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What are the Appropriate Roles for Government in Technology Deployment?

A White Paper with Author's Response to Comments

Jon Pietruszkiewicz

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1617 Cole Boulevard
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NREL is a U.S. Department of Energy Laboratory
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Executive Summary

WHAT ARE THE APPROPRIATE ROLES FOR GOVERNMENT IN TECHNOLOGY DEPLOYMENT?

Technology innovation and the welfare of the country are tightly linked. One-half of all economic growth since World War II is attributed to technical innovation. Starting with the founding of the U.S. Patent Office in the U.S. Constitution, the federal government has consistently recognized discrete roles for itself in the domain of technology innovation, implementing policy to affect market mechanisms and change markets to achieve desired public benefits. An array of government policy objectives, policy implementation mechanisms, and market mechanisms has been required to meet varying needs over time. Moreover, different technologies have required different assistance, depending upon the technology's nature, its commercialization pathway, and market characteristics.

The drive to balance federal budgets, in combination with a strong economy, have led to calls for less government participation in research, development, and especially technology deployment. There is increased expectation by government for the private sector to accomplish needed technology development and deployment. The primary purpose of this paper is to recommend appropriate roles for government in technology deployment and to provide guidelines for implementation.

To understand the potential and limitations of the private sector within current markets, it is useful to understand the nature of the research and development (R&D) and deployment processes. The ultimate purpose of R&D is to create technologies that are developed into products, which are "used and useful" in the marketplace. In the past, innovation was described as occurring in a sequence of orderly and sequential steps: basic science, applied research, development, demonstration, product development, and commercial products. Today, the innovation process is dynamic with extensive interactions and interconnectedness among all steps and with the marketplace. Feedback is provided from the marketplace and from follow-on steps to constantly update and enhance earlier steps. For example, information learned from a demonstration project or from marketing activity may reveal the need for more basic or applied research to enhance technology performance. Similarly, deployment activities provide marketplace information to influence R&D requirements.

The private sector invests to commercialize or deploy technology when the overall benefits of commercializing the technology are large compared to the size of the commercialization investment. It typically organizes its commercialization investment decisions by addressing pragmatic technology and market interaction questions similar to the following:

- Is the technology a solution, or a better solution, to a market need? (Right technology)
- Is the market for the technology large enough? (Right market size)
- Is the market sufficiently predictable? (Right market certainty)
- Is the cost of getting the technology to market low enough? (Right commercialization cost)

In today's world, the complex processes of technology development and product commercialization are inextricably intertwined with government policy and market interactions. It is not possible for the private sector to develop and deploy technology without collaboration with the marketplace and consideration of public policy. Overall, industry is inclined to under-invest in technology development and commercialization, especially when large capital investments are required. The consequence is that new technology is often under-deployed. This is particularly true for innovations linked to "public good." The marketplace often does not fully value the public good, making it difficult for private firms to capture sufficient benefits to make deployment financially attractive.

Government investment solely in R&D is not usually sufficient to cause technology deployment. Likewise, it is usually not possible for the government to cause deployment of new technology to achieve public good objectives without collaboration with industry and the marketplace throughout the interactive R&D and deployment process. But, by applying appropriate mechanisms at the appropriate times, the characteristics of the technology or the size and certainty of the market can be influenced, or the industry perceptions about the market or technology can be influenced, to stimulate industry investment in deployment. Government is frequently the only entity capable, or motivated, to spend resources on such activities, especially to achieve public good objectives.

Thus, appropriate roles for government in deployment of technology include any actions that assist the private sector in meeting public good objectives that cannot, or will not, be accomplished, by the private sector alone without government participation or leadership.

Government has roles all along the innovation pathway. Table ES-1 identifies a number of appropriate ones organized as market, policy, and technology actions, as well as information, education, and collaboration activities that enable the other actions.

Table ES-1. Appropriate Roles for Government in Technology Deployment

Information and Education • Information dissemination • Outreach • Education and training • Technical assistance • Technology transfer **Collaboration** • Information exchanges • Collaboration • Stakeholder facilitation • Business matchmaking • Alliances and partnerships **Technology Development** • Scientific research • Technology development • Technology demonstration • Intellectual property management • Market solutions	**Policy** • Policy information, education, and training • Policy analysis, policy design • Policy implementation (e.g. regulations, grants, assistance, etc.) **Market Development** • Market assessment and analysis • Market conditioning • Barrier removal • Standards development • Trade development and export assistance • Economic development • Federal sector procurement (early adopter) • Business incubators and small business assistance • Financing mechanisms, financial assistance, incentives, and subsidies • Support marketplace deployment transactions

Suggested Guidelines

The following are suggested guidelines for use on U.S. Department of Energy (DOE) technology development and deployment programs.

Public good: Societal benefits and public good objectives should be debated and decided by the legislative and executive branches and established as mission requirements of government agencies. The legislative and executive branches should articulate the desired relative weighting of competing public good objectives and pathways to achieving those objectives when establishing annual budgets as opposed to emphasizing specific projects and technologies.

Collaboration with all stakeholders: There is a need to integrate the perspective of the marketplace and the desires of policy makers into technology programs. Technology roadmapping with stakeholders offering the entire spectrum of marketplace, technology, and policy considerations is one mechanism to accomplish such collaboration. Commercialization pathways should be defined and deployment facilitation plans developed as part of the roadmapping or equivalent process.

Market and policy analysis: The desired public good should be achieved in the most effective and efficient way. Market needs should be identified, and potential impacts of applying specific market mechanisms should be understood. Policy analysis should identify the impact of both existing and new policies and should assess alternative policies for impact on technology development or commercialization. Market and policy analysis should support the stakeholder collaborative planning process. The marketplace cannot efficiently respond to quickly changing policies and resultant mixed market signals; stable policy should continuously be emphasized.

Focus on achieving results, not the mechanisms and processes: R&D alone will not cause deployment. Government has roles all along the innovation pathway, designing and implementing policy to create market mechanisms that facilitate deployment. Nearly all market mechanisms and policy tools are appropriate under some circumstance. Legislative and executive branches should not arbitrarily eliminate specific policy tools from consideration, but rather should focus on ensuring stakeholder collaboration to select the appropriate tools for each circumstance and then insist on getting the desired results from the tools used. DOE should encourage the progression of technology through appropriate government or private funding agencies and vehicles appropriate for each stage.

Criteria for government funding: DOE should limit support to activities with specific mission relevance. DOE actions should not compete with short-term, typically more specific, private-sector activities. While DOE funding should usually be restricted to pre-competitive activities, it is recognized that support may be needed to facilitate creation of suppliers and competition in new or emerging markets. DOE should not generally invest in commercial technology that is in the product development stage, very close to broad commercial markets. However, product development support roles are often required for technologies developed entirely for government use, for technology requirements imposed by regulatory agencies, and may be required to achieve deployment objectives for technologies having compelling societal benefits.

Program effectiveness: Oversight should ensure that programs are well managed and that program effectiveness is measured. Fiscal resources are better utilized if funding is predictable across several years. There should be acknowledgment that negative results of well-conceived and executed projects may be valuable. Some fundamental research should be directed to scientific questions identified in the applied R&D programs, to shorten the time from concept to deployment. There should be a broad range of interdisciplinary projects that foster collaboration among fields of research and industry, university, and federal laboratory partnerships.

Conclusion

Technology innovation and the welfare of the country are undeniably tightly linked. The federal government establishes government organizations with missions to achieve public good objectives. Development and deployment of technology are often essential ingredients for the accomplishment of such public benefit objectives. Markets frequently under-invest in the development and deployment of new technology for such public good benefits. By applying appropriate mechanisms at appropriate times, government can overcome market imperfections and facilitate technology deployment to efficiently and effectively accomplish its public good missions. Appropriate government roles that facilitate deployment occur throughout the entire innovation process. Funding of R&D alone is not normally sufficient. Other policy and market mechanisms must also be employed to overcome market imperfections. Achievement of mission objectives is the priority, not ideological debate about government participation in individual innovation process steps. The focus should be on using mechanisms that get the desired results.

WHAT ARE THE APPROPRIATE ROLES FOR GOVERNMENT IN TECHNOLOGY DEPLOYMENT?

Introduction

The United States is a recognized world leader in development and implementation of new technology. Technology leadership is broadly believed to be a key driver in maintaining our strong economy and global economic leadership. Technology is also an essential ingredient in our country's ability to achieve important public objectives and government missions in areas such as public health, environmental protection, defense, space, and energy. The federal government has a long history of involvement in the successful development and commercialization of technology. Many of the country's current technology leadership positions (e.g., aerospace, computers, the Internet, or medicine) came directly from government programs. In recent times, however, questions have arisen regarding the appropriate role for government in technology development and deployment. The drive to balance federal budgets, in combination with a strong economy, have led to calls for less government participation in scientific research, technology development, and especially technology deployment. While there is some degree of consensus that the federal government should continue to play a significant role in basic research and other long-term, high-risk research and development,[1, 2, 3] less agreement appears to exist with respect to the federal government's role in near-term research and deployment. Any government role appears to be susceptible to being labeled as "corporate welfare."

Greater consensus would likely exist with a broader common understanding of both the technology development and commercialization process, and the relationship between public policy and market actions. The purpose of this white paper is to enhance that common understanding, to recommend the appropriate government role in technology deployment in the context of that understanding, and to suggest guidelines for deployment activities.

The paper is organized in six sections. The first section covers the historical perspective: what's been done before, and does it work? The second section looks at the research and development (R&D) process, a changed model for changing times. The third section covers the deployment process: what impels the private sector to deploy new technologies? The fourth section discusses the appropriate role for government in deployment, while balancing the public good and the benefits of free market mechanisms. The fifth section explores the when, what, and how of setting priorities. And, the last section covers the guidelines for managing the national investment.

Historical Perspective: What's Been Done Before and Does It Work?

The U.S. Constitution established the federal government's role to "promote the general welfare" of the people. It also established a federal role in science and technology by creating the U.S. Patent Office "to promote the progress of science and the useful arts by securing for limited times to inventors the exclusive right of their respective discoveries."

Technology innovation and the welfare of the country are tightly linked. "Studies show that half of all U.S. post-World War II economic growth is a direct result of technical innovation."[4] In fact, The President's Council of Advisors on Science and Technology (PCAST) identified innovation as the "single most important source of long-term economic growth, with returns on investment in research and development (R&D) being several times as high as the returns on other forms of investment." [Appendix A][5] Throughout its history, the federal government has consistently recognized discrete roles for itself in the domain of technology development and deployment, implementing policy to affect market mechanisms and change markets.

There is ample precedent for a strong government role in deployment of key technologies. The nation's fledgling railroads were subsidized with huge land incentives during the mid-1800s to achieve federal objectives of linking the country from coast to coast. The government-created Rural Electric Authority supported rural electrification and the associated hydroelectric plants during the 1930s to provide jobs and enhance the economic development potential of rural America. In both cases, technology was an essential ingredient in the successful growth of the country, and government participation was essential to achieving widespread use of the technology.

During the middle half of the twentieth century, government-funded development and deployment of military technology were essential to the country's existence. Later, World War II technology provided the foundation for the nuclear power industry of the '60s,'70s, and '80s. Federal actions required to develop the nuclear power industry included government-funded R&D and enactment of the Price-Anderson Act, a law intended to reduce private sector risk to facilitate private sector deployment.

Similarly, government procurements funded early jet engine development and deployment for military purposes and assisted in the follow-on modification and demonstration of this technology for utility-scale power generation. Other examples include technology development and deployment in the space program— with "spin-offs" like Teflon to the private sector—and the Clean Coal Technologies program in the 1980s to demonstrate cleaner and more efficient technologies for obtaining electric power from coal. More recent government investments include the Internet and the Human Genome Project. Countless other examples of government action to stimulate technology deployment abound.

Appendix B identifies some of the federal government organizations that have missions linking technology and economic growth objectives. An array of government policy objectives, policy implementation mechanisms, and market mechanisms has been required to meet the needs of the times. Moreover, different technologies have required different assistance, depending upon the nature of the technology, its development and commercialization pathway, and the character of the market. The government's role has been, and continues to be, to provide the right balance of public policy mechanisms needed to achieve the desired public good that could not be adequately achieved without government action.

There is much to learn from the past. But, in today's more mature, strong economy, with a high standard of living and without major military challenge, public policy drivers are fewer and less compelling than in the past. There is increased expectation by government for the private sector to accomplish any needed technology development and deployment. To understand the potential and limitations of the private sector within current markets, it is useful to understand the nature of the R&D and deployment processes.

The R&D Process: A Changed Model for Changing Times

The ultimate purpose of R&D is to create technologies that are then further developed into products which are "used and useful" in the marketplace. In the past, the "pipeline" model shown in Figure 1 was used to describe innovation as occurring in a sequence of orderly and sequential steps: basic science, applied research, development, demonstration, product development, and commercial products. The PCAST[6] and others[7, 8] have documented the fact that although this model worked reasonably well for quite some time, it no longer is adequate, and its use can even be counterproductive.

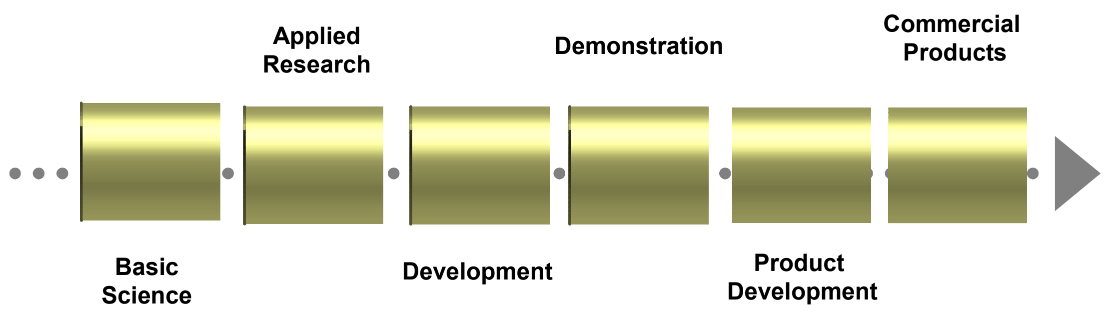

Figure 1. Pipeline model for technology innovation

Market considerations are completely absent from the "pipeline" model. With increased competition, ever-shorter product cycles, increasingly sophisticated technology, and mass customization to meet the needs of individual customers in mass markets, the linear model does not describe today's actual R&D and technology commercialization processes. Today, the innovation process is dynamic with extensive interactions and interconnectedness among all stages, and with consideration of markets and policy. Figure 2 shows this interconnected process. Feedback is provided from the marketplace and from follow-on stages to constantly update and enhance earlier stages. For example, information learned from a demonstration project or from marketing activity may reveal the need for more basic or applied research to enhance technology performance. Similarly, deployment activities provide information from the marketplace to influence R&D requirements. A frequently overlooked fact about innovation is that: "At any given time, most R&D involves product improvement and technological refinement, not the creation of new knowledge or revolutionary new products."[9] Clearly, the phases of technology development are fully successful only when the end result is a technology that is used in the marketplace.

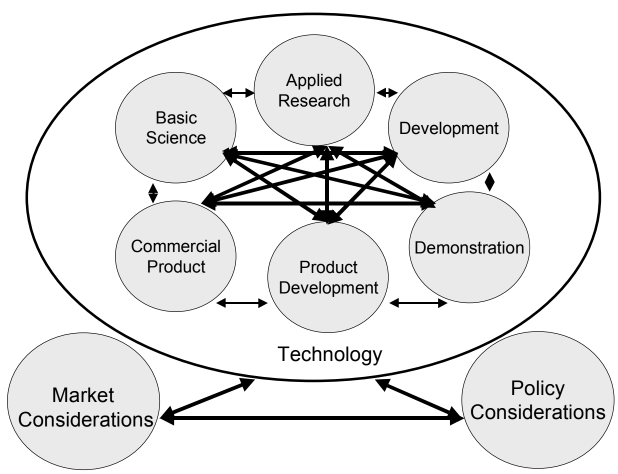

Figure 2. Interconnected model for technology innovation

The Deployment Process: What Impels the Private Sector to Deploy New Technologies?

The private sector makes investments to commercialize technology when the overall benefits of commercializing the technology are large compared to the size of the commercialization investment. In a free market system, the primary objective of the private firm is profit maximization. Firms invest in innovation with the expectation that this activity will generate profit for the company. To generate a profit, the financial benefits to the firm must be greater than the costs incurred for making the investment.

While recognizing that the modern innovation process is not linear, the private sector still organizes its commercialization investment decisions by addressing discrete, pragmatic technology and market interaction questions to assess profit potential. Typically, as a minimum, four questions must be answered affirmatively:

- Is the technology a solution, or a better solution, to a market, need? (Right technology)
- Is the market for the technology large enough? (Right market size)
- Is the cost of bringing the technology to market sufficiently low? (Right cost of commercialization)
- Is the technology performance, market, and commercialization cost certain enough? (Right market certainty)

The Right Technology

Industry knows it has the right technology when that technology, its performance and its cost, as well as other defining characteristics, meet a well-defined market need.* This may be a completely new need or just the need to improve upon existing alternatives. When the technology characteristics are not fully aligned with the perceived market requirements, or the market requirements are not easily discernable, industry is not inclined to invest in the technology development or commercialization.

The Right Market Size

The size of the potential market for a technology product is important in that it points to the revenue or profit potential that may be achievable once the product is fully developed and commercialized. A small company making a small investment in manufacturing and distribution capability may require only a modest revenue stream (from say a small, high margin, niche market) to justify investment. A large company making a large investment in manufacturing and distribution of a capital-intensive product may require much larger markets and revenues. Likewise, the higher the cost of developing the technology into commercial products, the larger the market necessary to justify the investment. Industry will not pursue technology development and product commercialization without the prospect of an appropriately large market share in an appropriately large market.

The Right Cost of Commercialization

There is a cost to develop or acquire technology and to carry out the commercialization of technology products. This is often called the total cost of commercialization or the "cost of market entry." That cost varies depending upon the characteristics of the technology and the characteristics of the target market. But, the cost of research, development, and demonstration is often small compared to the other costs required to bring the demonstrated technology to commercial reality in the marketplace. Industry will

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* The ultimate test of a product's "rightness" is its ability to command a price in the marketplace that provides an adequate profit margin to the supplier.

invest in the development, or acquisition of technology, and commercialization of that technology only if the potential benefits (profits) are sufficiently large compared to the cost of market entry. The right cost of commercialization is one that fits the size of the firm and is sufficiently small compared to the potential downstream profits.

The Right Market Certainty

Markets are uncertain. Industry knows that its assessments of the technology, market size, and cost of commercialization are imperfect at best. Uncertainties due to such risks as technology obsolescence, competition, and changing regulations or government policy may significantly change the end result. Industry assesses these risks and seeks confidence that the market will, in fact, exist at the expected size and profitability. If the market is highly competitive, or subject to frequent changes due to regulations or other public policy, or if policy incentives are uncertain from year to year, industry will have difficulty estimating market size and profitability or will greatly discount them. Often this discounting results in a determination that the market of interest is not sufficiently large (not "the right size") or profitable, and investment is not made.

In real markets, there are additional risks and uncertainty associated with evaluating the rightness of each of these four factors. There are also different criteria for each company in defining "right." For new technologies, information is less available in the marketplace and there is less certainty in the available information. There are also different perceptions of risk that translate to different evaluations of risk by different companies. Small entrepreneurial companies need and want different things than large mature organizations. Many mature organizations evaluate risk conservatively, because they perceive they have more to lose if they are wrong. Industry can also become "locked-in" to existing technologies based on economies of manufacturing scale and other factors. Thus, overall, industry is inclined to under-invest in technology development and commercialization,[10, 11] especially when large capital investments are required. The consequence is that new technology is often under-deployed.

A fact that significantly affects the conduct of deployment activities is that technology is inherently partly private and partly public. New technologies, new findings, new ways of doing things are not fully appropriable by their finder or creator—be they public or private participants—but are always to some extent shared.[12] A firm will often not be able to capture the entire market for, or benefits resulting from, a technology that may have developed entirely on its own.[13] U.S. technology policy has generally recognized that the private sector will under-invest in basic research, and has allowed for a government role in key basic research areas. But the tendency of the private sector to under-invest applies to *all* phases of the innovation process, including deployment.

This is even truer for innovations linked to "public good." The marketplace often does not fully value the public benefit, making it difficult for private firms to capture adequate financial benefits. Because the private returns are less than the investment required to achieve the public good, the private sector under-invests in innovations that may "promote the general welfare of the people" but are not fully valued by the marketplace.

Prime examples of such underinvestment in technology to achieve public good objectives can be found in the energy sector. Energy is key to the successful performance of the U.S. economy and a contributor to our economic concerns. Roughly one-third of the nation's balance-of-trade deficit is attributable to overseas purchases of fossil fuels. In addition, many believe the nation's reliance on overseas suppliers for a significant part of its energy needs creates a national security risk, with all the attendant costs. Moreover, conventional energy resources are finite, and their use carries measurable environmental costs.

Nevertheless, today's market signals reinforce the continued use of conventional energy resources and technologies. Because the marketplace does not allocate all related costs (such as environmental clean-up or military protection of supply lines) in the price "at the pump," these energy sources and related technologies are seen by end users as the lowest-cost option.

In addition, the delivery and service infrastructure for conventional energy are in place and well understood. Significant investment has been made in this infrastructure, thus "locking in" the current suite of technologies and "locking out" new options. Price instabilities and large capital requirements also inhibit private investment.

Many believe that public good will result from development and deployment of cleaner and more efficient coal fueled power plants; safer and cheaper nuclear power; more use of renewable energy resources and associated technology; or cleaner and more efficient transportation options. Within our democratic process, a specific desired public good outcome is defined through adequate debate and consensus building. To achieve the desired public good once it is defined, specific government actions are often required to overcome the limitations of the free market.

Appropriate Roles for Government in Technology Deployment: Balancing the Public Good and the Benefits of Free Market Mechanisms

In today's world, the complex processes of technology development and product commercialization are inextricably intertwined with government policy and market interactions. It is not possible for the private sector to develop and deploy technology without collaboration with the marketplace and consideration of public policy. Likewise, for the reasons identified above, it is usually not possible for the government to cause deployment of new technology to achieve public good objectives without collaboration with industry and the marketplace throughout the interactive R&D and deployment process. Further, government investment solely in R&D is not usually sufficient to cause technology deployment. Historical experience suggests that direct federal support for R&D has often been less important for commercial success than has its support for diffusion and use.[14] Thus, "Government investment in R&D is crucial but needs to be supplemented by standards, incentives, information, and education programs."[15] "What matters from an economic point of view is whether R&D can be integrated with marketing, production, and finance, effectively and in a timely fashion."[16]

By applying appropriate mechanisms at the appropriate times, the characteristics of the technology or the size and certainty of the market can be influenced; or the industry perceptions about the market or technology can be influenced, to stimulate industry investment in deployment. The following are a few important examples of actions that can encourage greater commercialization investment and deployment by the private sector.

- Enhance industry's perception of the "rightness" of the technology by:
  - Improving stakeholder collaboration to identify market needs
  - Performing market analysis to understand the market needs
  - Performing technology assessment to understand existing and potential alternative solutions to market needs
  - Facilitating a better match-up between market needs and new technologies
  - Educating stakeholders and end users to help them to understand and value all characteristics (e.g., externalities such as environmental performance, jobs created, etc.)
  - Promulgating regulations, standards, or guidelines requiring certain technology performance or characteristics.

- Enhance industry's understanding of actual "market size," or increase the actual market size by:
  - Improving analysis of market size and potential market share
  - Educating and training stakeholders to create new customer values
  - Creating incentives, subsidies, and regulations and requirements that motivate the creation of markets
  - Reducing transaction costs through market aggregation or other means.

- Enhance the understanding of the actual "cost of market entry" or reduce actual cost of market entry by providing:
  - Small business or technology development grants
  - Supply-side guarantees
  - Policy regulation
  - Economic development incentives
  - Export/import barrier removal
  - Improved production technology
  - Subsidization of production, advertising, distribution, and service
  - Business incubation and start-up business assistance
  - Technology transfer cost minimization
  - Technical assistance
  - Production credits
  - Creation of markets with government sector applications
  - Trade development assistance
  - Promotion of the creation of industry consortia
  - Stimulation/development of actual "demonstration projects."

- Enhance industry's understanding of actual "market certainty," or improve actual market certainty by:
  - Performing analysis of the market to establish actual certainty or to suggest mechanisms to reduce uncertainties
  - Communicating market information and educating
  - Committing to stable government policy
  - Facilitating long-term contracts, futures markets, or patents or other means of reducing likelihood of competing products
  - Guaranteeing purchases or prices.

Actions Focused on End-User Markets

Without end users or consumers, there is no market for a given technology. All phases of the development process need to consider the eventual deployment of the technology to end users. Market analysis plays a key role here. In addition, there are mechanisms oriented directly toward the consumer side of the market that can be critical in achieving the successful deployment of an innovation. These actions and mechanisms are oriented toward mitigating barriers to market success, including the fact that the technologies currently in use may be "locked-in." Consumer-oriented actions and mechanisms that help to create markets include the following:

- Implementing policy to create a market of early adopters in the government or other strategic niche
- Disseminating information to advertise or enhance image
- Establishing procedures for certifying the performance of the new technology
- Helping coordinate the transition to new technology standards

– Creating financing and risk management mechanisms to increase customer ability to pay.

Government's Unique Role

Government* is frequently the only entity capable, or motivated, to spend resources on such activities directed at changing industry or marketplace perceptions, or directly influencing the marketplace. Many technologies are not capable of meeting industry investment criteria without such government participation or assistance. When public good results, as determined by adequate debate and consensus, such government assistance is right.

Thus, appropriate roles for government in deployment of technology include any actions that will assist the private sector in meeting public good objectives that cannot be accomplished, or will not be accomplished, by the private sector alone without government participation or leadership.

Government has roles all along the innovation pathway, designing and implementing policy to implement market mechanisms that facilitate deployment. Examples of a number of technology deployment roles appropriate for government have been derived from the above discussion and are explained in Appendix D to highlight the broad range of deployment techniques that are necessarily used by government. Table 1 summarizes these roles. They are organized as market, policy, and technology actions, as well as the information, education, and collaboration activities that enable the other actions.

Table 1. Appropriate Roles for Government in Technology Deployment

Information and Education • Information dissemination • Outreach • Education and training • Technical assistance • Technology transfer **Collaboration** • Information exchanges • Collaboration • Stakeholder facilitation • Business matchmaking • Alliances and partnerships **Technology Development** • Scientific research • Technology development • Technology demonstration • Intellectual property management • Market solutions	**Policy** • Policy information, education, and training • Policy analysis, policy design • Policy implementation (e.g., regulations, grants, assistance, sector reform, etc.) **Market Development** • Market assessment and analysis • Market conditioning • Barrier removal • Standards development • Trade development and export assistance • Economic development • Federal sector procurement (early adopter) • Business incubators and small business assistance • Financing mechanisms, financial assistance, incentives, cost buy-down, and other subsidies • Support marketplace deployment transactions

Nearly all such market mechanisms and policy tools are the appropriate ones under some set of circumstances. And, a portfolio of deployment facilitation activities appears to be a better option than putting all the eggs in one basket. The pertinent questions then are: when should the government be

* While the emphasis in this paper is on the federal government, federal, state, and local governments all play a significant role in facilitating deployment by the private sector. Likewise, within the private sector, trade associations, other industry organizations, foundations, and nongovernment organizations (NGOs) also participate in some of these roles. Similarly, in the international context, multilateral and bilateral lenders, and others are added to the list.

involved; what roles are the right ones in each circumstance; and how do we balance the roles to best achieve the desired results and minimize the undesired results that get labeled as corporate welfare?

Setting Priorities: When, What, and How?

Recently, many policy makers and stakeholders have moved from ideological debate and begun to grapple with practical issues with respect to how these questions should be answered and how technology priorities should be set. The right debate is one that focuses on how best to achieve government public benefit missions, which includes deployment of new technology to achieve mission objectives. While debate regarding deployment issues is not widely documented, the arguments surrounding government technology development are; such arguments with respect to when the government should participate are usually directly applicable to deployment. Bozeman and Crow suggested that "government technology development is likely to be appropriate when:

- "There are conflicting national objectives and also a need to consolidate those objectives in a given technology
- The regulatory environment is such that market signals become complicated by unpredictable regulations
- There is an interest in stimulating a technology for which there is no significant market yet
- The user of the product is a government agency, *and* there is a need for particularly strong ties between the technology developer and the user
- The scale of development and its cost is so great that not even the largest firms can expend sufficient resources." [17]

Branscomb has suggested that the correct criterion for when the federal government should invest is that the public will be the primary beneficiary of that investment. He recommended public-funded basic research, and that it may be appropriate for government to fund both research and technology development when the government makes the market through federal procurement or regulation. He further suggested that resource allocation decisions for need-driven research should be made based on the legislative mandates provided to the funding agencies. The level of research investment should reflect the priority accorded to the mission objective by the political process and the opportunity that research offers for enabling mission success.[18]

The Environmental Engineering Division of the Council on Engineering of the American Society of Mechanical Engineers (ASME) International recently published a *Position Statement on the Role of Federal Government in Environmental Technology Development,*[19] which makes recommendations similar to those referenced above for Bozeman and Crow, and Branscomb. ASME's position statement provides some useful categories and guidelines intended for use in optimizing government agency investments in environmental technology development. The following discussion borrows liberally from that work. It is adapted and summarized here for application in the broader technology deployment context of this paper. ASME suggests four categories: technologies developed entirely for government use, technology requirements imposed by regulatory agencies, technologies having compelling societal benefits, and technologies that advance commerce.

Technologies Developed Entirely for Government Use (Category I)

The federal government develops and deploys technology for its own use in military service, for environmental cleanup of government weapons sites, or for other purposes such as the exploration of space.

The federal government's role in cases where the government solely and exclusively uses the technologies is to provide funding and policy mechanisms to cause development and subsequent deployment within the government for the intended purpose. Although private companies may be willing to develop the needed technology, the cost of development is subsequently added to the cost of operation. Accordingly, the government must pay for the development either initially or during deployment. The choice depends upon the availability of an organization willing to invest in the development of the technology or the availability of government funds to support the technology.

There are situations in which technologies developed for government purposes may ultimately be used in other applications. If the government desires to identify private sector needs, and cause development and subsequent deployment in the private sector of technology originally developed for use by government, the government should provide resources and other actions necessary to cause the private sector to invest in the technology commercialization. Actions may be necessary to create the "right technology," "right market size," "right market certainty," or "right cost of commercialization" as understood or perceived by the private sector. The level of government resources committed should depend on the relative priority of the public good driver and the type of actions required to facilitate deployment.

Technology Requirements Imposed by Regulatory Agencies (Category II)

Regulatory agencies, seeking to implement congressionally passed statutes, often impose regulations that impact industry. Some of these regulatory actions require the use of specific technologies; others require a specified level of performance. In some cases, the technologies are available, but in others, the technologies may only be partially available or not available at all.

The government's role in supporting Category II technologies is often less clear. In many cases the regulatory agency maintains that a needed technology is available. Certain agencies have traditionally supported the development of specific technologies expressly for the purpose of compliance with their respective regulations. However, organizations affected by the regulation have sometimes disagreed, arguing that the cost of development and implementation of environmental controls is in effect a tax. In any case, the agency issuing the regulation should ensure that the benefits of proposed regulations outweigh the costs of implementation.

Technologies Having Compelling Societal Benefits (Category III)

This category includes technologies that may provide significant benefits to society as a whole. There is a public interest in ensuring that such technologies are deployed in the economy. Where the private sector will not provide these technologies on its own, a government role may be warranted.

Many different factors can prevent the private sector from developing such beneficial technologies. Technologies whose benefits would be realized in the distant future, making private sources of funding unavailable are included. Also included are technologies whose development must be accelerated because of compelling societal need, such as minimizing the discharge of disease-causing agents to avoid the spread of epidemics. There are also technologies whose experimental nature makes their probability of success uncertain. Such risky technologies that, if successful, could be highly beneficial for a number of applications, are also included. Other technologies included are those that have been successfully demonstrated at the pilot stage, but need to be scaled up by several orders of magnitude to establish commercial viability. "The government has a stake in promoting the demonstration and commercialization of technologies that provide public goods and integrating these demonstration and commercialization activities with the R&D process so as to optimize the efficacy of the R&D and increase the return on public investment."[20] "Embryonic industries face particular difficulties."[21] Specific commercialization efforts are often appropriate to address their needs. This variety of factors illustrates that the government may need to play a role at any point in the innovation cycle. The success of the technology—its ultimate deployment in the marketplace—requires the success of all phases of the innovation process.

There is a great deal of societal judgment necessary to assess the potential usefulness of various Category III technologies and to prioritize them for financial support. There are many issues, and many debates, surrounding the development of these priorities, which are beyond the scope of this discussion. For the identified priorities, the government proceeds to develop technology options for the future and to facilitate their deployment in the private sector. The government provides resources and other actions necessary to cause the private sector to invest in the technology commercialization. Again, actions may be necessary to create the "right technology," "right market size," or "right cost of commercialization," and the "right market certainty" as understood or perceived by the private sector.

Technologies that Advance Commerce (Category IV)

Technologies that are routinely developed by the commercial sector with little or no direct government support are included in Category IV. Many such technologies are, however, indirectly derived from government support for basic research and support for technologies in the three above categories. Others result from industrial development.

The government's role in supporting Category IV technologies generally is limited to programs specifically focused on technology-based economic development, such as the Advanced Technology Program (ATP), the Small Business Innovation Research (SBIR), and the Small Business Technology Transfer (STTR) program. These government programs provide funding for technology development with a distinctly commercial purpose to improve global competitiveness. Through those programs, companies compete for relatively small awards to develop specific technologies believed by the government to be in its best interest to support.

Congress and the executive branch establish public good objectives, federal policy, agency missions and specific mission objectives, often with considerable public debate and political process. Over time, the public political process has yielded a de facto portfolio of government sponsored activities, projects, and programs that results from a combination of bottoms-up assessment of technology needs recommendations, and top-down politically motivated activities that meet the needs of individual constituencies. There are benefits and disadvantages of this process. However, many believe that the government-sponsored portfolio could be enhanced with more and broader expert influence and stakeholder participation. With that approach, Congress could focus more on identifying the mission requirements, establishing specific objectives, and then work with the executive branch to monitor progress toward achievement of the desired results. The emphasis would be on mission requirements (societal objectives) not the specific actions, programs, and projects that are more suitably established, prioritized, and evaluated by experts and other stakeholders after clear mission requirements are established.

ASME suggested that each of the categories requires its own process for assessing value based upon weighing science and engineering on one side, and societal objectives on the other. That suggestion is consistent with the previous sections of this paper, which established the importance of incorporating market and policy considerations into the technology development and commercialization process.

Many formal and informal processes exist for obtaining and using expert influence for market, policy, and technology considerations to achieve appropriate or optimum government leadership, or participation for achieving mission objectives. Recently, technology roadmapping has become one of the more important and more widely used processes to formulate and communicate an informed vision of technology futures.

Roadmaps assist in creating a broad consensus and can be used as a tool in prioritizing and allocating resources. Such roadmapping can be accomplished by a small group of technical experts to identify a set of technology development milestones that, if achieved, will lead to development of a technology product with desired or targeted characteristics. Often, when used in this way, the roadmapping process may be led by a particular set of technology experts in the specific industry of interest. If so, it could potentially ignore important market or societal factors that will affect the ability to achieve societal and commercial objectives.

Roadmapping is most effective at addressing the spectrum of issues relevant to achieving the entire mission objective when technical, market, and policy issues are all addressed by the complete spectrum of stakeholders that can influence or be influenced by the activity. These stakeholders can include scientists and technologists; industry business managers; federal, state, and local political advisors and policy makers; NGOs, government managers; financiers; public interest groups; multilateral organizations; and environmentalists, as well as other relevant individuals and organizations. Scenarios should be developed to address alternative futures or pathways for technology, policy, and markets. These scenarios can then be used to address preferred technology development pathways and other actions needed to influence the market as necessary to achieve the ultimate mission objectives.

Guidelines for Deployment Activities: Managing the National Investment

Government agencies and the people who are employed by, or operate under contract to these agencies, are involved in managing significant national investments or national assets and must do so in the national interest. Both because technology developments are incompletely appropriable, and because of the importance of technology to achieve national economic growth and development, it is useful to propose and discuss a set of guidelines for planning and conducting technology deployment activities to meet the objectives of the federal government's "mission" agencies. The following are guidelines suggested for use on U.S. Department of Energy (DOE) technology development and deployment programs.

Public good

- Societal benefits and public good objectives are debated and decided by the legislative and executive branches and established as basic mission requirements of government agencies.
- The legislative and executive branches of government should emphasize the desired relative weighting of the competing public good objectives and pathways to achieving those objectives when establishing the annual budget as opposed to focusing on specific projects and technologies.

Collaboration with all stakeholders

- There is a need to integrate the perspective of the marketplace and the desires of policy makers into technology programs. The trade-offs between specific projects and technologies should be decided in collaboration with stakeholders. Technology roadmapping done in conjunction with stakeholders representing the entire spectrum of the marketplace, technology, and policy considerations is one mechanism to accomplish such collaboration.
- Technology commercialization pathways should be defined and deployment facilitation plans developed as part of the technology development roadmaps or equivalent process.

Market and policy analysis

- Market needs should be established, and the potential impact of applying specific market mechanisms must be understood. The desired public good must be obtained in the most effective and efficient way, including consideration of the impact of the legacy of past policy.

- Policy analysis should be done to identify the impact of new policies on technology development or commercialization; or to assess the merits of alternative policies as they might impact technology development or commercialization.
- Market and policy analysis should support the stakeholder collaborative planning process.
- The marketplace cannot efficiently respond to quickly changing policies and resultant mixed-market signals. The need for stable policy should be strongly considered.

Focus on achieving results, not the mechanisms and processes

- Legislative and executive branches should not arbitrarily eliminate specific deployment tools or mechanisms from consideration, but rather focus on ensuring broad stakeholder collaboration to select the appropriate tools for each circumstance and then insist on getting the desired results out of the tools used.
- DOE should encourage "the progression of technology through funding agencies and vehicles appropriate for each stage."[22]

Criteria for government funding

- Consider using the ASME categories listed above when making decisions regarding government financial or policy support for technologies.
- DOE support should be limited to technology having specific relevance to its mission. Its activities should not compete with or displace short-term and typically more specific nature private-sector activities.[23]
- While DOE funding should generally "be restricted to pre-competitive activities leaving competitive activities for the private sector,"[24] it is recognized that support is often required to facilitate creation of suppliers and competition in new or emerging market segments.
- DOE should not invest in Category IV "commercial technology that is in the product development stage, very close to the broad commercial marketplace."[25] However, support of early product development and other deployment roles are frequently required for Category I and II and may also be required to accomplish deployment objectives for Category III.
- Benefits should accrue broadly across the economy: broad classes of consumers should benefit, directly or indirectly, from the deployment of the technology. This does not necessarily mean that the benefits should be spread across a number of different suppliers. Only one or a few suppliers may produce some technologies, such as very large electric generators, aircraft, medicine, or environmental remediation techniques, but the social benefits (public good) may still be provided widely throughout the private sector.

Program effectiveness

- Oversight should be provided to ensure that programs are well managed.
- There should be an effective process for measuring program effectiveness.
- "Fiscal resources would be better utilized if program and project funding is predictable across several years."[26]
- There should be acknowledgment that negative results of well-conceived and executed projects may still be valuable.[27]
- Federal fundamental scientific research should be better coordinated with applied R&D programs. Specifically, some of the overall fundamental research effort should be directed to addressing scientific questions identified in the applied R&D programs, to accelerate the time between concept and deployment.[28]
- There should be commitment to a broad range of activities and interdisciplinary projects that foster collaboration among fields of research.[29]
- Industry, university, and federal laboratory partnerships should be fostered.[30, 31]

Conclusion

Technology innovation and the welfare of the country are undeniably tightly linked. The federal government establishes government organizations with missions to achieve public good objectives in fulfillment of its role to promote the general welfare of the people. Development and deployment of technology are often essential ingredients for accomplishment of such public benefit objectives. Markets frequently under-invest in the development and deployment of new technology for public good benefits that cannot be fully captured by the private sector. By applying appropriate mechanisms at appropriate times, government can facilitate technology deployment to efficiently and effectively accomplish public good missions. *The appropriate roles for government in deployment of technology include any actions that will assist the private sector in meeting public good objectives that cannot be accomplished, or will not be accomplished, by the private sector alone without government participation or leadership.* Actions that facilitate deployment occur throughout the entire innovation process. Funding of R&D alone is not normally sufficient. Other policy and market mechanisms must also be employed to overcome market imperfections.

Congress and the executive branch establish mission priorities. Project and program priorities, and selection of appropriate deployment roles to fulfill these mission priorities, should be established with intense stakeholder involvement to address technical, market, and policy issues relevant to achieving a desired mission objective. Roadmapping or other similar mechanisms should be used to involve the complete spectrum of related stakeholders for this purpose. Market and policy analysis should support this stakeholder collaboration and roadmapping process. Government funding and other policy mechanisms should be applied based on the needs identified in the process rather than artificial boundaries or definitions of steps in the innovation process. Achievement of mission objectives is the priority, not ideological debate about government participation in individual steps in the innovation process. The focus should be on using mechanisms that get the desired results.

Endnotes

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[5] Report of the Energy Research and Development Panel. *Federal Energy Research and Development for the Challenges of the Twenty-First Century.* The President's Committee of Advisors on Science and Technology (PCAST), November 1997; p. 7-15.
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[15] Report of the Energy Research and Development Panel, p. 3-9.
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[19] "Position Statement on The Role of the Federal Government in Environmental Technology Development."
[20] Report of the Energy Research and Development Panel, p. 7-12.
[21] Report of the Energy Research and Development Panel, p. 7-14.
[22] Frist et. al.
[23] Ibid.
[24] Ibid.
[25] Ibid.
[26] Ibid.
[27] Ibid.
[28] Report of the Energy Research and Development Panel, p. 7-14.
[29] Frist et. al.
[30] Ibid.
[31] Report of the Energy Research and Development Panel, p. 7-14.

Author's Response to Comments

This white paper was originally prepared to educate stakeholders about technology commercialization, to generate dialogue and discussion about the appropriate role for government in technology deployment and to make recommendations consistent with the ideas presented. During its preparation, numerous useful comments were received; most were highly complementary, speaking to the complexity of the subject and the need for such a paper to provide a foundation for debate about the government's role in deployment. Many also suggested that the draft material on what industry needs before it will invest in technology development and deployment provided an original and useful basis for discussion. Reviewers also noted that while they tended to agree with the broad spectrum of roles identified in the paper, they recognized that recent actions by Congress were tending toward a substantially more limiting set of roles for government.

The following comment by C. Dan Brand, Chairman, Federal Laboratory Consortium, National Center for Toxicological Research reflects that point of view. He said that he thought there is a lot of good information and perspective in the paper and that he could not take issue with any of it, coming from a laboratory technology transfer view point. He thought some labs would see the paper as foreign and others would see it as consistent with much of what is going on at their lab. Lastly, he indicated that any comments counter to the ideas in the paper would likely come from a political ideological viewpoint representative of those who dislike any government participation in the marketplace.

Additional reviews and comments were solicited from a broader audience after the initial completion of the paper. Positive and negative reactions were received.

Scott Brown, Dean of the Tucker Foundation, Dartmouth College said: "I have to admit I'm not particularly enthusiastic about the paper. It seems to restate in a rather lengthy way several fairly obvious observations. It also does not seem to focus enough on what government support for deployment should do, and perhaps more importantly what it should not do. The most concise statements came from quotes of Boseman and Crow, and Branscom on pages 7 and 8. These quotes focus appropriately on what the limited criteria may be for government investment. I would push in this direction and leave out some of the filler."

I suspect that Dr. Brown already had a strong awareness of the foundation materials in the paper and did not need as much background as some readers might. However, I also suspect that he may not be intimately involved with the diversity of opinions that exist on this subject and the difficulty in arriving at a specific "right answer" in any given situation.

The NREL National Advisory Council acknowledged the complexity of this issue in their June meeting report, stating: "The deployment area is very complex, sophisticated and challenging." Comments by Henry Cialone, Ph.D., Vice President & General Manager, Energy Products Division, Battelle also pointed to the complexity of the subject. He wrote: "This is a very difficult subject, given the changes that have taken place in this arena over the past 50 years… I think your paper does an excellent job of offering a useful context for re-considering government's role and identifying a viable role that can impart real societal value… As an organization that views itself as a partner of government in the continuum from scientific discovery through technology deployment, Battelle has a keen interest in understanding how the role of government has evolved and where it is likely to go. Furthermore, many of the folks I know in both industry and government would benefit from a 'playbook' of this sort. Opinions vary widely as is to be expected in a dynamic environment. Your suggested set of guidelines is an excellent starting point to frame the debate."

Richard Balzhiser, Ph. D., President Emeritus, Electric Power Research Institute also addressed the need for the paper and reinforced several other important points. He wrote: "I must first complement you on the White Paper, which focuses on technology deployment, the oft forgotten element when we deal with government labs. Your paper is refreshing in acknowledging this challenge which has been largely overlooked by most other labs in the past."

"I urge that you stress the importance of industrial participation in producing technology roadmaps…Roadmapping must include the customers and developers point of view in all planning steps to assure a comprehensive and objective assessment of the full costs and residual risks."

"The government must lead with policy and regulations that define the useable resource. Demos where required to assess risk should be undertaken only when industry is a willing participant and funder of the project. Industry should be willing to fund at least 50%, perhaps as a consortium, to demonstrate their strong interest."

"I'm supportive of your skepticism about the relevance of yesterdays pipeline model for technology innovation…The cross fertilization among students, faculty and industrial interests, including venture capitalists, is a new and productive environment for stimulating new concepts and business opportunities."

"Deployment can be facilitated by government but the decision to build typically resides in the private sector. Energy facilities typically require not only solid technology but informed investors, A&E's with the range of competencies to rapidly and reliably design and construct the facilities, and skilled operators to achieve performance expectations. This point is made to illustrate the breadth of private sector/industry decision making necessary to commercially deploy technology at the scales associated with energy supply."

"In summary; I believe roadmapping must coordinate industry and government interests and concerns. Collaboration in their preparation should be encouraged. 2) Industry should partner with government in demo projects where technology risks are a key determinant in risk assessment. 3) Venture capital financing of university and other networked research results can accelerate the exposure of cutting edge technology to the marketplace. It doesn't all cross the threshold. 4) Today's paradigm is not a linear progression from science through engineering to business. Rather it's new science and technology from many disciplines with cross fertilization leading to new startups, new product lines and a global marketplace."

The white paper makes the case that when there is a government mission objective involved there is usually an appropriate and required government role to be considered throughout the commercialization continuum from research through deployment. The exact role, how much, how long, etc. would be determined based upon an understanding of the mission objective, its relative priority and the needs of the particular technology given the market conditions and policy requirements. The paper further argues that the government cannot fund long term research and leave it to the market place to take it from there; while that is desirable, it does not reflect actual experience. Walter Cunningham, General Partner, Genesis Fund took issue with this, stating that: "The white paper …on government's role in technology 'deployment' creates an impression that it is a manageable function, which can be pushed out from the top down, so to speak. After many years in venture capital, I am convinced it is controlled by the marketplace and capable entrepreneurs…The government cannot 'change the market.' Technology is not 'pushed out,' like toothpaste; it has to be 'sucked up' through a straw from an adequate reservoir (NREL among others). It is never the job of the marketplace to 'fully value the public good.'…NREL should (perhaps) do market studies for decisions on where to put its research dollars but let the best entrepreneur do his own market study. The lab can focus better on selection of entrepreneurs. Table ES-1 reflects an impression that you can be successful by doing a better job of controlling the marketplace."

When I look at the world from a venture capitalist's (VC) point of view, I find much to agree with in Mr. Cunningham's comments but also some to disagree with. Entrepreneurs represent a significant and important avenue for technology commercialization and entrepreneurs are the primary focus of a VC. The VC's look to sources of technology and good, experienced entrepreneurs as the raw ingredients in which they invest. And, in general, VC's often want to stay away from markets driven by government incentives, control or other "interference" because of the uncertainties that often accompany that government participation. While a discussion of these issues is an additional level of complexity that was beyond the scope of this initial white paper, NREL's report entitled "NREL Industry Growth Forums --Lessons Learned, NREL/MP-720-25870" is quite informative with respect to the needs of small and new businesses. Market pull and technology push must of course be balanced and a different balance exists when a government public good objective is involved than when one is not. Also, consideration must be given to the fact that markets are influenced and change not only through the actions of entrepreneurs but also through the actions of large existing organizations with existing market share. I would prefer to think in terms of the government "facilitating" and "catalyzing" rather than "controlling" the marketplace and government actions need to be consistent with the entire makeup of the market. I believe the issue is: "which actions are appropriate in each situation?" I also believe the broadest spectrum of stakeholders is required to be involved if the most appropriate actions are to be identified.

Other commentors also identified important issues beyond the scope of the initial paper. L. T. Papay, Sc. D., Senior Vice President and Manager, Bechtel Technology and Consulting recommended giving consideration to the role of other agencies to get beyond DOE-only mechanisms and funding sources. Referring to the PCAST international report, he pointed to the role of such international assistance organizations as AID, TDA, OPIC, Ex-Im Bank, World Bank, GEF, etc. and also to mechanisms which host countries would have to create to participate in deployment. I am in complete agreement that international, state and local organizations and many other organizations have important roles beyond those of the federal government and I am hopeful that a series of papers might help better document the unique perspectives and contributions of these organizations.

Irvin L. (Jack) White, Ph. D., Managing Director, The Winslow Group and Executive Director, ASERTTI provided additional thoughts for consideration. He wrote: "As I stated in my preliminary comments about your White Paper on Technology Deployment, I congratulate you for your contribution to what will almost certainly be an ongoing discussion. I don't really disagree with anything you say. But I believe your white paper would be more useful to those in government who have to make funding decisions if the discussion was richer in detail…my comments about the details I find missing fall into two principal categories: Defining the Public Good and Government's Appropriate Role, and Filling in the Gaps or Pushing Technologies…You focus on …and enumerate five categories that you believe are 'appropriate' based on your definition of 'public good' …I accept your definition and at the level of generality they are presented, your five categories…As you suggest, almost nothing is purely public or private. There is almost always some mixture of the two. And for both government officials and private sector executives, the issue is almost always one of balance…it would be more helpful if you also addressed the more difficult issue, i.e., what is appropriate within and across your categories…I encourage you to include a discussion of the need for government agencies to find ways to operationalize the balance between commonality and competitive advantage.

"You also suggest that government has an appropriate role to play in filling in the gaps, i.e., in '…assisting the private sector in meeting public good objectives that cannot, or will not, be accomplished, by the private sector alone without government participation or leadership'. Again, I share your view…Your examples are instructive and useful. In my view, from a high helicopter perspective, the role of government is to determine and articulate high priority objectives. The problem we've encountered in the past…is when government goes beyond setting policy objectives and government program managers substitute their wisdom for that of the private sector in deciding which technology solutions are appropriate…For me the starting point is to establish the public purpose, articulate the specific policy goals and objectives, and undertake the enhancements you enumerate for technologies the private sector is willing to invest in to achieve those objectives."

"I agree with you about stakeholder involvement, including obviously involvement in determining and defining public purpose, goals, and objectives as well as identifying S&T needs. But in my view, government leaders/managers fail to meet their public responsibility if what they do in setting the public RDD&D agenda is fund the items that fall below the funding line for the private sector. For example, if an industry, through its various collaboratives, establishes a list of 20 RDD&D priorities, and in, for example the Natural Gas Initiative proposal to DOE includes only the bottom 8, how should DOE react. It could react by undertaking the enhancements you suggest. But wouldn't you be concerned if they did? Wouldn't there be good reason to raise the issue of corporate welfare?"

Mark Mazur, Ph. D., Director, Policy Office, Department of Energy also pointed to an appropriate question for future discussion. He asked: "When should government stop providing support?"

While there are many aspects of this question, I think a key part of the answer lies in getting adequate stakeholder collaboration. Just as stakeholders can help define what actions are the most appropriate ones for government to pursue, they can also help define when the government should stop providing support. While this is not a criterion, it is a mechanism. Additional questions not answered in this first paper appear to be ripe for discussion. These include:

- How does the government know which assistance to provide?
- How should the government prioritize to allocate scarce resources?

I expect to put additional focus and attention on answering these questions in the future.

APPENDIX A

Reprinted from Pages 7-14 through 7-20 of the
Report of the Energy Research and Development Panel
Presidential Committee of Advisors on Science and Technology
Federal Energy Research and Development for the Challenges of the Twenty-First Century
Report dated November 1997

COMMERCIALIZATION ISSUES

Research and development are part of a process intended to lead to the successful commercialization of innovative products in the marketplace. Traditionally, this process was viewed as orderly and sequential—like a pipeline with researchers injecting basic science at the first station, and then subsequently and independently injecting applied research, development, and demonstration, until commercial products finally emerged. There was believed to be little interaction among these various stages.

This model worked passably well for many years (although it often failed to reflect actual practice). With globalization and increased competition, ever shorter product cycles, and increasingly sophisticated technology, this model no longer works well and can even be seriously counterproductive. Rather than a pipeline, a more realistic image today might be a complex tapestry, with the various stages—basic science, applied research, development, demonstration, commercialization—all strongly entangled and inseparable throughout the process. R&D today is a dynamic process with extensive interactions among all stages. This is now widely observed and understood and is a key factor in the conduct of most corporate research. The SEAB Strategic Energy R&D study also made this observation and recommended that DOE management practices take this into account.*

This interconnectedness has several important implications: First, fundamental scientific research should be better coordinated with applied R&D programs. Specifically, some of the overall fundamental research effort should be directed to addressing scientific questions identified in the applied R&D programs, to enhance the prospects for accelerated technological progress in these programs. While differently motivated from basic research conducted without thought of practical ends, as has been the case for much federally supported basic science since World War II, the research needed to support the technology programs is nevertheless fundamental research, not applied research (see Box 7.3). This issue will be revisited in the Management discussion below.

Second, applied research and development, in turn, should be carried out and should, in most cases, be driven by consideration of markets (through demonstration and commercialization). For this to happen requires the formation of industry led partnerships with national laboratories and universities. This is increasingly being done and the trend should be strengthened as discussed above.

Applied R&D is not truly successful unless the technologies developed are successfully commercialized. New technologies and embryonic industries face particular difficulties. In many cases, new technologies face the chicken-and-egg problem of being generally high cost and thus limited to low market volumes, but needing large market volumes to drive costs down; and embryonic industries don't have the resources to provide the necessary support.

As a result, specific commercialization efforts may be appropriate to address the barriers facing particular technologies. The overall process can be represented as finding ways to climb over "the mountain of death," represented by the high costs of first-of-a-kind products, or to survive the trek through the "valley of death," represented by the negative cash flow to the enterprise as the product is brought to market (Figure 7.5).

* SEAB (1995b), p. 47).

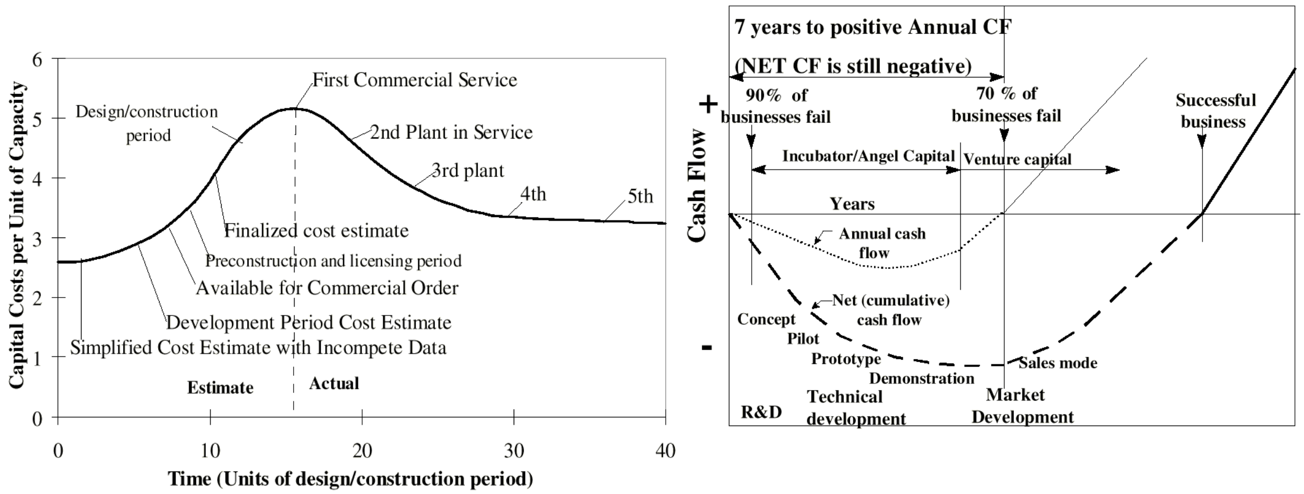

Figure 7-5: The "Mountain of Death" and "The Valley of Death" associated with the technological innovation process. Note that positive annual cash flow does not assure business success; 70 percent of businesses still fail at this point. Net Cash Flow is still negative when annual cash flow turns positive. Sources: "Mountain of Death" is from the Electric Power Research Institute; "Valley of Death" is from Helena Chum, NREL, and Irvin Barash, VenCom Management, Inc., personal communications. See also, Mitchell (1995).

This cost barrier can be surmounted. Volume production provides economies of scale, generates experience in manufacturing, installation, and operation, and opens new opportunities for incremental technological improvements—all of which lead to lower costs. If the needed growth in production is pursued solely through high-value niche markets, however, the cost-reduction process will often be so slow that it will be difficult to attract significant financial resources for product and market development. Successful commercialization often requires strategies to speed up the cost reduction process by accelerating early market development.

There is a consensus among policymakers that government support for long-term R&D is appropriate and necessary. Economists point out that innovation is the single most important source of long-term economic growth, with returns on investment in research and development being several times as high as the returns on other forms of investment. Yet private firms are unable to appropriate the full benefits of their investments in long-term R&D and thus tend to underinvest in it. These factors compel public support for long-term R&D to promote economic well-being. Over the last half century, public support for science has made the United States the world's preeminent scientific power.

In many cases, it is possible for private firms to appropriate the benefits of their investments in near-term R&D and demonstration and commercialization activities, despite the risks involved. In principle, once a new technology is proven, there should be entrepreneurs willing to accelerate its commercialization by absorbing the costs of buying down its price (e.g., by forward pricing of the product) if there are good prospects for cost reduction and a clear, large, and profitable market opportunity for the technology at the target price. The potential role of energy service companies in the restructured energy industry could be particularly important.

Box 7-3: Pasteur's Quadrant

A half century ago Vannevar Bush articulated in *Science, the Endless Frontier* the paradigm that all technological innovation is rooted in basic research conducted without thought of practical ends. He argued that basic research becomes a dynamo that enables economic progress when applied research and development convert its discoveries into technological innovations. This linear model of technological progress—flowing from basic research, to applied research and development, and on to production or operations—has guided science and technology policy planning for much of the post-World War II era. Bush also expressed the belief that the creativity of basic science will be lost if it is constrained by premature thought of practical use, and that applied research invariably drives out pure if the two are mixed.

It is now known that the relationship between basic research and technological innovation is far more complex than is suggested by this linear model. In the ongoing science and technology debates about this linkage, an important insight has been provided by Donald Stokes in his new book *Pasteur's Quadrant: Basic Science and Technological Innovation* (Brookings Institution Press, 1997). Stokes has shown that, contrary to the common view, fundamental research is often motivated by considerations of use as well as curiosity. His premier example is the fundamental research carried out by Louis Pasteur, who wanted both to understand and to control the microbiological processes he discovered. Irving Langmuir's desire to understand and to exploit the surface physics of electronic components, and John Maynard Keynes's interest in both understanding and improving the workings of modern economies are other examples.

This new insight is timely in light of the growing interest in harnessing science for the technological race in the global economy. Stokes suggests that Bush's one-dimensional model of technological progress be replaced by the two-dimensional matrix shown below. The linear model would involve only Bohr's Quadrant (research driven by the quest for fundamental understanding, as epitomized by the physics research of Niels Bohr) and Edison's Quadrant (research guided solely by applied goals, without seeking a more general understanding of the phenomena in the field, a good characterization of the research of Thomas Edison). Stokes adds to the array Pasteur's quadrant: research that seeks to extend the frontiers of understanding but is also inspired by considerations of use. (Stokes also suggested that his fourth quadrant might be named Peterson's Quadrant after Roger Tory Peterson, whose *Guide to the Birds of North America* is an example of curiosity-driven research about a particular thing, inspired neither by the goal of fundamental understanding nor by the goal of use, although he felt that this is too limited an example to warrant the name.)

Stokes' insight is important for the deliberations of the PCAST Energy R&D Panel because of its findings that many of the energy-technology programs at DOE could be markedly improved if buttressed by research activities addressing fundamental questions raised by technology developments. Contrary to the Bush view that consideration of use implies that such research would be applied research, which would tend to crowd out fundamental research, the Stoke's model suggests instead that adding consideration of use as a driver would expand opportunities for fundamental research, while providing needed inputs to technological development activities.

Stokes's Quadrant Model of Scientific Research

Research Is Inspired By:		Considerations of Use?	
		No	Yes
Quest for Fundamental Understanding	Yes	Bohr's Quadrant	Pasteur's Quadrant
	No	?	Edison's Quadrant

Despite the theoretical appeal of relying fully on the private sector for commercialization, there are substantial barriers limiting the commercialization of many new energy technologies under present and prospective market conditions. These barriers, which include the following, are particularly troublesome for environmental energy technologies (EETs):*

- Financial support for developing and commercializing new energy technologies is difficult to obtain, because (1) energy prices, particularly for natural gas, are so low as to pose extraordinarily stiff competition for any new energy technology; and (2) energy is a commodity with very thin margins and substantial risks of price drops. This contrasts with the pharmaceutical and semiconductor industries where there are large margins on innovative products that encourage venture financing, and where aggressive pricing to pull costs down the learning curve is routine.

- Large companies normally have many investment opportunities, so the (internal) competition for financial and other resources is intense. The natural tendency is to fund those technologies that are less risky, nearer term, and incremental. For new technologies to be funded, they must therefore offer a commensurate high level of risk-weighted returns.

- Entrepreneurial start-up companies with only one technology option (or a limited number) are more likely to "bet the company" on the development of a technology than large companies are, but they have limited financial resources to commercialize the products they are developing and have difficulty attracting external financing.

- Infrastructures in which the new technologies would be used are often not well developed. For example, low temperature fuel cells can be deployed at very small scales in buildings as distributed electric-power sources, but the current electric power generating industry is organized around central-station power plants and is not well suited to handle distributed systems. †

- Innovative energy-supply and end-use technologies are often more capital intensive (and less fuel intensive) than conventional technologies, which can deter potential users. The environmental benefits of EETs, which are the focus of R&D programs, are generally undervalued in the market, reducing private incentives to develop or invest in these technologies.

Thus, for technologies that provide public goods—such as reduced pollution or increased safety—in addition to private benefits, *temporary* government support for demonstration and commercialization is often warranted. This would be the case for EETs that provide public goods in the form of a cleaner and safer environment. The government has a stake in promoting the demonstration and commercialization of technologies that provide such public goods and integrating these demonstration and commercialization activities with the R&D process so as to optimize the efficacy of the R&D and increase the return on the public investment.

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* These are energy technologies—such as many renewable energy technologies, fuel cells, and a wide range of energy-efficiency-improving technologies—that are characterized by a high degree of inherent cleanliness and safety.

† In the case of fuel cells, natural gas is an effective and efficient fuel for which there is a well developed and comprehensive infrastructure.

The many barriers to commercializing EETs noted above show why government support will often be needed to help launch EETs in the market. Incentives for providing this assistance should be:

- effective in quickly establishing reasonably large production and market demand levels for EETs, allowing companies to scale up production with some confidence that there will be a market to compete for;

- efficient in driving down costs as cumulative production increases;

- minimally disruptive of existing energy-financial systems during the transition period;

- able—within available financial resources—to support a diversified portfolio of options;

- easily and transparently administered and require minimal administrative overheads; and

- temporary, with "sunset" provisions built into the commercialization incentive scheme *ab initio*, but long enough to catalyze the desired activity.

It is highly desirable to find ways to provide commercialization supports without tapping scarce resources from R&D programs. This will be politically difficult if all the resources are "in the same pot," since commercialization programs tend to be politically more glamorous than R&D programs.

A wide variety of policy instruments for providing commercialization incentives are available. Past experience shows, quite simply, that *you get what you ask for***.** Policy tools used in the 1970s and 1980s included loan guarantees and investment tax credits, which generated loans and investments, respectively, but—with a few exceptions—did relatively little toward creating viable industries, developing energy technologies, or even generating energy.

In the late 1980s and early 1990s, the focus turned toward performance-based incentives such as guaranteed prices for energy or energy production credits. Guaranteed energy prices or energy production credits give vendors a high degree of confidence that there will be a market for their product and can be effective in quickly building up large capacities of new energy technologies. But such instruments are inefficient in driving down prices and can sustain technologies (e.g., grain-derived ethanol*) that have poor prospects of ever being competitive. Moreover, as capacity for a particular technology grows, the required subsidy can quickly become very large, crowding out available public sector support for commercializing other technologies. However, where it is not practical to introduce more efficient incentives, production credits for EETs might be considered.†

A carbon tax has been frequently suggested as an instrument for encouraging the use of low-carbon energy technologies. (Of course, such a tax would encounter significant political opposition.) However, to be effective in directly helping commercialize new technologies, a carbon tax may have to be so large that it would significantly change the workings of the overall energy economy, and is, therefore, a policy with implications that are beyond the scope of this report. The same is true for international and national carbon cap-and-trade systems. While these mechanisms may be effective in generating a range of low-cost responses, they may not provide adequate incentives for the introduction of new technologies in

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* In contrast to ethanol derived from grain, ethanol derived from cellulosic feedstocks, the focus of the DOE biofuels R&D program, has very good prospects for being competitive with oil.
† The Renewable Electricity Production Incentive enacted in the Energy Policy Act of 1992 may be a useful example.

all instances because they do not directly address the gap between the costs of first-of-a-kind and mature products.

Auctions are one option for directly supporting the commercialization of qualifying technologies. An auction selects, through a bidding process, the most competitive options in each qualifying technology category. A subsidy makes up the difference between the winning bid and the market energy price. To be effective in reducing costs, a series of auctions is needed over a number of years to provide corporate planners a consistent market to target and scale up production for.* An example of how auctions work in electricity markets is provided by the Renewables Non-Fossil-Fuel Obligation in the United Kingdom, in which the price of renewable offerings was cut in half in just six years. The cost of the program is paid for by consumers in the form of higher electricity prices, which has amounted to less than a 0.5 percent increase.

Renewable Portfolio Standards (RPS) are another option intended to maximize the use of market forces in establishing renewable energy industries, particularly in the context of electric industry restructuring.† Under an RPS, each retail supplier of electricity must provide a specified‡ minimum percentage of qualifying renewable energy technology in its portfolio of electricity supplies. Individual obligations would be tradeable through a system of renewable energy credits (RECs)—created when a kWh is generated from a renewable source of energy. Retailers could choose among owning their own renewable energy facilities to obtain RECs, purchasing them from other suppliers of renewable electricity, or purchasing them from a broker. The administrative requirements of government are less under an RPS than under a series of auctions, because the market rather than an administrative process would choose winning options and suppliers. The RPS standard could be generalized into an Environmental Energy Portfolio Standard (EEPS) aimed at promoting the commercialization of a range of new energy technologies that are able to meet specified local, regional, and global goals in relation to environment, energy-supply diversity, and security.

The market mechanism envisaged for an RPS is very similar to that for the cap-and-trade system for reducing SO_2 emissions written into the 1990 Clean Air Amendments. Early predictions had been that cutting SO_2 emissions percent as required under the Clean Air Amendments—would cost $1,500 to $2,000 per tonne. Instead, with an open market created for SO_2 emissions permits (at half the original emissions level) industries have been able to cut emissions for only $100 to $150 per tonne. This success reflects the ability of firms to choose the least costly option for complying with the well-defined environmental requirement. An RPS is similarly expected to have a very modest impact on rates paid by consumers, as in the case of the experience with the Renewables Non-Fossil-Fuel Obligation in the United Kingdom.§ In summary, that experience indicates that auctions and tradeable credit systems tend

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* Wiser and Pickle (1997).

† Rader and Norgaardv (1996).

‡ The government would decide on the number of RECs required in relation to the total electricity sales by each retailer, based on renewable energy resources in the region, policy objectives, and potential costs. Separate requirements would likely be necessary for different classes of renewables (e.g., wind and photovoltaic sources) to account for different levels of technological maturity. The number of RECs in a given technology class might start at a low level, and increase over time as renewable energy experience increased.

§ The Tellus Institute (Steve Bernow, private communication, August 1997) has estimated the effect of a national RPS mandating that 4 percent or 8 percent of electricity generation should be from non-hydroelectric RETs by 2010 to be an increase in the average electricity price by $0.0004/kWh or $0.0017/kWh (0.6 percent or 2.6 percent of the retail electricity price), respectively. These estimated cost penalties are probably higher than they would actually be, because they were derived using the NEMS model of the Energy Information Administration, which does not adequately take into account cost reductions from both learning and technological improvements in RETs that are expected in this period.

to be efficient, whereas investment tax credits and ad hoc technology demonstrations have often not been efficient mechanisms.

Other mechanisms are under widespread discussion for addressing public benefits at risk due to structural changes in the electricity sector. Particularly notable is the Systems Benefit Trust modeled after similar mechanisms used in telecommunications industry and others. A Systems Benefit Trust or similar mechanism could provide support for public benefits (e.g., energy assistance for low-income households, customer service protections, energy efficiency programs, R&D, etc.) that would otherwise be neglected in a restructured competitive electric industry. Such a Trust might be used in conjunction with an RPS or an EETs.*

Temporary public funding in launching new industries based on a few key new EETs† could be very effective in supporting multiple energy policy goals. These technologies would sharply reduce local and regional air pollutant emissions without the need for complicated end-of-pipe control technologies, make possible deep reductions in CO_2 emissions, and increase energy supply diversity—both for U.S. markets and for developing country and other international markets that would be served by U.S. exports of such technologies.

While technology commercialization tends to be more costly than R&D, overall costs for commercializing a diversified portfolio of EETs using efficient, market-based instruments for buying down their prices (e.g., auctions or EEPS) should be relatively modest. Many EETs are small-scale and modular, which also reduces the high costs of "scaling up" in the development process. The high degree of inherent safety and cleanliness of such technologies also minimizes requirements for improving safety and environmental performance. The cumulative costs of buying down the prices of such new technologies via progress along learning curves can often be low relative to learning costs for large-scale technologies.

The amounts of money involved are significant but by no means impractical or disproportionate to environmental benefits. For example, the World Energy Council has estimated that to be competitive with conventional options, various solar energy technologies may need, in addition to support for R&D, cumulative subsidies at the global level of the order of $7 to $12 billion to support initial deployment until manufacturing economies of scale are achieved.‡ For the U. S., the total investment required to commercialize four different fuel cell technologies for stationary applications has been estimated to be $2 billion.§ Efficient market mechanisms could be similarly used in aggressive federal procurement to buy down prices of environmental energy technologies.

<u>Recommendation</u>: **The Panel recommends that the nation adopt a commercialization strategy to complement national R&D work in specific areas. This strategy should be designed to reduce the prices of these technologies to competitive levels and should be bound by cost and time.**

* Cowart (1997).

† This could include wind turbines, photovoltaic systems, biomass gasifiers for power generation and fluid fuels production, fuel cells for transport and stationary combined heat and power generation, and associated enabling technologies such as various electrical and hydrogen storage technologies, biomass production technologies, and underground sequestration of the CO_2 produced as a by product of producing hydrogen or hydrogen-rich energy carriers for use in fuel cells.

‡ WEC (1994).

§ Penner et al. (1995a, 1995b).

APPENDIX B

Federal Organizations with Missions and Activities in Technology, Sustainable Economic Growth, and Energy

Technology innovation and the welfare of the country are intertwined, with technology innovation having been identified as the single most important source of long-term economic growth. Government policy and market mechanisms work together to drive or restrict technology development and commercialization. The following are executive and legislative branch organizations in the U.S. government with current missions and activities linking objectives and activities directed at technology development and commercialization, sustainable economic growth, and energy. Similar state and local organizations exist with parallel objectives.

Executive Branch

The **U.S. Department of Energy's** (DOE) mission is to foster a secure and reliable energy system that is environmentally and economically sustainable . . . and to ensure that the United States retains its leadership in science and technology.

The DOE Office of Energy Efficiency and Renewable Energy's mission is to lead the nation to a stronger economy, a cleaner environment, and a more secure future thorough the development and deployment of sustainable energy technologies.

The **Department of Commerce** promotes job creation, economic growth, sustainable development, and improved living standards for all Americans, by working in partnership with business, universities, communities, and workers to:

- Build for the future and promote U.S. competitiveness in the global marketplace, by strengthening and safeguarding the nation's economic infrastructure
- Keep America competitive with cutting-edge science and technology and an unrivaled information base
- Provide effective management and stewardship of our nation's resources and assets to ensure sustainable economic opportunities.

The Office of Technology Policy has the explicit mission of developing and advocating national policies that use technology to build America's economic strength. The National Institute of Standards and Technology promotes economic growth by working with industry to develop and apply technology, measurements, and standards. The National Technical Information Service collects and disseminates scientific, technical, engineering, and related business information produced by the U.S. government and foreign sources.

The mission of the **U.S. Environmental Protection Agency** (EPA)is to protect human health and to safeguard the natural environment—air, water, and land—upon which life depends.

EPA's purpose is to ensure that . . . National efforts to reduce environmental risk are based on the best available scientific information . . . Environmental protection is an integral consideration in U.S. policies concerning natural resources, human health, economic growth, energy, transportation, agriculture, industry, and international trade . . . Environmental protection contributes to making our communities and ecosystems diverse, sustainable, and economically productive.

The **United States Agency for International Development (USAID)** is the independent government agency that provides economic development and humanitarian assistance to advance U.S. economic and political interests overseas. The mission statement is: "USAID contributes to U.S. national interests through the results it delivers by supporting the people of developing and transitional countries in their efforts to achieve enduring economic and social progress and to participate more fully in resolving the problems of their countries and the world . . .Sustainable development, nonproliferation, and public diplomacy are now more central than ever to American foreign policy . . ."

The **U.S. Trade and Development Agency** assists in the creation of jobs for Americans by helping U.S. companies pursue overseas business opportunities. Through the funding of feasibility studies, orientation visits, specialized training grants, business workshops, and various forms of technical assistance, we enable American businesses to compete for infrastructure and industrial projects in middle-income and developing countries.

The **Overseas Private Investment Corporation's** mission is "to mobilize and facilitate the participation of United States private capital and skills in the economic and social development of less developed countries and areas, and countries in transition from nonmarket to market economies, thereby complementing the development assistance objectives of the United States . . . "

The **U.S. Export-Import Bank's** mission is to create jobs through exports . . . for continuing export growth the Bank is focusing on critical areas such as emphasizing exports to developing countries, aggressively countering trade subsidies of other governments, stimulating small business transactions, promoting the export of environmentally beneficial goods and services, and expanding project finance capabilities."

The White House **Office of Science and Technology Policy** was created to provide the President with timely policy advice and to coordinate the science and technology investment.

Legislative Branch

House Appropriations Committee Subcommittees:

- Agriculture, Rural Development, Food and Drug Administration, and Related Agencies
- Commerce, Justice, State, and Judiciary
- Defense
- District of Columbia
- *Energy and Water Development*
- Foreign Operations, Export Financing, and Related Programs
- *Interior*
- Legislative
- Military Construction
- Transportation
- Treasury, Postal Service, and General Government
- VA-HUD and Independent Agencies

House Committee on Science Subcommittees:

- Basic Research
- Energy and Environment
- Space and Aeronautics
- Technology

House Committee on Commerce Subcommittees:

- Telecommunications, Trade, and Consumer Protection
- Finance and Hazardous Materials
- Health and Environment
- Energy and Power
- Oversight and Investigation

Senate Appropriations Committee Subcommittees:

- Agriculture, Rural Development, and Related Agencies
- Commerce, Justice, State, and Judiciary
- Defense
- District of Columbia
- *Energy and Water Development*
- Foreign Operations, Export Financing, and Related Programs
- *Interior*
- Labor, Health and Human Services, and Education
- Legislative Branch
- Military Construction
- Transportation
- Treasury and General Government
- Veterans Administration, Housing and Urban Development, and Independent Agencies

Senate Committee on Commerce, Science, and Transportation Subcommittees:

- Aviation
- Communications
- Consumer Affairs, Foreign Commerce and Tourism
- Manufacturing and Competitiveness
- Oceans and Fisheries
- Science, Technology, and Space
- Surface Transportation and Merchant Marine

Senate Committee on Energy and Natural Resources Subcommittees:

- National Parks, Historic Preservation, and Recreation
- Forest and Public Land Management
- Energy Research, Development, Production and Regulation
- Water and Power

APPENDIX C

Definitions

Alliances—Informal or formal relationships formed for mutual benefit, often to further common interests. Alliances may include any combination of two or more private entities, government organizations, academic institutions, philanthropic organizations, or any other organizations.

Applied Research—Activities designed to gain knowledge or understanding to determine the means by which a specific, recognized need may be met.

Basic Research—Activities designed to gain a more complete knowledge or understanding of the subject under study, without specific applications in mind.

Business Incubators—Physical facilities and organizations that exist to assist in the creation and nurturing of new businesses.

Business Matchmaking—The bringing together of business entities to explore and develop business relationships.

Business Planning—The process of creating plans that establish business objectives, goals, and expectations.

Collaboration—To work together in an intellectual effort.

Commercialization—The overall process of applying business methods and techniques to achieve sustainable financial gain or profit.

Corporate Welfare—Although no formal definition exists, some have defined corporate welfare as any action by government that gives a corporation or an entire industry a benefit not offered to others. It can be a subsidy, a grant, real estate, a low-interest loan or a government service. It can also be a tax benefit—a credit, exemption, deferral, deduction, or a tax rate reduction. Although these actions are all mechanisms used by government to achieve public policy objectives or *public good, corporate welfare* is usually used in a negative context to emphasize excesses, abuses, lack of transparency, or lack of achievement of desired results.

Demonstration—The act of showing or proving something. A demonstration project can have the purpose of: showing technical efficacy; proving a specific new application; showing that multiple proven systems work when integrated together into an overall process or larger system; proving durability and reliability; establishing cost or overall economic viability; or, any combination of these objectives. Demonstrations can also show or prove the *technology* in a new or different situation or location.

Deployment—To spread out and utilize or to put into broad use within the marketplace.

Deployment Facilitation—The act of assisting *deployment* or making it easier. Examples include: information dissemination, *education* or *demonstration* to increase knowledge and awareness about a *technology* or *policy*; *incentives*; *financial assistance;* or *business matchmaking.*

Economic Development—The process or some total of actions, activities, and processes necessary to cause an increase in the production of material wealth of a region or country.

Education—Knowledge or skill provided by a learning process.

Export Development—The conduct of activities to cause an increase in domestic goods and services being transported and traded abroad.

Financial Assistance—Help that provides, or leads to the providing of, funds or capital.

Financing Mechanisms—Methods and approaches that provide or raise funds or capital.

Government Sector—That portion or sector of the market that pertains to government organizations and entities, that excludes entities and organizations in the private sector.

Implementation—The act of putting something into practical effect.

Incentives—Reward or punishment that induces action or motivates effort. Incentives can be financial or non-financial.

Information Exchanges—Providing and receiving knowledge reciprocally.

Intellectual Property—Patents, licenses, proprietary knowledge, and know-how.

Market or Marketplace—The entire enterprise for buying and selling goods and services or the entire world of business and commerce.

Market Analysis—Methodical examination of a market by breaking it down into parts to understand its whole. *Market Analysis* is most often done to understand the potential demand for a *technology*, product, or service and the characteristics that the *technology*, product or service must have to be valued and used in the *market sector* being examined. National laboratories do *market analysis* to understand: 1) the value of their intellectual property; 2) what characteristics and attributes *technology* must have to be valued and used in a particular *market* or markets; and 3) the size, relevance, and certainty of markets for specific technologies and categories of *technology*.

Market Assessment—The act of determining the significance or extent of the demand for a *technology*, product, or service.
Market Barriers—Something that obstructs or impedes entry into the *market* or efficient natural operation of the *market*.
Market Conditioning—Conducting activities that accustom the *marketplace* in order to cause it to adapt.
Market-based Mechanisms—Processes and techniques that depend or rely on the operation of *market* forces to accomplish the desired outcome.
Market Sector—A subset of the *market* that has a specific common set of characteristics. The industrial sector, the state of California, and the software market are such specific subsets of the overall *market*.
Outreach—A systematic attempt to provide services beyond conventional limits, as to particular segments of a community, *market*, or *stakeholder* group.
Policy—Government plans or courses of action intended to influence decisions and actions in the private sector, public sector, or both.
Policy Analysis—*Policy* analysis is the methodical examination of a *policy* by breaking it down into parts to understand its potential influence and impact or the comparison of content and impact of various alternative policies.
Policy Design—The act of creating or formulating a *policy* to achieve a specific goal or purpose.
Private Investment—Commitment or spending of money or other resources by a private-sector entity.
Private Sector—That portion or sector of the market that pertains to private entities and organizations and excludes government organizations (*government sector*).
Product—The complete solution that is offered and sold to meet a need defined by the marketplace. Technology products can be individual components, complete processes, integrated systems, or hardware and software products marketed together in a manner that provides increased value to the end customer.
Public Good—Something provided for the benefit of the people as a whole (the general public); usually referring to something that would not likely be provided or be attained without government intervention.
Project Identification—Activities and actions leading to the identification of specific undertakings requiring concerted efforts.
Regulations—Rules, principles, or laws to control or govern conduct and actions.
Regulatory Policy—Government plans or courses of action intended to influence the amount and nature of regulation and *regulations*.
Research—Scientific investigation or activities designed to gain knowledge or understanding; typically subdivided into two categories: (1) basic research and (2) applied research.
Science—The observation, identification, description, experimental investigation, and theoretical explanation of phenomena; knowledge gained through experience; systemized knowledge.
Stakeholders—Individuals, organizations, or entities that have actual or perceived interest or may be affected by specific action or inaction.
Subsidies—Monetary assistance granted by a government in support of an enterprise regarded as being in the public interest or providing *public good*.
Technical Assistance—To provide help or support based on scientific knowledge, skills or know-how, or the use of *research* facilities.
Technical Standards—An acknowledged standard of comparison or set of requirements based on practical knowledge and scientific methodology.
Technology—The application of *science* to achieve a practical purpose.
Technology Commercialization—The overall process of applying business methods and techniques to achieve sustained financial gain or profit from a *technology*. *Technology development* and *technology deployment* are steps or parts of *technology commercialization.* May also be used in a narrower sense as those activities subsequent to demonstration*.*
Technology Deployment—The sum total of actions required to cause *technology* to be put into use, or sometimes referring more specifically to commercial use in the *marketplace*.
Technology Development—The process or sum total of actions, activities, and processes necessary to cause a *technology* to come into being.
Technology Transfer—The overall process of passing *technology* from the government to the private sector or the more specific act of conveying title for *intellectual property* from one entity to another.
Trade Development—The conduct of activities to cause an increase in goods and services being exchanged.
Training—The process of teaching through specialized instruction and practice.

APPENDIX D

Illustrations of Various Government Roles for Facilitating Deployment, with Examples from the Wind Industry

The purpose of this appendix is to provide illustrations of various components of government roles in facilitating deployment. The examples of components are all taken from a single technology area—wind energy—to illustrate how components link together and complement each other. However, these illustrations are not meant to fully characterize the U.S. Department of Energy Wind Program (USDOEWP), which is a more complex endeavor than can be captured in a short appendix. And although the examples are predominately taken from the USDOEWP, they are not limited to USDOEWP actions when examples from outside the U.S. program help to identify a more complete set of possible or potential actions. Overall, the examples do illustrate a fairly broad range of activities potentially required to cause technology commercialization.

Information and Education Roles

Information dissemination. General information may be appropriately disseminated to inform the general public in order to help them be wise consumers and voters (e.g., energy scenarios, technology characterizations, and status reports). Similarly, specific information may be provided to: 1) specific groups (e.g., states, other federal agencies, nongovernmental organizations [NGOs], foreign partners or industry trade associations) about specific technology, markets or policy; 2) deployment project decision makers about project opportunities; or 3) legislators and regulators about technologies and policies. During the past decade, the federal government has increasingly leveraged its resources by relying on state and local governments and organizations for production and dissemination of information. Lobbying regulations and guidelines ensure that all information disseminated by government and contractor organizations is appropriate to accomplishing the assigned mission.

Wind Example. *The USDOEWP supports the development of recommended practices, guidebooks, and information products needed to enable potential users of wind technology to make informed, intelligent decisions regarding wind energy development. The National Renewable Energy Laboratory (NREL) and DOE operate a number of Web sites that make technical information available to a broad audience. This information ranges from technical characterizations of the full range of renewable energy technologies to summaries of research programs and project experiences around the globe. Likewise, most other national wind research and deployment programs have Web sites as part of their information programs.*

Outreach. Outreach activities may be used to identify and focus communication on audiences, or specific segments of the community, market, or stakeholders that have potential for great deployment impact and are therefore of strategic significance. These activities may also include interactions with key stakeholders to: 1) inform and provide for input and feedback on priorities for research and development (R&D) and deployment activities; 2) seek stakeholder support of goals; 3) identify opportunities for collaboration and partnerships; and 4) make procurements, rulemakings, and other announcements.

Wind Example. *Publications have been designed for specific groups that are involved in, or whose activities have an impact on, wind energy development, including local and state legislators, government agencies, utility regulators, financiers, and the media.*

Education. Materials that educate and relationships with the educational community are important deployment mechanisms. Activities that have proven effective include development of education materials and providing educational forums for the general public, creation of educational materials to support curriculum development for K-12, and development of education materials and implementation of education venues to support deployment project decision makers in considering project opportunities. University intern programs are also effective tools, as is funding of graduate education. Leveraging federal government and government contractor resources with state and local resources leads to broader education impact than might otherwise possible**.**

Wind Example. *The Utility Wind Interest Group (UWIG) provides wind energy planning and implementation support to utilities. It was originally established as a nonprofit organization in 1989 by DOE, the Electric Power Research Institute (EPRI), and a number of utilities, to serve as an informal source of wind power information for utilities. It then expanded its efforts to include promotion of utility interests in wind energy at the national level, serving as a source of information on government/utility cost-sharing programs. UWIG coordinates with other organizations including the wind industry, utility regulators, utility consumer advocates, environmental organizations, and federal and state governments.*

Training. Specific actions may include training for state and local or foreign governments in policy analysis and development in a given subject such as energy issues or specific technology applications. Training for companies to transfer technology or technical know-how or training for deployment project decision makers in order to move projects forward are other examples that facilitate deployment. Government organizations should normally transition training to private-sector organizations as early as possible, and should collaborate with other agencies and state, local, and international organizations to maximize effectiveness and leverage resources.

Wind Example. *The Federal Energy Management Program (FEMP) conducts training on the implementation of renewable energy projects for federal facilities. A recent course provided definitions of the important terms applicable to wind turbine projects as well as a basic introduction to the technology, reports from successful projects, resource assessment, the leasing of federal land for wind farm development, and wind project development.*

Technical assistance. Cooperative research and development agreements (CRADAs) and work-for-others (WFO) agreements are technical assistance agreements that may be used to support industry participants with government resources to accomplish mission objectives. Joint work may be focused on, and be of general value to, specific industry segments, such as the construction and transportation industries. Technical assistance can also be provided to other federal, state and local organizations, and international customers of deployment projects that support and cause projects to be implemented by the private sector. WFO agreements allow unique federal laboratory capabilities and facilities to be provided to industry in a way that is fully cost reimbursable, and in a way that does not compete with the private sector.

Wind Example. *The USDOEWP conducts highly specialized work for other U.S. government agencies, such as wind mapping and technical assistance in countries where the United States has a near-term deployment interest and where the work is complementary to the main program mission.*

Technology transfer. Peer-review publications, Web sites, staff exchanges, conferences, the development of patent applications, and licensing of those patents, as well as appropriate WFO arrangements and CRADAs, are all effective technology transfer mechanisms. Know-how diffusion is often also accomplished through collaborative projects supported through competed subcontracts.

According to Bozeman and Crow,∗ cooperative R&D is among the most effective technology transfer mechanisms.

Wind Example. *NREL jointly holds a patent dealing with advanced airfoil technology. Wind turbine manufacturers now license this technology for use. The initial concept was formulated in the early 1980s in a research project that resulted in analytic models for the optimum cross section of the blade. Following a succession of modeling, wind tunnel tests, prototype development, and field testing involving consultants, blade manufacturers, turbine manufacturers, turbine operators, and others, the products are now made and used under license. New applications for the tailored blade cross sections are being explored for use in large fans in cooling towers.*

Information and Collaboration Roles

Information exchanges. Technical knowledge, policy and regulations, or market information exchanged with other organizations, including foreign governments, is often used to accelerate deployment of new technology. Such exchanges are among the most frequent government-sponsored activities.

Wind Example. *The International Energy Agency (IEA) provides a mechanism for Organization for Economic Cooperation and Development (OECD) countries interested in the development of wind energy technology to share technical information. The Implementing Agreement is the mechanism developed by IEA to achieve this goal. Current activities under the Implementing Agreement on Wind Turbines include: development of recommended practices for wind turbine testing and evaluation; joint actions in the form of workshops and symposia on subjects such as aerodynamics of wind turbines, fatigue of wind turbine blades, offshore wind systems, and wind conditions/turbine loads; reviewing progress in the implementation of wind energy by the IEA Member Countries to provide an overview of progress in the commercial development of wind turbine systems to present to decision makers in government, planning authorities, the electricity supply industry, financial institutions, and the wind energy industry; and validation of wind turbine testing procedures through a round-robin test program. Parties to the agreement include representatives of 17 countries (Australia, Austria, Canada, Denmark, Finland, Germany, Greece, Italy, Japan, Mexico, the Netherlands, New Zealand, Norway, Spain, Sweden, the United Kingdom, and the United States) and the European Commission.*

Collaboration. Formal interactions with other government or private organizations are used to accomplish research, development, demonstration, deployment, policy analysis and development, or other objectives, and frequently are used as vehicles to leverage federal resources and to accelerate the interaction between the steps in the interactive innovation process. Problem-oriented collaboration with a university, government agency, or at an industry cooperative research center, is reported to be the most effective of all technology transfer mechanisms at federal laboratories†. Government-funded technology developed without industry collaboration can result in technology for which industry has no need. Technology developed with government agency/industry collaboration but without end-user collaboration can result in technology for which there is no market. Technology developed with government agency/industry/end-user collaboration, but without the involvement of federal, state, and local policy makers, special interest groups, and others, can result in technology development and deployment that is counter to the public good, including bias toward short-term industry needs.

Wind Example. *A significant portion of the USDOEWP R&D budget is subcontracted to industry, resulting in a collaborative government/industry R&D effort. NREL collaborates with the World Bank,*

∗ Bozeman, B.; Crow, M. *Limited by Design, R&D Laboratories in the U.S. National Innovation System.* New York: Columbia University Press, 1998; pp. 192, 272.
† Ibid.

the United Nations Development Program, the IEA, and other entities where there is a harmony of interests. This cooperation ranges from joint funding of activities and conducting collaborative pre-competitive research, to personnel exchanges.

Stakeholder facilitation. Government organizations organize forums to facilitate stakeholder debate and consensus, building on such things as technology roadmaps, technology development plans, and deployment facilitation plans. Government also implements advisory groups and participates in industry or stakeholder associations and events to facilitate communication, buy-in, and championing of technology deployment activities and objectives.

Wind Example. *The deployment of wind technology within the United States is of concern to a wide variety of interests, including consumers, environmentalists, utilities, industry, regulatory agencies, power marketers, state and local governments, and federal agencies. They each possess differing viewpoints that must be accommodated for the long-term deployment of wind energy to be a success. Over the years, NREL, DOE, and EPRI have sponsored meetings of representatives from these diverse sectors for the purpose of developing (a) a long-range vision of how best to meet the many challenges along the path toward responsible, sustainable, and significant use of wind power; and (b) a consensus-based process for identifying key issues, defining activities to address these issues, and then catalyzing the execution of these activities. Organizing such regular forums has helped to identify issues that impact the use of wind power, has served as a catalyst for dialogue and debate, and has built consensus among the varied stakeholder groups on several major issues. In 1994, the efforts of NREL, DOE, and EPRI were strengthened by the creation of the National Wind Coordinating Committee (NWCC). The NWCC is a membership organization consisting of representatives from all of the sectors listed above.*

Business matchmaking. Government forums are used to bring together business entities to explore and develop business relationships. These and other activities also serve as a catalyst in bringing groups of companies together with a wide range of stakeholders. New collaborations, communications, alliances, and ventures result in growth of embryonic industries and development and deployment of technology in the marketplace, thus furthering the mission objectives.

Wind Example. *NREL's Industry Growth Forum Program brings small companies in the renewable energy industry together with venture capitalists and senior business executives to catalyze linkages and learn about business growth strategies and possible partnerships. Managers of these companies have the opportunity to discuss strategic financing and related issues, and obtain expert insight and advice from the financial community.*

Alliances and partnerships. "As large firms have…eliminated their central research laboratories and reduced their share of funding invested in basic research, the number and extent of industry ties with universities and federal laboratories have multiplied…While only 750 inter-firm alliances were formed in the U.S. in the 1970s, 20,000 were initiated between 1987 and 1992."* Industry, university, and government partnerships are often formalized to accomplish specific technology development and commercialization objectives. These may encompass work in any of the science, technology, deployment, or education and outreach areas. Subcontracts for joint R&D with groups of industry participants are one type of alliance. Informal stakeholder relationships, such as with groups of investors with an interest in renewables, may also be created. Fairness of opportunity and the avoidance of conflicts of interest must be observed in any such activities.

* Atkinson, R. D. "Federal Technology Policies Need to Support for Collaborative Research." *Technology Business*, Volume 6, No. 3, McLean, VA: Technology Business LLC, November/December 1998; p. 78.

Wind Example. *Laboratory Partnership—The Wind Energy Program uses the unique skills that exist at two of DOE's principal research laboratories: NREL and Sandia National Laboratories. NREL has been designated as the lead laboratory for the wind program. The National Wind Technology Center (NWTC) staff and facilities provide a broad range of capabilities in aerodynamics, structural testing, field testing, structural-code development, systems analysis, utility analysis, and subcontract management. Sandia provides capabilities in advanced manufacturing, component reliability, aerodynamics, structural analysis, material fatigue, and control systems.*

University, Government, Industry Partnerships—The USDOEWP accomplishes nearly one-half of its work through subcontracts with universities, industry, and other stakeholders. Program participants are actively working to involve scientists and engineers of U.S. educational institutions in fundamental energy research programs. These subcontracts are normally awarded competitively, though some are awarded to university programs with recognized unique capabilities of special interest to the program. This activity maintains and increases the involvement of university research organizations in DOE's wind energy technology research and enlarges the base of scientific and technical knowledge of wind energy by developing centers of wind energy research excellence in the United States. Additionally, the work enhances graduate research training opportunities and the development of highly qualified scientific and engineering personnel to meet future national needs in wind and other energy fields.

Technology Development Roles

Scientific research. The federal government sponsors scientific research that supports a government agency mission or objective (collaboratively with U.S. industry where possible), including the objective of creating fundamental knowledge. Research is conducted or subcontracted in assigned programs. The mix of long-term basic research, applied near-term research, and deployment facilitation activities must constantly be balanced to achieve government objectives.

Wind Example. *In the 1970s, the USDOEWP emphasized fundamental research in wind and wind turbine dynamics. Today, an advanced turbine component of the program includes the acquisition of large-scale, heavy-duty experimental test turbines to provide a test bed in a size range in keeping with the scale of current turbine technology. The test beds are used to conduct research testing designed to improve the fundamental understanding of wind turbine technology. This includes evaluating novel designs and architectures, validating design codes, and quantifying scale effects. These test-bed units are also capable of being configured for a wide variety of rotors and power trains exposed to diverse operational conditions to permit advanced component development testing on promising wind technology that the U.S. wind industry is unlikely to do because of risk, cost, or complexity.*

Technology development. Technology development is typically performed by government or under government contract to meet mission requirements.

Wind Example. *The overall approach to meet the USDOEWP objective is to conduct research that expands the knowledge base, explores new and innovative systems; and supports the cost-shared development and testing of advanced wind turbines that must occur before widespread market penetration can be achieved. These advanced turbines will use innovative designs and materials to reduce manufacturing costs, improve energy capture, enhance robustness, and reduce operating and maintenance costs.*

The burden of achieving advanced turbine designs capable of meeting cost parity with current fossil fuel generation must fall on applied research. Lower-cost turbine designs will be lighter weight and thus more dynamically active. The technologies required to address the trade-offs among the design requirements of weight, cost, and active vs. passive control pose a significant challenge. Ultimately, a *much better understanding of the design and safety factor tolerances driving cost and reliability must be achieved if advanced turbine system designs are to be truly optimized. Taking turbine designs to the "limit" of cost and performance will require advances in several research disciplines. For example, a much better understanding of the wind resource, and the nature of inflow and the impact on turbine performance and reliability must first be achieved. New components and architectures must be explored that reduce structural loads, but that, at the same time, also increase performance and energy output. Design and performance codes must continue to improve if innovation is to be sustained.*

Most notable are the improvements in design and prediction tools used in the analysis and development of utility-class machines. When coupled with improved models for wind forecasting and inflow structure, the capability to accurately predict the performance of advanced turbine prototypes through virtual simulation is slowly becoming a reality. These technological advances represent a cycle of synergistic R&D events in which powerful analysis tools free designers to pursue more innovative and complex architectures, which in-turn drives the need for better tools. This recursive interaction results in advanced wind turbine designs capable of achieving low cost of energy and high reliabilities sustained over 30-year operational life spans.

The reduction of system costs is essential to attaining competitive utility-grade wind turbines. Breakthroughs in the manufacturing of turbine components, especially blades, can significantly lower turbine capital costs and the cost of wind-produced energy. Research in blade manufacturing is conducted in several areas, including design-to-manufacture tools, manufacturing processes, cost/performance trade-offs, and quality control.

Technology demonstration. Demonstration projects play a key role in facilitating deployment. Their purpose may be to: 1) show technical efficacy; 2) prove a specific new application (e.g., prove the technology in a new or different situation or location); 3) show that multiple, proven systems work when integrated together into an overall process or larger system; 4) prove durability and reliability; 5) establish cost or overall economic viability; or 6) any combination of these objectives. The government also implements programs that work with the private sector to demonstrate commercially available new technologies in order to increase early deployment in the federal market sector.

Wind Example. *In 1992, DOE (through NREL) began a two-phase joint technology research and demonstration effort with the Centro de Pesquisas de Energia Eletrica of the Federal Republic of Brazil. The program has three main objectives: (1) to establish technical, institutional, and economic confidence in renewable energy systems to meet the needs of the citizens of rural Brazil, (2) to establish ongoing institutional, individual, and business relationships between the U.S. and Brazil in order to carry out sustainable programs, and (3) to lay the groundwork for large-scale rural electrification with renewable energy systems.*

Intellectual property management. Intellectual property (IP) derived from government-supported activities must be managed to protect the IP and package it so that it can provide competitive advantage in the marketplace. IP that provides competitive advantage has value in the marketplace and therefore facilitates technology deployment.

Wind Example. *An NREL patent dealing with advanced airfoil technology was discussed above in the "Technology Transfer" section. Protecting such IP through the patent process makes it valuable to U.S. industry and increases its competitiveness. Similarly, by patenting the technology, awareness is increased and opportunities for new applications for the tailored blade cross sections are readily explored, in this case for use in large fans in cooling towers.*

Market solutions. Individual technologies must be packaged into products or systems that meet market needs. Very often, private industry cannot see the value of the technology until it has been packaged or cannot afford the cost of packaging the technology. The government participates in the development of generic products or systems that meet a market need when properly developed into a value-added commercial offering, when that participation is necessary to accomplish a mission objective. The relative magnitude of the government participation should be determined by the likely distribution of public and private benefits.

Wind Example. *In a remote village, the least-cost power supply system is likely to be a hybrid system—i.e., it will probably consist of a diesel generator, one or more wind machines, a photovoltaic (PV) array, and a bank of storage batteries. DOE, through NREL, has created a Hybrid Power Test Bed that permits researchers, system operators, and equipment manufacturers to simulate the operation of such systems. Using simulated village loads, the interaction of the hybrid components can be explored under realistic conditions. Design engineers can work through actual problems the system may encounter in the field. System operators and system planners from developing countries can be trained at this facility. Ultimately, this technology product can be further developed and packaged as a market solution. The individual technologies and the integrated technologies are further integrated with a marketing strategy and approach to become a market solution.*

Policy Roles

Policy information, education, or training. Information dissemination, education, or training, on policy or policy issues may be required for state, local, and federal policy makers, or foreign governments or others, wanting to understand policy alternatives before or after implementation.

Wind Example. *The American Wind Energy Association (AWEA) is a national trade association that represents wind power plant developers, wind turbine manufacturers, utilities, consultants, insurers, financiers, researchers, and others involved in the wind industry. AWEA provides up-to-date information on policy developments related to wind and other renewable energy development. It is an industry clearinghouse for legislation and policy changes; analytic documents on technical and policy issues, and a wealth of education and communications materials. Its annual industry conference highlights the latest industry trends,and technology and policy developments. Its Web site is visited more than 2,000 times per week.*

Policy analysis and design. The federal government analyzes the impact of new policies on technology development or commercialization; assesses the merits of alternative policies as they might impact technology development or commercialization; and supplies input for the information, education, and training activities as identified above. Policy design is required to allow federal, state, and local or foreign governments to create policy for implementation. Relevant policy tool examples include economic policy, regulatory reform, trade policy, taxation, procurement, standards, and intellectual property rights. The full range of policy tools should be used to stimulate the market, meeting different needs of different technologies, industries, regions, and missions.*

Wind Example. *An interesting and informative comparison of the policies of the United States and Denmark during the 1980s is contained in "Chapter 4, Wind Energy: Resources, Systems, and Regional Strategies," in* Renewable Energy Sources for Fuels and Electricity *(ed. T. B. Johansson, et al.). Michael Grubb and Neils I. Meyer trace the evolution of the technology as well as the policies that most heavily*

* Branscomb, L. M. and Keller, J. H., "Towards a Research and Innovation Policy," Chapter 18. Branscomb, L. M. and Keller, J. H. *Investing in Innovation, Creating a Research and Innovation Policy That Works.* Cambridge, MA: The MIT Press, 1998; p. 473.

affected grid-connected wind deployment in the two countries. They contrast the rapid development in California (where both the Public Utillity Regulatory Policies Act and state incentives were in force) with a more methodical approach in Denmark. The authors take care to note that without the U.S./California policies and the resulting investments, "wind energy would not have reached its current stage." They also point out that about half the machines sold in the California market during that period were Danish machines and that the export earnings were $900 million at that time.

Policy implementation. (e.g., regulations, grants, and assistance)**.** Policy is implemented by the appropriate government organizations as required by the authorizing legislation, executive order, or regulation. Policy mechanisms are frequently required to encourage the deployment necessary to meet a desired public good not attainable through the natural action of the marketplace.

Wind Example. *Section 543 of the National Energy Conservation Policy Act, as amended by the Energy Policy Act of 1992 and supporting Executive Orders, has directed federal agencies to implement cost-effective energy and water efficiency measures. DOE has implemented these policies by establishing FEMP which provides information, technical assistance, and performance contract financing mechanisms for use by other federal agencies. FEMP projects include a range of renewable energy technologies, including wind turbines. In 1998, FEMP funded a third turbine at a naval facility on San Clemente Island (California). In 1999, a wind turbine system at a National Guard facility will be funded.*

A more controversial policy example is that of the extensive use of domestic incentives and international export mechanisms and subsidies used by the Danish government to grow the Danish wind industry. Sixty percent of the global market is met by the Danish industry. Tied aid is one of the mechanisms used.

Market Development Roles

Market assessment and analysis. Market analysis is used by governments to understand: 1) what characteristics and attributes technology must have in order to be valued and used in a particular market or markets; 2) the size, relevance, and certainty of markets for specific technologies and categories of technology; and 3) the value of intellectual property.

Wind Example*. It is necessary to assess the market for evolving wind technology in the changing business and policy environment. As costs come down, the USDOEWP continually assesses the potential market for wind power. This includes monitoring the competitive technologies, assessing electric demand needs, and evaluating the impact of electric-sector restructuring and associated policy changes. Utilities and others in the power sector need to be kept abreast of new knowledge resulting from research activities and changes in the marketplace. To facilitate deployment, it is important to transfer knowledge of modeling techniques, planning and operational experiences, and wind resource assessment data to the various actors in the electric sector. Case studies using new analysis techniques and new data clarify the value of wind-generated power and explore the shorter-term operating impacts of wind turbines on the power grid. To facilitate transfer of this information, much is accomplished through a competitively awarded subcontract to provide support for UWIG. Activities of UWIG transfer wind project experiences between utility companies, thereby increasing the base knowledge and accelerating deployment of wind technology.*

Market conditioning. Market conditioning activities may include information dissemination or outreach activities that seek to accustom the marketplace to new ideas, concepts or opportunities. This may include working collaboratively in the federal market sector with suppliers, customers, and other supporting organizations such as trade associations to create deployment project opportunities, including facilitating collaborative forums, seeking rulemaking input, reviewing generic federal bid specifications, and developing Presidential Executive Orders that pertain to deployment.

Wind Example. *The Global Environmental Facility (GEF) was established as a joint undertaking of three multilateral public institutions—the World Bank, the United Nations Development Program, and the United Nations Environment Program. One component of the program established by the GEF is the promotion of renewable energy by removing barriers and reducing implementation costs. The GEF provides co-funding for investment activities of, for example, the World Bank, for projects that are country driven, consistent with sustainable development, and technology transfer that is environmentally sound and adapted to suit local conditions. Many applications of renewable energy technologies are already cost effective compared to fossil fuels, or would be if the implementation costs could be lowered. The lag in adoption of renewables in these cost-effective applications is frequently attributed to the existence of numerous barriers that prevent seemingly profitable market transactions from taking place.*

Barrier removal. Identification of barriers to adoption of new technology, development of programs to remove barriers, and other such activities are frequently necessary to allow the marketplace to operate effectively. In the federal, state, and local market segments, work may be done collaboratively with the private sector to identify and propose regulatory, rulemaking, and legislative solutions to create and encourage deployment opportunities.

Wind Example. *The potential impact of wind turbines on birds, including resident, breeding, and migratory species, has frequently been a concern at both new and existing wind power sites. The concern is driven by two primary factors: (a) possible litigation over the killing of even one bird if the species is protected by the Migratory Bird Treaty Act and the Endangered Species Act; and (b) the need to understand the effects of wind turbines on avian mortality in bird populations. As a result, the program continues to identify ways to reduce or avoid avian fatalities due to wind energy development.*

Standards development. The federal government may collaboratively lead or participate (including providing technical support), in the development of federal, state, and local codes and standards for buildings (commercial and residential), energy-using equipment (e.g., appliances and lighting) and energy-producing equipment (wind turbines and PV panels/systems). Standards have frequently been a means to accelerating deployment. Coordinating the transition to new technology standards is particularly important in cases where the transition is infeasible unless substantially all users convert at the same time, such as changes to communications-network protocols.

Wind Example*. The USDOEWP has provided financial and technical support to the development of wind industry consensus standards since 1978. Working with the standards subcommittees of the AWEA, NREL and Sandia personnel have contributed technical expertise to the development of standards in the areas of performance, electrical interconnection, design criteria, acoustics, wind-diesel systems, small wind turbine safety, terminology, and certification, among others. Recently, with the internationalization of the wind power market, certification has become a requirement for international wind turbine sales.*

The shift from domestic to international markets has pushed the wind industry and the program into the arena of compliance with international standards and certification requirements. The IEA and International Electrotechnical Commission, as well as major foreign research laboratories, play strong roles in defining and specifying these requirements. It is essential that the USDOEWP work closely with these organizations, not just to ensure that the interests of U.S. companies and users of wind technology are addressed, but to fulfill an important international role in wind power development. Sales of wind turbines abroad depend increasingly on meeting the requirements of the growing body of standards. The USDOEWP, at the request of the wind industry, will continue to play a major role with these agencies in the development of international standards and their application for certification test and accreditation programs.

Trade development and export assistance. Such assistance activities may be used to cause an increase in goods and services being transported and exchanged abroad (e.g., international deployment). They may be leveraged among agencies such as the U.S. Agency for International Development, the Department of Commerce, the Trade Development Program, or others having relevant missions.

Wind Example. *AWEA is the largest renewable energy association in the world and is made up of mainly national affiliate societies, companies or organizations involved in wind-related activities. Through these national affiliations, AWEA has a total membership of over 15,000. Many of the member firms are international not simply in terms of sales, but have manufacturing facilities in more than one country as well as through joint-venture agreements.*

Though the domestic European wind market is large in itself, export sales is a key element of the market. The Danish wind industry had gross sales of just under $1.0 billion in 1998. "Danish wind companies utterly dominate the global export market; more than half of the new wind turbines installed worldwide in 1998 were made in Denmark." Danish companies have also formed successful joint-venture manufacturing companies.*

More than 1.5 gigawatts of wind energy capacity is being installed around the world each year. Renewable Energy Systems (a UK firm) reports that it has more than 1,000 megawatts (MW) of capacity at various stages of development around the world and that most of their sales in the last two years have come from outside the UK. The company's success is linked to a business approach driven by long-term market development considerations.

Economic development. Government organizations provide various incentives to encourage financial growth in a given geographic area. Most states offer subsidies such as tax abatement, grants, tax-exempt bonds, free land or job training to encourage firms to move into their territories. Sometimes such assistance is focused on nurturing new technology businesses. With respect to national laboratories, Bozeman and Crow† found that "an emphasis on economic development is clearly the most closely tied to success" of technology transfer activities. All other motives for doing technology transfer had less correlation to technology transfer success.

Wind Example. *The Executive Committee of the IEA Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems announced that worldwide wind energy installed capacity reached 10,000 MW. Five nations account for more than 80% of the global installed capacity: Germany, the United States, Denmark, India, and Spain.*

Wind energy was the world's fastest-growing renewable energy source for the fourth straight year in 1998, with an additional 2,100 MW installed and equipment sales reaching more than $2.0 billion worldwide during the same year. Global growth has been driven by a number of factors, including improved technology and supportive government policies. The European Union (EU) estimates that more than 40,000 MW will be installed in EU countries by 2010. Part of that capacity will be in offshore installations planned by Denmark and the Netherlands. The United States estimates that 10,000 MW will be installed domestically by 2010, most of which should be located in the Great Plains.

Wind energy provides a substantial industrial development opportunity that can create thousands of jobs worldwide, while responding to environmental concerns such as global warming and clean air by displacing emissions from fossil-fueled electric-generation sources.

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* "A Force to be Reckoned With: The Wind Power Marked Boomed in 1998." *Renewable Energy World*, Vol. 2, No. 2, London, UK: James & James (Science Publishers) Ltd., March 1999; p. 19.
† Bozeman et. al., pp. 192, 272.

Federal-sector procurement. Federal procurement programs create an initial market. For a period of time, Department of Defense and NASA programs created the initial market for many high-technology goods. Currently, programs such as FEMP provide an opportunity for the government to encourage deployment and set an example for others by being an early adopter of new energy efficiency and renewable energy technologies.

Wind Example. A recent Executive Order established goals and requirements for federal facilities to consider use of renewable energy, including wind energy.

Business incubators and small business assistance. The failure rate of small businesses is very high. Such firms seeking to commercialize new technology typically have a number of weaknesses that can be addressed with information, education, and direct interaction. These firms commonly wait too long to pay serious attention to business planning, marketing, market development, and customer issues that help them transition from a technology-driven R&D company to a market-driven commercial entity.* Business assistance organizations typically have in-house personnel and linkages to others that can provide experience in starting and operating small businesses. Appropriate forms of business assistance are consistent with fairness of opportunity, and the appropriate use of DOE funds according to program directives. These include, but are not limited to, appropriate business assistance, technology transfer, alliances, and "catalyzing" business matchmaking as described above.

Wind Example*. The Small Business Innovation Research Program (SBIR) was legislatively created in 1982, and strengthened and reauthorized in 1992. The purposes of the program are to increase private-sector commercialization of technology developed through federal R&D, as well as increase small business participation in federal R&D. Federal agencies with extramural R&D budgets of more than $100 million are required to establish an SBIR program using a set-aside stated percentage of their budgets. The DOE SBIR program budget for FY 1999 is expected to be about $75 million.*

To assist awardees in seeking private capital, DOE has sponsored a Commercialization Assistance Project that has provided individual assistance in developing business plans and in preparing presentations to venture capital firms and large corporations. Half of the companies that completed projects in 1991 and 1993 have received a total of $50 million for commercialization. Further, these companies have increased sales from their SBIR work by more than $40 million. Renewable energy is one of the research topics covered. In 1998, four awards were made for the development of innovative applications involving small wind turbines. Three projects involve ice-making technologies. Ice is a valued product in remote areas of developing countries and its availability at a reasonable cost could directly raise the income of fishermen and other groups. The fourth award is for an innovative electronic control system for water-pumping technologies that would expand the size of the market for wind-electric water-pumping applications.

Creation of financing mechanisms. Government assists in developing methods and approaches that can be used to provide or raise funds or capital for new-technology businesses. This can involve identification and communication of new or existing financial mechanisms. The government may even fund front-end costs of developing new finance mechanisms. Federal, state, and local government agencies often work together to implement alternatively financed (such as energy savings performance contracts) deployment projects with the private sector.

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* Murphy, L. M. *NREL Industry Growth Forums-Lessons Learned.* MP-720-25870. Golden, CO: National Renewable Energy Laboratory, 1999; p. 1.

Wind Example*. In 1996, the World Bank undertook to create a special facility (the Solar Development Corporation, or SDC) to support the provision of technical assistance and financing for the express purpose of strengthening the distribution component of the photovoltaic industry in developing countries. Through DOE, NREL provided a full-time senior international market analyst who worked inside the World Bank with the Bank team to design the SDC and the necessary implementation process.*

Financial assistance and subsidies. Financial assistance to facilitate technology development and deployment can be provided through a number of means. Mission-directed, performance-based subcontracts and the associated award process represent the most common form of assistance. Fair access to this assistance is provided through the procurement process. Similarly, subcontracts that provide funding to universities are competed through a peer-review process. Business matchmaking is used to link entrepreneurs to private sources of finance. Government grant and subsidy programs represent the most direct form of financial assistance.

Wind Example. *In 1997, the World Bank convened a workshop on Financial Incentives for Renewable Energy Development with the expressed purpose of assisting the government of China in developing market-based incentives. The workshop compared the incentive structures of the five countries represented. The primary incentive offered in most countries was a guaranteed buyback rate for grid-connected systems; in the European countries the rate ranges from 5.0 cents to 10.5 cents (U.S.), while the U.S. incentive is a 1.5 cent production tax credit. The key incentive used in India has been a remarkable 100% depreciation in the first year of operation. The types of incentives used include concessional import duties, excise-tax benefits, corporate and personal income tax benefits, subsidized investment costs, low-interest loans, and premium power purchase prices.*

Business creation. Government does not usually become directly involved with business creation or the ownership of businesses unless under the aegis of a separate privately funded entity with the appropriate corporate “firewalls” that assure fairness of opportunity, and preclude even the appearance of conflicts of interest and the augmentation of government funds. However, assistance is frequently needed and therefore provided to create new businesses to meet mission objectives when the private sector does not naturally meet this need.

Wind Example*. The USDOEWP funds small and entrepreneurial companies through competitive contracting processes to perform specific research and development. Through business assistance and matchmaking activities, these organizations often partner, ally or merge with other larger organizations, sometimes creating new entities. This indirect involvement in business creation is often critical to the broader development of a new industry.*