriers make it unlikely that hydrogen will come into widespread use as an energy carrier. Accordingly, the administration's $137 million request for hydrogen RD&D represents a $43 million cut from the FY 2010 appropriation, taking the program below the funding level it had in FY 2004. The program focuses on fuel cell systems for stationary, portable, and transportation applications and on addressing the most critical barriers to the development of fuel cells, including membranes, catalysts, electrodes, and modes of operation.

INTERNATIONAL COOPERATION

As countries around the world face serious energy challenges and are investing in new technologies to meet them, international energy RD&D cooperation is likely to be a key to successfully meeting the energy challenges of the 21st century. Today, however, there does not appear to be any focused, integrated strategy for international energy RD&D cooperation.

Most of DOE's entities do have some level of cooperation with actors in other countries (e.g., visits, workshops, information sharing, discussions about codes and standards). International cooperation activities currently take place at national labs, within technology programs, and at the program office levels, while management and coordination of international cooperation activities takes place within separate programs, at the level of program offices, and in the Office of Policy and International Affairs (PI). Our analysis suggests that there is some overlap in both activities and management responsibilities among the different labs, programs, and offices engaged in international

Figure 5. Breakdown of DOE Funding for Energy Efficiency RD&D Between 1998 and the FY 2011 Request*
(in millions 2005$)



* Figure 5 includes funding in the ARRA 2009, but excludes funding for program direction.

collaboration, and that there is no consistency in managing international cooperation programs among the different program offices. For example:

- International cooperation activities on biomass and biofuels take place at Ames Laboratory, at Oak Ridge National Laboratory, and at Pacific Northwest National Laboratory, while the biomass program within EERE is also involved with International Energy Agency Bioenergy Agreements and bilateral collaborations.

- EERE, PI, and the Energy Information Administration (EIA) all have activities aimed at assessing the technical and market potential for the deployment of biomass activities in foreign markets.

- Activities to engage businesses and to promote the export of U.S. biomass energy technologies are coordinated within EERE yet do not seem to be aligned with technology export activities for coal in the Office of Fossil Energy (FE) or with export activities of nuclear energy technologies within the Office of Nuclear Energy (NE).

- Both the 'International Program Support' and the 'Coal Technology Export' program from FE seem to support similar activities.

These examples do not point to an overarching and consistent strategy within DOE, and data quantifying the extent of these activities are not available. It is therefore difficult to evaluate the efficiency of DOE's international activities. The FY 2011 request, however, provides insight about some of DOE's activities in the area. Below, we summarize the information on programs and activities within the different DOE Offices focused on international projects. Note that while the amounts set aside for international cooperation are too small to finance any substantial amount of joint RD&D, other parts of these programs offices can pursue international cooperative projects with their funds when that appears to be the best way to meet these programs' goals.

- ***Office of Energy Efficiency and Renewable Energy (EERE).*** The FY 2011 request includes an increase in support for international projects in EERE from $10 million to $25 million through the International Program Support subprogram. These projects include work on cooperative RD&D, market transformation, and assessments of global clean energy potential. They are carried out within the framework of the International Energy Agency and other bodies, and through bilateral partnerships with OECD countries, major emerging economies (e.g. China, India, Brazil), and Israel. The recent set of agreements with China under the Strategic and Economic Dialogue, the Energy Efficiency Action Plan, and the U.S.-China Renewable Energy Partnership are particularly important if they are carried forward. They include cooperation on building and industrial efficiency, electric vehicles, biofuels, wind, and solar energy, and joint R&D through the U.S.-China Clean Energy Research Center. The total funding for these international efforts remains very small, however.

- ***Office of Nuclear Energy (NE).*** The FY 2011 request also includes $3 million for International Nuclear Energy Cooperation through NE. This new subprogram would work on developing, negotiating, and executing international bilateral and multilateral agreements; providing policy analysis and guidance on U.S. international civil nuclear activities; and supporting international nuclear energy cooperation and monitoring of activities associated with the export of U.S. nuclear energy goods and services.

- ***Office of Fossil Energy (FE).*** FE includes just over $1 million for International Program Support and Coal Technology Export to fund FE's work with the International Energy Agency, and to "enhance the competitiveness and adoption of U.S. environmental technology in China and utilize specific initiatives to protect local and global environments through the use of U.S. Clean Coal Technologies in targeted countries."

- ***Office of Science (OS).*** The OS request includes $80 million to fund the U.S. contribution to the International Thermonuclear Experimental Reactor (ITER) located in Cadarache (France), and $5 million to support the research of U.S. scientists on fusion energy facilities in Europe, Japan, China, South Korea, the Russian Federation, and India—the ITER members.

DOE's budget request correctly reflects the increased importance of coordinating international cooperation activities in response to the recent high-level energy cooperation agreements with China and India. Budgets for the coordination of energy efficiency and renewable energy technologies have increased substantially (from $10 million to $30 million) and new programs have been developed to evaluate nuclear energy technologies ($3 million in total). But there is little apparent consistency in managing international cooperation programs among the different program offices.

Next Steps: International Cooperation

Since the United States has signed several agreements, most importantly with China and India, on a range of energy technologies and energy innovation activities, it is important that DOE's structure be aligned to pursue international cooperation efficiently. In particular, it is important to coordinate activities focused on specific energy technologies taking place with different countries, along with synergies among different energy technologies being pursued with a specific country. Furthermore, it is important for DOE to strengthen its evaluation of the impact of international cooperation projects and to establish clear objectives and performance criteria for these projects. By taking such steps, DOE will be better able to follow through with these international cooperation agreements, build trust between countries, and pursue deeper collaborations on projects like joint carbon capture and storage demonstration projects in the future.

DEPLOYMENT

The FY 2011 budget request includes $920 million for a variety of programs to support deployment of clean energy technologies. The request also asks Congress to authorize DOE to provide an additional $36 billion in loan guarantees for deployment of new nuclear power plants and to appropriate an additional $500 million in government funds to pay the costs of $3 to $5 billion in loan guarantees for innovative energy efficiency and renewable energy projects. The loan guarantee proposal would roughly triple the $18.5 billion in nuclear loan guarantee authority previously available. The appropriations request for deployment programs would represent a $600 million increase over the FY 2010 appropriation, though the deployment funds are only a fraction of those available in ARRA, some of which are still being spent.

Loan Guarantees

For nuclear loan guarantees, there would be no appropriation, as the firms receiving the guarantees would pay a "credit subsidy fee" equal to DOE's estimate of the cost to the government of bearing the risk of having to pay the guarantee amount if the project goes bankrupt. The money to pay this fee would typically be added to the capital cost of the project. In contrast, the Obama administration argues that this approach of having the companies pay the fee is "cost prohibitive for many project sponsors such as start-up and pre-revenue generating companies that are common in the energy efficiency and renewable energy sector,"[23] and has therefore proposed that the government pay the fee for projects in these categories. In addition to these loan guarantee programs, the Energy Policy Act of 2005, the Energy Improvement and Extension Act of 2008, and the 2009 appropriations bill provide a total of $11.15 billion in loan guarantees for clean coal demonstration projects.

Loan guarantees can seem an almost magical tool to policymakers, allowing an appropriation of a few hundred million dollars—or of no money at all, if the recipients pay the government's cost of offering the guarantee—to support tens of billions of dollars in clean energy projects. But loan guarantees do not create free money—they simply shift risk from investors and lenders to taxpayers, thereby making capital-intensive projects cheaper to finance and more economically viable. *If* DOE estimates the risks correctly, the cost to the government of offering the guarantees will be modest (or zero, when the firms pay the expected cost); but if more projects default than expected, taxpayers would have to pay billions of dollars to cover the guarantees.[24]

On balance, DOE's loan guarantee proposal is worthy of support, though it represents a calculated gamble that only a modest number of these plants will default. Given the large risks of building the first few plants of a new generation of nuclear designs—in an environment in which no reactor has been built in the United States in decades, win which the estimated capital costs of nuclear plants have increased dramatically in the past seven years, and in which the first unit of the European Pressurized Reactor (EPR) design, under construction in Finland, is experiencing long delays and huge cost overruns—it is unlikely that any significant number of new nuclear power plants

[23] DOE. 2010. "FY 2011 Budget Congressional Budget Request." Vol. 2, DOE/CF-0048. Washington, D.C.: DOE, February 2010, p. 268.

[24] If private firms believed the risk of default could be estimated with confidence, then insurance for this risk would be available on private markets at reasonable rates and federal loan guarantees would not be needed.

would be built in the United States without loan guarantees. With the increased estimates of plant cost, the $18.5 billion previously available would only have been enough to support 2-4 reactors. The hope is that an expanded program of guarantees for deployment of a larger number of reactors will make it possible to reduce risks and costs for subsequent plants to a level that will be economically competitive without further loan guarantees, but this result is by no means assured.

Estimating the real risk of default in these projects and structuring guarantees so that they adequately protect the taxpayer without unduly burdening the supported projects is a difficult challenge, and has required DOE to hire new staff with financial expertise for a new loan guarantee office. The FY 2011 request calls for $58 million in spending just to administer this effort (though this cost would be paid by the firms receiving the loan guarantees). The initial efforts to implement the loan guarantee program were very slow, provoking Congressional complaints, but several major guarantee agreements have now been announced, including $8.3 billion to support construction of two new nuclear reactors, announced in early 2010. DOE's goals for its loan guarantee program are extraordinarily ambitious: it is hoping that 85% of the projects receiving loan guarantees will be in commercial operation by the end of FY 2014, with guaranteed projects totaling 9 GWe of installed capacity by then—only four and a half years from now.[25] Recent experience with nuclear construction suggests that there is little chance that any nuclear projects will in fact be in commercial operation at the end of FY 2014.

Assessing the relative value of loan guarantees and other deployment programs

Loan guarantees are one of several policy tools that can be used to support deployment of clean energy technologies. Which policy tool is most appropriate depends on the particular state of different technologies, and the principal market barriers they face. For example, in building a new solar plant the time and cost to build can be estimated reasonably accurately in most cases, but the cost is high. In that case, tools that guarantee an electricity price high enough to cover the cost—such as long-term power purchase agreements or feed-in tariffs—or tools that reduce the production cost (such as production or investment tax credits) can encourage deployment. In the case of nuclear power, where the risk of higher-than-expected costs and longer-than-expected delays is high, loan guarantees may be more important. Other deployment incentives, from efficiency standards to renewable portfolio standards, can also play important roles. Ultimately, the most important deployment incentive will be getting the prices right by putting a substantial price on carbon, a step which would benefit all low-carbon energy technologies equally. (A substantial price on carbon would also reduce the risk that guaranteed projects would default, reducing risk to the taxpayer.) Given the wide range of tools available, and their potentially differing roles in promoting different

[25] DOE. 2010. "FY 2011 Congressional Budget Request." Vol. 2, p. 265.

Table 1. DOE Energy Technology Deployment Programs in FY 2008, FY 2009, the ARRA 2009, FY 2010, and the FY 2011 Budget Request*

(all numbers in current U.S.$)

Program	FY 2008	FY 2009	2009 ARRA	FY 2010	FY 2011
Conservation Weatherization Program Excluding Training and Technical Assistance	223	446	4,878	207	293
Federal Energy Management Program	20	22	22	32	42
State Energy Program Grants	44	50	3,085	50	75
Energy Efficiency and Conservation Block Grants	0	0	3,184	0	0
Advanced Technology Vehicles Manufacturing Loans	0	7,510	10	20	10
Other ARRA Deployment - energy efficient appliance rebates, advanced battery manufacturing, alternative fueled vehicles pilot grant program, transportation electrification, information and communication efficiency	0	0	3,034	0	0
Title 17 - Innovative Technology Loan Guarantee Program: renewewable, adv. fossil, fuel cells, CCS, adv. nuclear, efficiency, poll. control, refineries	5	0	0	0	500
Smart Grid Investment Section 1705 Temporary Loan Guarantee Program - commercial technologies, incl. renewables, thermal energy, T&D, innovative biofuels (to be spent by 2011)	0	0	3,960	0	0

* The funds on this table are appropriated amounts. In the case of loan guarantees, the amount of the loans that would be guaranteed would be far larger.

technologies, Congress should consider asking for an independent review of the relative value of loan guarantees and other policies to support deployment of clean energy technologies.

Other Deployment Programs

Almost half of the funding for deployment programs proposed in the FY 2011 request would be directed toward energy efficiency programs—the Conservation Weatherization Program, the Federal Energy Management Program, and the State Energy Program grants (see Table 1). The Advanced Technology Vehicles Manufacturing Loans program would receive $10 million to aid the administration of the $7.5 billion appropriated by the FY 2009 budget.

There are several sources of funding for the deployment of advanced coal technology power plants. The Energy Policy Act of 2005 authorized $1.65 billion in tax credits for clean coal projects that utilize Integrated Gasification Combined Cycle (IGCC), advanced coal technologies, or gasification projects for chemicals production. In addition, the 2009 appropriations bill provided $8 billion in loan guarantee volume for coal projects. The Energy Improvement and Extension Act of 2008 further added $1.5 billion in tax credits, including $1.25 billion for power projects and $0.25 billion for gasification projects. Finally, $5 billion were proposed for FY 2011 for Advanced Energy Manufacturing Tax Credits.

Similarly, the Energy Policy Act of 2005 authorized production tax credits, standby insurance to cover regulatory risk, and other supports for the first few new nuclear power plants to be built in the United States. These tax-based deployment incentives were not included in Table 1 because they do not involve appropriations.

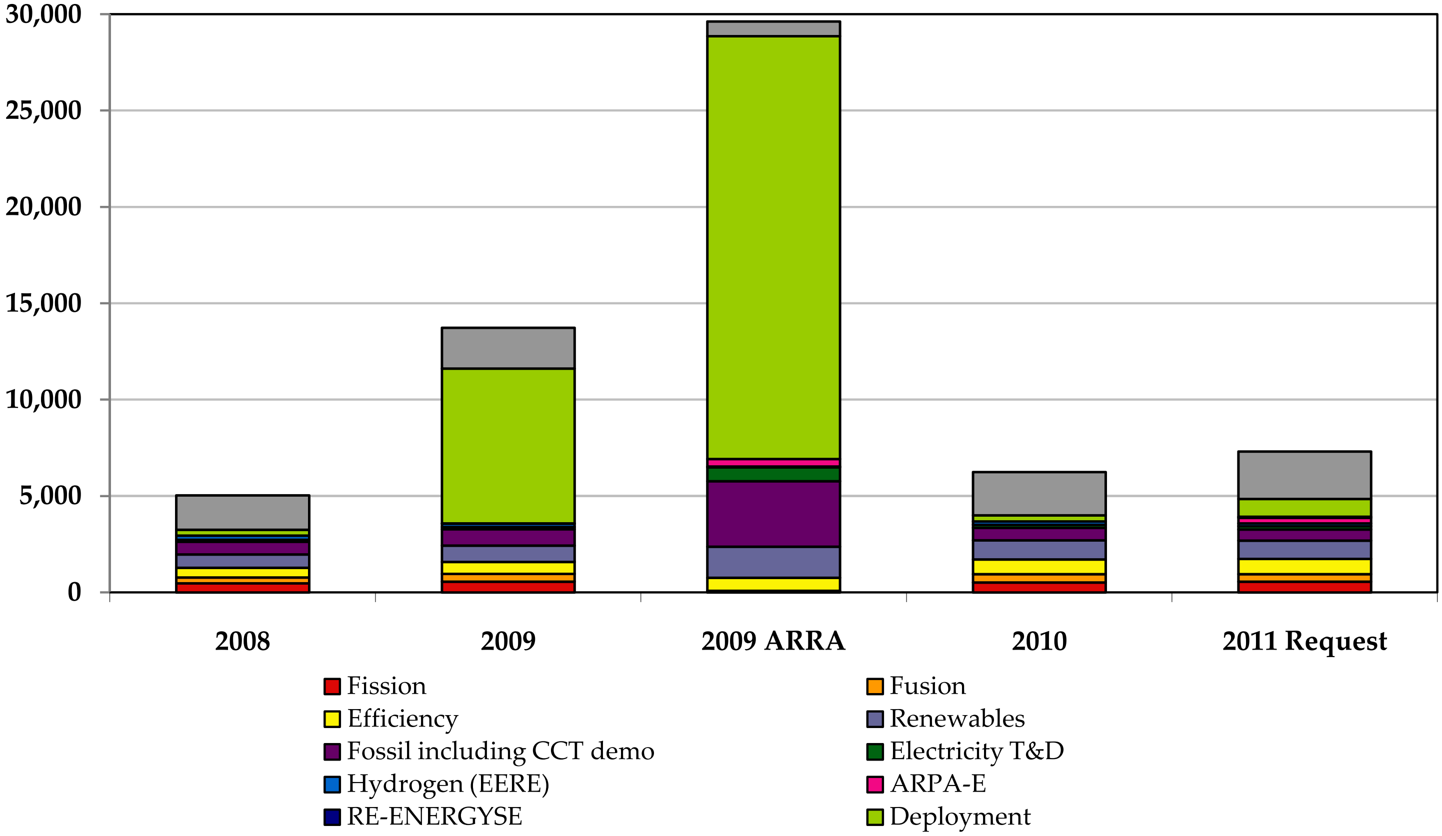
CONCLUSIONS AND RECOMMENDATIONS

The total of applied RD&D programs, basic energy sciences, biological and environmental research, and support for deployment through appropriations—i.e., excluding tax credits or other deployment incentives that do not work through appropriations—requested for FY 2011 is $7.3 billion, 8% above FY 2010 levels, and 44% greater than the last DOE budget of the Bush administration in real terms (see Figure 6). If one assumes that the basic research, energy RD&D, biological and environmental R&D, and energy technology deployment incentives in ARRA ($29.6 billion) will be spent roughly evenly over three years (FY 2009, FY 2010, and FY 2011), the Obama administration would spend around $17 billion in FY 2011 in energy technology innovation, thereby fulfilling its promise to spend over $15 billion per year, even without including tax-based deployment incentives. Once the ARRA funds are spent, however, it is unclear how this level of funding will be maintained.

Congress and the administration should work together to take several steps to further strengthen U.S. energy innovation:

- ***Funding.*** Congress should support the administration's request for increased energy RD&D funding, and should consider additional increases in key areas, including carbon capture and sequestration (especially support for a variety of demonstrations relating to different technological approaches and geologies, and support for RD&D on post-combustion capture), ARPA-E, and strategic international cooperation projects.

Figure 6. U.S. DOE Energy RD&D and Deployment Spending FY 2008-FY 2011 Request*
(in millions of current $)



* Figure 6 includes funding in the ARRA 2009 for BES and biological and environmental research, and for program direction.

- ***Mechanisms**.* As described above, Congress and the administration should give ARPA-E the time it needs to demonstrate its value; act to strengthen the national labs; implement more structured and strategic approaches to cooperation with international partners and with the private sector; establish new institutional approaches to manage large-scale demonstration projects for new energy technologies; and institute approaches that effectively balance stability and flexibility in DOE's energy innovation strategy. Similarly, Congress needs to give the other "experiments" in new energy institutions time to develop, and judge them on the overall performance of the portfolio rather than on the success of each project.

- ***Loan guarantees and other deployment supports.*** Congress should consider asking for an independent review of the relative value of loan guarantees and other policies to support deployment of clean energy technologies, and the circumstances in which these different tools are most effective.

ABOUT THE ENERGY TECHNOLOGY INNOVATION POLICY GROUP

Energy Technology Innovation Policy Research Group

The overarching objective of the Energy Technology Innovation Policy (ETIP) research group is to determine and then promote adoption of effective strategies for developing and deploying cleaner and more efficient energy technologies, primarily in three of the biggest energy-consuming nations in the world: the United States, China, and India. These three countries have enormous influence on local, regional, and global environmental conditions through their energy production and consumption. ETIP researchers identify and promote strategies that these countries can pursue, separately and collaboratively, to accelerate the development and deployment of advanced energy options that can promote economic growth while reducing conventional air pollution, greenhouse-gas emissions, dependence on oil, and poverty. ETIP's focus on three crucial countries rather than only one not only multiplies our leverage on the world scale and facilitates the pursuit of cooperative efforts, but also allows for the development of new insights from comparisons and contrasts among conditions and strategies in the three cases.

www.energytechnologypolicy.org

Energy Research, Development, Demonstration & Deployment (ERD3) Project

The ERD3 Project is a three-year effort within ETIP funded by the Doris Duke Charitable Foundation aimed at producing a set of comprehensive recommendations for the Obama administration to accelerate energy technology innovation (ETI). ERD3 Project members are working in three main areas: (a) identifying the opportunities for government-funded energy research development and demonstration (RD&D), and developing a portfolio of U.S. government investments in energy RD&D as components of a coordinated ETI strategy; (b) understanding the private sector's current role in carrying out and funding energy RD&D in the United States and drawing conclusions about effective structures of public-private undertakings and other incentives to promote private sector innovation; and, (c) analyzing the global picture of ETI to make recommendations on a strategy and priorities for international cooperation on ETI for the United States.

http://belfercenter.ksg.harvard.edu/project/10/energy_technology_innovation_policy.html?page_id=213

Please contact us by e-mail at **stpp@hks.harvard.edu.**

Belfer Center for Science and International Affairs
Harvard Kennedy School
79 JFK Street
Cambridge, MA 02138
Fax: (617) 495-8963
Email: belfer_center@harvard.edu
Website: http://belfercenter.org