Energy Technology Innovation Policy Research Group

Transforming the Energy Economy: Options for Accelerating the Commercialization of Advanced Energy Technologies

Findings of the Executive Session on Energy Technology Demonstration at Harvard Kennedy School December 1-2, 2010

By Venkatesh Narayanamurti, Laura Diaz Anadon, Hanna Breetz, Matthew bunn, Henry Lee, and Erik Mielke

HARVARD Kennedy School
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We have tried to accurately represent the views expressed during the workshop but we are responsible for the content.

Cover photo: The world's first grid-scale, flywheel-based energy storage plant is being built in Stephentown, New York. When completed, the 20 MW plant will operate continuously, storing and returning energy to the grid to provide approximately 10% of New York's overall frequency regulation needs. The plant is being built by Beacon Power Corporation (NASDAQ: BCON) and is supported by a $43 million loan guarantee from the Department of Energy.

Source: Gene Hunt, Beacon Power Corporation.

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Executive Summary

On December 1-2, 2010, a group of senior representatives from government, industry, finance, and academia convened at Harvard Kennedy School for a workshop on "Energy Technology Demonstration." The purpose of the workshop was to discuss options for accelerating the commercialization of advanced energy technologies, which are needed to meet the mounting energy challenges facing the United States.

Given the diverse constituencies present at the workshop, the expectation was that a simple consensus would not emerge. Three shared policy goals, however, shaped the discussion: energy security, economic competitiveness, and environmental sustainability.

The focus of the workshop was on the demonstration stage of the technology innovation cycle. Current policies do not adequately address the private sector's inability to overcome the demonstration "valley of death" for new energy technologies. Investors and financiers fear that the technology and operational risks at this stage of the cycle remain too high to justify the level of investment to build a commercial-sized facility.

There is general acceptance that the government has a positive role to play in support of R&D. It is also accepted that the private sector is ultimately responsible for deployment and will only do so if it is incentivized by an adequate expected return or by regulation, both of which are influenced by government policy. There is less consensus on support for the more challenging demonstration stage, and limited support demonstration projects from current policies.

Many participants agreed that demonstrations are particularly important to the energy innovation system because: (a) they are currently a bottleneck and a rate-limiting step to the commercialization of energy technologies; (b) they test new business models that provide critical knowledge to different stakeholders; and (c) absent a clear price signal, the need to support innovative energy technologies becomes more urgent.

Several policy principles and recommendations are outlined in the report. The most important of these are:

- **Long-term policy:** The most consistent theme from the workshop was that if government wants to unlock private sector investment, it must create a predictable and sustainable policy environment.
- **Materiality:** Government support for accelerating the commercialization of energy technologies should focus on projects that have the potential to have a material impact on one or more of the three key policy objectives.
- **Public-private partnerships:** Because the ultimate objective is to enable the private sector to move any new capability forward into the market, government policy should emphasize working with industry, obtaining private sector input, and enabling private sector investment.
- **Unproven technologies:** Currently there are no permanent mechanisms for supporting the demonstration of unproven innovative technologies. While some of these may "fail," the potential benefit from those that do succeed could be huge

and would dwarf a more risk-averse portfolio. Further, it is the unproven as opposed to the proven, where government support can create the greatest benefit.

- **Information dissemination:** There is a clear public interest in making the information acquired from demonstration projects more widely available, although this will need to be balanced with the protection of private intellectual property rights to ensure private sector participation in these projects.
- **Exit strategy:** Government support for technology demonstration and deployment projects should be conditional on performance and based on transparent performance benchmarks, and if these are not met, funding should be discontinued. In other words, the government should have a clear strategy for ending its support of under-performing projects.
- **Targets and objectives:** Targets for demonstration programs should be based on technical performance criteria as opposed to far-reaching, large-scale production targets, which can be expensive and inefficient, as their achievement often depends on technological advances and commodity prices.
- **Portfolio approach:** The government should adopt a portfolio approach that supports a range of competing technologies, and a variety of policy and financial mechanisms. However, given the large scale of investments, not all projects and technologies can be supported, and real-world constraints dictate a need to be selective. For instance, some participants prioritized support for CCS and nuclear energy, due to their potential to address the overarching policy objectives, and their high cost which makes it very difficult to attract private financing.

There was broad, although not universal, support for two policy initiatives currently being discussed by policy makers. One is the **Quadrennial Energy Review (QER)**, which was recently proposed by the President's Council of Advisors on Science and Technology (PCAST) to bring some much-needed coherence, stability, and predictability to energy policy in the United States. The other is the **Clean Energy Deployment Administration (CEDA)**, which was viewed by many as a useful policy tool for enabling energy technology demonstrations. The fact that CEDA has already received bi-partisan support in the Senate was an important factor in the support.

There was substantial agreement that the U.S. government cannot wait to accelerate the commercialization of novel energy technologies: speed is of the essence. Even if the private sector were able to commercialize new technologies without government assistance in the long term, to the extent that government action could catalyze early adoption, the economic, security, and environmental benefits of such early adoption would justify expanded government intervention. In addition, some experts expressed the view that the United States risks ceding leadership in too many energy technologies to other countries. The United States continues to be a world leader in the invention and design of revolutionary energy technologies, but unless it recaptures its leadership in the commercialization of these technologies, other countries will capture greater market share, and the jobs and economic benefits will accrue to those countries instead.

1. Introduction

There is broad consensus that new, advanced energy technologies are urgently needed to improve the security of supply, to use energy more efficiently, to reduce local air pollution and greenhouse gas (GHG) emissions, to maintain economic competitiveness, and to improve grid reliability. The accelerated transformation of the U.S. energy system cannot be achieved without government intervention to spur the demonstration and deployment of new technologies, which are vital steps towards commercialization.

What could, and should, the U.S. government do to accelerate the commercialization of advanced energy technologies? On December 1-2, 2010, a group of senior executives from government, industry, finance, and academia convened at the Harvard Kennedy School for an off-the-record workshop on "Energy Technology Demonstration" to discuss these issues.

The workshop focused primarily on the role of government in supporting the demonstration stage of the technology innovation cycle, as this stage is viewed by many as the current rate-limiting step for innovation in many different energy technologies. The demonstration challenge has also received relatively less attention from policymakers than other stages of the technology innovation process, although all of these stages need more long-term attention from policy makers.

This document reports on the policy guidelines and options discussed at the workshop. A complementary *framing statement*, prepared in advance of the workshop, addresses the challenges inhibiting the rate of energy technology demonstration in the United States. The framing statement is included in Appendix 3 and can also be downloaded from the Energy Technology Innovation Policy website.[1]

[1] http://belfercenter.ksg.harvard.edu/publication/20728/

2. Energy Technology Demonstrations

The government plays an important role in all aspects of the U.S. energy industry, by extensively regulating energy production and consumption, by taxing throughout the value chain, by consuming large amounts of energy, and by supporting and incentivizing energy innovation. In short, the government is already a factor in the private sector investment in different energy technologies. While many believe that the government should do more in each of these areas, the question for the workshop was "is there a specific need for government support for *demonstration* of new energy technologies?" A technology demonstration involves the design, construction, and operation of the prototype of a technology at or near commercial scale with the purpose of providing technical, economic, and environmental information to industrialists, financiers, regulators, and policy makers.[2]

The demonstration challenge is particularly great for supply-side technologies, and therefore the main focus of the workshop was on energy supply. Supply-side technologies are typically more capital intensive than for the demand-side, have longer asset lives and therefore have a longer-lasting influence on the energy system.

2.1. The Demonstration "Valley of Death," the rate-limiting[3] factor

The technology innovation cycle can be divided into four "stages" of innovation: Research, Development, Demonstration, and Deployment.[4] There is general acceptance that the government has a positive role to play in support of basic and applied science (R&D). It is also generally accepted that the private sector is ultimately responsible for deployment (selecting, financing and maintaining the energy capital stock), although it will only do so if it is incentivized, either by an adequate expected return (e.g., government support through loan guarantees or production subsidies), or as required by regulation as part of the cost of being in the business.

In between R&D and Deployment, the Demonstration stage – the construction and operation of a technology at a commercial scale for the first time – is often financed readily by the private sector, but this is not always true for the energy sector. Indeed, there is a demonstration "valley of death" for new energy technologies. The demonstration challenge is particularly great for the energy sector due to high investment needs, low capital turnover, competition from incumbent, mature technologies, and commoditized nature of the end product.

Most participants agreed that the lack of demonstration or commercial scale testing of novel technologies is a serious bottleneck in the energy technology innovation cycle. The

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[2] Demonstration projects are not uniform. Different demonstration projects may emphasize obtaining technical over financial information, for instance. Government policy should be able to accommodate different types of demonstration projects.

[3] The rate-limiting step is the slowest step in a series, which determines the overall rate of change.

[4] These stages are a simplification. Indeed, energy innovation is not a simple linear process, as it involves multiple feedback mechanisms, and often the stages take place in parallel. The innovation framework is discussed in greater detail in the framing statement in Appendix 3. Deployment can in turn be divided into "market formation" and "diffusion."

importance of demonstration is partly due to the need for an interconnected innovation system in which research and development (R&D) are connected to demonstration and deployment. In general, there is broad consensus that government has a role to play in support of R&D; this is not necessarily the case for demonstration projects.

Many participants expressed the view that the demonstration "valley of death" — the poor prospects for novel energy technologies to obtain financing to enable commercial scale demonstrations — is a major factor impeding investment in R&D. One participant framed this finance dilemma as *"unless other sources of financing exist down the road, it doesn't make sense to do [venture capital] financing."*

"Unless other sources of financing exist down the road, it doesn't make sense to do VC financing"

2.2. Importance of information from demonstrations

Some stakeholders highlighted that the value of demonstration projects is linked to the information they provide to market participants throughout the value chain. Furthermore, the information about the technical and commercial viability of specific energy technologies, as well as possible adjacency effects[5] throughout the energy system, surpass the possible benefits accruing to a single investor or group of investors. This information is not readily available from a pilot facility; the smaller scale of pilot projects does not allow the economic, technical, and environmental performance of many technologies to be determined. Each sector gains measurable benefits from demonstrations:

- **Industry:** Demonstration projects allow industry to learn how a technology fits into the overall energy supply chain, and to validate design and operational assumptions. One participant emphasized the importance of this point: *"In industry, while technologies are important, they're not nearly as important as supply chains, because that's where you make money."* Demonstrations are also crucial for providing information about possible adjacency effects, such as the adjacency effects Tesla Motors has had on increased private sector interest in electric vehicles.[6]
- **Finance:** Demonstrations provide financial, industrial, and government stakeholders with information they can use to determine whether or not to invest in particular technologies, such as new information on costs and technical and operating performance.
- **Government:** Demonstration projects serve to inform government policy. For example, if carbon dioxide sequestration at commercial scale turns out to be too expensive and unreliable, then it may become more important for the

[5] *Adjacency effect* in this context refers to the impact that a new technology or business model could have on other parts of the energy system, both positive and negative.
[6] Tesla Motors used existing technologies for batteries, electric motors, etc. Its biggest innovation was to combine different technologies into one product and to utilize parallel processing technologies to increase energy efficiency and power of its systems, allowing vehicles to have advanced navigation, information, and control systems.

government to pursue other technological avenues more aggressively. In addition, the design, construction, and operation of demonstration projects could expand the overall intellectual capital and experience base of the economy.

"In industry, ...technologies are... not nearly as important as supply chains, because that's where you make money"

2.3. Need for speed

The need for a speedy transformation of the U.S. energy system is an additional impetus for government action for two reasons. First, even if the private sector were able to commercialize new technologies without government assistance in the long term, government action could be justified if it catalyzes early adoption, which would have significant economic, security, and environmental benefits.

Second, some experts expressed the view that without speedy government action the United States risks ceding leadership in too many technologies to other countries, such as China. In these economies, the investment going into the energy system is higher than that in developed economies where the investment focus is primarily on maintenance and replacement of existing capacity. As one participant expressed it, *"speed is of the essence... this is a race."*

"Speed is of the essence... this is a race"

Third, some participants argued that, from an environmental perspective, the cost of the "insurance premium" is likely to increase the longer action is delayed.

2.4. Progress in the absence of a carbon regime

The absence of carbon pricing or some other regime limiting GHG emissions, and the reduced likelihood of such policies being introduced in the next few years, increases the need for separate and more targeted government policy to encourage the development of new energy technologies. In addition, the majority of participants supported the view that carbon regulation alone would not be sufficient to address the energy technology demonstration challenge.

2.5. Technology leadership and competitiveness

Many participants stated the United States has already lost the lead in terms of markets and production, and that government action was essential to promote U.S. technology leadership.

The United States continues to be a world leader in the invention and design of revolutionary energy technologies, but unless it recaptures its leadership in the commercialization of these technologies, other countries will capture greater market share, and the jobs and economic benefits will accrue to those countries instead.

3. Principles and Recommendations

Consensus developed about the need for clear policy goals to guide government action in accelerating the commercialization of energy technologies. Three policy goals received support from the group: energy security,[7] economic competitiveness, and environmental sustainability. New energy technologies are essential to meet these long-term goals.

Some participants also expressed the need to place investments in energy technology demonstrations in a wider context – as a small insurance premium – summarized by one participant as *"miniscule investments in macro terms. If this were a corporation, it would be a no-brainer."*

*"[These are] miniscule investments in macro terms.
If this were a corporation, it would be a no-brainer"*

Deciding which technologies to support is a perennial challenge. The exact implementation of the following principles would need to be carefully considered in the design of policies or mechanisms to support demonstrations.

3.1. Long-term policy

The need for *long-term* policies received universal support. As one participant framed it: *"Our biggest concern is how to finance 20-year projects based on one-year policy*."

*"Our biggest concern is how to finance 20-year
projects based on one-year policy"*

The policy uncertainty, i.e., the lack of sustained policy objectives, vision, and strategy, was highlighted by several participants as the single biggest barrier to private sector investment. One participant referred to this as *"the destructive impact of oscillating policies."*

"The destructive impact of oscillating policies"

There is a need for more sustainable and consistent government policies. One example of where such policies have catalyzed private sector investment is advance biofuels (e.g., the Renewable Fuel Standard has provided a degree of long-term visibility on demand). The Department of Energy has provided support in the form of R&D, and federal assistance to private companies and to state governments. The biofuels example does not imply that the group thought the current biofuels policies are perfect (in fact, several experts argued that the current policies are not well-designed, e.g., the use of mandates and subsidies to support first-generation technology corn ethanol), only that some of the long-term signals have been beneficial to catalyze private sector investment and innovation. In contrast, an example of "oscillating policies" is the production tax credit (PTC) for wind

[7] While the group agreed on a definition of energy security that involved ensuring reliable and affordable supplies of electricity and fuels, there was some disagreement regarding the extent to which the reduction of oil imports should be a policy goal as part of energy security.

energy. The PTC has to be renewed annually and has expired three times (1999, 2001 and 2003) resulting in sharp reductions in installations the following year (2000, 2002, and 2004).

3.2. Commercial viability and credibility

Demonstration support should be directed towards technologies that are judged to have potential to be commercially viable and credible within a reasonable timeframe (even if they are "unproven" today). Otherwise the technology is not yet ready for demonstration projects.[8]

Some participants emphasized that commercial considerations should not solely reflect current market prices, but should also consider the value of technologies in different market conditions, such as higher oil and natural gas prices than today.

3.3. Materiality

Support should focus on projects that have the potential to have a material impact on one or more of the three key policy objectives (security, environment, and economic competitiveness). However, while there was broad agreement that this was a useful criterion, there was less clarity on how this principle would be applied in practice to support different technology projects.

3.4. Information dissemination

Navigating the balance between the protection of private intellectual property rights and the public sharing of information is a perennial challenge for collaborative public-private projects. A group of participants flagged this "IP problem" as a design element that would need to be resolved, most likely on a one-by-one basis. One participant specifically suggested that the dissemination of information ought to be a central feature of demonstration projects to facilitate beneficial knowledge spillovers.

3.5. Exit strategy

There was consensus that the government should have clear exit strategies: one strategy for specific projects, and the other for winding down funding for particular areas or financing mechanisms.

Government support for technology demonstration and deployment projects should be conditional on performance. The government should design an exit strategy – based on transparent and predictable performance benchmarks – for ending its support of under-performing projects.

For certain support mechanisms, such as production-linked tax credits, one participant suggested that support be tapered off rather than ended overnight, a feature which has already been applied in several energy technology programs at a state-level in the United

[8] Nevertheless, programs should be framed in such a way that when individual technologies ultimately are not commercially viable (which is to be expected), the apparent "failure" should not undermine support for the policy as a whole. The demonstration of technologies that do not end up being used widely can still have substantial value – see *2.2. Importance of information from demonstrations*.

States and internationally. Another participant clarified that exit strategies may only apply to certain kinds of project-based government support.

3.6. Public-private partnerships

It was acknowledged that, all too often, government officials do not have a deep enough understanding of the industries or supply chains that they are trying to catalyze.

There are real benefits to be derived from deeper collaboration between government agencies (which have the resources to support early demonstration and deployment) and industrial actors (which have critical technical, market, and systems knowledge and that must eventually be able to commercialize and deploy these technologies).

3.7. Cost sharing

Greater public-private collaboration may also imply greater sharing of the costs and risks of a demonstration project. One participant proposed that all demonstration and deployment projects should have a standard 50% cost-share, as it would demonstrate that a project is worth pursuing. On the other hand, another participant observed that the private sector may not be willing to shoulder such high cost-sharing requirements, and therefore some flexibility in cost sharing would be valuable, depending on the risk and the scale of investment required for the specific technology. This may particularly be the case for first-of-a-kind demonstrations with limited or no immediate commercial value, e.g., carbon capture and sequestration (CCS).

3.8. Targets and objectives

How success of a demonstration project, a support program for a specific technology, or a program to support demonstration in a range of technologies is defined and measured matters. First, it influences type and amount of investment, with a corresponding impact on the usefulness of the program. Second, it could also influence the support for sustaining a policy, if early projects are deemed to have not met the objectives.

One participant suggested that "*project failures risk becoming an albatross around the neck of policy*" as "losers" will be more publicized than "winners," and suggested that this was already the case with some of the loan guarantees.

"Project failures risk becoming an albatross around the neck of policy"

One suggestion is to have very specific targets and objectives for a demonstration project, focusing primarily on technical performance and avoiding targets (e.g., production targets), which could be undermined by changes in commodity markets or other external factors. Indeed, even demonstration projects which may be deemed to be commercially unsuccessful, generate valuable information and care should be taken to capture and disseminate the knowledge and experience from those projects.

3.9. Portfolio approach

There was agreement that the government should pursue a portfolio approach, both in the sense of promoting the commercialization of a wide range of competing technologies, and of using a variety of policy and financial mechanisms as appropriate. A portfolio approach is necessary for satisfying multiple goals and constituencies, for hedging against different market and conditions and technology developments, and for ensuring flexibility in the long term. Several participants noted that there are limits to the portfolio approach and that it should not be seen as a substitute for making national policy choices. Even the United States cannot afford an unlimited portfolio, so there will always be a need to pick specific projects and technologies.

Some participants argued that government involvement should be focused on a narrow subset of technologies — particularly carbon capture and sequestration, nuclear energy, and energy storage. CCS and nuclear energy were given particular support as the most likely technologies to be able to meet the three overarching policy objectives (economic competitiveness, energy security and environment). They believe that given budget constraints, investing in too wide a portfolio of technologies would result in investments that are too small in any particular area to produce any real long-term benefit.

In addition, a portfolio approach is also an important feature in the design of a robust demonstration program in order to withstand individual the type of project failures to be expected from a technology demonstration program. Indeed, if the program had a 100% success rate, then government action may have been unnecessary and it might have crowded out private sector investment.

3.10. International partnerships

While most participants agreed that the need to remain competitive internationally is an important reason for government intervention, there are also areas where cooperation, rather than competition, should be a cornerstone of government policy.

This is especially true in the context of global environmental issues, but it also applies to energy security. The U.S.-China Clean Energy Research Center[9] was mentioned as an example of a positive initiative (albeit for R&D, not demonstration projects), which plays to each country's strengths, e.g., taking advantage of China's expansion of coal-fired power plants to develop advanced "clean coal" technologies.

[9] The U.S.-China Clean Energy Research Center (CERC) was established in 2009 to facilitate joint research and development on clean energy technologies, specifically (i) building energy efficiency, (ii) clean coal including carbon capture and storage, and (iii) clean vehicles.

4. Policy Options

4.1. Introduction

The previous section outlined some of the key principles and recommendations for government action on enabling energy technology demonstration projects to accelerate the commercialization of advanced technologies in the United States. This section provides a summary of the discussion about specific policy proposals.

Policy responses need to be flexible and tailored appropriately to adjust for the heterogeneity of energy technologies, with, for example, very different challenges facing demonstration of advanced nuclear technologies compared to smart-grid technology. The energy companies are equally diverse in their willingness to adopt new technologies, varying greatly across subsectors, by size and geography, but more importantly, also by risk appetite (e.g., large oil and gas companies compared to the electric utilities).

As previously stated, the most consistent theme from the workshop was that if the government wants to unlock private sector investment, a predictable policy environment built around long-term policies is necessary. Another area of wide agreement was that no single technology or policy would be sufficient to meet the energy challenges facing the Unites States.

There was broad, but not universal, support for two policy initiatives currently being discussed by policy makers. One is the Clean Energy Deployment Administration (CEDA). The other is a Quadrennial Energy Review (QER), which was recently proposed by the President's Council of Advisors on Science and Technology (PCAST).

4.2. New institutions (CEDA)

A majority of participants supported the creation of the Clean Energy Deployment Administration (CEDA). One participant expressed support as *"CEDA is the best attempt to find intelligent solutions to the issue, in part because it includes flexibility."* CEDA is a bipartisan initiative aimed at creating an attractive investment environment for the development and deployment of new clean energy technologies. The Senate version of CEDA (i) allows the administration to issue loans, letters of credit, loan guarantees, insurance products, or other credit enhancements; (ii) requires it to use a portfolio approach to mitigate risk, with the expectation that it becomes self-sustaining by balancing riskier investments with revenues from other services and less risky investments; and (iii) would have CEDA take over the loan guarantee program to be restructured under a new Clean Energy Investment Fund.[10]

"CEDA is the best attempt to find intelligent solutions to the issue"

[10] In the Senate version, the Clean Energy Investment Fund would receive a $10 billion injection as seed capital for CEDA, in addition to the appropriations applicable to the Loan Guarantee Program.

Should CEDA support unproven technologies or should it focus primarily on lower-risk technologies? The House and Senate versions of CEDA, for example, differ in terms of their support for unproven energy technologies. The Senate version explicitly supports breakthrough technologies (i.e., unproven), but not exclusively, while the House version contained no explicit mandate for breakthrough technologies. Currently, other than *ad hoc* programs by departments, such as the smart grid demonstration projects funded by the American Recovery and Reinvestment Act of 2009,[11] no long-term mechanisms exist to support the demonstration of unproven technologies. Enactment of CEDA could fill this gap.

However, there was less consensus on how CEDA should be structured or financed. Several participants suggested that ARPA-E would be a suitable institutional role model, i.e., within the Department of Energy but with greater autonomy and discretion for hiring and decision-making than is normal for government institutions. In general, there was support for the view that for any new agency to be effective, flexible, and quickly operative, it should be released from many of the limitations of government employment and procurement rules. Unlike ARPA-E, CEDA should be sophisticated enough to deal with large-scale system-wide challenges and projects, which may require even more independence from the Department of Energy.

Some of those more skeptical of CEDA expressed concern that it would be overly focused on creating something new, when a small, new agency may not be sophisticated enough to address such a system-wide challenge. Instead, they felt it would be more effective to restructure the current institutions within the Department of Energy.

4.3. Quadrennial Energy Review

The PCAST proposal[12] for a QER received support from several participants as a process that could overcome the current absence of predictable, transparent, consistent, and comprehensive energy policies for the United States.

In its recommendation, PCAST envisioned a QER process that would provide a multiyear roadmap that:

- Lays out an integrated view of short-, intermediate-, and long-term objectives for federal energy policy in the context of economic, environmental, and security priorities
- Outlines legislative proposals to Congress
- Puts forward anticipated Executive Actions (programmatic, regulatory, fiscal, and so on) coordinated across multiple agencies
- Identifies resource requirements for the RD&D programs and for innovation incentive programs
- Provides a strong analytical base

[11] See the framing statement (Appendix 3) for more details on the program
[12] PCAST made this recommendation in a report to the President issued on November 7, 2010. The summary of QER is based on the published PCAST report http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-energy-tech-report.pdf

An interagency body at the level of the Executive Office of the President would lead the QER, with substantial input from Congress, the energy industry, academia, state and local governments, and others. The Department of Energy would serve as the Executive Secretariat for the preparation of the QER, with input and participation from other Federal agencies, other levels of government, academia, and the private sector.

4.4. Procurement and other mechanisms

Government procurement was one of the more specific, but also more controversial, policy options discussed in the workshop. A majority of participants expressed support for using the government selectively as a "first customer," leveraging the purchasing power of federal agencies such as the Department of Defense to create market demand for innovative technologies. Although this could potentially involve long-term purchase agreements, the goal would not be to create a permanent government niche market. Rather, as one industry participant described it, the purpose would be having a buyer to "get you out of the gate" for an initial deployment. Government procurement could also take the form of reverse auctions.[13] Reverse auctions have the advantage of only resulting in expenditures if particular cost and performance parameters are met.

One current example of a public entity potentially playing the role of "first customer" is the Tennessee Valley Authority (TVA), which is considering installing first-of-a-kind small modular nuclear reactors.

A couple of participants, however, asserted that government energy procurement was not nearly as effective a mechanism as people wished it would be, that it was too "small potatoes" to stimulate meaningful deployment and would merely divert resources from other missions and projects.

Participants were supportive of the loan guarantee program but acknowledged that there are serious concerns about the current procedures.[14]

Grants were felt to be most suitable in earlier stages (see also *3.7. Cost sharing*, page 12), while loans and loan guarantees are more suitable for technologies closer to deployment.

Above all, the group's view was that any agency enacting the policies and administering the mechanisms should be able to act quickly, as well as co-invest (i.e., take equity) and other ways of sharing risk with the private sector on projects.

[13] For instance, the Energy Policy Act 2005 authorized the use of reverse auctions to encourage development of advanced biofuels. The lack of progress is discussed in more detail in the framing statement (Appendix 3).
[14] The framing statement (Appendix 3) has a more detailed overview of the loan guarantee program and details some of the concerns about the program, such as the calculation of the credit subsidy cost.

5. Further Research

5.1. Continued stakeholder dialogue

The workshop was a unique forum for dialogue between key stakeholders from government, industry, finance, and academia. It is important to continue this type of multi-stakeholder dialogue to ensure that future government policies are designed appropriately for the intended stakeholders, and for industry and the financial sector to provide feedback to policy makers.

5.2. Procurement

The potential role of procurement in the demonstration of advanced energy technologies was an area where there was disagreement. There are few examples in which government procurement has been successful. Further, there is a difficulty defining what constitutes "procurement" and "success." One case of a procurement-type incentive program from the private sector that could be studied is the "Super Efficient Refrigerator Program."[15] Another example could be the price guarantee of $120 million that the Synthetic Fuels Corporation offered to the Cool Water Coal Gasification project in 1983, the first large scale IGCC plant. Beyond this, more recent and unexplored examples at the Department of Defense could also be fruitful areas for research.

5.3. Institutions

There was support for the view that if any new agency is to be effective, flexible, and quickly operative, it should be released from many of the limitations of government employment and procurement rules. As stated earlier, several participants suggested that ARPA-E would be a suitable institutional model for a new agency. Future research could compare different models of institutional design, e.g., ARPA-E and FERC, to assess the advantages and disadvantages, departmental cohesion, congressional oversight, and other factors, which may influence an agency's ability to operate effectively.

5.4. Appropriate financial mechanisms by technology area

Impediments to private sector finance vary by technology and maturity of technology. A new agency should have flexibility in selecting appropriate mechanisms, including grants, (with or without cost sharing), reverse auctions, loans, loan guarantees, direct equity investment, and other mechanisms. Future research could compare the effectiveness of different mechanisms and clarify the criteria for selection different mechanisms. The appropriate use of exit strategies or declining (tapered) financial incentives would also benefit from further research. For instance, would providing visibility on declining financial incentives create additional incentives to be a first-mover[16] or risk locking in current technologies?

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[15] The Super Efficient Refrigerator Program (SERP) was organized by a consortium of 24 utilities, who presented a request for proposals to refrigerator manufacturers for a refrigerator that was 25-50% more efficient than 1993 DOE standards. The bid winner would receive an incentive of about $100 (1992 U.S.$) per unit sold before July 1997. A 1999 study evaluated SERP and two other efficiency procurement programs (http://economic-analysis.pnl.gov/pubs/reports/lessons_learned.pdf)

[16] With most relevant technologies, there is a strong interrelationship of cumulative volume and cost. If policy makers could quantitatively define the gap, one option for incentives is the gap between current costs and (initial) market acceptable prices, with the incentive declining as the total volume installed goes up.

6. Conclusions

The workshop provided a rare opportunity for very senior executives from government, industry, finance and academia to jointly focus on a single issue: how to enable energy technology demonstrations to accelerate the commercialization of advanced energy technologies. There was broad consensus that such energy technologies are urgently needed to achieve the three policy objectives: energy security, economic competitiveness, and environmental sustainability.

The focus was on the demonstration stage of the energy technology innovation cycle. There was general agreement that current policies do not adequately address the private sector's inability to finance demonstration projects due to relatively high risk and large scale, the so-called demonstration "valley of death." Participants also agreed that demonstrations are particularly important because: (a) they are currently a rate-limiting step to the commercialization of energy technologies; (b) they test new business models that provide critical knowledge to different stakeholders; and (c) absent a clear price signal, the need to support innovative energy technologies becomes more urgent.

The most important policy principles and recommendations were:

- **Long-term policy**: a predictable policy environment built around long-term policies is necessary.
- **Materiality**: focus on projects that have the potential to have a material impact on one or more of the three key policy objectives.
- **Public-private partnerships:** government policy should emphasize working with industry, obtaining private sector input, and enabling private sector investment.
- **Unproven technologies:** currently there are no permanent mechanisms for supporting the demonstration of unproven innovative technologies.
- **Information dissemination**: make the information acquired from demonstration projects more widely available both of projects with technologies that reach widespread deployment, and those that do not.
- **Exit strategy**: continued support should be conditional on performance, and based on transparent performance benchmarks; strategy for ending its support of under-performing projects.
- **Targets and objectives**: set technical performance targets as opposed to far-reaching large-scale production targets.
- **Portfolio approach**: support a range of competing technologies, and a variety of policy and financial mechanisms, but financial constraints force selectiveness.

In line with these principles, the majority of workshop participants expressed support for **CEDA** (which has bi-partisan support in Congress) as a suitable solution to many of the challenges, including the current lack of support for unproven technologies. Furthermore, the proposed **QER** was also supported as an important step towards creating a more transparent and predictable environment for long-term energy policy.

Speed is of the essence. Rapid government action is needed to accelerate the commercialization of novel energy technologies and to catalyze private sector investment in scale-up and adoption.

Appendix 1: Workshop Participants

Paul Alivisatos
Director
Lawrence Berkeley National Laboratory
Department of Energy

Brandon Bethards
Chief Executive Officer
Babcock & Wilcox

Brian Bolster
Managing Director
Goldman Sachs

Matthew Bunn
Associate Professor of Public Policy
Harvard Kennedy School

Uma Chowdhry
Chief Science & Technology Officer
DuPont

Steven Chu *
Secretary of Energy
Department of Energy

** Due to time constraints, Secretary Chu was only able to participate in the workshop dinner, where he gave the keynote speech.*

Russ Conser
Leader of GameChanger Program
Shell

John Deutch
Institute Professor
Massachusetts Institute of Technology

Stephan Dolezalek
Managing Partner
Vantage Point Venture Partners

Karina Edmonds
Technology Transfer Coordinator
Department of Energy

Jonathan Epstein
Senior Staffer
Energy & Natural Resources Committee
United States Senate

Steve Fetter
Assistant Director At-Large
Office of Science and Technology Policy

Mark Gerencser
Executive Vice President
Booz Allen Hamilton

T.J. Glauthier,
TJG Energy Associates

Richard Goffi
Principal
Booz Allen Hamilton

Robert Goodof
Vice President
Loomis Sayles

Rebecca Henderson
Senator John Heinz Professor Of
Environmental Management
Harvard Business School

William Hogan
Raymond Plank Professor of Global
Energy Policy
Harvard Kennedy School

Bennett Johnston
Senator (D-LA, retired)

Henry Kelly
Principal Deputy Assistant Secretary
Energy Efficiency & Renewable Energy
Department of Energy

Scott Klara
Deputy Director
National Energy Technology Laboratory
Department of Energy

Steve Koonin
Under Secretary of Energy
Department of Energy

Henry Lee
Jassim M. Jaidah Family Director
Environment & Natural Resources Program
Harvard Kennedy School

Pete Lyons
Assistant Secretary for Nuclear Energy
Department of Energy

Arun Majumdar
Director
ARPA-E
Department of Energy

Jeff Miller
Partner
The Tremont Group

David Mohler
Chief Technology Officer
Duke Energy

Venky Narayanamurti
Benjamin Peirce Professor of Technology and Public Policy
Harvard Kennedy School / School of Engineering and Applied Sciences

Donald Paul
Research Professor of Engineering, Earth Sciences, and Policy, Planning, and Development; William M. Keck Chair of Energy Resources
University of Southern California

Arati Prabhakar
Managing Partner
US Venture Partners

Gary Rahl
Vice President
Booz Allen Hamilton

Bill Sahlman
Dimitri V. D'Arbeloff, MBA Class of 1955 Professor of Business Administration
Harvard Business School

Dan Schrag
Sturgis Hooper Professor of Geology
Professor, Environmental Science and Engineering
Director, Harvard University's Center for Environment,
Harvard University

Finis Southworth
Chief Technology Officer
AREVA NP Inc.

James Suciu
President, Global Power Sales
General Electric

Sanjay Wagle
Associate Director for Commercialization
ARPA-E
Department of Energy

ETIP research and content team

Laura Diaz Anadon
Director, Energy Technology Innovation Policy research group
Associate Director, Science, Technology, and Public Policy Program
Harvard Kennedy School

Erik Mielke
Research Fellow, Energy Technology Innovation Policy research group
Harvard Kennedy School

Appendix 2: Workshop Agenda

Wednesday, December 1, 2010

2.00pm	Welcome and introductions
2.15pm	Session I: The Challenge of Scaling Up Advanced Energy Technologies

Four introductory presentations followed by a moderated discussion for all participants led by Prof. Rebecca Henderson, Harvard Business School

a) *Framing the challenge*: Dr. Arun Majumdar, ARPA-E Director
b) *Industry perspective*: Dr. Uma Chowdhry, CSTO, DuPont
c) *Finance perspective*: Mr. Stephan Dolezalek, Managing Partner, Vantage Point Venture Partners
d) *Government perspective*: Mr. Gary Rahl, VP, Booz Allen Hamilton

3.15pm	Moderated discussion in break-out groups
4.30pm	Moderated discussion for all participants
5.30pm	Summary and feedback

Workshop dinner with Dr. Steven Chu, Secretary of Energy

Thursday, December 2, 2010

8.30am	Recap of previous day's discussion
8.45am	Session II: Thinking Through Solutions

Four presentations followed by moderated discussion for all participants led by Henry Lee, Director, Environment & Natural Resources Program, Harvard Kennedy School

a) *Framing the options*: Prof. Venkatesh Narayanamurti, Harvard Kennedy School / School of Engineering and Applied Sciences
b) *Industry perspective*: Prof. Donald Paul, University of Southern California
c) *Finance perspective*: Dr. Arati Prabhakar, Managing Partner, U.S. Venture Partners
d) *Government perspective*: Dr. Peter Lyons, Principal Deputy Assistant Secretary for Nuclear Energy, Department of Energy

9.45am	Moderated discussion in break-out groups
11.00am	Moderated discussion for all participants
12.15pm	Closing Remarks by Dr. Steve Koonin, Under Secretary of Energy
12.30pm	Closing summary and feedback

Brief for session I: The Challenge of Scaling Up Advanced Energy Technologies

What are the barriers to private sector commercialization of new energy technologies and what role could – and should – the federal government undertake to facilitate the development of such projects. Issues to be discussed include:

- *Barriers to Private Sector Investment:* What are the challenges that the private sector faces in investing in energy technology demonstration projects (e.g., technological risk, scale, regulatory, commercial, market access risks)? How are demonstration projects in the energy sector different from those in other sectors?

- *What are Possible Public Policy Objectives of Supporting Demonstration Projects:* Creating technical options for reducing CO_2 emissions; ensuring that technologies developed can be deployed in the United States; keeping selected technological capabilities in the United States; supporting collaboration with other countries.

  If overseas locations, such as China, offer less expensive capital with fewer regulatory constraints, should the United States be leave commercialization to others, or are there strategic reasons why some projects should take place domestically?

- *Energy Systems and Support Mechanisms:* The barriers to investment vary to some extent by technology – what are some of these differences? What kinds of technologies warrant government support for demonstration? What are the instruments available to the government historically, currently, and what new policy tools could be used? Are there examples (case studies) from the United States or overseas which illustrate successes and failures of government support or its absence?

Brief for Session II: Thinking Through Mechanisms and Solutions

Consider policies and mechanisms the federal government can implement to facilitate investment in demonstration projects. Several proposals have called for the establishment of new agencies to enable demonstration and deployments, e.g., the Energy Technology Corporation, the New Energy Challenge Program, the Clean Energy Deployment Administration, and a Green Investment Bank. Issues to be discussed include:

- *Method and Mechanisms:* What should be the objective or mandate of a program to promote technology demonstrations? How would specific technologies, projects, and appropriate tools be chosen? What mechanisms could be used to balance technical objectives with commercial expectations? How to manage the risk of the government crowding-out private investment? Should a new mechanism be entirely focused on demonstration, or include deployment?

- *New Institutions:* Should a new program or agency be based inside or outside the DOE? How should management of demonstration decisions be coordinated with other DOE programs and government agencies? What would be the appropriate levels of autonomy for a publicly funded institution? How can funding and policy goals be set to ensure the long-term viability of the institution?

- *Leveraging Outsiders:* How can external experts be engaged to ensure that the right technical, financial and management knowledge and skills are brought to bear?

Appendix 3: Framing Statement for Workshop on Accelerating the Commercialization of Advanced Energy Technologies

The following framing statement was prepared by Harvard Kennedy School's Laura Diaz Anadon, Erik Mielke, Henry Lee, Matthew Bunn, and Venkatesh Narayanamurti ahead of the workshop with contributions from Booz Allen Hamilton's Gary Rahl and Richard Goffi in four of the case studies.

TRANSFORMING THE ENERGY ECONOMY: OPTIONS FOR ACCELERATING THE COMMERCIALIZATION OF ADVANCED ENERGY TECHNOLOGIES

FRAMING STATEMENT

Executive Session at
Harvard Kennedy School
December 1-2, 2010

Prepared by Harvard Kennedy School's Laura Diaz Anadon, Erik Mielke,
Henry Lee, Matthew Bunn, and Venkatesh Narayanamurti with contributions
from Booz Allen Hamilton's Gary Rahl and Richard Goffi in four of the case studies.

Supported by a grant from Booz Allen Hamilton

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Executive Summary

Introduction to the Workshop

On December 1 and 2, a select group of senior representatives from government, industry, finance, and academia will convene at the Harvard Kennedy School for an off-the-record workshop on what the U.S. government could and should do to accelerate the commercialization of advanced energy technologies.

The purpose of this framing paper is to provide background information on the topic, establish a common framework, and ultimately stimulate discussion at the workshop. The report format is consistent with the workshop agenda: a discussion of the challenge, followed by a framework for designing policy options, and illustrative case studies.

The Need to Transform the Energy System

There is broad political consensus that the current energy system in the United States is unable to meet the nation's future energy needs, from the security, environment, and economic perspectives. New energy technologies are required to increase the availability of domestic energy supplies, to reduce the negative environmental impacts of our energy system, to improve the reliability of current energy infrastructure (e.g., smart grid, energy storage), and to increase energy efficiency throughout the economy.

Rapid transformation of the energy system would require wide-scale introduction and adoption of new, advanced energy technologies. Several factors make the introduction of new energy technologies inherently more difficult than in other sectors. These factors, some of which are listed below, have fostered a very conservative approach to investment in technology innovation, providing a challenging backdrop for rapid transformation.

- High capital cost and slow asset turnover give incumbent technologies an advantage
- Commoditized product leaves limited scope for differentiation other than cost
- The regulatory premium on reliability favors incumbent technologies, and the regulatory environment limits the upside from innovation

The Demonstration Challenge

If adequately incentivized, the private sector is usually able to take on the risk and financial burden of deploying new technologies. But before deployment can be realized, new technologies need to be demonstrated at near-commercial scale and in operating conditions closely approximating the commercial environment in which the technology would be deployed.

There are several barriers to private sector investment in demonstration projects, and they vary by technology and energy sub-sector. This framing report explores these barriers in greater detail, including seven mini-case studies, ranging from nuclear power, CCS, and biofuels to solar PV and smart-grid technology. These barriers can be summarized into three main categories:

- Access to capital for large-scale projects
- Technology risk

- Policy, regulatory and market uncertainties

Does the absence of private sector investment automatically mean that there is a sound public, as well as economic, policy argument for government intervention? There is general agreement that with the current regulatory environment, technologies such as CCS will not be demonstrated and commercialized without government support, but there is less agreement about whether the government has a role to play in supporting the large-scale manufacturing of new energy technologies, e.g., solar PV manufacturing.

Some reasons that have been articulated that may justify an increased government role in supporting the demonstration of energy technologies include:

- Without government support, many advanced technologies needed to reduce the environmental impacts of the energy sector may not be tested at a commercial scale as quickly as we need them to be.
- Enabling the demonstration of some technologies may be desirable to increase U.S. energy security and economic competitiveness.
- Having access to and knowledge about a wide array of new technology options could have long-term value to the U.S. economy and society as a whole, particularly as new circumstances arise that are difficult to predict today. This option value may not be adequately understood or captured by the private sector alone.
- Some technologies developed and demonstrated in other countries may not be appropriate for deployment in the United States, e.g., for regulatory reasons.

Options for Accelerating Commercialization

It is clear that the government cannot, and should not, support demonstration of all technologies. The heterogeneity of various energy technologies, and the energy industry itself, means that there is no one-size-fits-all or "silver bullet" solution. A framework to support energy technology demonstration projects should consider the following:

- *Choosing Projects*. What criteria should be used to decide which projects to support?
- *Institutional Design*. Should policy implementation rest within existing Department of Energy (DOE) agencies or would it be better to create new institutions. e.g., the Clean Energy Deployment Administration (CEDA)?
- *Appropriate Mechanisms*. Which of the current mechanisms work and should be expanded and/or improved? Are there any other options that should be considered?

Workshop Objectives

The lack of consensus on the appropriate course of action for the government partly reflects established technology biases (e.g., coal vs. nuclear vs. wind), as well as different perceptions of the role to be played by the government vis-à-vis the private sector in the general economy. A similar diversity of views is likely to be present at the workshop. The event is not intended, however, to resolve all questions.

Instead, by bringing together some of the most engaged individuals from the governmental, industrial, financial, and academic sectors, we hope that we will be able to identify: (1) areas where there may be a degree of agreement regarding the case for government intervention; (2) some of the appropriate tools that the government could use and mechanisms for the government to take action; and (3) areas where research or future workshops may be helpful to determine the best policy options.

1. Defining the Problem

1.1. The Energy System Poses Unique Challenges

There are several factors that make the energy sector structurally different from most other industries. Lessons can still be learned from the successes and failures of other sectors, but there are unique features, which make the rapid diffusion of advanced energy technologies (particularly in energy supply) harder to achieve and deploy, and favor incremental change. These factors have fostered a very conservative approach to investment, providing a challenging backdrop for rapid transformation.

- *High capital cost and slow asset turnover*. The U.S. energy infrastructure has been built up over many decades. It is a large, interconnected system of mostly very expensive facilities, often costing more than $1 billion per facility.[1] The energy-supply infrastructure also has much longer lives than is normal for industry. For instance, the median age of the current fleet of coal-fired power plants in the United States is 44 years.
- *Incumbent advantage*. The high cost and long life of the infrastructure give existing energy assets a substantial cost advantage over new competing technologies. New technologies may have superior operating performance, but high capital cost makes it harder to compete with incumbent projects with depreciated assets (e.g., 40-year old coal-fired power plants). It also emphasizes another important feature of the energy system: investment decisions made today will be part of the energy system for many decades to come.
- *Commoditized product with limited scope for differentiation*. Sectors that experience a rapid pace of innovation, such as the information and communications technology sector are able to offer significant product improvements to users from one generation to the next. The same is not true for the energy system. Consumers are generally indifferent about whether their source of electricity comes from a modern wind farm or a 40-year old coal-fired power station.[2]
- *Reliability premium favors incumbent technologies*. The energy system, especially the electricity sector, places a premium on reliability, as consumers, regulators, politicians, and other stakeholders' tolerance for blackouts or fuel shortages is very low. This favors existing technologies, which have already been tried and tested.
- *Regulatory environment limits upside*. Many aspects of the energy system are heavily regulated, especially the electric utilities. This can limit the upside from taking additional technology risk, with incentives geared towards reliability and low

[1] Typical power stations cost about $400 million for a 400 MW advanced combined-cycle gas turbine (CCGT) to $1.4 billion for a 550 MW integrated coal-gasification combined cycle (IGCC) facility. Cost estimates for new nuclear power plants carry greater uncertainty but would likely be close to or exceed $5 billion for a 1,350 MW facility (2008 estimates from DOE/EIA Annual Energy Outlook 2010). Modern oil refineries are also expensive, with an advanced 200,000 barrel per day refinery having a price tag in excess of $4 billion.

[2] Carbon pricing or portfolio standards may introduce a meaningful degree of product differentiation at the wholesale level.

costs in the present. As a result, electric utilities have limited incentive to be early adopters of new technologies.

1.2. The Need to Accelerate Energy Transformation

There is broad political consensus that the current energy system in the United States is unable to meet the nation's future energy needs, from the security, environment and economic perspectives. New energy technologies are required to increase the availability of domestic energy supplies, reduce pollution (including greenhouse gas emissions), improve the reliability of the grid with "smart" technologies and added storage capacity, and provide enhanced energy efficiency in the transportation section and in buildings.

The upward trend in oil prices over the past decade has added renewed urgency to the economic imperative for reduced reliance on imports, as have the prospect of rising competition for resources from the large emerging economies, especially China and India.

1.3. Energy Technology Commercialization

The private sector cannot shoulder this challenge alone. It has neither the financial capability nor the willingness to shoulder a disproportionate share of the financial, operating and demand risks inherent in new cutting edge technologies. If this is true -- what role should the government play in accelerating this transformation?

Without government support, many advanced technologies will not be tested at a commercial scale. And even where the private sector may ultimately be able to bring certain technologies to market, accelerating this process may be desirable to reduce the environmental impacts of the energy sector and to increase energy security and economic competitiveness in the United States.

Having access and knowledge about a wide array of new technology options could be seen as having long-term value to the U.S. economy and society as a whole. This option value may not be adequately understood or captured by the private sector alone. Carbon capture and sequestration (CCS), Gen IV nuclear power, and advanced biofuels technologies are some examples of what such technology options may be.

The desire to transform the energy economy and seize the growing energy technology market is shared by many other countries, some of whom have adopted more aggressive policies than the United States, e.g., China and the European Union. The international trend represents both an opportunity and a threat for the United States. The opportunity stems from the ability to share risk and leverage investment by others. It also provides U.S. companies with access to other markets. The threat is that the United States might not be able to compete and will lose not only international markets, but also domestic markets to China and other countries in what has become a highly competitive global market.

1.4. Government and Private Sector in Energy Innovation

This framing paper differentiates between four main "stages" of innovation — Research, Development, Demonstration, and Deployment (which is itself divided into market formation and widespread diffusion), while recognizing that energy innovation is not a linear process, as it involves multiple feedback mechanisms between the four stages, and phases are unlikely to be as discrete as is suggested by the headings. [3]

1.4.1. Government Versus Private Sector

There is general acceptance that the government has a positive role to play in support of basic and applied science (R&D), e.g., university research and federal labs, and other recent initiatives like ARPA-E and Energy Innovation Hubs.

It is also generally accepted that the private sector is ultimately responsible for deployment (selecting, financing and maintaining the energy capital stock). Although the government is not passive in the deployment phase, as regulation of the utilities, fiscal policies including taxation and subsidies, influence the private sector's decision whether and where to invest.

Deployment only takes place if the private sector is incentivized, either by an adequate expected return, or as required by regulation as part of the cost of being in the business (see Appendix III, Risk-Reward Framework).

The government is also a large consumer of energy, giving it a unique opportunity to influence energy supply.

1.4.2. Demonstration "Valley of Death"

The demonstration of new technologies – the construction and operation of a technology at a commercial scale for the first time – is usually a role played naturally by the private sector in most industries. The private sector will demonstrate a technology when it is close to being commercial, and the rewards of commercializing new technologies are adequate compensation for the higher risk investment.

This is not always true for the energy sector. There is widespread acceptance that there is a demonstration "valley of death" for new energy technologies. The term signifies the challenge that new technologies face when trying to move from the R&D laboratory to commercialization in the market place.

Demonstration projects are rarely commercially viable on a stand-alone basis, even if technically successful. They are intended to demonstrate that the technology works at a commercial scale and can support a particular revenue model, demonstrating economic feasibility in addition to the performance of the technology. They provide an important cost baseline, which should improve as more facilities are built, expanded, and operated. Demonstration projects also provide operating performance history and information about reliability, efficiency, and operating costs. Both of these factors increase the likelihood of obtaining commercial financing for future projects, and allaying concerns that the customers (the companies that will ultimately deploy the technology at scale) may have about cost and performance.

[3] There are many variations on this theme: e.g., Discovery, Development, Demonstration, Commercialization, and Maturation (CAP: How to Empower the Energy Innovation Lifecycle); and Invention, Translation, Adoption, and Diffusion (E. S. Rubin).

The demonstration challenge exists for all technologies, but it is greater for the energy sector for the reasons outlined earlier: high investment needs, low capital turnover, competition from incumbent, mature technologies, and commoditized nature of end product. The demonstration challenge also varies within the energy sector. There is general agreement that with the current regulatory environment, technologies such as CCS will not be demonstrated and commercialized without government support. Conversely, there is less agreement about whether the government has a role to play in supporting the large-scale manufacturing of new energy technologies, e.g., solar PV manufacturing.

1.4.3. Heterogeneity of Energy Technologies

Challenges and opportunities vary greatly by energy technology. For instance, constructing an advanced nuclear power reactor has fundamentally different challenges from those of demonstrating the potential of smart-grid technology. Likewise, the challenge of demonstrating a biorefinery technology at scale is very different from the challenge of commercializing a new energy storage technology. Policy responses need to be flexible, tailored appropriately to adjust for such differences, and yet be part of a coherent overall energy strategy.

1.4.4. Heterogeneity of Energy Sector Participants

The energy companies are equally diverse in their willingness to adopt new technologies. This willingness varies greatly across subsectors, by size and geography, but more importantly, also by risk appetite. A marked difference can be seen between the large oil and gas companies and the electric utilities. Both make very large investments in energy infrastructure, but with very different risk-reward profiles.[4] Electric utilities also vary greatly, depending on their ownership structure, technology mix, and exposure to regulated and deregulated electricity markets.

A policy mechanism for incentivizing investment should reflect the diversity of the energy sector. For instance, an oil company investing in a biofuels project may be willing to tolerate greater technology and price risk if the upside is uncapped. In contrast, a utility investing in grid-scale solar PV would settle for lower expected returns if these came with lower variability (e.g., through production tax credits or a feed-in tariff).

1.5. Barriers to Private Sector Investment

The heterogeneity of energy technologies and sub-sectors means that there is no "silver bullet" or one-size-fits-all solution to the demonstration and commercialization challenge. Nevertheless, some natural groupings of barriers to demonstration emerge. We summarize below each of the dominant barriers: (i) access to capital for large-scale projects, (ii) technology risk, and (iii) policy and regulatory uncertainty.

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[4] Integrated oil companies have historically provided significantly higher return on equity (ROE) compared to electric utilities, but with much greater volatility of returns for the oil companies (i.e., higher risk). For the last five years, the six largest oil majors averaged 20.5% ROE compared to 11.1% for the ten largest U.S. electric utilities (data sourced from Zacks Investment Research via ycharts.com).

For one group of technologies, the first (access to large amounts of capital) and second (technology) barriers are very important. These technologies include nuclear, advanced coal, and biofuels technologies. CCS also fits into this category, although the policy uncertainty about carbon pricing is the key barrier. Manufacturing of solar PV and energy storage devices also fit this description, albeit the scale challenge is due to the need to achieve economies of scale of manufacturing.

For another group of technologies, technology risk and policy and regulatory uncertainty are the primary barriers to investment. This group includes smart-grid, offshore wind, geothermal, and utility-scale storage technologies, and end-use efficiency improvements for vehicles, appliances and buildings.

We provide below seven examples in mini case studies to illustrate some of the barriers to the demonstration of energy technologies and some examples of current policies that might address demonstration needs. Technologies represented in the examples include CCS, nuclear, biofuels, solar PV manufacturing, and advanced coal. The policy tools in the cases include grants, loan guarantees, reverse auctions, and government funded and run test-bed facilities.

1.5.1. Access to Capital for Large-Scale Projects

There are different views on whether the private sector's inability to finance very large demonstration projects should be considered a separate part of the demonstration challenge, or rather the outcome of technology risk, and policy and regulatory uncertainty. If all technology risk could be removed, and political and regulatory uncertainty dealt with, would there still be a demonstration challenge? The answer would appear to be no, at least for commercially viable projects.

While this argument clearly has merit, it risks paying inadequate attention to the importance of size in companies' perception of risk. Companies view investment in new technologies as buying options, essentially options on different outcomes (technologies, commercial environment, regulation, etc.).

A company might view a $50 million-a-year R&D budget as a relatively low-cost option, even though the technology and other risks are very high at the R&D stage. A large demonstration facility with a $500 million price tag is a different story, even if the technology risk has been substantially reduced from the R&D stage. The project is competing with existing, mature technologies for limited risk capital, and the size of investment makes it a much more expensive option, as it significantly reduces the availability of capital for other investments (it has a high implied cost).

Nuclear, CCS, advanced coal and biorefineries are clear examples of how the scale of the investment acts as a barrier that significantly amplifies technology risk. For instance, the large size of the required investment is arguably one of the reasons for the increased interest in modular nuclear reactors.

Some technologies (e.g., biorefineries) need to be built at large scale to demonstrate reliability and performance, as small-scale pilots do not yield the necessary performance and cost information required to move to commercial deployment. For other technologies (e.g., solar PV), the project may need to demonstrate that costs will come down with manufacturing scale, even if the performance and reliability of the individual component (the product) may already known.

1.5.2. Technology Risk

Technology risk is perhaps the most obvious barrier to investment. If the technology risk did not exist, deployment of the technology would primarily depend on whether the technology is able to compete with alternatives under different market conditions.

The primary purpose of a demonstration is to verify that a technology costs and performs as intended. These risks differ during the construction and operating phases of a project.

The *construction* part of the demonstration project is meant to show whether the facility can be built to specification within a given timeframe and construction budget. The *operating* phase should demonstrate a variety of performance factors, including operating costs, efficiency/output performance, availability factor, and maintenance costs, as well as environmental performance.

1.5.3. Policy, Regulatory, and Market Uncertainties

Policy and regulations have a significant impact on almost all aspects of energy technologies. Lack of, or uncertainty about, policy and regulations are a major barrier to commercialization. The list below includes some of the uncertainties and factors that are likely to affect the private sector's willingness or ability to invest in commercialization:

- *Policy and market uncertainty.* The private sector is naturally reluctant to anticipate new policies when such policies are uncertain, e.g., carbon pricing or other regulation of carbon emissions. Uncertainty about whether current policies will remain can also have a detrimental effect on the incentives, e.g., wind deployment varied substantially as the production tax credit was on-and-off, making it harder for a successful domestic windmill manufacturing industry to thrive. This uncertainty can also extend to markets created by mandates, if there is evidence that the current policy may not be sustainable in its present form (e.g., the Renewable Fuel Standard's requirement for cellulosic ethanol), or that mandates will not materialize (e.g., a Renewable Portfolio Standard or a Clean Energy Portfolio Standard for electricity).
- *Legal uncertainty.* Some technologies would require enabling legislation, e.g., a legal and regulatory framework for carbon sequestration, irrespective of carbon pricing.
- *Network access.* Established networks favor incumbent technologies unless regulation can lower the barriers to entry. This is true for new fuels (e.g., compressed natural gas (CNG) and hydrogen), grid access for certain renewable technologies (e.g., offshore wind may not be able to compete with existing sources without access to the grid), and incorporation of smart-grid technologies.
- *Regulatory recognition.* It is unclear how those utilities investing in utility-scale energy storage will be compensated for their investment under the regulatory framework.

- *Uncertainty about infrastructure developments*. Establishment of new infrastructure for a new system, e.g., a supply network of biomass for biofuels and a charging network for electric vehicles.

1.6. Case Studies

The following seven short case studies illustrate the key barriers to commercializing new energy technologies, as discussed above. The studies are intended to give a sense for some of the more important barriers, and are not meant to provide a comprehensive review of any given technology or company.[5]

1.6.1. Access to Capital for Large-Scale Demonstration Projects Examples

For certain energy technologies, the scale of the project and the required capital acts as an amplifier of technical risk and other uncertainties. The following three case studies provide examples of: (i) a technology that has been unable to secure financing in the United States and is looking to China for capital instead (advanced coal gasification); (ii) an innovative approach to financing demonstration plants through reverse auctions for biofuels; and (iii) a solar PV maker seeking manufacturing on a large, commercial scale.

Case 1: Advanced Coal (GreatPoint Energy)

Issue: Potentially transformational technology with major long term significance, undercut by lack of funds for commercial scale demonstration plant and near term drop in commodity prices

GreatPoint Energy has developed a coal gasification process that has the potential to radically transform the use of coal and the associated capture of carbon dioxide. Its technology is a catalytic process that, compared to current gasification technologies, operates at much lower temperatures, involves fewer processes, is less corrosive, and is less expensive. It also produces pipeline quality natural gas, rather than syngas, that can be fed directly into the natural gas pipeline system for widespread use. This has the same transformational potential for coal gasification as catalytic cracking did for the petroleum industry, which replaced what had been the standard in the industry (thermal cracking of petroleum).

The GreatPoint technology has its origins in ExxonMobil's response to the natural gas crisis of the early 1970s. At that time, the primary source of natural gas was co-production with crude oil, and declining oil production had triggered serious concerns over U.S. natural gas supplies. The development of non-conventional sources such as coal-bed methane and Canadian imports alleviated the crisis, and the technology was put on the shelf.

Fast forward three decades later, to 2005: natural gas prices were at record highs, Canadian imports were projected to decline, coal bed methane resources were in decline, and the general industry consensus was that significant imported liquefied natural gas (LNG) would be required to meet U.S. demand. GreatPoint was launched in this environment and began development efforts to improve the legacy ExxonMobil catalytic gasification process to produce pipeline quality natural gas from coal and other feedstocks.

The company raised $140 million and is backed by strategic investors including Dow Chemical Company, Suncor Energy, AES, and Peabody Energy, and major financial institutions and venture capital firms such as Kleiner Perkins Caufield & Byers, Khosla Ventures, Draper Fisher Jurvetson,

[5] Even though cases often display aspects of more than one barrier, they are used to provide an example of one barrier.

Advanced Technology Ventures, and Citi's Sustainable Development Investments. GreatPoint operated a test facility at the Gas Technology Institute in Illinois, and successfully constructed and ran a pilot scale demonstration project at the Brayton Point power station in Massachusetts.

Next, the company had to build and operate a near-commercial scale demonstration plant in order to convince potential industrial and utility customers that its technology was ready for commercial deployment. That demonstration plant would require some $300 to $400 million of investment. If successful, however, the facility could be expanded into a full-scale commercial plant.

GreatPoint had difficulty raising the investment for the demonstration plant because of the significant capital cost and the technical risk involved in the project. The company's strategic partners were unwilling to put up the total cost of the facility. GreatPoint was also unsuccessful in securing federal government funding from DOE.

Its continuing efforts to secure funding for the demonstration plant suffered a major blow with the collapse of natural gas prices[6] in July of 2008. With the onset of the recession, natural gas prices dropped from $13.60/MMBTU to $6/MMBTU by year's end. Natural gas has traded between $3-$6/MMBTU through the present day, driven in part by a significant increase in domestic supply due to the development of gas shale reserves. GreatPoint's cost of production is estimated to be in the upper portion of the range of prices for new-drilled shale natural gas wells and in the higher end of natural gas's current trading range. The decline in natural gas prices and the increase in domestic reserves have severely reduced the value proposition for GreatPoint's technology. The option value of the (better, cleaner utilization of coal) is inadequate for the private sector to finance the demonstration plant with the medium-term outlook for commercial deployment in the United States dimmed by relatively low-cost natural gas.

With limited domestic prospects for funding the demonstration plant, the company looked overseas and, in late 2008, signed a deal with Datang Huayin Electric Power (DHEP). After conducting the early feasibility studies however, DHEP announced in December 2009 that it was cancelling its plans to build the synthetic natural gas (SNG) demonstration project due to the low financial return shown by the studies. GreatPoint has turned its strategy to look at co-production of hydrogen and CO2 for enhanced oil recovery. Uncertainty over CO2 regulation, the availability of lower cost CO2, and high capital costs have blocked any realization of projects to date.

Case 2: Production Incentives for Cellulosic Biofuels (Reverse Auctions)

Issue: Financing demonstration biofuels refineries is expensive and the fuel produced by the facility may not be cost competitive with gasoline and diesel. The provision of production incentives, with the incentives allocated using reverse auctions, could serve to promote the development of some of advanced biorefining technologies.

The Energy Policy Act of 2005 (EPAct), Section 942, established an incentive program for production of cellulosic biofuels, using reverse auctions[7] to set the level of incentives. The purpose

[6] All natural gas prices referenced are NYMEX Henry Hub.

[7] In a reverse auction, also known as a procurement auction, the role of buyer and seller are reversed. Sellers bid for a contract or agreement with one buyer. The winning bid usually reflecting the lowest price or some other transparent criteria specified by the buyer. The buying party specifies the requirements (e.g., quantity, quality, opening bid price, and bid decrement). Selling parties enter the marketplace and bid on the auction. One variation of a reverse auction is a company seeking to buy 10,000 gallons of heating oil for December 5-10 delivery at its facility in Cambridge, MA, at a price of no more than $3/gallon with bids in

of the program is to (1) accelerate the deployment and commercialization of biofuels, (2) deliver the first one billion gallons of annual cellulosic biofuel production by 2015, (3) ensure that biofuels produced after 2015 are cost competitive with gasoline and diesel, and (4) ensure that small feedstock producers and rural businesses participate in the development of the cellulosic biofuels business.

The Energy Independence and Security Act of 2007's (EISA) updated Renewable Fuel Standard (RFS2) introduced explicit mandates for cellulosic biofuels, with a target of 1 billion gallons for 2013, but made no changes to the reverse auction program.

The Section 942 program has certain limitations: (1) no more than $100 million can be awarded in any one year, (2) total program ceiling of $1 billion, and (3) no more than 25% of funds committed within each reverse auction to any one project.

EPAct required the first auction within three years (i.e., before August 2008), but progress has been slow. The DOE published final rules for the reverse auction in October 2009:

- Bidders to be pre-cleared ahead of the reverse auction.
- Each auction is for a contract period of six consecutive years of production, starting within three years of winning the auction.
- Bidders specify volumes (in gasoline-equivalent terms, adjusted for heat values) eligible for incentives.
- Bids are assessed on the lowest level of production incentive on a per gallon basis.
- The production incentive is limited to $1 per gallon for the first four years, declining to $0.95 thereafter.
- Producer must meet minimum 50% of agreed volumes in a given year to receive the incentive, with any volumetric shortfall carried forward to the next year.

In July 2010, the DOE issued a notice of program intent, with the first reverse auction anticipated in September 2010, with a budget of $4.6 million. The auction has not yet taken place and it is not clear whether an adequate number of companies pre-qualified to make it a competitive auction (i.e., five or more, as each project is limited to a max of 25% of the award per auction).

The slow pace of the reverse auction program and the modest funding actually appropriated by Congress ($5 million in the 2008 budget) means that this mechanism has not yet supported the construction of demonstration projects for cellulosic biofuels. If the first auction goes ahead as announced, and four bidders (the minimum) share the incentive award, the amount available to each producer would be at most $1.15 million, or $192,000 for each of the six years.

Case 3: Solyndra

Issue: Public sector financial support can enable a new technology to achieve manufacturing scale much more rapidly than it would otherwise. However, some of that financing is at risk depending on market conditions.

Solyndra was established in 2005 to develop an innovative solar photovoltaic (PV) technology using a cylindrical panel design for commercial rooftop applications. The novel design features include a rack of cylindrical tubes, as opposed to traditional flat panels, which are designed to

$0.01 decrements. Potential suppliers then bid starting at $3 with the auction continuing until there are no lower bids (e.g., 25 rounds leading to a price of $2.75/gallon).

produce more consistent power throughout the day than traditional systems. The innovative rack design also reduces degradation due to snow and dirt, and is easier and cheaper to install and maintain.

The company has been very successful in raising venture capital, securing more than $970 million. That money has fueled technology development and improvements as well as initial commercialization and production. To expand its manufacturing capacity and achieve large-scale commercialization of its technology, Solyndra secured a $535 million loan from the U.S. Treasury's Federal Financing bank, with the help of a guarantee from DOE. It embarked upon building a second manufacturing plant in Fremont, California, with annual production capacity to supply 500 MW of solar PV systems, and expanded its workforce to over 1,100.

As with many technology startups, Solyndra has faced several obstacles during its five-year journey from start up to large-scale commercialization. Two principal challenges have been scaling up production to commercial levels and reducing the product costs to compete effectively with alternative solar technologies. Nevertheless, the company has seen its systems installed commercially on rooftops in the United States and overseas, and had revenues of $100 million in 2009. In December 2009, Solyndra filed its plans with the SEC for an IPO to take the company public in 2010.

Market conditions in 2010, however, have been very difficult. First, the capital markets for new public offerings have remained sluggish. Second, the international market for PV systems has become increasingly price competitive. PV prices have been fallen substantially, driven down primarily Chinese manufacturers. Falling silicon prices and increasing manufacturing volumes lowered their unit costs, supported by Chinese government support (inexpensive credit, access to land, etc.). The lower silicon prices reduced some of Solyndra's supposed cost-advantage, as its technology uses fewer such materials.

In response to these market conditions, Solyndra announced in June that it was withdrawing its plans for an IPO in 2010. Then, in early November 2010, the company announced that it would stop its current expansion efforts. It is closing its first production facility and reducing its workforce by approximately 150 employees. It will use its remaining 110 MW annual manufacturing capacity to fulfill sales orders and will focus on reducing its production and installation costs. Its 2013 target for manufacturing capacity has been revised down from 610 MW to "up to 300 MW".

There is no public information yet about how much of its federal loan guarantee may have already been used in the manufacturing plant expansion to date, or about the extent to which the federal government guarantee is "at risk" or not. Are there corporate obligations to repay the loan fully, and release the federal guarantee, if the company continues in business?

Solyndra's experience demonstrates that innovative technologies can and will attract private capital for initial investment. The experience also shows how government support can help move a technology toward large-scale commercial production more rapidly than otherwise would have been realized. In the end, however, rapid changes in market conditions (faster decline in competitor costs than anticipated due to the collapse in silicon prices and rapid manufacturing expansion by Chinese companies), has challenged the business premise.

1.6.2. Technology Risk Examples

Technology risk is one of the most important aspects of demonstration projects. The following two mini case studies provide examples of how biofuels facilities at a national lab (NREL) and DOE funding for CCS projects are helping to reduce technology risk.

Case 4: NREL User Facilities for Biofuels

Issue: Access to advanced testing facilities improves the results of a pilot plant and reduces the technology risk of a demonstration facility. Test beds should reduce the cost of testing and should also improve the quality of the results. The National Renewable Energy Laboratory (NREL) operates two pilot-size facilities for biomass research that are available to industry partners.

An effective pilot project is an important part of reducing the technology risk of a demonstration facility, by allowing the company to fine-tune the design for a variety of feedstocks and operating conditions, before building the many-times more expensive demonstration facility.

In addition to its technology partnerships and licensing of technologies, NREL also operates facilities for biomass research, which are available to industry for testing feedstocks, processes, and equipment at the laboratory and pilot stage.

NREL has operated the Alternative Fuels User Facility (AFUF) for over 25 years. AFUF was originally created to provide a national center where partners could test out various processes for converting cellulosic feedstocks to ethanol or other products without having to invest in their own pilot plant. The facility allows testing of various combinations of operating conditions to determine the optimal settings for various feedstocks, enzymes/organisms. In 2010 and 2011, the AFUF is being expanded with an Integrated Biorefinery Research Facility, which will provide the cellulosic ethanol industry access to a bigger pilot and research facility.

Another biomass user facility operated at NREL is the Thermochemical User Facility (TCUF). The TCUF offers testing and development of various reactors, filters, catalysts, and other unit operations. It also has the capability to test new processes and feedstocks to obtain performance data on specific processes or equipment. TCUF operates the Thermochemical Process Development Unit, which allows testing of gasification and pyrolysis processes. It also has catalytic fuel synthesis reactors (syngas liquefaction), biomass conversion system (gasification and syngas conditioning), and fuel synthesis catalyst test facility (catalyst testing).

The private sector benefits from utilizing these facilities provided by NREL in three important ways: (1) access to advanced technology and know-how, (2) substantial cost savings compared to running tests independently, and (3) results produced at NREL facilities have greater credibility with third parties, which may reduce the perceived risk of a given technology and improve access to financing as a result.

Most of the User Facilities efforts are aimed at the pilot stage, which helps reduce the risk of subsequent demonstration projects. Are there ways that the program can be increased in scope or scale to increase the impact on enabling effective demonstration plants to be build?

Case 5: Carbon Capture and Sequestration Demonstrations

Issue: CCS technologies have such high economic and performance risks that advancements must be demonstrated to work at commercial scale before they will be adopted in the *marketplace. Absent strong market drivers, the federal government can reduce such risks by providing a large cost-share for these demonstration facilities.*

Over 50% of the electricity generated in the United States comes from coal-fired plants and these plants are likely to remain a significant source of electricity for decades to come. As a consequence, coal-fired generation will continue to be a major source of the nation's carbon-dioxide (CO_2) emissions unless addressed. In the absence of market drivers for reducing CO_2 emissions (e.g., a price on carbon emissions), carbon capture and sequestration (CCS) technologies are unlikely to be developed.

An Administration policy goal is the development and deployment of cost-effective technologies to reduce emissions that will allow for earlier deployment and will reduce emissions with lower overall societal costs. Under any scenario, however, the addition of CCS technology will increase the cost of generating electricity from coal. Recent estimates indicate that the current cost of CCS may be $120-180/ton CO_2, but analysis suggests that technology advancements could reduce that to $30-$70/ton CO_2.[8]

The achievement of substantial reductions in the costs of CCS technology will require major advances or breakthroughs in numerous systems involved in carbon capture (pre- or post-combustion), transport, and sequestration. DOE has made CCS a key element of its RD&D portfolio and is funding the next generation of advanced capture concepts for coal-fired power plants through the seven Regional Carbon Sequestration Partnerships, among other initiatives. The 2009 Recovery Act also appropriated $1 billion for FutureGen and over $575 million to accelerate CCS research and development for industrial sources. DOE's overall goal is to develop and successfully integrate advanced technologies capable of achieving 90% CO_2 capture at less than a 10% increase in the cost of electricity.

A number of policy options have been under consideration, to encourage more rapid commercialization of CCS. The proposals include allowing double credit for CO_2 captured during the first few years of a cap and trade regime; tax credits; investment and production credits and support; government guarantees on the performance of long-term sequestration; and for regulated utilities, allowing CCS plant capital costs to be recovered in the rate base.

1.6.3. Examples of Policy and Regulatory Uncertainty

The following two case studies provide examples of policy and regulatory uncertainties acting as barriers to the demonstration of energy technologies. The first case shows how a recent DOE initiative (funded by the American Recovery and Reinvestment Act of 2009) is addressing the network access problem for certain smart-grid technologies. The second study focuses on the impact of carbon pricing policy uncertainty on the investment flowing into CCS demonstration projects.

[8] The long-term estimate is for an "n^{th}-of-a-kind" facility. All cost estimates are from Al-Juaied, Muhammed, and Whitmore, Adam (2009), "Realistic Costs of Carbon Capture," http://belfercenter.ksg.harvard.edu/files/2009_AlJuaied_Whitmore_Realistic_Costs_of_Carbon_Capture_web.pdf

Case 6: ARRA-Funded Smart-Grid Demonstration Pilots

Issue: The federal government lacks the funds to invest in many large infrastructure projects, so it is supporting demonstration, monitoring, and verification projects that will reduce the barriers to local investment by utilities and approval by public utility commissions.

The development and deployment of a "smart grid" is widely viewed as a key enabler for a more resilient, secure and environmentally sustainable power system. The smart grid would replace the 20th century power grids with a modern "mesh" network that overlays the electrical grid with an information and real time management system that enables sophisticated computerized control.

The smart grid offers a number of potential benefits to utilities and consumers alike, including enabling active participation by consumers, optimizing asset utilization and efficient operation, anticipating and responding to system disturbances, accommodating renewable energy generation and storage options, providing power quality for the digital economy, enabling new products (such as electric vehicles), services and markets, and ensuring resilience against attack and natural disaster. Some utilities that have installed smart meters and communications systems, for example, have reported that they can save about 2% of their total energy costs by more closely matching generation to their actual customer demands throughout their systems.

However, the "smart grid" comes with a sizeable price tag. The Electric Power Research Institute has estimated a nationwide cost of $165 billion over the next 20 years. The American Society of Civil Engineers estimates the total investment needs by electric utilities by 2030 could be as high as $1.5 to $2 trillion including the cost of new generating units (solar, nuclear, etc.).

Faced with these sizeable costs, the utility industry has been slow to deploy smart grid technologies. One key barrier is the reluctance of public utility commissions (PUC) to approve smart grid investments due to the difficulty in quantifying the specific value of services and overall consumer benefit. For example, in June 2010 the Maryland Public Service Commission denied Baltimore Gas & Electric Co.'s application to deploy smart meters to all its customers because they viewed that the ratepayers would bear unnecessary financial and technological risks in return for uncertain benefits.

In the past, the federal government itself actually made some of the large-scale investments in the electricity grid, such as building the whole TVA system, the Bonneville Power System, the large hydroelectric dams in the west, and many of the high voltage transmission lines that make up today's Western Area Power Administration. In today's budgetary environment, however, that kind of federal investment is unlikely to be available.

What may be possible in today's fiscal environment is more modest federal funding for demonstration projects and efforts to monitor and verify the benefits of those smart grid projects that are being built. With that goal in mind, the American Recovery and Reinvestment Act (ARRA) included $4.3 billion of funding specifically for "smart grid" technology investment. The DOE has allocated these funds in 16 different smart grid demonstration projects (see Appendix V for a summary of the projects) that are designed to verify smart grid technology viability, quantify costs and benefits, and validate new smart grid business models, at a scale that can be readily adapted and replicated around the country. Information from these projects will be collected and provided to customers, distributors, and generators to change behaviors in a way that reduces system demands and costs, increases energy efficiency, optimally allocates and matches resources, and increases the reliability of the grid. Equally important, performance data from these demonstrations will be used by PUCs throughout the country to quantify the specific values of these multiple and inter-related benefits, helping to make informed cost allocation decisions.

Case 7: Loan Guarantee Uncertainty for New Nuclear (Constellation Energy)

Issue: The loan guarantee program is intended to mitigate some of the financing risks associated with large energy projects, including nuclear power. The project-specific loan guarantee credit subsidy and other credit conditions are contentious: if set too high, it undermines the purpose of the program; if set too low, the cost of the loan guarantee program to taxpayers may become politically and fiscally unsustainable.

Construction of nuclear power plants in the United States has been at a standstill for decades for a variety of reasons. Regulatory uncertainty, rising construction costs, and project delays, among other factors, made it virtually impossible to obtain commercial financing for new nuclear power plants.

The Energy Policy Act of 2005 included a variety of support mechanisms to help the first few new nuclear plants overcome these obstacles, including government insurance against the risk of regulatory delays, production tax credits, and federal loan guarantees covering up to 80% of construction cost. The first loan guarantee to a nuclear power project was an $8.33 billion conditional commitment offered in February 2010 to Georgia Power Company, for construction of two 1,100 MW nuclear reactors. At the time of the announcement, several other new nuclear plants were expected to get similar loan guarantees from the DOE.

One of the projects that was expected to receive a loan guarantee was the Calvert Cliffs 3 (CC3) project. CC3 is a 1,600 MW Evolutionary Power Reactor (EPR) at the Calvert Cliffs nuclear power plant in Maryland. The CC3 plant was to be built by UniStar, a joint venture between Constellation and Electricite de France (EDF), the French utility. (UniStar has three other similar expansion projects identified nationally.) In October 2010, Constellation withdrew from the CC3 project and exited the UniStar joint venture, leaving EDF the sole owner of UniStar.[9]

Constellation put forward the reasons why it withdrew from the CC3 project and the application for a $7.5 billion loan guarantee from the DOE, in a letter to the DOE from Michal J. Wallace, Vice Chairman and COO of Constellation. The letter identified the cost the government proposed to charge for bearing the risk of the loan guarantee (known as the credit subsidy cost) and the other conditions of the guarantee as “unreasonably burdensome.” Constellation specifically pointed fingers at the methodology for calculating the credit subsidy, which initially came in at 11.6% of the guarantee, or $880 million. According to Constellation, subsequent negotiations “failed to meaningfully and sufficiently lower the credit cost number” and added further conditions, which made the “project economics and risks more, not less, challenging.” As a result, at present the future of the CC3 project, and of other nuclear loan guarantees, is very much in doubt.

[9] The NRC is not allowed to issue a nuclear reactor license to a foreign entity, hence EDF would likely need a U.S. partner with over 50% ownership in UniStar, to be able to continue with CC3 and the other expansion projects.

2. Designing the Solutions

2.1. Choosing Projects and Appropriate Policy Tools

When the objective is to accelerate the commercialization or scale-up of new energy technologies, it is clear that not all technologies can or should be supported. Indeed, one of the most frequent objections to government support for different technologies is that governments should not "pick winners", but should instead provide a level playing field to allow market forces to decide.

The challenge, therefore, is to balance the need for accelerated commercialization with the desire for economic efficiency and effectiveness. Below are some of the key factors to consider when designing an institutional framework to support technology demonstration projects (Appendix IV, Policy Constraints, provides additional discussion on policy constraints):

- *Clear objectives*. The objectives of programs and mechanisms to enable the scale-up of energy technologies should be clearly defined. It is also important to specify how technologies, projects, and appropriate tools should be chosen.
- *Transparency*. For solicitations (e.g., request for proposals), transparency, appropriate deadlines, and application requirements are important to allow new entrants to compete for funds and access.
- *Commercial basis*. Market-based principles should be incorporated where possible in selecting project and setting appropriate incentives. Financial incentives should be designed to leverage private capital, thus creating a multiplier effect, while care should also be taken to minimize the risk of crowding-out of capital.[10]
- *Multiple awards*. As a way to avoid the charge of "picking winners" and to support the demonstration of competing technological designs, with the hope that one or more might succeed.
- *Accountability*. Transparent accounting of money spent and clear parameters for success should be implemented to enable value-for-money audits and to learn about how to improve the program.
- *Information sharing*. Information learnt from demonstration should be widely available to the public, to foster learning from these investments.
- *Integration*. The establishment of a system-wide view of the effort required for different technologies would improve the alignment of the bottom-up effort with the top-down priorities.
- *Stability*. Funding and policy goals should be set to reduce the risk of boom-and-bust policy cycles.

[10] Crowding out occurs when government expenditure causes a reduction in private sector expenditure. In this instance, government loans and other forms of financial support displace similar funding from the private sector, i.e., the project would have been supported by the private sector without public support.

2.2. Possible Mechanisms to Accelerate Commercialization

2.2.1. Considerations for Institutional Design

Policy makers designing an institution with the objective of supporting the commercialization of energy technologies aimed by reducing technical uncertainty, capital requirements, market risk, etc., should consider several questions:

- Should policy implementation rest within existing structures of DOE or would it be better to create new institutions? A new agency might have a clearer purpose and mission if separate from the existing DOE structures, but linkages with other parts of the DOE could be weaker resulting in lower cooperation and efficiencies. The creation of a new institution could potentially distract from the urgent action required, and its high profile as a stand-alone entity could make it vulnerable to political attack (e.g., a money pit supporting "white elephants").
- What would be the appropriate hiring policy, reporting lines, and levels of autonomy?
- Is the ARPA-E management structure a potential model for a new institution, e.g., CEDA? ARPA-E has received praise for the speed with which it was set up, its ability to attract new talent to DOE, and the methods that it has used for increasing flexibility while maintaining accountability.

Private sector involvement

Involving the private sector is essential to ensure that the projects supported are selected and managed in such a way that the private sector obtains the information it needs to continue pushing the technology forward. In this regard it is important to think about three aspects:

- The appropriate use of external private sector experts for: (a) selecting projects, (b) managing the day-to-day operations of the institutions, and (c) selecting the appropriate financial instruments and incentives.
- The creation of mechanisms to facilitate partnership with industry. These would include appropriate and transparent risk sharing, such as the use of auctions and streamlined structures like the Financial Institution Partnership Program.[11]
- What type of technical information should be released to the public (e.g., performance and cost data)?

Linkages

A policy to promote the scale-up of energy technologies is of greater value if it is connected to other parts of the innovation system, including R&D and the commercial deployment:

[11] The Financial Institution Partnership Program (FIPP) is a streamlined set of standards designed to expedite DOE's loan guarantee underwriting process and leverage private sector expertise and capital for the efficient funding of specific projects. Eligible financial institutions apply directly to the DOE for partial, risk-sharing loan guarantees, up to a maximum of 80% of principal and interest during the term of the loan. The project debt must obtain a credit rating of at least "BB", i.e., one step below investment grade or better.

- Mechanisms should be put in place to integrate the choice of demonstration projects with other aspects of promoting the innovation cycle, e.g., work at the national laboratories, ARPA-E, the capabilities of the loan guarantee program for deployment, etc.
- The public should understand why the government is supporting a specific technology. For example, does government only want to support first-of-a-kind facilities or does it want to provide funds to enable early deployment, or should it support both?
- If the focus of the institution is the commercial-scale demonstration of energy technologies, it is important to create mechanisms to increase probability of subsequent deployment.

2.2.2. Current Policy Initiatives

The following table summarizes some of the current policies that affect the private sector's risk and reward perception of investment in commercializing new energy technologies, or incentivizing such investment through regulation (mandates with financial penalties for non-compliance). The summary, which is not comprehensive, is provided for discussion purposes only, specifically to generate ideas for opportunities to improve, expand, or replace the policy mechanisms (see also Appendix III, Risk-Reward Framework).

Table 1: Examples of Current U.S. Policies Affecting Investment in New Energy Technologies

Mechanism	Purpose	Status
Production Tax Credit (PTC)	Encourage development of renewable energy projects with a 10-year inflation-adjusted production tax credit for power from wind, closed-loop biomass, and geothermal ($0.22/kWh), and landfill gas, open-loop biomass, municipal solid waste, qualified hydropower, and marine and hydrokinetic facilities ($0.11/kWh).	Currently, wind projects placed in service before the end of 2012 will be eligible to receive the 10-year PTC, while the other renewable technologies have an additional year to come online (i.e., until the end of 2013).
Investment Tax Credit (ITC)	Encourage development of renewable energy projects with a 30% ITC for qualifying project costs for solar, fuel cells, and small wind projects, and 10% ITC for geothermal, micro turbines, and combined heat and power projects.	The ITC is currently available to qualified projects that are placed in service prior to the end of 2016 (except for geothermal credit, which has no expiration date, and the solar credit, which, if not extended, reduced to 10%).
Elect ITC in lieu of PTC	ARRA provision to give greater financing flexibility for PTC-qualifying facilities. Allows 30% ITC in lieu of the PTC. If the ITC chosen, the election is irrevocable.	Applies to facilities installed in 2009-13 (2009-12 for wind).

Elect Cash grant in lieu of ITC	ARRA provision to give greater flexibility for ITC-qualifying facilities. PTC-eligible projects, which elect the ITC in lieu of the PTC, also qualify for the cash grant.	For projects which come commence construction before end 2010 and placed in service by 2013 for wind, 2017 for solar and 2014 for other qualifying technologies.
Loan Guarantee Program (LGP)	The LGP (section 1703) was designed to mitigate some of the barriers for obtaining financing for innovative technologies. The program was extended by ARRA to include commercial projects (section 1705). For section 1703 projects, the borrower covers the credit subsidy cost whereas for section 1705 projects the DOE covers the cost.	Section 1705 projects need to have commenced construction by September 30, 2011. To date (October 2010), the DOE has made four commitments under section 1703 ($10,656 million) and 12 guarantees under section 1705 with combined value of $8,959 million (four of these have closed; total value $774 million).
Corporate Average Fuel Economy (CAFE)	Mandated market for more fuel-efficient vehicles by setting standards for average fuel efficiency by vehicle manufacturer. Financial penalties for manufacturers who fail to meet the standard.	Currently applies to light-duty vehicles only (passenger cars and light trucks). The Obama Administration recently proposed extended CAFE standards to heavy-duty trucks, starting in 2014.
Renewable Fuels Standard (RFS)	Mandated volumetric targets for biofuels for blending with traditional fuels (gasoline and diesel).	First introduced with Energy Policy Act of 2005 and expanded in size and scope with the Energy Independence and Security Act of 2007 (RFS2).

2.2.3. Some Proposals for New Institutions and Mechanisms

This section highlights some of the current proposals for new mechanisms and institutions.[12]

Clean Energy Deployment Administration (CEDA)

CEDA is a bipartisan initiative aimed at creating an attractive investment environment for the development and deployment of new clean energy technologies. There are different versions of CEDA. The Senate version is contained in a Senate bill, S. 1462, *the American Clean Energy Leadership Act of 2009* (ACELA), and a variation was also in the Waxman-Markey bill *H.R. 2454, the American Clean Energy & Security Act 2009* (ACES). Although ACELA received bipartisan support in the Energy & Natural Resources committee, the full Senate has not voted on the bill.

ACELA summary

- CEDA would be an independent administration within the DOE, with a similar status to FERC.

[12] There are numerous other proposals for similar institutions. Several of these are reviewed in "Reforming the U.S. Energy Innovation System," Richard K. Lester, September 2008, including CEDA and ETC. Other proposed institutions include The Carbon Storage Research Corporation, The Climate Change Credit Corporation, The Clean Energy Investment Bank of the United States, and Discovery-Innovation Institutes.

- An Administrator and a Board of Directors (with experts from finance and energy) would govern and report to the Secretary of Energy.
- Permanent *Technology Advisory Council* to advise on technical aspects and to set goals for the administration.
- Focus on enabling deployment of high risk/high potential "breakthrough" technologies that are perceived as too risky by commercial lenders.
- May issue loans, letters of credit, loan guarantees, insurance products, or other credit enhancements, as the Administrator considers appropriate.
- Would use a portfolio approach to mitigate risk. Become self-sustaining by balancing riskier investments with revenues from other services and less risky investments.
- Would also take over the loan guarantee program to be restructured under a new Clean Energy Investment Fund. The Fund would receive a $10 billion injection as seed capital for CEDA.

ACES summary

- CEDA would be an independent corporation, chartered for 20 years and owned by the government.
- Portfolio approach with no single technology receiving more than 30% of total CEDA support.
- No single project to receive more than 80% of its estimated cost in loans or loan guarantees from CEDA.
- No explicit mandate for breakthrough technologies.
- Separate from DOE loan guarantee program.
- Initial funding to come from $7.5 *green bond* issue.

Energy Technology Corporation (ETC)

The creation of an Energy Technology Corporation was proposed by Peter Ogden, John Podesta, and John Deutch in "A New Strategy to Spur Energy Innovation," Center for American Progress, January 2008. In making the case for its creation, Ogden, Deutch, and Podesta state that: *"One of the recurring weaknesses in federal RD&D is the demonstration phase. Too often, this expensive stage in the energy innovation process is carried out in a manner that provides little useful information to the private sector."* The ETC would have the following characteristics:

- Semipublic organization, governed by an independent board of individuals nominated by the president and confirmed by the Senate.
- Mandate to finance and execute select large-scale demonstration projects in a manner that is commercially credible.
- Composed of people who have expertise in market forecasting, the use of indirect financing mechanisms, and industry requirements.

- As a non-federal agency, the ETC would be free from the federal procurement rules. It would not strive to meet production targets.
- Funded in a single appropriation, which would reduce the influence of Congress and special interest groups on its decision-making.
- Examples of demonstration projects that would dramatically improve the pace of energy innovation: Cellulosic biomass-to-biofuels plants; Carbon sequestration; Integrated coal-fired electricity generation and CO_2 capture; Smart electricity networks; Production of natural gas hydrates; Nuclear power projects based on the once-through fuel cycle; and Superconducting transmission lines.

Increased use of reverse auctions

An increase in the use of reverse auctions as a tool for choosing and allocating financial incentives to different projects has also been suggested by several interviewees.[13] This mechanism does not on its own answer the question of which technologies to support, but allows for an efficient and transparent way to select projects once those objectives have been specified.

An example of a reverse auction could be an extension of the current production incentive for cellulosic biofuels outlined in Case 2 earlier, on a larger scale with the explicit purpose of supporting larger demonstration plants. This program involves the creation of an offtake agreement for a specific volume of biofuels product. The government would specify the quantity, quality, and other characteristics of the biofuel for the tender.

An example could be an offtake agreement for 5 million gallons per year for cellulosic biofuels over three years. Companies would bid for the lowest fixed price for the fuel, e.g., $10 per gallon or $150 million for 15 million gallons over three years. The exact numbers would vary but the scale of magnitude is along the lines of that suggested by various interviewees (in contrast with the $1.15 million per project in Case 2).

Auctions could be for multiple contracts (i.e., several bidders are allotted an offtake agreement) and could include ceilings on the price the government is willing to accept (i.e., to keep it within a specific budget). In the current reverse auction mechanism for cellulosic biofuels, the bidder specifies the volumes it is willing to supply for a given incentive (the benefit of current approach is that it is easier to quantify the total cost of the program – the disadvantage is that there is the volumes involved may be too small to achieve the objective of advancing demonstration projects).

The advantages of the larger, reverse auction approach would include:

- Transparent and competitive auction provides level playing field.
- Focus on specific performance criteria in line with policy objectives and consistent with scale required for demonstration projects.
- Reduced risk of "white elephants" – failure to meet the performance criteria (i.e., supply specific volumes) would not be funded by the government.

[13] It came up frequently in the interviews we conducted in preparation for the workshop, and regularly receives support from industry groups (e.g., the Biotechnology Industry Organization).

The disadvantages could include:

- To be effective, reverse auctions require a significant number of bidders, which may not be feasible for a lot of technologies.
- Headline risk of paying above-market prices for a commodity.[14]

The use of reverse auction for allocating production incentives for demonstration projects is more likely to be effective if combined with other risk mitigation strategies, especially for reducing technology risk. But it could be a very efficient tool for allocating and choosing individual projects to support.

Government procurement

Several analysts have proposed the use of government procurement, especially in the Department of Defense (DOD), as a tool for spurring energy innovation and accelerating commercialization of new technologies.[15] The U.S. government is a very large consumer of energy, with DOD accounting for 80% of the government's total energy use.[16] DOD is also a major customer of energy-consuming systems and equipment (e.g., lighting, HVAC, vehicles, etc.) for its roughly 500 permanent installations.

DOD is already investing in alternative energy sources as part of a strategy of reducing its vulnerability in fuel convoys into war zones and increasing reliability and availability of energy resources in the United States. DOD is also playing a role promoting advanced biofuels. For example, Solazyme, a biofuels company, has supplied the Navy with 20,000 gallons of advanced biofuels in 2009-10, and a new contract was signed with the DOD for 150,000 gallons to be delivered in 2010-11. It has been proposed that DOD's role could be expanded.

President Obama has ordered all federal agencies to measure and reduce their carbon emissions, with specific targets to be proposed by each agency and approved by the White House Council on Environmental Quality and OMB. This may create a major opportunity for government purchases of new low-emission energy technologies, which could potentially serve as the initial large-scale demonstrations of some technologies.

[14] The proverbial "$500 hammer."

[15] See for instance CNA (2010) and Alic et al. (2010).

[16] According to the Energy Information Administration's Annual Energy Review 2009, Defense (including overseas) consumed 880.3 trillion Btu in 2009 out of total government consumption of 1,095.7 trillion Btu. The second largest user was the Postal Service (44.2 trillion Btu) followed by the DOE (31.1 trillion Btu). Approximately half of the total energy consumed was in the form of jet fuel (506 trillion Btu) with other petroleum products making another fifth (231 trillion Btu).

3. Concluding Thoughts

Energy is unique. As an industry, energy has significant challenges preventing rapid transformation. The energy sector is important given its importance spurring economic activity, and its associated environmental and security challenges. Defining the role of the government in advancing the commercialization of new energy technologies is essential.

This paper is intended to frame some of the discussion at the forthcoming workshop on accelerating commercialization of energy technologies. It is meant to set the stage for the discussion and provide some tangible examples of the challenge, but it cannot be comprehensive.

Where appropriate, we have included some of the new ideas from other studies or from the interviews we conducted ahead of the workshop (e.g., some of the reasons that have been put forward to justify government intervention, the increased use of reverse auctions).

At the end of the workshop, we hope to (1) achieve greater clarity of the challenges and (2) identify actionable recommendations for policy makers to help overcome some of those challenges.

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Appendix I: Production and Investment Tax Credits

Production Tax Credit

The Production Tax Credit (PTC) has been in place since 1992, and provides a tax credit for every kilowatt-hour (kWh) produced by qualifying sources of electricity generation. The tax credit, currently at $0.022 per kWh or $0.011 per kWh depending on technology, is adjusted annually for inflation and is generally available for 10 years after the date the facility is placed in service.

Table 2: Production Tax Credit Summary

	Incentive	Eligibility	Expiration
Production Tax Credit	$0.022 kWh	Wind, closed-loop biomass, geothermal	Wind projects placed in service before 12/31/2012; All other eligible technologies placed in service on or before 12/31/2013
	$0.011 / kWh	Open-loop biomass, qualified hydroelectric, landfill gas, municipal solid waste, marine and hydrokinetic power	Placed in service on or before 12/31/2013

Source: World Resources Institute: "The Bottom Line on Renewable Energy Tax Credits"

Investment Tax Credit

The Investment Tax Credit (ITC) provides for a 30% tax credit (subject to certain maximums) based on qualified expenditures for capital investment in certain renewable energy generation assets. The tax credit is available for systems placed in service before 12/31/2016, and is typically available in the first taxable year of the system's operation.

Table 3: Investment Tax Credit Summary

	Incentive	Eligibility	Expiration
Investment Tax Credit	30% of qualified capital expenditures	Solar, small wind, and fuel cells (subject to maximum incentive)	Placed in service on or before 12/31/2016 Incentive for solar reverts to 10% in 2016
	10% of qualified capital expenditures	Geothermal, Combined Heat and Power, microturbines (subject to maximum incentive)	Placed in service on or before 12/31/2016 Geothermal has no expiration

Source: World Resources Institute: "The Bottom Line on Renewable Energy Tax Credits"

Treasury Cash Grants

Treasury cash grants are an option for ITC-eligible projects to receive the cash value of the tax credit as a grant in lieu of receiving to a tax credit. This is particularly valuable to projects which do not expect to have taxable income in the near term (or sufficient tax liabilities to utilize the ITC amount), as it provides a payment of up to 30% of the qualified capital investment within 60 days of the project being placed in service (or within 60 days from the application date, whichever is later).

Table 4: Treasury Cash Grant Summary

	Incentive	Eligibility	Expiration
Treasury Cash Grant	30% of qualified capital expenditures	ITC eligible projects are eligible for grant (in lieu of ITC) – Solar, small wind, fuel cells (subject to maximum incentive)	Project must apply by 10/01/2011 Construction must begin by 12/31/2010 Project must be in service or construction commenced in 2009 – 2010 and thereafter in service by 2013 for wind, 2017 for solar, and 2014 for other technologies
	10% of qualified expenditures	ITC eligible projects are eligible for grant (in lieu of ITC) – Geothermal, Combined Heat and Power, Microturbines (subject to maximum incentive)	

Source: World Resources Institute: "The Bottom Line on Renewable Energy Tax Credits"

The American Reinvestment and Recovery Act (ARRA) extended several of the deadlines for PTC and ITC eligibility, and also allowed PTC-eligible projects to elect to receive the ITC instead of the PTC. Thus, by being eligible for ITC benefits, PTC-eligible projects can elect to receive a Treasury Cash Grant in lieu of ITC treatment, effectively allowing PTC-eligible projects to receive up to 30% of the capital cost of the project as a grant from the Treasury. This change in PTC and ITC eligibility was designed to help augment and continue the growth of the renewable energy industry despite country's current economic challenges.

For a PTC-eligible project, the decision to take advantage of the PTC, ITC, or Treasury Cash Grant is typically based on the project developer (or tax equity investor) expectations of future tax liabilities. The figure below outlines the flow of money between the electricity market, renewable generator, and project developer / tax equity investor.

Figure 1: Illustrative Example of Cash Flows in a Renewable Energy Project

	Category	Description
Tax Benefits	**PTC**	‣ Elected when developer / tax investor has low cost of equity, low current year tax liability, and expectation that generator will provide taxable income for the coming 10 years
	ITC	‣ Elected when developer has expectation of a high current year tax liability which can be offset by ITC
	Cash Grant	‣ Elected when developer has high cost of equity or limited sources of outside debt or equity

The PTC has been a key driver in the ongoing development of renewable energy resources since 1992. The impact of this tax policy can be illustrated by examining the annual installations of wind capacity, particularly over the past decade, in comparison to the years in which the PTC has briefly expired. The PTC has expired three times: in 2000, 2002 and 2004, each time only for a period of months, but the uncertainty in the ongoing viability of the tax credit is blamed for significant reductions in annual wind capacity additions.

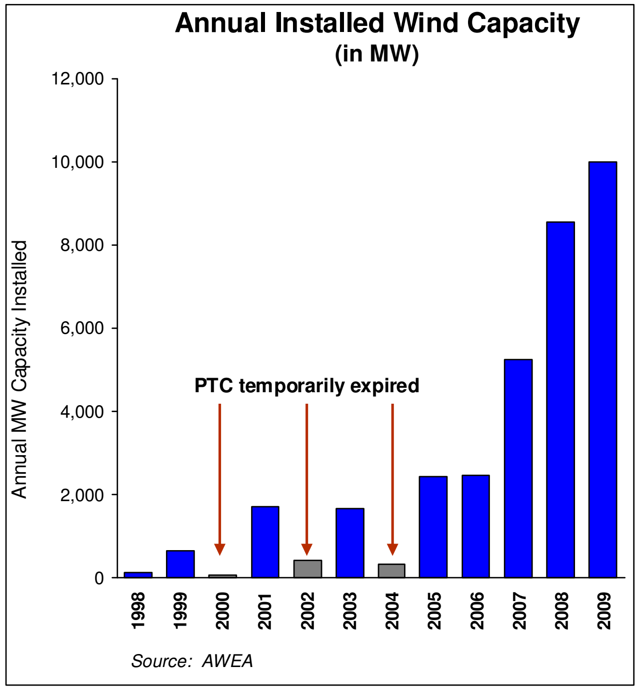


Figure 2: Annual Wind Capacity Installations

Currently the PTC for wind is effective for projects placed in service before the end of 2012, and for other renewable generation technologies through 2013, however the ability to elect the Treasury Cash Grant treatment for PTC-eligible projects will expire at the end of 2010 for projects that have not yet begun construction. PTC-eligible projects will continue to have the ability to elect ITC treatment through the current expiration date of the PTC, as the ITC is currently extended through 2016.

Appendix II: Loan Guarantee Program

The loan program was created to accelerate the deployment of innovative and advanced energy and vehicle technologies. The Loan Programs Office (LPO) within the Department of Energy (DOE) manages the programs. *Loan guarantees* are provided to eligible projects, i.e., agreeing to repay specific debt obligations in the event the borrower defaults. The LPO also manages the *direct loans* to eligible manufacturers of advanced technology vehicles and components. The LPO's website (www.lpo.energy.gov) provides more details and updates on the status of the loan program and is the main source for this appendix.

The loan program is made up of three separate programs: Section 1703, Section 1705 and Advanced Technology Vehicle Manufacturing (ATVM). These are discussed in turn.

Section 1703
The Energy Policy Act of 2005 (EPAct) enacted the current loan guarantee program, establishing Section 1703 of Title XVII. It authorized the DOE to support innovative clean energy technologies that are typically unable to obtain conventional private financing due to high technology risks. In general, under Section 1703, the borrower is responsible for paying the Credit Subsidy Cost (CSC), which is discussed in greater detail below.

- The guaranteed loan cannot exceed 80% of total project costs.
- If the DOE guarantees 100% of the project's debt, then the Treasury's Federal Financing Bank must be the lender.
- The term of the guaranteed loan cannot exceed 30 years.
- The project sponsors must procure a credit rating of the project (without the guarantee) if the project costs total more than US$25 million.

The technologies included in Section 1703 are biomass hydrogen, solar, wind power, hydro power, nuclear, advanced fossil energy coal, carbon sequestration practices/technologies, electricity delivery and energy reliability, alternative fuel vehicles, industrial energy efficiency projects and pollution control equipment. Technologies that have already been deployed three times or more for more than five years are excluded.

Table 5: Section 1703 Projects (Loan Program Office, DOE)

	Guarantee amount	**Jobs (perm/const)**	**Date of agreement**	**Locations**	**Status**
Georgia Power Company	$8.33 billion	800/3,500	February 2010	GA	Conditional Commitment
AREVA	$2 billion	310/1,000	May 2010	ID	Conditional Commitment
Red River Environmental Products, LLC	$245 million	70/500	December 2009	CO, LA	Conditional Commitment
SAGE Electrochromics, Inc.	$72 million	160/210	March 2010	MN	Conditional Commitment

Section 1705

The American Recovery and Reinvestment Act of 2009 (ARRA) added section 1705 to EPAct. Section 1705 is a temporary program that authorized the DOE to guarantee loans for projects using commercial technologies. Projects supported by the Recovery Act must employ renewable energy systems, electric power transmission systems, or leading-edge biofuels that meet certain criteria; begin construction by the end of fiscal year 2011; and pay wages at or above market rates. Under the Recovery Act, Congress has provided nearly $4 billion to cover the credit subsidy costs for projects that meet the criteria in Section 1705.

Section 1705 also introduced the Financial Institution Partnership Program (FIPP) as a risk-sharing partnership between the Energy Department and qualified finance organizations for loan guarantees issued under Section 1705 for certain renewable energy generation projects. It is designed to expedite the loan guarantee process and expand senior credit capacity for renewable energy generation projects that use commercial technologies. In a FIPP financing, the DOE pays the credit subsidy costs of loan guarantees and provides a guarantee for up to 80 percent of a loan provided to a renewable energy generation project by qualified financial institutions. These lenders apply on behalf of the project sponsors or developers and are required to hold a meaningful portion of the unguaranteed credit exposure to the project, aligning their interests with the Department and project sponsors. An Eligible Project under FIPP is a commercial technology renewable energy generation project and construction must commence by September 30, 2011.

Table 6: Section 1705 Projects (Loan Program Office, DOE)

	Guarantee amount	**Jobs (perm/const)**	**Date of agreement**	**Locations**	**Status**
Abengoa Solar, Inc.	$1.45 billion	80/1,600	July 2010	AZ	Conditional Commitment
Abound Solar	$400 million	1,500/2,000	July 2010	CO, IN	Conditional Commitment
AES Corporation	$17 million	30-May	July 2010	NY	Conditional Commitment
Beacon Power Corporation	$43 million	14/20	August 2010	MA, NY	Closed
BrightSource Energy, Inc.	$1.4 billion	86/1,000	February 2010	CA	Conditional Commitment
Nevada Geothermal Power Company, Inc.	$78.8 million	14/200	September 2010	NV	Closed
Kahuku Wind Power, LLC.	$117 million	10/200	July 2010	MA, HI	Closed

Advanced Technology Vehicle Manufacturing

The Energy Independence and Security Act of 2007 (EISA) established a program to provide direct loans to support the development of advanced technology vehicles and associated components in the United States. The ATVM Loan Program provides loans to automobile and automobile parts manufacturers for the cost of reequipping, expanding, or establishing manufacturing facilities in the United States to produce advanced technology vehicles or qualified components, and for associated engineering integration costs. Congress has appropriated $7.5 billion to support a maximum of $25 billion in loans under the ATVM Loan Program.

Table 7: Advanced Technology Vehicle Manufacturing Loans (Loan Program Office, DOE)

	Loan	Jobs (perm/const)	Date of agreement	Projects #
Ford Motor Company	$5.9 billion	33,000	September 1, 2009	13
Fisker Automotive	$529 million	2,000	April 1, 2010	2
Nissan North America, Inc.	$1.4 billion	1,300	January 1, 2010	2
Tesla Motors	$465 million	1,500	January 1, 2010	2

Credit Subsidy Cost

The CSC is a reserve established by the U.S. government to cover the risk of estimated shortfalls in loan repayments. The borrower is required to pay the CSC at the time the loan guarantee is provided for guarantees provided under Section 1703. For Section 1705 guarantees, the CSC is covered by an appropriation from the DOE.

The CSC represents the net present value of the estimated long-term cost to the U.S. government of the loan guarantee. Credit subsidy cost is primarily influenced by two key variables:

- Probability of default; and
- Any recovery after default.

These variables are used to "risk adjust" the borrower's principal and interest payments to the government, and provide an estimate of payment shortfalls. The calculation of the CSC has to be agreed with the Office of Management and Budget (OMB), irrespective of whether the CSC is paid by the borrower or by appropriation.

The exact CSC will vary by technology and project, and has been the subject of some controversy, most recently with respect to the Calvert Cliffs 3 nuclear power project, which is applying for a $7.5 billion Section 1703 loan guarantee.

For section 1705 loan guarantees, Congress has set aside $4 billion[17] to cover the credit subsidy costs for eligible projects. Simplistically assuming a CSC of 6% of the loan guarantee, the $6 billion appropriation would support guarantees of $100 billion of loans.

[17] Originally, Congress appropriated $6 billion but this was reduced to $4 billion as $2 billion was transferred to the "Cash for Clunkers" program in 2009.

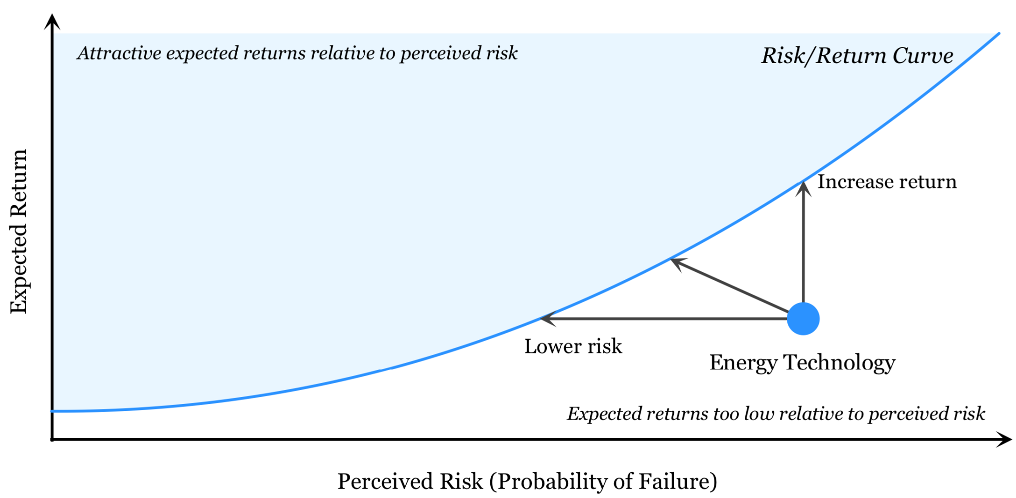
Appendix III: Risk-Reward Framework

The private sector invests in new technologies and projects because it expects to earn a return on this investment. The higher the risk of an investment, the higher the expected return would need to be to justify the specific investment over alternatives with a more attractive risk-reward profile. This is rational behavior and is, in most instances, not a reason for public policy action.

However, in the case of advanced energy technologies, there are additional payoffs to society that provide a strong case for public policy to enable accelerated investment in new energy technologies, primarily (i) improved energy security, (ii) mitigation of the negative environmental impacts of the energy system, and (iii) maintaining or gaining economic competitiveness.

Businesses also invest to comply with regulation, although such investment should always be seen in the context of supporting a profitable business. Hence, compliance-related expenditure is part of the risk-reward calculus for a given business. To alter the risk-reward calculus in favor of greater investment intensity, the policy response should seek to lower the perceived risk of the investment, increase the expected return, or a hybrid of the two (see Figure 3).

Figure 3: Private Sector Perfections of Risk and Returns



A similar way of categorizing policy tools is the distinction between Technology-Push and Market-Pull policies, with the former mostly representing policies used to lower the risks of investing in a technology (e.g., DOE research grants, cost-sharing) and the latter improving the expected return (e.g., loan guarantees, ITCs, PTCs, feed-in-tariffs, carbon pricing, etc). The risk-return framework is closer to the private sector's investment-decision process, while the Push-Pull characterization better reflects how some policy makers and scholars think about policy options.

Appendix IV: Policy Constraints

The creation and implementation of government initiatives to alter the risk-reward profile of the private sector and to catalyze the scale-up of energy supply and manufacturing technologies face several types of challenges, which may include:

Fiscal challenges
Many policy options require significant amounts of funding. Obtaining funding and sustaining it for a prolonged period of time is always difficult, and more so in the current fiscal climate. Indeed, several initiatives which received funding under the American Recovery and Reinvestment Act of 2009 (ARRA), such as the Advanced Research Project Agency for Energy (ARPA-E), face an uncertain funding future.

Regulatory challenges
A significant part of the energy system operates in a heavily regulated environment, especially the electric utilities. Some of the regulation is federal but most of the regulatory authority rests at the state level. The objectives of state-level regulators are primarily to ensure that inexpensive and reliable energy is available to consumers. This somewhat narrow objective can easily be at odds with the broader policy objectives of promoting energy security and economic competitiveness, and protecting the environment.

Political challenges
New legislation is required for most new policy mechanisms. Congress is often divided along geographical lines, rather than party lines, on many energy issues and it has proven difficult to obtain support for legislation—as exemplified by the stalemate over the Waxman-Markey and Kerry-Lieberman energy and climate bills. In addition, the U.S. political system has a very low tolerance for failure, which is at odds with the initiatives that are needed to promote innovation, which is often uncertain. Policies that are not designed in such a way that "failure" is recognized as part of the design may not be sufficiently robust to withstand the political cycle.

Economic efficiency challenges
Policy mechanisms should strive to achieve policy goals at a minimum cost. Policies should also be crafted in such a way that they complement, rather than replace, private sector activities.

Unintended consequences
Policy makers should consider the entire energy system and the broader economy when designing energy policies. For instance, increased use of distributed and intermittent energy sources place demands on the grid; and some biofuels may compete with the food supply for land.

Appendix V: Smart Grid Demonstration Projects

Table 8: Smart Grid Demonstration Projects Funded by the ARRA

Los Angeles Department of Water and Power Smart Grid Regional Demonstration Project: In partnership with a consortium of local research institutions, deploy smart grid systems at partners' university campus properties and technology transfer laboratories. The demonstration projects will also include gathering data on how consumers use energy in a variety of systems, testing on the next generation of cyber security technologies, and how to integrate a significant number of plug-in hybrid electric vehicles onto the grid.	**Irvine Smart Grid Demonstration:** Demonstrate an integrated, scalable Smart Grid system that includes all of the interlocking pieces of an end-to-end Smart Grid system - from the transmission and distribution systems to consumer applications like smart appliances and electric vehicles. The project will focus on the interoperability and interactions between technologies and systems working at the same time - such as communications networks, cyber-security requirements, and interoperability standards.
NSTAR Automated Meter Reading-Based Dynamic Pricing: Develop and implement a Smart Grid pilot program that will examine technologies to leverage existing automated home meters to include dynamic electricity pricing for homeowners (i.e., lower rates when demand is lower). By building on the existing meter infrastructure and broadband internet networks, utilities would be able to access some of the benefits of the Smart Grid - such as collecting data at meters at shortened intervals, communicating energy use data to consumers, direct load control, automatically reporting outages, etc. - while avoiding the full costs of implementing smart metering infrastructure or the costs associated with replacing meters prematurely.	**NSTAR Urban Grid Monitoring and Renewables Integration:** Demonstrate the use of advanced sensors and monitoring instrumentation on low voltage (secondary) networks in downtown Boston to improve grid reliability and safety. The project will provide additional visibility for operators, which will increase the system's capacity to integrate on-site energy technologies, such as solar photovoltaic energy systems, plug-in hybrid electric vehicles or battery storage. Knowledge gained from this demonstration will lay the groundwork for the broad application of smart grid and on-site energy generation programs for secondary area network grids in large urban areas such as New York City, Philadelphia, Chicago and Los Angeles.
KCP&L Green Impact Zone Smart Grid Demonstration: Demonstrate an end-to-end Smart Grid that will include advanced renewable generation, storage resources, distribution system automation, in-home customer systems and digital technologies, and innovative rate structures. The programs will benefit about 14,000 commercial and residential consumers, while providing the critical energy infrastructure required to support an urban revitalization effort, Kansas City's Green Impact Zone.	**Project Boeing SGS:** Demonstrating a Cyber Secure, Scalable, Interoperable, and Cost-Effective Smart Selection for Optimizing Regional Transmission System Operation. Demonstrate an advanced Smart Grid software technology with military-grade cyber security for improving regional transmission system planning and operation. The project includes Regional Transmission Operators (RTOs) and utilities that collectively serve all or part of 21 states and more than 90 million people. The Boeing Smart Grid Solution (SGS) software is designed to be scalable, secure, and compatible with multiple systems to help RTOs and utilities improve grid reliability and efficiency.
Secure Interoperable Open Smart Grid Demonstration in New York and New Jersey: Demonstrate a scalable, cost-effective smart grid prototype that promotes cyber security, reduces electricity demand and peak energy use, and increases reliability and energy efficiency. The system will include renewable energy generation, grid monitoring, electric vehicle charging stations, transmission automation, and consumer systems that will help expand the use of renewable energy and lead to greater consumer participation in the electricity system.	**Long Island Smart Energy Corridor:** Partner with two branches of the State University of New York (SUNY) to create a Smart Energy Corridor along the Route 110 business corridor, involving 800 customers. The project will demonstrate the integration of a suite of Smart Grid technologies on the distribution and consumer systems, such as smart meters, distribution automation, distributed energy resources, and electric vehicle charging stations. The project will also include testing cyber security systems, identifying the optimal combination of features to encourage consumer participation, and educating the public about the

	tools and techniques available with the Smart Grid.
Evaluation of Instrumentation and Dynamic Thermal Ratings for Overhead Lines: Demonstrate the effects that Dynamic Thermal Circuit Ratings (DTCR) technology can have on areas of the New York State transmission system where there is abundant wind generation potential. This project could result in a 5 to 15% increase in transmission line capacity to allow for more wind power, deferring millions of dollars in capital expenditures on transmission projects an enabling improved situational awareness for gird operators.	**AEP Ohio gridSMART Demonstration Project:** Demonstrate a secure, interoperable and integrated smart grid infrastructure for 110,000 consumers in the state that will maximize distribution system efficiency and reliability and enable consumers to reduce their energy use and save money. The project will include 13 different technologies from the substation to the customer, including distribution automation and control, smart meters and appliances, home area networks, plug-in hybrid electric vehicles, energy and battery storage, and renewable generation sources. These technologies are estimated to improve the reliability and efficiency of the distribution system 30-40%.
Technology Solutions for Wind Integration in ERCOT: Manage the fluctuations in wind power in the large Electric Reliability Council of Texas (ERCOT) transmission grid through better system monitoring capabilities, enhanced operator visualization, and improved load management. Project includes the installation of synchrophasors to enhance monitoring of grid conditions as variable wind resources move through the system, and the use of integrated Smart Grid technologies, including household and community battery storage, smart meters and appliances, plug-in hybrid electric vehicle sand homes equipped with 1-3 kW solar photovoltaics.	**The Pecan Street Project Energy Internet Demonstration:** Develop and implement an Energy Internet micro grid, located in a large mixed-use infill development site in Austin, Texas. This effort will build on Austin Energy's existing Smart Grid programs by creating a micro grid that will initially link 1,000 residential smart meters, 75 commercial meters, and plug-in electric vehicle changing sites. The project will be implemented by a unique Texas not-for-profit corporation created to research, develop and implement smart grid clean energy systems.
Dynamic Line Rating Project: Demonstrate the use of Dynamic Line Rating (DLR) monitoring technology to reduce transmission-line congestion and increase the carrying capacity of the transmission lines. The data and results from the demonstration project will help better understand DLR technologies, so that transmission systems can be utilized to their full capacity, decreasing congestion and deferring upgrades and additional construction.	**Enhanced Demand and Distribution Management Regional Demonstration:** Install and operate of a suite of diverse Smart Grid technologies and aggregate the data from 17 rural electric cooperatives across 10 states. Technologies will include over 130,000 meters, over 18,000 demand response switches, nearly 4,000 in-home displays or smart thermostats, and others. In addition to customer-focused technologies, the project will include voltage sensors and fault detectors. The demonstration data will be centralized for all sites and include studies on total demand, distributed energy resources, peak pricing, customer appliance control, and self-healing technologies for improved reliability
Pacific Northwest Smart Grid Demonstration Project: Spanning five states and affecting more than 60,000 consumers, demonstrate and validate new smart grid technologies and inform business cases; provide two-way communication between distributed generation, storage, and demand assets and the existing grid infrastructure; quantify smart grid costs and benefits; and advance interoperability standards and cyber security approaches.	**Fault Current Limiting Superconducting Transformer:** Demonstrate a Smart Grid-compatible Fault Current Limiting Superconducting Transformer for a utility substation that will help improve the stability of the system. The proposed 28 megavolt amp utility transformer will occupy approximately 50% of the physical size/weight of a conventional transformer, lower power consumption through reduction of losses, and increase the reliability of the electrical grid.