CEEPR Center for Energy and Environmental Policy Research

What should the government do to encourage technical change in the energy sector?

by
John Deutch

05-009 WP March 2005

A Joint Center of the Department of Economics, Laboratory for Energy and the Environment, and Sloan School of Management

What should the government do to encourage technical change in the energy sector?

John Deutch[ι]

Abstract

Government support of innovation – both technology creation and technology demonstration – is desirable to encourage private investors to adopt new technology. In this paper, I review the government role in encouraging technology innovation and the success of the Department of Energy (DOE) and its predecessor agencies in advancing technology in the energy sector. The DOE has had better success in the first stage of innovation (sponsoring R&D to create new technology options) than in the second stage (demonstrating technologies with the objective of encouraging adoption by the private sector). I argue that the DOE does not have the expertise, policy instruments, or contracting flexibility to manage successfully technology demonstration, and that consideration should be given to establishing a new mechanism for this purpose. The ill-fated 1980 Synthetic Fuels Corporation offers an interesting model for such a mechanism.

Introduction. Virtually every energy study recommends that the federal government mount technology research, development, and demonstration (R, D, & D) programs that require large and sustained budgetary support, of course, funded by the taxpayer. Contemporary examples include: (1) the call for a major effort on carbon capture and sequestration; (2) subsidies for renewable technologies, such as photovoltaics and wind; (3) development and demonstration of fuel cells and new techniques for hydrogen production, transmission, and storage; (4) clean coal technologies, such as the Integrated Coal Gasification Combined Cycle; and (5) biofuels, a vague term that encompasses a range of processes from corn based gasohol production to use of modern biotechnology to develop new organisms that can efficiently convert cellulose based feedstock to ethanol or other liquid products.

[ι] Institute Professor, MIT. E-mail jmd@mit.edu. This paper is based on a presentation made to the Twenty-Third MIT Global Change Forum Session 5: Public & private inducements for innovation & technical change, 22-24 March, 2005, Arlington, Virginia.

Every advocate for each of these technologies is genuinely convinced of the merit of each approach for achieving desirable technical change and the justification for government subsidy. However, candor is often lacking about the motivation to capture benefit for a particular interest group or constituency, whether farmers, university researchers, or private firms.

Reducing carbon emissions will undoubtedly require introduction of new energy technology on a vast scale – coal gasification, carbon capture and sequestration, alternative fuels for transportation, greater use of biomass feedstock, better energy efficiency in production, transportation and end-use, carbon free electricity generation from solar, wind, geothermal, and nuclear.

We need to understand what are likely to be effective and what are likely to be ineffective government policies to encourage the adoption of new energy technologies. The government must decide which of the many candidate R,D,&D programs to pursue, how large a program to mount, and how best to manage the effort. My purpose in this paper is to answer two questions: (1) *What have we learned from past government efforts at encouraging large scale energy R, D, & D technology programs? and (2) What tools do we have for doing so in the future*? I draw from my experience as an official in the Department of Energy from 1977 to 1980 and in the Department of Defense from 1993 to 1995, as well as my work with several private energy firms and national laboratories.

Innovation is the process by which technical change is accomplished. The innovation process consists of two steps: <u>The first step is technology creation -- the discovery of new science or technology</u>. The government, private industry, and foundations sponsor discovery activities. Industry, universities, and both federal and not-for-profit laboratories and hospitals perform this R&D.

The second step is the deployment of the new science and technology into an enterprise or the society. This is, by far, the more difficult step in achieving technical change, because it usually involves: (1) making an uncertain investment decision, (2) managing change in a production process, along with its work force, and (3) tailoring a new service or product to customer need.

Nations and firms that do innovation well have an advantage over their competition and enjoy greater economic growth. Innovation has as its objective both improved performance at fixed cost and fixed performance at lower cost. For example, in the case of accommodating to new environmental regulations, the objective of innovation is to maintain output while meeting more stringent standards, and at roughly the same cost as before the regulation.

The government role. The government has three functions in the innovation process. The first function is to set the rules for the innovation activity. Setting the rules enables innovation and determines whether the innovation process will perform well or not. Examples of important rules include:

- establishing patent, publication, and intellectual property rights;
- setting and publishing standards – such as for materials, products, safety;
- tax treatment for R&D activities;
- setting export controls on technology transfer and participation of foreign scientists and engineers in the U.S. R&D enterprise;
- educating scientists and engineers who will enter the technical work force;
- creating mechanisms for industry/university/government partnerships; and
- providing access to venture capital.

The importance of the rule setting function is frequently overlooked. However, countries that set the innovation rules "right" do a lot better than those who do not.

The second government function is supporting technology creation. The justification for this role is well founded, especially for the early stage of the discovery process. Uncertainty as to the eventual realization of long-term benefits from fundamental research means that private firms are not assured of capturing these benefits and so will invest less than what is optimal for the society. Accordingly, the government has a role in supporting early stage "pre-competitive" technology where the results are made available to all (since precise benefits are difficult to predict).

It is in the technology creation phase that the U.S. government has proven most successful in encouraging innovation. The federal government plans to spend above $132 billion in 2006 for all R&D activities ,[1] with $71 billion for DOD, $8.5 billion for DOE, and $0.6 billion for EPA. The total for technology base activities – basic and applied research – is $55 billion. The most important agencies in this effort in the past have been the National Science Foundation, the National Institutes of Health, the Department of Defense, and the Department of Energy.

2006 BA for R&D activities ($ billions)		
	All R&D	**Basic + Applied**
TOTAL	$132.2	$55.2
DOD	71.0	5.6
HHS	29.1	29.0
NASA	11.5	5.4
DOE	8.5	5.4
NSF	4.2	3.7
EPA	0.6	0.5

Federal support to basic and applied research and for the creation of research facilities has a long history in this country. No other nation has remotely as successful an enterprise, and our practices are the model for the rest of the world. The hallmark of the U.S. approach is

[1] The American Association of Arts & Sciences annually provides an informative analysis of the federal government R&D budget. See: http://www.aaas.org/spp/rd/prel06pr.htm.

project selection according to merit, and, in general, flexibility in accommodating education as an important byproduct of funded research activity. The successful government manager in an agency that fosters technology creation is knowledgeable about advances in the field and attentive to outside expert opinion; direct support of R&D projects is the manager's major tool.

The government's ability to influence technology adoption. The third function of government is to engage in the second stage of the innovation process. Here the government has a good deal more difficulty in accomplishing or influencing the process of transfer, adoption, and deployment of new technology. The closer the government sponsored activity comes to demonstrating a potentially useful commercial product, the more difficult it is to justify spending taxpayer money, rather than relying on private market decisions. Moreover, how should benefits be shared when the government supports a private firm in demonstrating the practical application of a technical advance?

<u>The government faces the technology transfer problem in two situations</u>: <u>In the first situation, the government is the sole customer of the technology that it has created</u>. The traditional examples are the nation's defense, intelligence, and space programs. For this category, the problem of technology transfer is simpler, because the government runs the activity. The desired technical change does not have to meet a market test but rather needs to meet performance goals established by the government. Examples are: NASA's Mars landing program or the DOD's effort to transform military technology. In this situation, the major uncertainty facing the government manager is whether a technology project will meet set performance, schedule, and cost objectives. Of course, the cultural hurdle of convincing existing institutions to accept change is present, but the uncertainties associated with a large private market are not.

History shows that the United States has been quite successful in utilizing technology for government activities and achieving the second step of the innovative process, for example, in exploiting technology for the military. To be sure, the process may be spectacularly expensive, but the job gets done by relying on an internal resource allocation process that applies some discipline to the entire activity.

It is important to appreciate that, in practice, much government funded technology creation to support public activities has an enormous range of unplanned benefits to the commercial economy. For example, DOD supported technical advances on network communications, computer systems, and solid state electronic devices, motivated by military applications, are largely responsible for today's modern information technology society. The United States enjoys a great advantage from the flexibility that this "dual-use" pattern provides – an advantage that other nations, for example, the Soviet Union, were unable to exploit.

<u>In the second situation, the government hopes to have the private sector adopt technology created through federally sponsored R&D</u>. However, the private sector will adopt new technology only when it believes the innovation will be profitable under anticipated market conditions. Thus, if the government hopes to encourage adoption of new technology the government program must take into account the uncertainties associated with a private market – for example, market prices – that send different signals for both the supply and demand of the products and services must be considered in addition to the uncertainties of the R&D process. There is the additional question that if the federal government pays for R&D that allows a private firm to achieve a valuable innovation, should the private firm be required to share the benefits with the government?

The government has a mixed record of achieving desired technical change in the private sector. The National Institutes of Health has been remarkably successfully in fostering advances in the biomedical sciences and transferring this knowledge and associated technology to both big pharma companies and small biotechnology companies born from NIH funded research at universities, medical schools, and hospitals. Over the years, the Department of Agriculture's extension service has successfully transferred technology and know-how to the American farmer, enabling a vast increase in agricultural productivity. The record of the Department of Energy and its predecessor agencies is decidedly more mixed.

Government efforts to cause technical change in the energy sector – "commercialization" of energy technology. In the United States, energy is part of the private sector. While there is broad agreement about the reasons for government concern with energy policy,[2] there has been much less agreement about the federal role in the later stages of commercialization of energy technologies, because such efforts require the federal government to make a judgment about future winners and losers in the private marketplace. There is considerable skepticism that the DOE can effectively make such judgments, because the government bureaucracy lacks the necessary skills, and the agency is subject to short-run Congressional interests.

Nevertheless, the DOE has always included technology commercialization as an important part of its mission, especially in the areas of energy efficiency, renewable energy, clean coal, and advanced nuclear power. DOE has tried a variety of mechanisms over the years to achieve this commercialization:

1. The DOE and its predecessor agency, the Energy Research and Development Administration (ERDA), have sponsored technology development in the Department's national laboratories. Although various efforts have been made to encourage transfer of these technologies to the private sector, it has generally proven difficult to accomplish. An important reason is that the national laboratories are focused on technical performance rather than cost.

---

[2] First, energy is an essential part of the economy, and therefore availability, price, and efficiency impact economic performance. Second, the adverse environmental impact of energy use, especially global warming, must be addressed. Third, dependence on imported oil, and increasingly gas, has important security implications for the United States and its allies.

2. Nuclear power has received special attention from DOE, ERDA, and its predecessor agency, the Atomic Energy Commission (AEC), because the technology originated exclusively from the government weapons program. While there were some notable technical successes, most knowledgeable observers would consider that the effort failed especially with regard to nuclear waste disposal and high capital cost.
3. Beginning in the 1980s, the DOE launched a program focused on clean coal technology that operated by competitive selection of strictly cost-shared industry projects. While there were some successes, the results of this effort were mixed.
4. Another approach relied on government-funded demonstration plants (sometimes conducted with industry partners): examples include the Clinch River Breeder Reactor, the Barstow Solar Power Tower, and several synthetic fuel plants. The record here is particularly poor. The projects frequently were over budget and conveyed little useful information to the private sector.
5. On several occasions, the DOE has undertaken smaller scale demonstrations, e.g., photovoltaic, wind, and fuel cell projects. However, these efforts are more a response to Congressional interest than a serious attempt at technology transfer.
6. The DOE has from time to time experimented with supporting industry consortia on the reasonable ground that industry managed efforts have a greater chance to cause technical change in the private sector. Examples include support for the Gas Research Institute (GRI, now abandoned), the Advanced Battery Consortium (ABC), the Partnership for a New Generation of Vehicles (PNGV), and encouraging (but not directly funding) the Electric Power Research Institute (EPRI). Each of these efforts has made some contribution, but none has been sufficiently successful to suggest adopting consortia as a general model.
7. From time-to-time, federal purchase programs, for example, for natural gas or electric vehicles, are suggested as an effective way to demonstrate new technology. More problematic are proposals for buy-down campaigns (for example, for photovoltaic modules), as an effective way to drive unit costs of new technology down to economic levels.

8. Federal and state subsidies, usually in the form of tax credits for favored technologies, such as wind and bio-fuels, are offered as an effective way to promote energy technology. The rationale for this approach is using public money to provide information to the private sector about the economic, technical, and environmental performance of new energy technology, and that successful demonstration projects should influence actions by the entire industry.

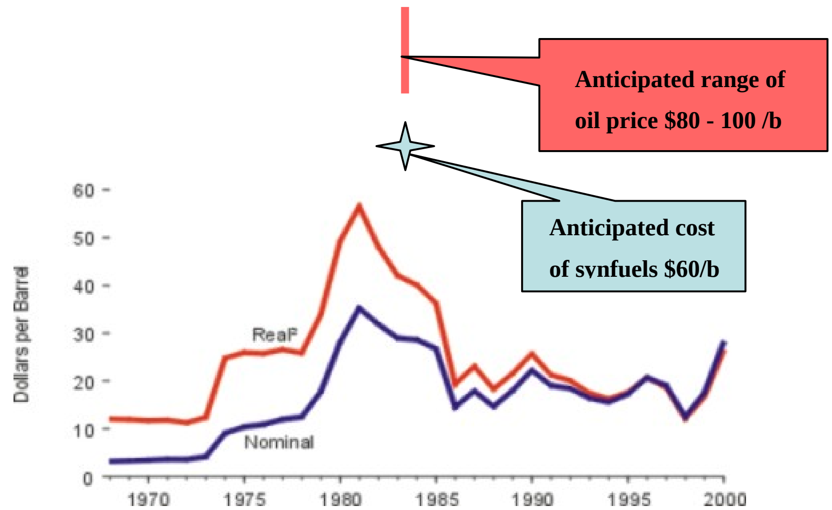
On one occasion, the government mounted a much larger scale attempt to introduce technology that would change the course of energy development in this country. The significance of this case is that it was the only effort that approaches the scale of government action that many believe is necessary today.

Lessons from the Synthetic Fuels program. I ask you to recall the infamous Synthetic Fuels Program, launched in 1980 and ignominiously abandoned in 1986. The lessons of this experience go beyond the criticism of censorious economists of government involvement in technology commercialization.

The Energy Security Act of 1980 established the U.S. Synthetic Fuels Corporation (SFC)[3] at the height of the oil crisis for the purpose of establishing a domestic industry to produce synthetic gas and liquids from tar sands, shale, and coal, as an alternative to oil imports. At the time of the SFC debate, oil prices were about $40/barrel and seemed to be headed for $80-100/b. With little relevant experience, engineering estimates were that synfuels would cost about $60/b. Accordingly, there was significant political pressure to demonstrate a

[3] The Energy Security Act of 1980 [S.932 Public Law: 96-294 (06/30/80)] contains much more than just the creation of the SFC. It contained "something for everyone" (funded from the windfall profits tax), which explains why it passed. It was the first legislation, I believe, to authorize and fund a study of the climate effects of greenhouse gases: Title VII Subtitle B: Carbon Dioxide directed the Director of the Office of Science and Technology Policy to enter into an agreement with the National Academy of Sciences to carry out a comprehensive study of the projected impact on the level of carbon dioxide in the atmosphere, of fossil fuel combustion, coal-conversion and related synthetic fuels activities. The law required a report with recommendations, to be submitted to Congress.

domestic synfuels production capability that would act as a "backstop" to the seemingly endless upward movement of imported oil prices. Congress, industry, and a surprising number of informed energy and international security experts argued that the proper way to demonstrate this "backstop" price was to establish a production target: 500,000 b/d for phase one.



The initial "first of a kind" plants were expected to cost more, justifying a larger subsidy to begin the "learning" process that many believed would result in lower costs. As late as 1982, in the Reagan administration, the DOE estimated that synfuels production in 2000 could be between 474,000 and 3.2 million b/d oil equivalent.[4]

The subsequent sad story is well known. In fact, the price of oil did not go to $100/b but rather tumbled to less than $20/b. The SFC struggled on, managing a handful of projects,

---

[4] *Energy projections to the year 2000 – July 1982 update* – DOE/PE-0029/1. This same document projected a range of 130 – 169 GWe U.S. nuclear power capacity in the year 2000; in fact it turned out to be about 100 GWe.

until it was terminated in 1986.[5] Most of the projects selected by the SFC were brought in on schedule but at a cost vastly above the prevailing market price.

The most charitable, but wrong characterization of the principal lesson of the SFC is that the mistake was to misestimate future oil prices. There are many aspects of the SFC that can be criticized, but to condemn the basic rationale because the price of oil fell, is like faulting someone for buying an insurance policy, paying the premium, and then living. It is not a mistake *per se* to buy insurance or a hedge that later proves to be unneeded.

The primary lesson of the SFC story is that the government should be very cautious in establishing large programs based on the assumption that current estimates will come to pass. The potentially expensive word “demonstration” should be carefully defined to avoid adopting either production targets or fanciful buy-down or learning ideas independent of real market experience and unexpected political, regulatory, and technical events. The SFC experience would have been more successful or, at least, less expensive, if “demonstration” had meant providing information to the private sector on the technical, environmental, and cost of a synfuels technology, rather than attempting to achieve production targets independent of the prevailing market price for conventional oil and gas. The SFC experience warns against formulaic approaches, such as “renewable portfolio standards” and arbitrary emission reduction targets, as a safe or efficient way to encourage new technology.

However, the SFC offers other lessons that are relevant today:

<u>First</u>, indirect incentives – production payments or tax credits, loans or loan guarantees, guaranteed purchase – are more effective for “demonstrating” to the private sector that a particular technology can be economic and profitably deployed. The alternative of direct

[5] Termination of United States Synthetic Fuels Corporation Act; April 7, 1986, P.L. 99-272, Title VII, Subtitle E, 100 Stat. 143

DOE involvement in the design and the payment for the cost of a demonstration plant[6] is simply not credible to the private sector.

Second, the strength of federal support for R&D lies in the earlier stages of innovation, especially in creating the basis for new technology. Government procurement rules are not germane, and the expertise of government R&D managers is not relevant to the decision-making required for investment under uncertainty that is at the heart of the commercialization phase of a new technology.

Third, large energy outlay programs attract more than normal Congressional interest. Understandably, members like to have the projects in their districts and seek to influence the DOE decision-making process. A quasi-public corporation, such as the SFC, insulates the program to some considerable degree from Congressional pressures and the annual budget cycle.

The way forward. Given these observations, what can I say about the way forward? My general proposition is this: If we want to bring about significant reduction in carbon emissions over the next half-century and stabilize greenhouse gas concentration thereafter, without greatly sacrificing economic growth, we must achieve tremendous technical change in the energy sector. Accomplishing this technical change in an efficient and timely way requires considerable government involvement. At present, the adequate resources have not been made available, and the capacity of the U.S. government to demonstrate usefully new technology is uncertain. If the government signals to the private sector that there is a significant cost for greenhouse gas emissions, such as CO_2, there will undoubtedly be a market response of adopting new technology, deploying more energy efficient capital, fuel switching, and shifting to less energy intensive products and services. But progress, and

[6] The large DOE synfuels demonstration plants – Exxon Donor Solvent and Solvent Refined Coal I and II were terminated in 1981 and 1982 after vast expenditure.

especially technology adoption, will be slower absent an effective government program for technology creation and demonstration.

Availability of energy technology development and demonstration resources. The FY2006 DOE R,D, &D budget is about $2.2 billion for all energy supply and conservation technologies – renewables, fossil, nuclear, energy efficiency.[7] This amount is significantly less than the FY80 budget provided for comparable activities, not including the SFC.

2006 BA for DOE Budget	
($ billions)	
TOTAL	**$2,188**
Renewables	364
Conservation	847
Electric T&D	96
Fossil	491
Nuclear	390

In my opinion, the budget authority should be two or three times the proposed amount, at least $5 billion per year for the next decade. The level might well rise if the United States decided to participate in a major way in international R, D, & D. Justification of an increase of this magnitude would require not only a shift in administration policy as to the importance of avoiding global climate change, but also a considerable improvement in DOE's ability to manage a balanced technical program (balance with regard to both technology choice and between R&D and demonstration).

Unfortunately, it is virtually certain, given today's fiscal concern with the twin trade and budget deficits, that increases in discretionary programs – especially those that lack administration support – are unlikely to be appropriated by Congress. On the other hand, greater spending on R, D, & D should be an effective argument against more expensive alternatives, for example, government buy-down programs.

[7] The FY2006 budget includes only $67.2 million for carbon sequestration.

DOE’s capacity to manage technology commercialization efforts. We should be realistic about the capacity of the DOE system to manage technical innovation. The Department’s strength in technology management is with R&D -- the discovery phase of the innovation process. Technical program managers can rely on the considerable expertise that resides in the Department’s laboratory system. Appropriated funds directly support the cost of the R&D, so there is reasonable control over the work effort, whether performed by government laboratories, universities, or industry.

On the other hand, how well can DOE meet the criterion for a technology commercialization success? For a first-of-a-kind demonstration, the criterion is whether information obtained about technical performance and cost influences private sector investment decisions. As I have mentioned, the DOE has no expertise at making investment decisions under uncertainty that is the key to private sector innovation. It is unreasonable to believe that the DOE, or indeed, any government agency, can develop this expertise in-house or (as has been attempted from time to time) contract for it. But, there are other hurdles as well. The federal and DOE procurement rules and management practices make it difficult to structure a demonstration project that is credible to the private sector. The DOE is accustomed to financing projects by paying directly all or a portion of project cost, and it does not have experience or authority in the use of indirect incentives, such as guaranteed purchase or favorable financing that might place a demonstration project, for example, a photovoltaic production plant, on a commercial footing.

Most importantly, the success of any commercialization project requires a stable source of funding on a set project schedule. Frequent changes in direction mandated by a new administration or a Congressional committee is not good. Finally, DOE and its oversight committees in Congress are continually lobbied by special interests – coal, carbon, California – who argue for projects that benefit their industry, community, or public interest constituency. Under these circumstances, it is almost impossible to adopt and sustain an objective and analytically based energy technology commercialization strategy.

Adopting new energy commercialization mechanisms. I conclude a successful government program of demonstration of new energy technologies requires the establishment of a new mechanism, significantly different from the current DOE program approach. To be successful the new mechanism must be able to:

1. provide indirect incentives in order to make the demonstration as credible as possible to private investors;
2. rely on commercial practices free from the government procurement rules that govern funding of R&D projects;
3. have access to adequate, multi-year funding that permits efficient execution of the demonstration projects.

How might such a new mechanism for selection and management of projects that receive government assistance be organized? It is conceivable that a separate unit within DOE might be established with these authorities, but I doubt it. Some years ago, Professor Paul Romer offered an interesting suggestion of relying on self-organized industry investment boards that would operate somewhat as a bank to finance projects of collective interest.[8] I prefer an approach that creates a separate quasi-public corporation – the Energy Technology Corporation (ETC) [9] – that is based on the best features of the SFC. The ETC would select and manage technology demonstration projects without favoring particular fuels or supply

[8] Paul M. Romer, Implementing a National Technology Strategy with Self-Organizing Investment Boards, p. 345, in *Brookings Papers on Economic Activity, Microeconomics 1993:2, edited by* Marin N. Baily and Peter C. Reiss, Brookings Institution Press 1993. [I thank my colleague Richard Lester for pointing out this interesting proposal to me.]

[9] In 1991, a panel on *The Government Role in Civilian technology* of the National Research Council (board on science, technology, and economic policy) made a similar recommendation for establishment of a Civilian Technology Corporation with a broader mandate to demonstrate technology based on R&D advances. See also. *Priming the high-tech pump*, Harold Brown, John Deutch, & Paul MacAvoy, The Washington Post, April 9, 1992. page A27.

over end use. Just as in the case of the SFC, the ETC would be composed of independent individuals with experience and knowledge about future market needs, industry capability, and best use of indirect financial incentives – loans, loan guarantees, production tax credits, and guaranteed purchase – in order to run a project on as commercial a basis as possible. The ETC would not be subject to federal procurement rules, and if financed with a single appropriation, would be somewhat insulated from congressional and special interest pressure.   The key difference between the SFC and ETC is that the ETC would buy information and not produce pre-determined output quantities. The information would guide the future investment decisions of private sector entities (and the banks that finance their activities); therefore the charter of the ETC would need to be carefully drawn.

It does not make much sense to establish such a mechanism unless the scale of the effort is substantial; such as capital in the range of $10 billion. This amount would permit the ETC to provide sufficient financial incentives (but not to pay the entire cost) for a range of technology demonstration projects, for example: (1) capture ready IGCC, (2) photovoltaic module fabrication, (3) new nuclear plants, (4) electric grid modernization, (5) time of day metering, (6) stationary fuel cell plants, (7) hybrid vehicle production.   The ETC would not sponsor R&D or fund process development units – these activities would remain the responsibility of the DOE. Thus the ETC would not support carbon capture and sequestration science but would support a demonstration project.

Conclusion. The social cost of reducing carbon emissions in the long term requires major technical change. Currently, we -- the United States and the world -- do not have the necessary mechanisms in place and are not devoting the level of resources necessary to encourage the needed private sector adoption of new technology. Successful government action requires both more resources and a willingness to change the conventional approach to government’s support for energy technology commercialization.