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REFORMING THE U.S. ENERGY INNOVATION SYSTEM

Richard K. Lester

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292 Main Street, E38-104, Cambridge, MA 02139-4307
617-253-7522
web.mit.edu/ipc/www

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Richard K. Lester

Industrial Performance Center

Massachusetts Institute of Technology

rklester@mit.edu

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I. INTRODUCTION

The problem of energy technology innovation has moved to the forefront of public and political debate for the first time since the energy crises of the 1970s. Politicians of both major parties, scientists, business leaders, and pundits are calling for a major new national commitment to accelerating energy innovation. They argue that this is an essential ingredient of any successful strategy for dealing with the three major and interconnected energy-related challenges confronting the nation: escalating energy prices, oil supply vulnerabilities, and global climate change. To address these challenges will require the country to make a transition away from its current heavy dependence on petroleum for transportation and on high-carbon fuels (mostly coal) for electricity generation, towards a much more energy-efficient economy based on alternative fuels and low or zero-carbon electrical generating technologies.

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Innovation in a broad range of fields will be necessary in order to accomplish this transition—variants of which will also be required in other countries around the world. In addition to calls for large new public expenditures on energy technology development and deployment,[†] several proposals have been made to create new public or quasi-public structures for financing and managing energy innovation. These include new federal agencies, public and private trust funds, quasi-governmental corporations, federal investment banks, customer-funded energy innovation boards, and prize foundations. While some of these proposals are complementary, in that they focus on different technologies or are directed towards different stages of the innovation process (e.g., fundamental and applied research, technology demonstrations, commercial deployment), others overlap to a significant degree. Underlying these proposals is a shared belief that current federal efforts in energy innovation do not measure up to the task now facing the nation. There is also a sense of frustration about missed opportunities in the past. Some of the proponents of these new institutions have voiced deep misgivings about scaling up public spending on energy innovation without addressing what they regard as the structural failures of the federal Department of Energy (DOE) – currently the lead government agency for energy innovation. They caution against 'throwing money at a broken system'. Others argue that the problem has less to do with what DOE is doing than with what it is not doing. They believe that action is needed in areas not currently being addressed by DOE or other Federal institutions, and that new institutions will be necessary for this.

The goal of this paper is to examine several of the proposals to create new institutions for energy innovation. I will ask: (1) what problems are these institutions intended to solve? (2) how are they expected to solve them? (3) what criteria should be used to assess their effectiveness? and (4) how effective are they likely to be?

[†] Democratic presidential candidate Barack Obama has called for $150 billion of federal spending over the next 10 years on wind, solar, and biofuels. Republican candidate John McCain has also called for much more Federal support of energy technology development.

Most of the proposed new institutions have been described in some detail by their advocates, but until now there has been no systematic effort to consider them together. One of the main purposes of this paper is thus to propose a general framework within which this can occur. The goal is not to identify the 'best' of the proposals. As already noted, they are in many cases complementary. And even when this is not the case, the problem of institutional choice may have as much to do with the rest of the innovation system to which they belong as to the particular features of the institutions themselves. Nevertheless, the premise of this paper is that there is value in assessing each of these proposals against a common set of benchmarks and, where it is appropriate to do so, comparing them.

The outline of the paper is as follows. In the next section some relevant features of the U.S. energy innovation system are described, with special attention to the role of the Federal government. In Section III, seven recent institutional proposals are briefly introduced. Section IV provides more detailed information about these proposals. In Section V a set of evaluation criteria is introduced, and the proposals are evaluated against these criteria. Section VI concludes.

It is important to emphasize that the scope of this paper is limited. A comprehensive strategy for accelerating energy innovation must consider a broad range of mechanisms in addition to the possible creation of new institutions. The problem of how to combine these different elements into a workable, effective innovation system will be taken up in future work.

II. THE ENERGY INNOVATION SYSTEM AND THE ROLE OF GOVERNMENT

The scale of the energy transition that lies ahead for the U.S. cannot be quantified precisely. But there is no doubt that massive investment in new energy infrastructure will be needed over the next few decades. It is also clear that this investment will be distributed across many fields of application, from central station power generation and

transmission to residential and commercial buildings, vehicles and associated transportation systems, and industrial processes.

Since a significant fraction of this investment will involve new technologies, the demands on the nation's energy innovation system are likely to be great. The term 'energy innovation system' here refers to the complex of markets, direct government support mechanisms, indirect government incentives, banks, venture capital funds, and other financial institutions, public and private research and educational organizations and programs, government regulations, codes, and standards within which new technologies are developed, commercialized, and taken up by energy suppliers and users. In the coming decades, this system will be called upon to deliver hundreds of billions of dollars of mostly private investment in innovative technologies, make hundreds of sites available for the construction of sometimes controversial new facilities, and prepare an energy sector workforce of some hundreds of thousands of people at skill levels from craft laborers to Ph.D.-level scientists and engineers.

The energy innovation system encompasses every stage of the innovation process, including research, development, commercial demonstrations, initial adoption of new technologies, and deployment of these technologies at scale. The latter two activities, and especially the last, are not always understood to be part of the innovation process. But there are both conceptual and practical reasons for including them. Conceptually, innovation can be said to occur whenever new knowledge is applied to create value of some kind.[‡] That knowledge may be 'new to the world', in which case its application is by definition the first of its kind. But even when not new to the world, if the knowledge is new to the organization that is applying it, that organization, in implementing the technology, will be doing something it has never done before, and this, too, is an aspect of the innovation process. The innovating organization will need to mobilize resources and manage risks that are out of the ordinary, and these challenges, though different in

[‡] The discovery of new knowledge is not itself innovation. Innovation only occurs when that knowledge is applied to some practical purpose.

degree, are not qualitatively different from many of those that are encountered in first-of-a-kind innovation. For most of the energy technologies under consideration, progressing from initial adoption to deployment at scale will involve many suppliers and/or users engaging in innovation in this more limited sense.

The practical reason for considering these downstream aspects of the innovation process is that the essence of the energy innovation problem is to achieve large-scale deployment of non- or low-carbon technologies and alternative fuels. An innovation system that develops new technologies but that does not succeed in encouraging their adoption on a large scale will not have succeeded at all. The whole point is to achieve scale.

The role of government. A central theme of this paper has to do with the role of government in the energy innovation system. New energy technologies are adopted primarily through the deployment of private capital by private business firms and individuals. But the government plays an important promotional role, and there are both general and energy sector-specific reasons for it to do so.

In general, whenever innovation-related activities produce beneficial 'spillover' effects that cannot be captured by private actors, there is an argument for supplementary public investment. Important spillovers occur especially during early-stage research. It is often difficult for private firms to appropriate all the benefits of their investments in these activities. They therefore tend to underinvest in them, and public investment is needed to compensate. Similar arguments also justify public investment in complementary innovation assets and resources, such as education and training and the development and enforcement of the system for protecting intellectual property. In this, the energy sector is no different from other industries where government intervention in support of innovation occurs.

But in another sense energy *is* different. This is because a major impetus for energy innovation comes from outside the marketplace. Two of the three interrelated problems mentioned in the introduction – the nation's dependence on oil imports, and the prospect of global climate change—generate social costs that are not factored into most of the millions of decisions made in the marketplace every day by suppliers and consumers of

energy. So, even if innovation can help solve these problems – and there is no doubt that it can – the economic incentives created by the play of market forces alone will not be sufficient to bring it about fast enough. The fundamental policy goal is to accelerate the deployment of new energy technologies relative to what would happen if this were left entirely to market forces, and that acceleration will not be achievable without public intervention of some kind.

It is important to recognize that this second argument for public action is both distinct from and independent of the case for government funding of early-stage energy R&D. Both arguments are essentially about the need to overcome a form of market failure. But in the first case the market failure occurs on the supply side: potential innovators cannot prevent their competitors from garnering some of the benefits of their investments in early-stage R&D, so they underinvest. In the second case, the problem is that energy users are not paying the full cost of energy services whose provision is either contributing to global climate change or resulting in increased import dependence, or possibly to both, so innovators have fewer incentives to develop and deploy new technologies with lower impacts in these areas.

One way to address the second problem is via the price mechanism. This approach would consist of incorporating the full costs of energy provision and use into the market price paid by consumers, including the cost of mitigating greenhouse gas emissions or their consequences, and the full cost of ensuring uninterrupted flows of oil from the Middle East and other politically fragile or hostile regions, and then relying on market forces to respond – partly through reductions in energy demand, but also partly through innovation. It could even be argued that if only the price were right, the market would do the rest – that is, a properly adjusted energy price, by equalizing private and social rates of return to investment in new technologies, would call forth the necessary innovations at the necessary rate.[1] In this view, while new government institutions might be needed to manage and enforce the price adjustment mechanism, no further government intervention in support of innovation would be required.

But for several reasons an innovation strategy based purely on price internalization is unlikely to suffice. First, as a practical matter, the goal of 'getting the price right' is almost certainly not realistic. For example, while the U.S. will probably set a carbon price at some point – perhaps even quite soon – this is sure to have escape ramps, exemptions for critical sectors, and other loopholes that will make it fall well short of what the economic models prescribe, which is to say a uniform price across the economy which ramps up at the economically optimal rate. Even more elusive, of course, is the ideal of a carbon price that is harmonized across the globe. Moreover, applying a security premium to the price of oil to reflect the true costs of import dependence is, if anything, an even more distant prospect. In the absence of these adjustments, the case for government intervention in active support of technology development and deployment is stronger.

Second, even in the very unlikely event that these price adjustments were made in full, there would still be other reasons to consider additional, pro-active public measures in support of innovation. These include the many other price distortions in energy markets, at least some of which – for example, fuel and energy subsidies, and non-marginal electricity pricing—act as obstacles to innovation. Moreover, a strategy of leaving to chance the timing of the availability of technology alternatives would carry large risks. For example, the introduction of a carbon price mechanism in the absence of substitutes for carbon-based fuels could lead to very high carbon prices. So there is a strong argument for coordinating pricing strategies with pro-active innovation support.

Finally, aside from these economic arguments, there is also the political reality that non-price-based public interventions are inevitable in any case, since most politicians will find it much more appealing to be seen to be doing something directly to support energy innovation than to be associated with price increases intended to achieve the same result.

The focus of this paper is on one particular form of public action: the creation of new public or quasi-public institutions for financing and managing energy innovation. But there are many other possible forms of public intervention, and the case for creating new

institutions will depend partly on the current and likely future status of these other efforts.[§]

The U.S. Department of Energy. The creation of a new governmental or quasi-governmental institution would inevitably entail substantial transactional and political costs (one need only recall the turbulent origins of the Department of Homeland Security). A new institution should therefore offer significant advantages over the status quo. In this case, the status quo is represented mainly by the Department of Energy. Could the DOE, suitably upgraded or augmented, achieve results comparable to the new institution?

One of the difficulties in answering this question is that it requires a comparison between an existing institution, whose imperfections and failures are a matter of public record, and a 'paper' one, whose likely performance can only be inferred.

In related research we are investigating the performance of the Department of Energy in several different areas. Here, we briefly note the following facts:

- The DOE was created in 1977, at the height of the energy crisis of that period. It brought together, within a single cabinet-level department, energy R&D programs that had previously been distributed among several government agencies,

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[§] Other forms of public support for energy innovation (some of which would also be provided by the proposed new institutions) include: (1) direct public funding for energy research, development and demonstration; (2) indirect public subsidies for research and development, demonstrations, or deployment (e.g., investment tax credits, production tax credits, accelerated depreciation incentives, feed-in tariffs, loan guarantees, interest rate reductions, purchase guarantees, etc.); (3) price stabilization measures (e.g., price guarantees to innovators, or setting a floor price); and (4) regulatory forcing actions (such as portfolio standards and vehicle or appliance efficiency standards). Another type of public intervention designed at least partly to encourage innovation involves industry or market restructuring – for example, deregulation, or mandatory vertical disintegration, or mandatory unbundling of services. While the main focus of activity in these areas has traditionally been at the federal level, state and local policies also play a role. One consequence of the general absence of federal leadership on energy policy over the last several years has been a proliferation of overlapping and sometimes conflicting state-level initiatives in these areas.

including the Atomic Energy Commission, the National Science Foundation, the Department of the Interior, and the Environmental Protection Agency.**

- Since its creation, a major part of DOE's portfolio has consisted of non-energy-related activities. The largest of these have been the Department's nuclear weapons and defense programs. Other important non-energy programs include high energy and nuclear physics and, in more recent decades, environmental remediation activities, mostly at federal nuclear weapons and defense-related facilities. In FY 2008, DOE's defense-related programs alone accounted for 62% of the total departmental budget of about $24 billion. Energy research, development, and demonstration (RD&D) activities (including Basic Energy Sciences) accounted for just 21%.[2]

- Much of the Department's basic and applied scientific and engineering research is funded through its network of national laboratories. (About two-thirds of DOE's total RD&D spending – energy and non-energy -- is directed to the national laboratories.[3])

- In real terms, the DOE energy RD&D budget peaked in its first year of operation. It declined rapidly during the 1980s, and then declined further during much of the 1990s. By 1998, spending on energy technology RD&D had fallen to 21% of its level in 1978. Beginning in 2000 spending began to increase slowly, and today it is back to where it was in the mid-1980s, but is still only a third of the 1978 peak.

- As a fraction of Federal RD&D spending of all kinds, spending on energy RD&D has declined more or less continuously since 1978, when it accounted for 12% of

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** The consolidation of federal energy R&D activities had actually occurred two years earlier, with the formation of the short-lived Energy Research and Development Administration (ERDA) under the administration of President Gerald Ford. One of the first acts of his successor, President Jimmy Carter, was to elevate the energy portfolio to cabinet status under the leadership of the first Secretary of Energy, James Schlesinger.

the Federal RD&D total. Today, even after several years of increases, it accounts for just 1% of that total.[4]

- Cumulatively, the Department has allocated about 31% of its energy RD&D spending to fossil fuel technologies, 20% to energy efficiency, 18% to fusion, 16% to renewables, and 13% to fission. There have been significant shifts among these application areas during this period, as well as shifts in emphasis between applied technology development and long-term, high-risk research.

- For much of its three decades of existence the Department has faced criticism of its performance and even of its basic mission. Some of the most pointed criticisms have been directed at its difficulties in carrying out large-scale commercial technology demonstration projects. According to a recent assessment by Ogden, Deutch and Podesta: "[t]he underlying fundamental difficulty is that the DOE, and other government agencies, are not equipped with personnel or authorities that permit the agency to pursue a first-of-a-kind project in a manner that convincingly demonstrates the economic prospects of a new technology."[5]

- DOE's record in technology demonstrations has been punctuated by several high-profile failures such as the Clinch River Breeder Reactor Project (1972-83), the synthetic fuels demonstration program of the early 1980s, and the troubled, still unfolding sagas of FutureGen, the DOE's erstwhile flagship project to demonstrate carbon capture and sequestration, and the Yucca Mountain nuclear waste repository project.

- Several factors have been implicated in these problems, including[6]:

    - a systematic tendency on the part of DOE officials to underestimate project costs (perhaps as a requirement to generate political support);

    - a failure to anticipate and plan for the possibility of future variability in fuel prices (e.g., oil price declines in the case of the Synfuels program, and uranium price declines in the case of Clinch River);

- Congressional interference in facility siting decisions and personnel appointments, and Congressional pressures limiting the ability of officials to adjust or terminate projects after conditions have changed;

- political cycles in Congress and the Executive Branch and the resulting lack of constancy in policy and funding over the life of the projects;

- funding and management uncertainties generated by the annual budgeting and appropriations process;

- inefficient business practices mandated by restrictive federal procurement regulations and bureaucratic rules governing human resource management, auditing requirements, and the use of federal facilities.

- Notwithstanding these difficulties, the DOE has enjoyed some successes. For example, a cost-benefit analysis of DOE's energy efficiency and fossil energy research programs conducted by the National Research Council found that benefits had exceeded the public investment in those programs by a large margin.[7]

- In addition to providing direct support for RD&D, the DOE administers other programs and policies that stimulate energy innovation indirectly (e.g., the ENERGY STAR voluntary labeling program, the Building Technology Assistance Program, the Clean Cities Program, etc).[††] A major new program in this category is the Title XVII Loan Guarantee Program, under which the Secretary of Energy is authorized to provide loan guarantees for up to 80% of the cost of projects employing innovative technologies to avoid, reduce or sequester greenhouse gases or other air pollutants.

[††] Many other such programs are administered by other Federal agencies, including the Department of Health and Human Services, the Department of Agriculture, the Department of Transportation, and a large number of tax incentive and expenditure provisions administered by the IRS.

- Taken as a whole, the Federal government's indirect support mechanisms for energy innovation outweigh its direct support for energy RD&D by a substantial margin, at least when measured in terms of budgetary impact. [8]

III. PROPOSALS FOR INSTITUTIONAL REFORM

In this section we briefly introduce several current proposals to establish new institutions for energy innovation. These are:[‡‡]

- The Carbon Storage Research Corporation (Boucher)
- The Energy Technology Corporation (Deutch, Podesta and Ogden)
- The Climate Change Credit Corporation (Lieberman-Warner)
- The 21st Century Energy Deployment Corporation (Bingaman)
- The Clean Energy Investment Bank of the United States (Domenici)
- ARPA-E (various)
- Discovery-Innovation Institutes (National Academy of Engineering)

This is not an exhaustive list; taken together, however, these proposals are broadly representative of the ideas now being debated publicly.

[‡‡] For the reader's convenience, the principal advocates of these proposals are referred to in parentheses.

Carbon Storage Research Corporation

Legislation introduced by Congressman Rick Boucher (D.-VA) in June 2008 (H.R. 6258) calls for the creation of a Carbon Storage Research Corporation to accelerate the demonstration and early deployment of technologies to capture and sequester carbon dioxide emissions from fossil-fueled electricity plants.[9] The Corporation would be formed if a two-thirds majority of electric utilities voted for it. (Voting rights would be based on the quantity of fossil-fuel-based electricity delivered to consumers.) The Corporation would achieve its goal by issuing grants or contracts to private firms, government organizations, or academic entities to carry out these projects. The Corporation's activities would be funded by a user fee on retail sales of fossil-generated electricity. It would operate as a division or affiliate of the Electric Power Research Institute (EPRI), a non-profit R&D organization serving the electric power utilities. The Boucher legislation draws on a recommendation previously advanced by the Pew Center on Global Climate Change to establish a special purpose Trust Fund for Carbon Capture and Sequestration (CCS). The Pew Trust Fund proposal would similarly have been funded by a fee on sales of fossil-fuel-generated electricity, and would have provided full funding for ten or more commercial scale CCS demonstration projects at coal-fired power plants around the country.[10]

Energy Technology Corporation

A proposal advanced by Ogden, Podesta and Deutch under the auspices of the Center for American Progress would create a semi-public organization, the Energy Technology Corporation, for the sole purpose of financing and executing large-scale energy technology demonstration projects.[11] The goal of the Corporation would be to demonstrate the technical and economic readiness of a wide range of new energy technologies. The Corporation would not be an agency of the Federal government, and according to the authors would operate 'like a private corporation embarked on . . . first of a kind technology development.' The proposed Energy Technology Corporation is part of a larger plan advanced by the authors to reorganize the energy activities of the federal government. This also includes a proposal to establish an Energy Innovation Council, which would be charged with developing a national energy RD&D strategy. The Council

would be housed in the Executive Office of the President, with a membership drawn from all relevant federal agencies.

Climate Change Credit Corporation

One of the key provisions in the Lieberman-Warner Climate Security Act of 2008 (S.3036), the complex legislation introduced with the broad goal of establishing a market-based cap-and-trade scheme for controlling greenhouse gas emissions, is to establish a Climate Change Credit Corporation.[12] The responsibilities of the Climate Change Credit Corporation, a non-profit entity without stock, would include the conduct of auctions of greenhouse gas emissions allowances. The Corporation would then allocate part of the proceeds from these auctions to a variety of programs for low carbon energy technology development, demonstration and deployment. The targets would include carbon capture and sequestration technologies, cellulosic biofuels, and other renewable technologies. According to the Lieberman-Warner bill, the Corporation is explicitly not to be considered as a Federal government entity.

21st Century Energy Deployment Corporation

In July 2008 Senator Jeff Bingaman (D. NM) introduced legislation that would establish the 21st Century Energy Deployment Corporation (S. 3233)[13]. The broad goal of the legislation is to accelerate the development and deployment of advanced clean energy technologies, and the Corporation, described in the bill as a 'quasi-independent' government entity, would essentially be a financing facility, designed to enable clean energy projects to gain access to affordable debt capital that might not otherwise be available, especially to high-risk projects.

Clean Energy Investment Bank of the United States

Similar legislation introduced a few months earlier by Senator Pete Domenici (R.-NM) would establish the Clean Energy Investment Bank of the United States (S.2730).[14] Again, the goal is to accelerate the introduction of clean energy technologies by creating a new government entity that would increase the debt capital available to eligible energy projects. The Energy Investment Bank is described in the legislation as a government corporation, and also as an agency of the executive branch. The details of the financial

model differ somewhat from that of the Bingaman proposal. Also, the Energy Investment Bank would only finance projects deploying technology that was already in commercial use, whereas the Bingaman proposal primarily focuses on 'breakthrough' technologies that the capital markets would regard as having high technical risk.

ARPA-E

One of the recommendations contained in *Rising Above the Gathering Storm*, the influential 2005 National Academies report on U.S. competitiveness in science, technology and innovation, was to create a new Federal entity, the Advanced Research Projects Agency – Energy (ARPA-E), to fund innovative energy research and development.[15] Modeled after the Defense Advanced Research Projects Agency, ARPA-E would be a small, nimble organization housed administratively in the Department of Energy. Like DARPA, the new agency would perform no research itself. Rather, its role would be to fund universities, startups, national laboratories, and established companies to conduct 'creative "out-of-the-box" transformational generic energy research that industry by itself cannot or will not support and in which risk may be high but success would provide dramatic benefits for the nation.' The goal of ARPA-E would be to act as a bridge between basic research and industrial development. The proposal to create ARPA-E has since been enacted into law, but until now the Bush administration has not sought to appropriate funding for the new entity.

Discovery-Innovation Institutes

A National Academy of Engineering panel, in its 2004 evaluation of the U.S. engineering research enterprise, proposed the creation of a national network of Discovery-Innovation Institutes which would address the major challenges facing the nation, including energy.[16] These institutes would be funded by federal and state governments, industry, foundations, and venture capital firms. They would be based on research university campuses and would provide a focus for long-term fundamental and applied engineering research addressing national priorities. The institutes would stimulate the creation of startup firms and attract other businesses to the area, and in this way contribute to regional economic development. The Academy report likened the Discovery-Innovation

Institutes to academic medical centers, which combine research, education, and clinical practice in state-of-the-art facilities. The chair of the panel, James Duderstadt, subsequently advanced a more specific recommendation to establish a group of such institutes in the Great Lakes region that would focus on energy research.[17]

IV. MORE DETAILS

Hardly any of these proposals are fully developed, in the sense of having a complete organizational design. But the main dimensions along which they vary, either explicitly or implicitly, are the following:

- Type of governance
- Scope of operations (functional and technological)
- Source of funds
- Criteria for allocating resources
- Mechanisms for disbursing resources
- Disposition of knowledge assets/intellectual property
- Management and staffing
- Performance goals and metrics

Type of governance: The various proposals range along the spectrum from purely public to purely private. ARPA-E would be a conventional executive branch agency – albeit one based on the relatively unorthodox Defense Advanced Research Projects Agency, which historically has operated with unusual flexibility and independence both from Congressional oversight and from the Defense Department, within which it is housed. At the other end of the spectrum, the Carbon Storage Research Corporation (Boucher) would

essentially be a private organization, affiliated with EPRI and with a board of directors appointed by that Institute and drawn in significant part from the power industry, although the Corporation's authority to continue collecting user fees (or to adjust the magnitude of the fee significantly) would be contingent on an Act of Congress.

Several of the proposed institutions are intermediate or hybrid public-private entities. The Clean Energy Investment Bank (Domenici) is described as a 'government corporation', with an independent board of directors nominated by the President and confirmed by the Senate. The Energy Technology Corporation (Ogden, Podesta, and Deutch) is described as a 'semi-public' organization that would function like a private firm but whose independent board, again, would be appointed by the President with the advice and consent of the Senate. The 21st Century Energy Deployment Corporation (Bingaman) is described as a 'quasi-independent' government entity whose board of directors would be appointed by the President, and which would be overseen by the Department of Energy. Finally, the Climate Change Credit Corporation (Lieberman-Warner), a non-profit corporation without stock, 'shall not be considered an agency or establishment of the Federal government', although its board of directors would again be nominated by the President and confirmed by the Senate.

These hybrid organizations, according to their advocates, would be enabled to bypass civil service employment laws and regulations, and in at least one case (the Energy Technology Corporation) would be free from federal procurement regulations. On the other hand, they would benefit in various ways from their special standing as creations of the Federal government, as discussed in more detail below.

There are a number of similarities between these hybrids and the Government Sponsored Enterprises (GSEs) that Congress has occasionally created over the past several decades to enhance the flow of capital to particular sectors of the economy, most notably housing and agriculture. The most prominent examples of these GSEs, the Federal National Mortgage Association (Fannie Mae) and the Federal Home Loan Mortgage Corporation (Freddie Mac), were recently placed into federal conservatorship to avoid the possibility that these two organizations, which together own or guarantee a large fraction of home

mortgages, would become insolvent. In the aftermath of this dramatic government intervention, the GSE model has been heavily criticized for what one authority described as the 'inherent conflict and flawed business model embedded in the GSE structure.'[18]

Government Sponsored Enterprises are formally defined as federally-chartered, privately-owned financial corporations created by Act of Congress with the power to raise money by borrowing and to make loans or loan guarantees to targeted sectors.[19] None of the proposed organizations discussed here would appear to meet this definition, since none would be a corporation owned by private shareholders. On the other hand, as with the GSEs the operations of some of them would be backed by implicit government financial guarantees.[§§] Of these, the 21st Century Energy Deployment Corporation probably comes closest to the GSE model. Like Fannie Mae and Freddie Mac, this organization would create a secondary market in securitized loans – in this case extended to clean technology projects. Like the other energy innovation hybrids discussed here, the 21st Century Energy Deployment Corporation would not be an investor-owned entity. But whether this distinction would be enough -- either in reality or in perception -- to offset what in the current climate will almost certainly be a strong political reaction to any proposal with overtones of the GSE model is questionable.

Technical scope: While all seven organizations are intended to accelerate energy innovation, they vary in their technological and functional focus. Most have a relatively broad technological portfolio. The exception is the Carbon Storage Research Corporation (Boucher), whose domain would be limited to carbon capture and storage technologies. The others would support a much broader range of innovations. For example, the 21st Century Energy Deployment Corporation (Bingaman) would be enabled to finance all 'clean energy technologies', defined to include any technology

[§§] Earlier debates over whether the government guarantees of GSEs were actually explicit or implicit were rendered moot in September 2008 when the government took control of Fannie Mae and Freddie Mac.

> ‘related to the production, use, transmission, control, or conservation of energy’ that contributes to improving energy efficiency, to diversifying U.S. energy supplies so as to include supplies that are ‘environmentally sustainable’, or to stabilizing greenhouse gas emissions through ‘reduction, avoidance, and sequestration of energy-related emissions.’

The Clean Energy Investment Bank of the United States would also be enabled to finance ‘clean energy technologies’, but in this case eligible projects would be those using a commercial technology that

> “the Bank determines avoids, reduces, or sequesters one or more air pollutants or anthropogenic emissions of greenhouse gases more effectively than other technology options available to the project developer.”

The Energy Technology Corporation (Ogden et al) would be limited to large-scale demonstrations of ‘select’ technologies. No definition of ‘select’ is provided, but the examples cited by the authors to illustrate the potential range of the Corporation’s activities include: cellulosic biomass to biofuels plants; carbon sequestration; integrated coal gasification-combined cycle plants with carbon capture; smart electricity networks; production of natural gas hydrates; once-through nuclear fuel cycle projects; and superconducting transmission lines.

Innovation stage: The proposals differ widely with respect to the stage of the innovation process they are supposed to address. The advocates of ARPA-E say that it is designed to fill a gap between fundamental energy research and applied industrial development and innovation. Its mission would be ‘transformational, high-risk, high payoff R&D that would be a challenge for today’s electric utilities, petroleum companies and large energy equipment manufacturers to address and which are not very attractive to the entrepreneurial world.’[20] The Energy Technology Corporation would be restricted to large-scale technology demonstration projects. The Carbon Storage Research Corporation would support ‘early’ deployments as well as large-scale demonstrations (though only for

CCS technology), while earlier-stage development projects would not be eligible for support.

The 21st Century Energy Deployment Corporation (Bingaman) would, as its name implies, focus on providing financing for commercial deployment projects. This would also include 'first-of-a-kind commercial deployments' – a category that, though not defined in the legislation, presumably consists of commercial demonstration projects. At least 75% of this support is supposed to be directed to 'breakthrough' technologies whose development has been impeded 'due to perceived high technical risk by the commercial financial sector'. There is some uncertainty about the relative emphasis that would be placed on financing commercial demonstrations versus post-demonstration commercial deployment projects.[***]

The Clean Energy Investment Bank (Domenici) would be restricted to making investments in commercial projects using clean energy technologies that are already in general use in the commercial marketplace. This might seem to preclude high-risk projects, which in any case are not singled out for special support.

[***] In his remarks introducing the legislation, Senator Jeff Bingaman implied that there would be greater emphasis on demonstration projects: 'The missing ingredient that this bill seeks to supply concerns traversing the so-called "valley of death." This is the part of the development cycle of a new technology when the technology has been demonstrated at a lab or pilot scale and is ready to be demonstrated at a commercial scale. It is here, we are told, where new technologies, and particularly capital-intensive energy technologies, often languish for want of funding. Banks traditionally aim for moderate risk and predictable returns and simply have very little incentive to bet on unfamiliar technologies with speculative returns. Venture capitalists, who are more comfortable with technology risk, simply can't supply the billions of dollars necessary to push these technologies forward at the pace we need.'

The Climate Change Credit Corporation (Lieberman-Warner) would allocate its resources to a broad range of activities, only some of which would be intended to accelerate energy innovation. Of those, the Corporation would support both demonstration and deployment projects in a broad range of technological areas including cellulosic biofuels, advanced coal technologies, and energy efficiency projects. It would also provide financial incentives to manufacturers of high-efficiency consumer products and low or zero-carbon power generating technologies, as well as to automobile manufacturers and component suppliers for converting their manufacturing facilities to the production of more fuel-efficient vehicles. Additional funds would be used to support energy R&D, but those would be administered by ARPA-E rather than the Corporation itself.

Project Selection Criteria: A few of the proposals specify quite detailed selection criteria for the projects that are to be supported. Mostly these are concerned with factors intrinsic to the technology. For example, the Carbon Storage Research Corporation (Boucher) would support projects that "encompass a range of different coal and other fossil fuel varieties, be geographically diverse, involve diverse storage media, and employ capture and storage, or capture and conversion, technologies potentially suitable either for new or for retrofit applications." But in at least one case, the Climate Change Credit Corporation (Lieberman-Warner), several exogenous factors are also specified. For example, support for manufacturers of energy efficient products should be preferentially directed towards states with high levels of unemployment, and to manufacturers that can document the greatest use of domestically sourced components and parts. There is also a stipulation that manufacturers of fuel-efficient vehicles should guarantee not to shed domestic employees subsequent to receiving the Corporation's support.

Source of Funds: The sources of funds for the proposed new institutions are of three types: (1) special-purpose taxes or fees levied on energy users; (2) general Federal tax proceeds; and (3) the revenues from auctioning greenhouse gas emissions allowances.

Only one of the new proposals, the Carbon Storage Research Corporation, would be funded by a user fee. The fee would be applied to all retail sales of electricity generated

using fossil fuels (with the fee adjusted to reflect differences in carbon emissions from coal, natural gas, and other fossil fuels.) As previously noted, the fee would be mandatory if two-thirds of the distribution utilities voted for it, with voting rights determined by sales of fossil-fuel based electricity. The fee would be set so as to generate a revenue stream of about $1 billion annually, which would add $3 to $5 per year to a typical residential electricity bill.[21] The funds generated by the fee would be managed by the Corporation, and would not be treated as public money subject to appropriation by the U.S. Congress. On the other hand, the authority of the Corporation to collect the fee would itself be conditional on an act of Congress, and any significant change in the size of the fee would apparently also require Congressional approval.

ARPA-E, as a regular executive branch agency, would be funded by annual Congressional appropriation. The authorizing legislation calls for funding of roughly $1 billion per year for five years.

The Energy Technology Corporation (Ogden et al) would be funded in a single Congressional appropriation (of unspecified amount), and this, according to the authors, would reduce Congressional and special influence group influence on its resource allocation decisions.

The Clean Energy Investment Bank (Domenici) would draw on a revolving fund in the U.S. Treasury, and would also be allowed to borrow up to $2 billion in short-term funds from the Treasury. Its loan portfolio would not be permitted to exceed $100 billion.

The 21st Century Energy Deployment Corporation (Bingaman) would not draw directly on government funds, but rather would be designed to promote private lending by securitizing and creating a secondary market for such loans.

The Climate Change Credit Corporation would be funded by the proceeds from auctioning off greenhouse gas emissions allowances. This stream of revenues would not be subject to annual Congressional appropriation. It has been estimated that more than $15 billion of revenues would be generated in the first year of the program, with the amount increasing over time. According to the legislation, 52% of these revenues would

be allocated to energy deployment projects, and another 2% to advanced energy research and development.

Mechanisms of Disbursement: The proposed institutions would use a variety of tools and mechanisms to promote innovation. ARPA-E, the new Federal agency, would disburse its funds through competitive grant-making, cooperative agreements, and research contracts. The non-governmental Carbon Storage Research Corporation (Boucher) would similarly use a mixture of competitive grants and contracts. It would also be permitted to purchase carbon dioxide for use in tests and demonstrations of carbon sequestration technology.

Few details are provided about which specific tools the Energy Technology Corporation (Ogden) would use to demonstrate the technical and economic readiness of new technologies, though the implication is that it would rely heavily on indirect financing tools such as loan guarantees, guaranteed purchases of product, and equity investments.

The Clean Energy Investment Bank (Domenici) would use a variety of project financing tools, including loans, loan guarantees, and other forms of 'credit enhancement', as well as equity investments. The Bank would also be authorized to issue insurance against project risks. The Title XVII loan guarantee program currently housed in the Department of Energy would be transferred to the Bank.

The main support mechanisms of the 21st Century Energy Deployment Corporation (Bingaman) would be to assist clean energy technology projects in gaining access to 'affordable' private debt and to develop a secondary market for private loans to such projects. It would not, however, be authorized to offer loan guarantees or other forms of credit enhancement.

The Climate Change Credit Corporation (Lieberman-Warner) would use a range of tools, including loan guarantees, cost-sharing grants, lump-sum payments, and production payments to zero or low-carbon electricity generators.

Performance goals and metrics: Some of the proposed organizations have quite specific performance goals and metrics. For example, 5- and 10-year numerical technology deployment targets would be set for the 21st Century Energy Deployment Corporation.

These targets would consist of specific deployment goals for different clean energy technologies, such as the tonnage of carbon to be captured and sequestered, and the required electricity production cost to be achieved by a given date for various deployed technologies such as wind, photovoltaics, geothermal, and so on. In contrast, the authors of the Energy Technology Corporation proposal state that this entity would be exclusively concerned with technology demonstrations and would not be required to meet numerical production targets (arguing that this was the fatal mistake that undermined the the U.S. Synthetic Fuels Corporation in the early 1980s.)

V. EVALUATION

All of the institutional proposals described above are intended to accelerate the energy innovation process. Each adopts a different approach to the problem, and in most cases the rationale for adopting that particular strategy instead of others is not spelled out. Can a more systematic approach be devised? For example, are certain parts of the energy innovation system more in need of attention than others? Is it possible to identify a set of general 'design' criteria which any successful institutional intervention ought to satisfy? Should such interventions be kept separate, or should they be consolidated within a single institution? We explore these questions next.

It is important to acknowledge the difficulties involved in evaluating institutions whose purpose is to accelerate innovation. Much time may elapse between a specific action to promote innovation and its actual outcome in the marketplace, and the presence of many intervening variables may further complicate the attribution of cause. Moreover, the definition of success is itself ambiguous. The fact that an R&D project does not succeed, or that an innovation is introduced commercially but fails the final test of market success, is not necessarily proof of the failure of a particular intervention, still less of the innovation process as a whole. Innovation, by definition, is not a sure thing. Similarly, the fact that a particular technology or project fails to receive financial or other support is not necessarily proof that a valuable opportunity is being missed, or that the innovation system is broken. The project may simply be unattractive relative to the alternatives.

That said, a preliminary reading of recent experience points to several criteria against which any new institutional proposal ought to be evaluated:

1. *Does the new organization offer significant advantages over the status quo?* As already noted, any new institutional initiative should provide demonstrable benefits relative to the alternative of upgrading and/or augmenting the federal Department of Energy.

2. *Is the purpose of the new organization clear?* Since the capabilities required by the new organization will depend on which stage of the innovation process is being targeted (i.e., fundamental research, applied research and development, commercial demonstration, initial commercial adoption, deployment at scale), it is important to be clear about the goals. Moreover, even for a given stage of the process there may be several possible purposes, each with different implications for the new organization. For example, a demonstration project might be designed to: (a) generate information that is credible and useful to private investors about the performance of the new technology in a market setting; or (b) demonstrate the commercial competitiveness of the technology; or (c) offset the risks associated with first-of-a-kind regulatory action. Projects designed to achieve each of these three objectives would be unlikely to be organized and financed in the same way. Similarly, an initiative designed to stimulate early commercial adoption of a new technology might be intended: (a) to help private industry move down the learning curve; or (b) to achieve certain production targets. Again, we might expect to see different organizational and financial approaches in each case. Finally, if the organization is focused on financing and executing specific projects, the demands on the organization will depend on the physical and financial scale of those projects.

3. *Is the new organization able to provide stable, predictable financial support?* Or will its funding be susceptible to federal budget pressures and other constraints that can lead to schedule stretch-out and other inefficiencies?

4. *Are the financial and other tools at the disposal of the new organization well matched to its purpose?* Different forms of support – e.g., direct cost reimbursement, cost-sharing grants, loan guarantees, price guarantees – create different incentives and distribute risks differently. Is the organization authorized to provide support in the form best suited to the projects it is managing or otherwise assisting? Moreover, does it have the flexibility and the internal management capabilities to switch among different mechanisms as needed?

5. *Can the new organization reasonably be expected to achieve best-in-class performance with respect to hiring, contracting, and other management practices?* Most important, will it be able to attract the personnel who – because of their knowledge of product and/or financial markets -- are best qualified to make resource allocation decisions?

6. *Are the new organization's decision processes subject to adequate financial discipline and accountability, especially with respect to cost estimation, project selection, and termination decisions?* Is the organization operating within a framework of rewards and incentives that are likely to yield high-quality decision-making? Will the organization be able to resist political pressures to make or to avoid making particular decisions?

7. *Is the governance of the new organization properly aligned with its mission?* Too many participants in the organization's governance mechanisms will likely result in a lack of focus and direction, whereas if participation is too narrow key stakeholders may not be adequately represented.

8. *Will the new organization actually fill a need that would otherwise be unmet by private firms?* Or will the financial and other support it provides be more likely to substitute for private action?

As discussed in an earlier section, the various proposals range from purely public to purely private organizations, with a government agency (ARPA-E) at one end of this spectrum, and a more-or-less private entity (the Carbon Storage Research Corporation) at

the other. Several are public-private hybrids. There is a rough but not perfect correspondence between the position of the organization on this spectrum and the stage of the innovation process it is designed to address. In the rest of this section we analyze each proposal in light of the above criteria.

ARPA-E: ARPA-E is intended to fill a need that its advocates say is not now being met by the DOE -- that is, to conduct 'translational' R&D to bridge the gap between fundamental research and industrial innovation, and to create 'platform technologies' on which subsequent applications can be built. These roles have been played effectively at DoD by DARPA, but whether they are actually absent at DOE is less clear. Even if they are, moreover, the DARPA model may not be exactly what is needed to fix the problem. The translation performed by DARPA-funded R&D is between fundamental research and the needs of the armed forces. The goal is to exploit new scientific concepts and inventions as quickly as possible to support the execution of a military mission. Military utility is the principal driver; cost is a lower priority. But in the energy domain cost is crucial, and the gap that needs to be filled is between fundamental research and commercial systems which have the potential to be competitive in the energy marketplace. This implies a different kind of translational R&D, which in turn suggests that the DARPA model may need to be modified if it is to work in the DOE context. DARPA relies heavily on technologically expert program managers pursuing what are often radically new concepts and operating with a great deal of discretionary authority. At the very least, the background of ARPA-E program managers would need to be more oriented towards industrial-scale implementation and marketplace considerations.

Bringing other aspects of the DARPA model into the DOE context would likely pay dividends -- for example, DARPA's lean organizational structure, with only one management layer between program managers and the director. This structure has helped to give DARPA the agility and independence to start and stop programs quickly based on relevance and results, and there would surely be advantages in creating a similar management structure within DOE. There would also be clear advantages in giving ARPA-E program managers the independence to engage the best and brightest scientists and engineers from whatever source – academia, industry, national laboratories – rather

than relying primarily on the Department's system of national laboratories, as is the case today. But could ARPA-E program managers be expected to enjoy the kind of independence enjoyed by their DARPA counterparts? Moreover, could a clear line be drawn between ARPA-E and the existing energy technology program offices at DOE (in energy efficiency and renewable energy, fossil energy, nuclear energy, and so on), whose goals at least partly overlap with the intended mission of new organization?[†††]

Energy Technology Corporation: The purpose of the Energy Technology Corporation – to carry out commercial demonstrations – is clear and focused, and the DOE's previous struggles with this function provide a strong argument for creating a separate organization to carry it out. A new entity that could avoid cumbersome federal procurement rules, that could more easily recruit staff with commercial project experience, and that would be less susceptible to Congressional micromanagement could bring significant benefits relative to the alternative of housing the demonstration projects within DOE. Also, at least for very large demonstration projects it seems unlikely that the new corporation would displace private sector activity, since individual firms, left to themselves, would be unwilling to incur the risks involved. This is less obviously true of demonstrations on a smaller scale, and the question of where the line would be drawn between demonstrations that would and would not fall within the ambit of the Energy Technology Corporation needs to be addressed. More generally, how will decisions about which technologies to demonstrate be made? What criteria will the Corporation use to allocate its scarce resources among these alternatives? Will the organization be essentially reactive, responding to proposals from private firms for financial assistance? Or will it pursue a pro-active strategy, allocating its capital based on its own view of the

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[†††] In the original National Academy proposal, the director of ARPA-E would report to the Undersecretary of Energy for Science. In subsequent Senate enabling legislation, the new organization would be physically separated from DOE headquarters. The Bush administration has since made clear its concerns about setting up an additional bureaucracy within the DOE that might draw resources away from the Department's basic research function and that might also engage in activities that would be more appropriately carried out by the private sector. In part because of these concerns, the administration has not sought to appropriate funds for the new agency.

way forward?

Another set of questions concerns the extent of the Corporation's operational role. Will it operate essentially as a bank, focusing on the provision of capital resources for the demonstration projects it supports? Or will it take on the role of managing the construction and operation of those projects? Perhaps the biggest question concerns the independence of the Corporation. In principle the risk of political interference in its operating decisions should be lessened by the strategy of relying on a one-time Congressional appropriation to fund its work. But as a practical matter this is not so clear. Will the Congress be willing to remove itself from such decisions, especially for large projects that are likely to have major implications for the communities where they are located? Since the Corporation will not be self-financing, it may at some point need to return to the Congress for additional funds, and this question will then become more germane. Even for a one-time appropriation, funds carried over from one year to the next may be at risk of being re-programmed to other purposes.

21st Century Energy Deployment Corporation: The stated goals of this organization are to 'promote access to affordable debt financing' for commercial deployment projects, and to develop 'a stable secondary market for clean energy technology loans'. The focus would be on projects involving higher risk, 'breakthrough' technologies. The Corporation would securitize a portfolio of loans to such projects and sell these into a secondary market, using the implicit guarantee of the Federal government to provide assurance to private investors who might otherwise be unwilling to hold securities in higher risk projects. The intended effect would be to reduce the cost of capital for the projects.‡‡‡ There is little risk of overlap with DOE here, since it is very unlikely that the latter could play this role. On the other hand, the function of securitizing loans to energy projects is already carried out by some private banks, and the question of whether the proposed institution would crowd out such private sector activity must be considered. Other things equal, energy

‡‡‡ The obvious (and not reassuring) parallels with GSEs like Fannie Mae and Freddie Mac have already been pointed out.

projects receiving loans from the new corporation at a discounted interest rate would be advantaged relative to projects financed solely in the private markets. According to the legislative proposal to create this new corporation, at least 75% of its investments would be allocated to higher-risk ('breakthrough') technologies, which would presumably be less likely to qualify for purely private financing. But the legislation also sets numerical targets for the deployment of specific energy technologies, and the pressure to achieve those performance goals could be expected to drive the organization toward allocating more of its financial resources to lower risk projects, hence increasing the likelihood that private sector activity would be crowded out. More generally, there is an important unresolved question concerning how projects would be selected to receive financial support from the Corporation. According to the legislation, an Advisory Council to the Corporation's board would determine the priorities. The prioritization would apparently consider energy security, climate change avoidance, and the competitiveness of America's energy industries, as well as economic viability. This is obviously a different and broader calculus from that used by private investors, for whom the question of economic viability is paramount, but it is not clear how different. Would the Corporation only support projects that did not meet private risk-return standards, provided they contributed in some way to the other objectives? Or would it also provide assistance to projects that could attract private investment if they additionally contributed to meeting the Corporation's other goals?

Clean Energy Investment Bank. Similar questions apply to the other hybrid entities considered here. The Clean Energy Investment Bank would apply a broad array of financing tools such as loans, loan guarantees, and purchases of equity shares, and would draw on Treasury funds to do so. The Title XVII loan guarantee program would be removed from DOE and placed in the Bank. Since the stated goal of the Bank is to invest in deployment projects employing clean energy technologies that are already in general commercial use, there is clearly a potential for direct competition with private firms. Like the 21st Century Energy Deployment Corporation, the Bank would invoke other selection criteria in addition to profitability. But once again it is not clear how or to what extent these criteria would differ from those of private investors.

Climate Change Research Corporation. The Climate Change Research Corporation would have a broad mandate to fund programs ranging from research to commercial deployment. Since its research and development activities would be delegated to ARPA-E, there would seem to be no conflict with DOE in this area. The source of the Corporation's funds would be the proceeds from auctions of carbon emissions allowances, and this revenue flow would not be subject to the annual Congressional appropriations cycle. As with the other hybrids the potential for displacing rather than augmenting private investment must be considered. The investment selection criteria identified in the Lieberman-Warner legislation are clearly different from those that would be invoked by private investors, and include such factors as the desirability of targeting high-unemployment regions and a preference for firms engaging in domestic sourcing, as well as environmental and energy security factors. Once again it is not clear how these considerations would be prioritized, and the fact that they range so widely risks muddying the Corporation's role while increasing the risk of mission 'creep'.

Carbon Storage Research Corporation. The role of the Carbon Storage Research Corporation, the only private organization we are considering here, would be limited to large-scale demonstration and early deployment projects for carbon capture and sequestration (CCS). Research and development in this field would remain the province of the Department of Energy, while the new Corporation would take over DOE's current role in CCS demonstrations.[§§§] The Corporation would have access to an assured stream of revenues that would not be subject to the vagaries of the Congressional appropriations process (although Congressional action would be required periodically to renew the user fee.)[****] As a private organization itself, there would be fewer questions about the

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[§§§] Until early in 2008, the DOE's demonstration strategy centered on the FutureGen project, a 275 MWe integrated coal gasification combined cycle plant that was to be built in central Illinois with government and industry cost-sharing. The program was subsequently restructured, with most of the DOE funds that had originally been allocated to FutureGen redirected to several CCS technology development and demonstration projects.

[****] The benefits of avoiding the Congressional appropriations process are highlighted by the case of the Nuclear Waste Fund, also funded by a user fee – in this case a 0.1

Corporation's knowledge of private sector practices and of the commercial marketplace, and hence about the usefulness of its projects in generating information useful to the private sector. Moreover, the Corporation would be much less likely than a public-private hybrid to invoke project selection criteria other than technical and economic feasibility, and would consequently be less susceptible to the politicization of resource allocation decisions and to the risk of mission 'creep'.

On the other hand, the inclusion of the new corporation within EPRI would mean the addition of roughly $1 billion of annual activity to an r&d organization with a $300M budget, raising the question of whether an expansion on this scale could be accommodated without distorting the priorities of the parent organization. A more serious concern has to do with the risk that the corporation would discriminate against newer and potentially superior technologies in favor of more established approaches. This is in fact quite likely if the governance of the corporation is primarily comprised of representatives of utilities and other companies with an interest in the continued development of the latter. An industry-wide organization dominated by large, established players might well develop a strong bias against new technological entrants.

VI. CONCLUSION

Pressures to accelerate the energy innovation process, coupled with frustrations over aspects of DOE's past performance, are stimulating calls to create new public and quasi-public institutions for developing, commercializing and diffusing new technologies for energy supply and use. The traditional case for government support of innovation focuses

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cent/kilowatt hour surcharge applied to all retail sales of nuclear electricity. The proceeds from the nuclear waste fee are paid into the U.S. Treasury, and expenditures are appropriated annually by Congress. To the frustration of almost all concerned, the process of appropriating these funds has become highly politicized.

on the early stages of that process, where market mechanisms are poorly suited to the organization of activities requiring untrammeled, open-ended communication among participants with diverse organizational and functional backgrounds.[22] Government intervention to compensate for this type of market failure usually takes the form of direct and indirect financial support for fundamental research and early-stage applied R&D. In the particular case of the energy sector, additional arguments for government support hinge on the role of innovation in helping to achieve important social goals whose value is not fully captured in the market price of energy services. Here, because the ultimate goal of policy is to accelerate the take-up of new technologies in energy markets, a case can be made for government support of activities further downstream in the innovation process, including commercial technology demonstrations and even early commercial adoption decisions.

Regardless of the stage at which it occurs, public intervention implies some level of government participation in technology and project selection decisions, in the assumption of costs and risks, and in the operational management of innovation. In general, government participation in these activities is likely to be more problematical as we move downstream in the innovation process, if only because government decision-makers can be expected to be less than fully informed about conditions in the energy marketplace and hence about the factors that make for good and bad decisions.

The case for creating new institutions for energy innovation, as opposed to strengthening and upgrading the Department of Energy, mainly rests on two arguments: (1) the difficulties facing DOE, as an executive branch agency, in recruiting and keeping people with the knowledge -- of financial markets and markets for capital goods and energy services -- needed for effective decision-making in the downstream stages of the innovation process; and (2) the value of insulating these decisions from the annual Congressional appropriations process and from legislative and executive branch debates about general budget priorities and the deficit.

With respect to the establishment of new institutions, there are two basic alternatives. One is to create a hybrid organization, involving some mix of government and private

sector participation in its key financial, managerial and human resource functions. The other is to use government regulatory authority to create the space (and the source of funds) for a private organization to promote innovation more aggressively. Compared to the former, the latter uses the tax system in a different way to create the necessary source of funding, and also delegates more of the decision-making responsibility to representatives of private, for-profit firms. Relative to the private organization option, hybrids run an increased risk of confusion of purpose because of the broader range of goals they will pursue. Furthermore, though all would operate outside the Congressional appropriations process, some would still face a residual risk of political interference because, in the end, they would depend either directly or indirectly on the U.S. Treasury for their financial resources. On the other hand, the private firm option might more susceptible to bias against new technological entrants.

The biggest drawback to all of these proposed institutions is that, if they fail to perform effectively, there is no mechanism that can be relied upon to correct the problem or, if this is not possible, to shut them down. All organizations confront the dangers of inertia and complacency, and a basic objective of organizational governance is to protect against these risks. For private, for-profit entities, competition in the marketplace is the primary mechanism for either upgrading performance or driving poor performers out of business. For government agencies, Congressional oversight plays a similar role. But for the hybrid organizations discussed here, the Congressional oversight function is at minimum diluted, and may actually be absent altogether. The advocates of these organizations implicitly assume that the advantages of this arrangement outweigh the disadvantages, but this is a serious question that deserves more discussion. In a similar vein, the private Carbon Storage Research Corporation is guaranteed to receive a flow of revenues from electricity user fees. This will enhance the financial stability of the corporation's activities, but it may also foster complacency. The general problem of how to build effective performance incentives and disincentives into the design of new institutions for energy innovation deserves much more attention than it has yet received.

NOTES

[1] William Nordhaus has recently made exactly this argument: "To a first approximation, raising the price of carbon is a necessary and sufficient step for tackling global warming. The rest is at best rhetoric and may actually be harmful in inducing economic efficiencies." (W. Nordhaus, *A Question of Balance: Weighing the Options on Global Warming Policies*, Yale University Press, 2008.)

[2] Unless otherwise noted, the data on federal energy RD&D spending in this section were obtained from the database maintained by Kelly Gallagher and her colleagues in the Energy Technology Innovation Policy Group at the Kennedy School of Government, Harvard University. See www.energytechnologypolicy.org

[3] National Science Board, *Science and Engineering Indicators – 2008*, Chapter 4, http://www.nsf.gov/statistics/seind08/c4/c4s4.htm#ffrdc

[4] National Science Foundation, "TABLE 37. Federal research and development obligations, budget authority, and budget authority for basic research, by budget function: FY 1955–2008" http://www.nsf.gov/statistics/nsf07332/content.cfm?pub_id=3798&id=2, From "Federal R&D Funding by Budget Function: Fiscal Years 2006–08 Detailed Statistical Tables | NSF 07-332 | August 2007"

[5] Peter Ogden, John Podesta, and John Deutch, "The United States Energy Innovation Initiative", Center for American Progress, October 2007.

[6] See, for example, Linda Cohen and Roger Noll, *The Technology Pork Barrel*, Brookings Institution Press, Washington, D.C., 1991.

[7] National Research Council, *Energy Research at DOE: Was It Worth It? Energy efficiency and fossil energy research from 1978 to 2000*, National Academies Press, Washington, D.C., 2001.

[8] See, for example, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternative Fuels, *Federal Financial Interventions and Subsidies in Energy Markets 2007*, SR/CNEAF/2008-01, April 2008.

[9] See http://thomas.loc.gov/cgi-bin/query/z?c110:H.R.6258:

[10] Pena, N. and E.S. Rubin, *A Trust Fund Approach to Accelerating Deployment of CCS: Options and Considerations*, Coal Initiative Reports, White Paper Series, Pew Center on Global Climate Change, Arlington, VA , January 2008.

[11] Peter Ogden, John Podesta, and John Deutch, "The United States Energy Innovation Initiative", Center for American Progress, October 2007.

[12] See http://thomas.loc.gov/cgi-bin/query/z?c110:S.3036.PCS:

[13] See http://thomas.loc.gov/cgi-bin/query/z?c110:S.3233.IS:

[14] See http://thomas.loc.gov/cgi-bin/query/z?c110:S.2730.IS:

[15] National Research Council, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future,* A Report of the Committee on Prospering in the Global Economy of the 21st Century, National Academies Press, 2007.

[16] National Academy of Engineering, *Engineering Research and America's Future: Meeting the Challenges of a Global Economy*, A Report of the Committee to Assess the Capacity of the U.S. Engineering Research Enterprise, National Academies Press, 2005.

[17] James J. Duderstadt, *Engineering for a Changing World: A Roadmap to the Future of Engineering Practice, Research, and Education*, University of Michigan, 2008.

[18] Statement by Treasury Secretary Henry M. Paulson, Jr, on Treasury and Federal Housing Finance Agency Action to Protect Financial Markets and Taxpayers, September 7, 2008, hp-1129.

[19] See United States Code Title 2, Chapter 17A, Section 622, part 8.

[20] Steven Chu, Statement before the Committee on Science, U.S. House of Representatives, March 9, 2006.

[21] Edward S. Rubin, Statement before the Subcommittee on Energy and Air Quality, Committee on Energy and Commerce, U.S. House of Representatives, July 10, 2008.

[22] See Richard K. Lester and Michael J. Piore, *Innovation – The Missing Dimension*, Harvard University Press, Cambridge, 2004.