American Energy
Innovation Council

CATALYZING AMERICAN INGENUITY:

The Role of Government in Energy Innovation

ABOUT THE AMERICAN ENERGY INNOVATION COUNCIL

www.americanenergyinnovation.org

American Energy Innovation Council

Who we are

American Energy Innovation Council (AEIC) members are **Norm Augustine**, former chairman and chief executive officer of Lockheed Martin; **Ursula Burns**, chairman and chief executive officer of Xerox; **John Doerr**, partner at Kleiner Perkins; **Bill Gates**, chairman and former chief executive officer of Microsoft; **Charles O. Holliday**, chairman of Bank of America and former chairman and chief executive officer of DuPont; **Jeff Immelt**, chairman and chief executive officer of GE; and **Tim Solso**, chairman and chief executive officer of Cummins Inc. The AEIC is staffed and hosted by the Bipartisan Policy Center.

Our mission

The mission of the American Energy Innovation Council is to foster strong economic growth, create jobs in new industries, and reestablish America's energy technology leadership through robust, public investments in the development of clean energy technologies.

BIPARTISAN POLICY CENTER

About the Bipartisan Policy Center

Founded in 2007 by former Senate Majority Leaders Howard Baker, Tom Daschle, Bob Dole and George Mitchell, the Bipartisan Policy Center (BPC) is a non-profit organization that drives principled solutions through rigorous analysis, reasoned negotiation, and respectful dialogue. With projects in multiple issue areas, BPC combines politically-balanced policymaking with strong, proactive advocacy and outreach. For more information, please visit our website: www.bipartisanpolicy.org.

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PRELUDE

The ability to access vital energy services, produced in an environmentally responsible way and at a reasonable price, has a fundamental and direct impact on the economic health of the nation. The American Energy Innovation Council (AEIC) came together in 2010 around a shared conviction: America has a great deal to gain from smart, ambitious innovation investments in the energy sector.

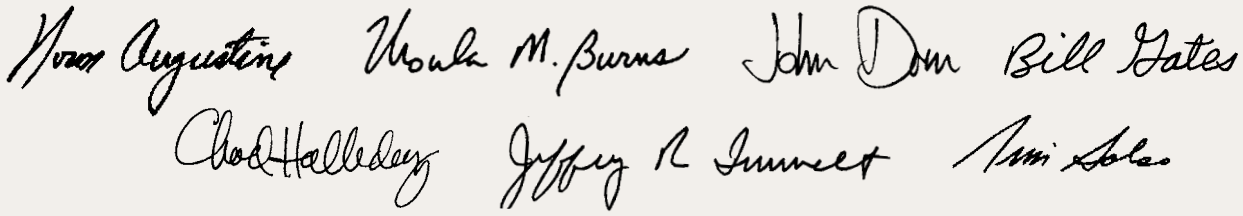
Last summer, we released a report, *A Business Plan for America's Energy Future*, which called for a more vigorous public commitment to energy technology development and presented actionable recommendations to unlock the ingenuity needed to reach these goals. Numerous studies have since confirmed our findings and echoed our recommendations.

One year later there have been some signs of progress, but our recommendations remain largely unfulfilled.

Drawing on our own experiences leading large businesses in competitive industries, we understand that innovation-based programs are essential to maintaining America's long-term competitiveness. This is true for businesses; it is also true for the country, especially for its energy interests. Even in an era of constrained public resources, we strongly believe that government has a critical role to play in stimulating clean energy technology innovation.

Building on our previous report, this update highlights the need for an active government role in energy innovation, recommends ways to improve the effectiveness of government innovation programs, and highlights options to pay for energy innovation investments.

Now is the time to make smart, aggressive investments to address America's energy challenges.



Prelude

America has a great deal to gain from smart, ambitious innovation investments in the energy sector.

EXECUTIVE SUMMARY

Innovation is the core of America's economic strength and future prosperity. New ideas and technological advances fundamentally shape our quality of life. They are the key to fostering sustained economic growth, creating jobs in new industries, and continuing America's global leadership.

Throughout the history of the United States, the federal government has played a central role in catalyzing and driving innovation and technology development in a variety of strategic areas—defense, health, agriculture, and information technology, to name a few—and it has often done so with strong results.

However, of all the sectors in the economy where innovation has a critical role to play, the energy sector stands out. Ready access to reliable, affordable forms of energy is not only vital for the functioning of the larger economy, it is vital to people's everyday lives. It also significantly impacts the country's national security, environmental well-being and economic competitiveness.

Executive Summary

Unfortunately, the country has yet to embark on a clean energy innovation program commensurate with the scale of the national priorities that are at stake. In fact, rather than improve the country's energy innovation program and invest in strategic national interests, the current political environment is creating strong pressure to pull back from such efforts.

Increasingly, three principal arguments are being made against an increased federal role in energy innovation:

~ Energy innovation should be the responsibility of the private sector.

~ If there is a role for government in energy innovation, our current federal government is not equipped to invest taxpayer dollars wisely and in a way that is likely to yield real results.

~ Even if there is a government role and government programs are organized and empowered to achieve success, there isn't any money to fund these activities in this fiscal climate.

Based on history and on our own experiences leading innovative companies, we don't subscribe to any of these arguments.

1. Why does government need to play a role in supporting energy innovation?

- Although we agree that the private sector is and will continue to be an important source of innovation, we believe the federal government has an integral role to play in advancing energy innovation.

- The U.S. government has a long and successful history of supporting publicly-funded research and development (R&D) projects that foster the development of new technologies.

- History shows that support for innovations that serve a fundamental national interest cannot be left to the private sector alone for two primary reasons:

  – Private markets generally do not exist for certain benefits, such as providing for a strong military, improving public health, and protecting the environment.

  – The private sector has tended to systematically under-invest in R&D relative to the potential gains to society — even where a market for the desired technology exists — because it is difficult for any individual firm to monetize all the benefits of these types of investments.

- The energy sector in particular has suffered from under-investment in research, development and demonstration (RD&D), for three main reasons:

  – Energy is not valued in and of itself, but rather for the goods and services it provides. This means that product differentiation does not drive innovation in energy supply options in the same way that it would for other types of products and services.

  – Many energy technologies are capital-intensive and long-lived, with the result that many require significant up-front cash with a slow return. Slow turnover of capital assets combined with the need for large up-front investments mean that the sector as a whole is subject to a high degree of inertia, a tendency to avoid risk, and domination by incumbent firms.

  – Energy markets are not perfectly competitive, due to regulatory uncertainty, market fragmentation, and distortions introduced by past policies—all of which generally slow the adoption of innovative technology.

- Government-funded R&D programs in a number of areas — such as defense, health, agriculture, and information technology (IT) — have enabled the United States to lead not just in specific technologies but in entire industries. Unfortunately, federal efforts thus far in support of clean energy R&D have been inadequate to the task and paltry in comparison with other sectors.

- We strongly recommend increased government support and leadership to develop and demonstrate new energy technologies to meet this century's challenges.

2. How should the government play a constructive role in energy innovation?

- To enhance U.S. leadership in clean energy technologies, the federal government must not only maintain a robust effort across the innovation continuum, but it must also promote an environment that favors innovation throughout the energy economy.

- The United States is fortunate to have a number of strong assets — celebrated national labs and universities, world-class entrepreneurs, a sophisticated financial industry, a legal system that protects the sanctity of contracts, and large technology and energy companies with the skills to scale technologies — ready to contribute to energy innovation. But the country lacks a defined sense of national purpose around this issue and a strategy for building innovative energy systems.

- Looking at past examples of government innovation and drawing from our own private-sector experience, we believe three principles should guide the U.S. government's innovation programs:
  - Focus on specific market failures in areas that can make a significant impact on strategic priorities.
  - Catalyze private-sector competition by providing incentives aligned with strategic outcomes.
  - Use the most cost-efficient actions to facilitate positive outcomes.

- Drawing on these three principles and building on our previous report, we recommend five concrete actions to improve the effectiveness of the U.S. energy innovation program:

A. Develop and implement a comprehensive, government-wide Quadrennial Energy Review (QER) that seeks to align the capacities of the public and private sectors. The QER should pinpoint key market failures and technology chokepoints in order to better orient federal programs and resources.

B. Support "innovation hubs" that concentrate resources and knowledge and thereby accelerate the development of new technologies. We strongly support the direction of U.S. Department of Energy (DOE) Innovation Hubs, Bioenergy Research Centers and Energy Frontier Research Centers and believe they should receive full funding.

C. Support and expand the new Advance Research Projects Agency–Energy (ARPA–E). As we have noted previously, ARPA–E challenges and empowers innovators across a range of technology pathways. By nearly all accounts, it appears that ARPA-E is being managed as a highly efficient, risk-taking, results-oriented organization. At a minimum, ARPA–E should receive at least $300 million per year. Going forward, investments in ARPA–E should be prioritized and increased.

D. Make DOE work smarter along the ARPA-E model. DOE has a critical role to play but needs to evolve beyond its current program structure and culture to be maximally effective. We argue for "ARPA-izing" a larger portion of DOE and the national labs by expanding some of the new authorities, tools and processes that are embodied in ARPA–E to other parts of the agency.

E. Develop a first-of-a-kind technology commercialization engine along the lines of the proposed Clean Energy Development Administration (CEDA). Previously, we called for a new government-backed institution dedicated to overcoming financing hurdles for new advanced, commercial-scale energy technologies. We believe the CEDA legislation aligns with our original recommendation and would mobilize significant private-sector capital to bridge the transition from demonstration to commercialization.

3. How Can the U.S. Government Pay for Energy Innovation in a New Era of Fiscal Austerity?

- There is no way to make the progress this country requires without increasing federal support for energy innovation across the entire innovation continuum. Even in these challenging fiscal times, we believe that underfunding energy innovation would be a grave mistake. Supporting innovation is an investment, not a cost.

- We previously called for a three-fold increase in annual energy innovation investments and maintain that such a

Executive Summary

level should be our country's target over the next decade. At the same time, the AEIC fully understands the gravity of the nation's current fiscal situation.

- As a result, we see an urgent need for a new energy innovation funding regime that accounts for current budgetary realities, but still ensures that our nation makes targeted, smart, basic investments in its energy future. We must develop a funding regime that is dedicated, consistent, and not beholden to annual appropriations. In general, federal funds for energy innovation should originate from revenues from the energy sector itself rather than from general revenues.

- We have identified a number of options that could provide funding for energy innovation investments that are commensurate with our original recommendations. These options include:
  - Diverting a portion of royalties from domestic energy production;
  - Reforming and redirecting energy industry subsidies;
  - Collecting a charge on sales of electricity;
  - Levying fees on other energy or pollution sources; and
  - Streamlining DOE.

- AEIC does not advocate for one revenue option over another; the only unacceptable option is to fail to make these investments. The resources to support increased innovation investments are available. Wise investments in a new generation of energy technologies are not only justified, but vital to our future. We urge our political leaders to direct them appropriately.

The Payoff

We know the federal government has a vital role to play in energy innovation. We know the federal energy innovation system can be structured effectively to achieve real results. And we know there are several ways to pay for public investments in this domain.

If the U.S. fails to invent new technologies and create new markets and new jobs that will drive the transformation and revitalization of the $5 trillion global energy industry, we will have lost an opportunity to lead in what is arguably the largest and most pervasive technology sector in the world. However, if the U.S. successfully innovates in clean energy, our country stands to reap enormous benefits.

It is time to put aside partisan interests and embark, as a nation, on a path to achieving our clean energy goals.

Chapter One:

1

Why does government need to play a role in supporting energy innovation?

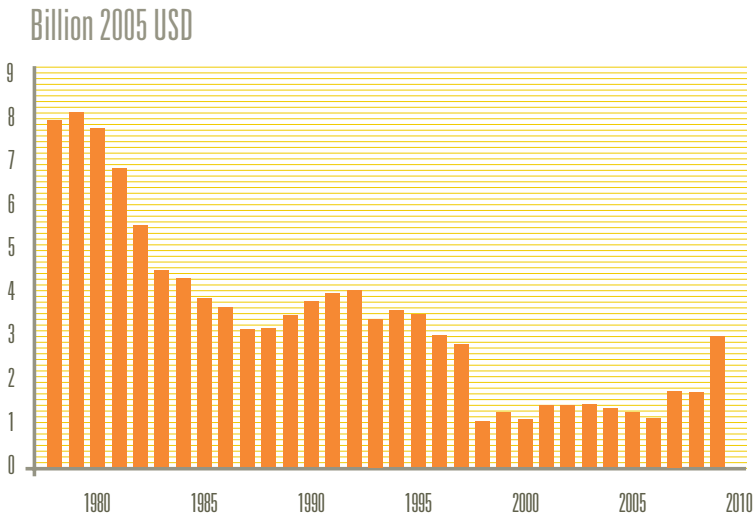
In this chapter we focus on the rationale for an active government role in supporting technological innovation in the energy sector.

THE IMPORTANCE OF INNOVATION

Technology innovation has long been central to American prosperity and to American leadership on the world stage. From its beginnings, the United States fostered a market system that allowed for the free flow of ideas, capital, and people. Over time, this system has proved uniquely successful in unleashing the creativity and entrepreneurial ambitions of individual citizens and in harnessing those energies for productive and wealth-generating purposes. As Joseph Stiglitz said in his acceptance speech for the 2001 Nobel Prize in Economics: "Changes in technology, R&D, are at the heart of capitalism."[1] From gas turbines to smartphones, medical imaging to communications satellites, GPS to the internet, innovation has improved lives, created jobs, and supported more than a century of U.S. preeminence economically, technologically, and militarily. As business leaders we are acutely aware that America's future success depends on its ability to carry forward this tradition of innovation and continue generating new ideas, technologies, processes and products.

Figure 1

Public Energy R&D Spending, 1978-2009*



* 2009 Preliminary data.
Note: 2009 data include FY 2009 funding in addition to funds appropriated through the American Recovery and Reinvestment Act of 2009.

Of all the sectors in the economy where innovation has a critical role to play, the energy sector stands out. Ready access to reliable, affordable forms of energy is not only vital for the functioning of the larger economy, it is vital to people's everyday lives and significantly impacts the country's national security and environmental well-being. Innovation-driven improvements in energy productivity in the late 19th century (especially the development of the electricity, automobile, and oil industries) gave consumers unprecedented improvements in quality of life. Although these innovations drove economic growth for much of the 20th century, they also prompted rapid growth in domestic and global energy demand.

At this point in history, securing clean, scalable and inexpensive energy supplies is a high-stakes innovation challenge. Failure would almost certainly lead to a lower quality of life for most Americans, but success will open up vast new markets and establish U.S. leadership while making our world cleaner and more secure.

But all this is well known. We all agree that technology innovation has boosted our economy and improved lives. We all agree that to break out of our current economic malaise, America needs to innovate, manufacture and build new technologies. This is true in many sectors of our economy, and it is certainly true in energy.

Where the consensus breaks down, however, is in deciding how the country should set out to achieve a leadership position in future energy markets. In these debates, some argue that government serves little essential role in innovation (other than enforcing the rule of law and preserving the sanctity of contracts) and that actual innovation—especially for energy—should be solely in the hands of the private sector.

Based on history and on our own experiences leading innovative companies, we disagree. Although we agree that the private sector is and will continue to be an important source of innovation, **we believe the federal government has an integral role to play in advancing energy innovation**—specifically in energy research, development and demonstration (RD&D).

RD&D = research, development & demonstration

Figure 2

R&D Spending by Utilities

THE CASE FOR AN ACTIVE GOVERNMENT ROLE IN ENERGY INNOVATION

The U.S. innovation engine is the envy of the world. In fact, throughout the nation's history, businesses, entrepreneurs, and researchers have worked to create new, game-changing technologies in a host of sectors. In the process, they have profoundly changed the status quo. While businesses have driven much of this progress, targeted and deliberate public support has also been crucial. At the most basic level, government's role in innovation is to foster an environment that is conducive to the creation, development, and commercialization of new ideas and technological advances. This notion is widely accepted and dates back to the founding of the republic; indeed, the U.S. Constitution recognized the awarding of patents "to promote the Progress of Science and useful Arts" as one of the central functions of a national government.[2] But the role of government goes beyond creating the right market and institutional environment. In fact, the U.S. government has a long and successful history of supporting publicly-funded research and development (R&D) as well as demonstration projects, procurement practices, and other policies (taxes, subsidies, regulations, etc.) that foster the development of new technologies.[3]

The rationale for government intervention is two-fold. First, history shows that support for innovations that serve a fundamental national interest cannot be left to the private sector alone. Private markets generally do not exist for certain benefits, such as providing for a strong military, improving public health, and protecting the environment. Therefore, it falls to government to ensure that these benefits are supplied at the level society demands. A second rationale rests on the theory and practice of knowledge spillover and the 'free-rider' problem. When firms make investments in basic science or R&D, they create knowledge spillovers that benefit society as a whole, as well as other firms. Those other firms get a free ride on their competitors' R&D investment. Because it is difficult for any individual firm to monetize all the benefits of these types of investments, the private sector has tended to systematically *under*-invest in R&D relative to the potential gains to society—even where a market for the desired technology exists.

In fact, real-world evidence supports the proposition that important energy industries are even more likely to under-invest in R&D than other sectors. Utilities, in particular, steer remarkably few resources to R&D. Across all U.S. industries, private firms spend an average of 3.5 percent of revenues on R&D.[4] By contrast, utility spending on R&D averages 0.1 percent of revenues. Moreover, Figure 2 shows that utility R&D spending has declined in absolute terms since the mid-1990s.[5] Although on average U.S. firms employ 63 R&D engineers and scientists per 1,000 employees, utilities employ just 5—fewer than any other sector and trailing far behind the next-lowest sector, which is retailing (with 9 R&D personnel per 1,000 employees).[6] As executives, we know that these current resource commitments are not sufficient to support a fundamental transformation of today's energy systems.

Under-investment in R&D is, not surprisingly, much less of an issue where strong market incentives exist for technology improvement. It is not clear, for example, that government support is needed to advance oil and gas exploration and drilling technologies. On the other hand, where public interests that are not valued in the marketplace are at stake, government may be the only or primary driver of innovation. In the case of climate change, the current absence of comprehensive regulation of

greenhouse gas emissions means that private firms face weak or non-existent incentives to pursue low-carbon innovations. The challenge this creates is compounded by other features, unique to the energy sector, that present additional hurdles to innovation.

One is that energy is generally not valued for its own characteristics, but rather for the goods and services it enables. As a commodity, one kilowatt-hour of electricity is indistinguishable from any other kilowatt-hour—regardless of how it was generated. Similarly, most people don't care what they put in the gas tank, provided their vehicle can travel equally far for the same money. This means that product differentiation does not drive innovation in energy supply options in the same way that it would for other types of products and services.[7]

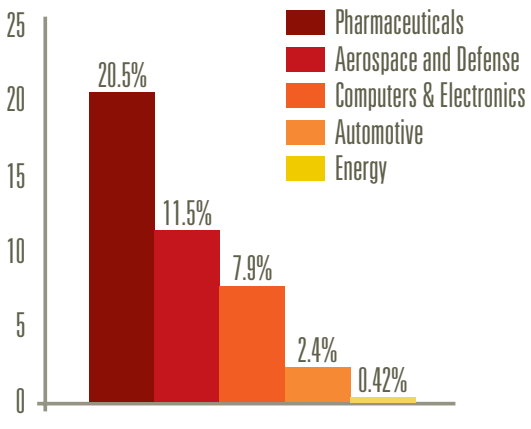
A second impediment to innovation in the energy realm is that many of the technologies and systems involved are capital intensive and long-lived. This is true on both the supply side of the equation (e.g., power plants, pipelines, and refineries) and on the demand side (e.g. buildings and automobiles).[8] Slow turnover of capital assets combined with the fact that many new energy supply or end-use technologies require large up-front investments mean that the sector as a whole is subject to a high degree of inertia, a tendency to avoid risk, and domination by incumbent firms. Markets do not drive innovation especially well for investments that are lumpy, high-cost and high-risk—particularly when the outcomes of these investments play out over decades in a context where energy prices are volatile and many facets of our national energy policy are in flux. The magnitude of required investments to develop new energy technologies is markedly different from many other technologies. It is one thing to prototype a new smartphone; it is quite another to prototype a new nuclear reactor.

A third issue is that energy markets—particularly for electricity—are far from perfectly competitive. The power sector, which is heavily regulated at the state level, is especially fragmented, but energy markets more generally may be slow to adopt innovations because of regulatory uncertainty, lack of information, and distortions introduced by past policies—including numerous existing subsidy programs.

All of these factors together create a clear and compelling justification for direct government support of energy innovation, particularly given the economic, national security, and environmental interests at stake. The question is not so much whether active intervention can be justified, but rather the details around how that intervention should happen and to what extent.

Figure 3

Total R&D Spending as a Share of Sales



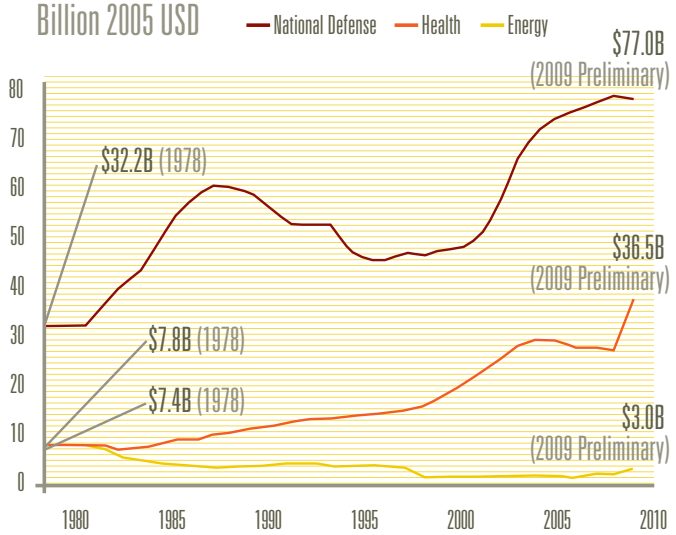
Note: Includes data for latest year available.

THE U.S. GOVERNMENT'S HISTORY OF SUPPORT FOR TECHNOLOGY INNOVATION

The federal government has played a central role in catalyzing and driving innovation and technology development throughout the history of the United States—often with strong results. This kind of support took a variety of forms. In the 19th century, government scientists mapped out natural resource endowments and Army officers surveyed routes for railroads, including helping to plan and sometimes to manage their construction. In the early and mid-20th century, programs such as rural electrification and massive public works projects, such as the construction of the Interstate Highway System, enhanced mobility and connectivity and directly or indirectly contributed to the development of new technologies and industries.

Figure 4

Federal R&D Spending in National Defense, Health, and Energy



Note: 2009 data include FY 2009 funding in addition to funds appropriated through the American Recovery and Reinvestment Act of 2009.

Federal efforts thus far in support of clean energy R&D have been inadequate to the task and paltry in comparison with other sectors.

Modern arguments for a sustained, broad-based government role in basic science and technology R&D did not emerge, however, until World War II revealed that America was lagging far behind Britain and Germany in the development of critical military technology such as radar and jet engines.[9] Since then, the U.S. government has supported a vast array of technologies and scientific enterprises with considerable success. For instance, government efforts to develop guidance systems for the military played a role in the development of digital computers and microchips. Navy support for aviation technology led directly to Boeing's 707—one of the first major commercial jetliners. The Defense Advanced Research Projects Agency (DARPA) created a distributed network of computers called ARPANET, which laid the early foundation for the internet. The U.S. government played a direct and indispensable role in launching the commercial nuclear power industry. Much of the initial technological know-how was developed through government efforts—working with firms like GE—to design nuclear power reactors for the Navy, and the Atomic Energy Commission (AEC) then extended financing to utilities for a series of demonstration plants.

Global Positioning System (GPS) technology was invented by the military but was opened to widespread commercial use in 1996 and is now omnipresent in communications and transportation systems. In fact, government support for basic research and for the mission-driven programs of agencies like the Department of Defense (DOD) and the National Aeronautics and Space Administration (NASA) has sparked a long list of landmark innovations.[10]

In many of these cases, government innovation efforts involved the private sector, which often conducted design, development, demonstration, and testing of systems and equipment under contract to federal agencies. Those systems and equipment often had important spin-offs; in particular, jet engines and gas turbines both found important applications in the energy sector, multiple sectors of the economy make use of Earth-orbiting satellites and remote sensing, and a host of less visible technology advances such as fiber-reinforced composite materials and micro antennas have been incorporated into numerous consumer products. These innovations enabled the United States to lead not just in specific technologies but in

entire industries. Federal efforts thus far in support of clean energy R&D have been inadequate to the task and paltry in comparison with other sectors.[11]

ENERGY INNOVATION SHOULD BE A HIGHER NATIONAL PRIORITY

Today, federal funding for all types of R&D totals nearly $150 billion per year. This funding flows through 30 different agencies in the executive branch: half (along with 70 R&D-supporting sub-agencies) are in federal agency departments (this former group includes DOD and DOE), and half are "independent" and outside of direct presidential control (this latter group includes the National Science Foundation and NASA). Many of these federal agencies in turn fund research by private firms, universities, nonprofits, and the government's own laboratories. Each of these agencies manages its research programs differently. This decentralization has had certain advantages, but has also led to inconsistency, duplication, and gaps in the national R&D portfolio. Support for energy R&D constitutes a relatively small part of the overall federal R&D portfolio—representing less than 2 percent of the total federal R&D budget.

We believe this must change. Energy innovation should be a higher national priority.

It is increasingly clear that the nation simply cannot afford to leave future energy technology challenges solely to the marketplace. The environmental and economic trade-offs in energy, domestically and globally, are becoming more urgent and more complex. At the same time, jobs and international competitiveness considerations have moved to the forefront of the nation's priorities. The governments of China, Germany, Japan, and Korea, among others, are all making significant investments in energy innovation. This is creating large new markets and millions of high-paying jobs in manufacturing and services, and will undoubtedly shape the future evolution of the $5 trillion global energy industry.

We strongly recommend increased government support and leadership to develop and demonstrate new energy technologies to meet this century's challenges. The more difficult question is how to ensure that government plays this role more effectively.

John Doerr

Partner, Kleiner Perkins Caufield & Byers

I met KR Sridhar, an Indian born American entrepreneur, in 2001 in his lab at the University of Arizona. He was, literally, a rocket scientist. With a federal grant to develop technology to sustain life on Mars for NASA, he invented and built a remarkable device capable of producing air and fuel from electricity to meet this challenge.

KR soon realized that this technology could have an even greater impact here on earth. By running the system in reverse, he could transform any hydrocarbon (natural gas, biomass, animal waste) to generate electricity at very high efficiency—all without burning the hydrocarbon.

In 2001, I made the initial investment to help him achieve his goal of changing the way the world generates and consumes energy. The team packed up three Uhauls and headed to NASA Ames Research Center in Silicon Valley, and Bloom Energy was founded.

Over the next few years, the technology quickly developed from concept, to prototype, to product, as the major technological challenges were solved and the systems became more powerful, more efficient, more reliable, and more economical.

Bloom is now powering several Fortune 500 companies such as Google, Walmart, FedEx, eBay, and others. They have grown into a 1000+ person company with headquarters and manufacturing operations in California. They've built a global supply chain, and recently announced plans to build a new manufacturing facility in Delaware, taking over the abandoned Chrysler plant and reinvigorating job growth.

Bloom is a story of success in American energy innovation and job creation. It began with federally funded university basic research to enable a transformative technology, under the leadership of an immigrant to America with an amazing entrepreneurial spirit and vision.

For every Bloom many other innovative ventures will fail; that's the discipline of capitalism and power of markets. America must embrace risks in innovation and invest heavily in R&D to create a full pipeline of good ideas today so that dozens more—even hundreds more— American Blooms will bloom.

Chapter Two:

How should the government play a constructive role in energy innovation?

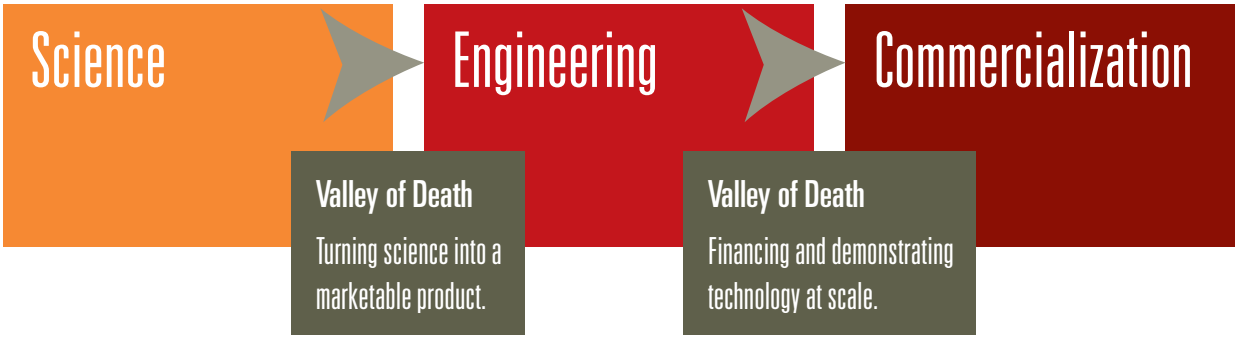
ENHANCING THE FEDERAL GOVERNMENT'S ABILITY TO EFFECTIVELY INNOVATE

The United States still holds a lead in many key energy technologies and can draw on an extraordinary depth of talent and experience. These advantages create a real opportunity for the U.S. to carry its global leadership position into the advanced energy technology marketplace of the 21st century. But America today is only partially equipped to meet this challenge.

In this chapter we focus on how the government can effectively and efficiently support the development of new energy technologies and systems.

Figure 5

Three Stages in the Energy Innovation Value Chain



	Science	Engineering	Commercialization
Definition	Basic research and development. Primarily conducted at the "bench" scale to solve underlying challenges in physics, chemistry and biology challenges.	Turns research into practice by converting science into workable product. Also addresses problems with pilot projects.	Deploying new products, processes and supply chains at national scales.
Where Conducted	Mostly in universities and national labs; a few large companies.	Companies and labs. Start-ups and venture capitalists.	Companies

To enhance U.S. leadership in energy technologies, the federal government must not only maintain a robust effort across the innovation continuum, but it must promote an environment that favors innovation throughout the energy economy. We know from history and from our own business experiences that great innovation successes can emerge from a strong public-private partnership in technology development. Similar successes are achievable in energy, but only if the country bolsters its energy innovation capacity and investments and the nation's political leaders and business community work together to make a clean and secure energy future a reality.

THE CURRENT LANDSCAPE

The U.S. energy sector is a massive enterprise of interconnected and interrelated systems. Direct energy expenditures comprise roughly 9 percent of U.S. gross domestic product (GDP), but the importance of energy to virtually all U.S. economic activity far exceeds that. The U.S. "energy enterprise" is predominantly managed by the private sector, though there are numerous federal and state policies and programs that affect private-sector decisions on nearly every aspect of energy investment, production, delivery and end use.

The U.S. is fortunate to have a network of celebrated national labs and universities, robust venture capital resources and proficient entrepreneurs, a sophisticated financial industry, a legal system that protects the sanctity of contracts, and large technology and energy companies with the skills to scale technologies. What America arguably lacks compared to countries like China, Germany, Japan, Korea and others, however, is a collective sense of national purpose around this issue and a strategy for building innovative energy systems. The governments of our competitors, by contrast, are very clearly boosting their efforts to catalyze scientific and technological progress in the energy domain.

Furthermore, as pointed out in our initial report, total U.S. investment in energy innovation, by both the public and private sectors, pales in comparison to the levels of investment typical of other technology-dependent sectors such as pharmaceuticals, aerospace, computers, and electronics.

SIGNS OF PROGRESS

The good news is that solutions to this problem of under-investment exist. To achieve them, however, great care must be taken to leverage the strengths of the private sector while strategically and efficiently managing specific public interventions. A government-funded, government-directed approach — reminiscent of the "Apollo" and "Manhattan" projects — is unlikely to be either effective or politically viable. In those historical examples, enormous federal resources were concentrated on a single, defined technological challenge. Government was the sole customer and was willing to pay essentially any price to achieve the desired outcome. By contrast, the effort going forward requires targeted, limited government interventions at *appropriate points* in an energy innovation *value chain* that culminates in new consumer choices based on competitive cost and performance.

Fortunately, there are some encouraging signs of progress.

First, the federal government has provided clear and consistent support for basic science research for at least a decade now. Recent administrations have endeavored to increase federal expenditures for basic research even in the face of pressure to reduce spending.

Second, the current administration is taking specific steps to focus the DOE's basic science programs on technology challenges with high economic and environmental returns, while simultaneously improving links with the engineering community. These steps can improve the likelihood of achieving transformative scientific breakthroughs.

Third, Congress has recently authorized new efforts, such as the Advanced Research Projects Agency-Energy (ARPA-E), to translate early-stage science and engineering work into products with commercial potential. The federal loan guarantee program enacted in the bipartisan Energy Policy Act of 2005 issues loan guarantees to energy projects and advanced manufacturing facilities that could not otherwise secure financing. In our view, both programs face challenges but are directionally correct.

A common feature of these programs is that they attempt to address specific hurdles or "pinch points" in the energy innovation chain. Going forward, the government's key role should be to help fill gaps and address missing links along this chain.

THREE PRINCIPLES TO GUIDE FEDERAL INNOVATION ACTIVITIES

Building on our own private-sector experience and looking across the many examples where government has succeeded — and failed — in its efforts to support energy innovation, three simple principles emerge:

First, the federal government needs to focus its efforts on specific market failures in areas that can make a significant impact on strategic priorities.

The most significant market failures for energy technology center on the difficulty of finding adequate private-sector support for basic research, early pilot demonstrations (in the case of capital-intensive projects), and first-of-a-kind commercial deployment for new technologies. Private companies are deterred from basic research and early pilot demonstrations because they don't quickly earn adequate returns and can't prevent their competitors from also capturing some of the commercially valuable knowledge gained through these investments. When financing first-of-a-kind technologies, the risks are too great for traditional infrastructure investors to bear while the costs are too large for technology investors.

The federal government should intervene in those areas where a significant gap exists between national priorities and unaided private-sector outcomes. Focusing on specific steps in the value chain where the market falls short is likely to be more successful than trying to develop solutions from beginning to end. This kind of staged approach to investment demands private-sector involvement to (1) provide important market discipline, (2) reduce the potential waste of taxpayer resources, and (3) ensure that the government plays a constructive role at each stage.

Ursula Burns

Chairman and CEO, Xerox

Making clean energy technology a widespread commercial reality requires more than just invention. It requires a complex optimization along the dimensions of performance, manufacturability, business model, markets, supply chain, ease of adoption/user experience, and low cost. The key to achieving this complex optimization along all dimensions is collaboration among different players in the innovation ecosystem, from government agencies and large corporations, to startups and universities. By incorporating PARC in 2002 as an independent subsidiary that is in the business of open innovation with numerous clients in this ecosystem, Xerox helped create at PARC a new model for R&D partnerships. This model facilitates the kinds of strategic collaborations that are needed in energy — and other domains — to leverage the strengths of partners, reduce risks, and fill in gaps for what's needed to accelerate breakthroughs to market.

I'd like to share a specific example of a collaboration where U.S. government support catalyzed PARC's strategic relationships with an innovative startup, allowing PARC to apply capabilities originally developed for Xerox to key challenges in innovation.

Recently, PARC partnered with SolFocus, Inc., a solar concentrator startup that was incubated at PARC where it grew to 50+ employees and began its first commercial deployments. Based on its in-depth and longstanding work for Xerox in optics for laser printers, PARC was able to provide breakthrough, manufacturing-friendly optical design concepts to SolFocus. However, the ability to achieve the necessary cost and reliability performance for the SolFocus systems would not have been possible without the U.S. government's National Renewable Energy Laboratory (NREL). Throughout SolFocus' development phase at PARC, NREL provided expert guidance in solar cell performance and efficiency, as well as early reliability testing of the critical mirror and packaging approaches. These inputs from NREL were vital to insure that the products would have the necessary performance and lifespan once deployed in the field.

Effective partnerships like these are the only way clean energy technology can become a widespread reality.

Effective partnerships like these are the only way clean energy technology can become a widespread reality.

A focused approach also means pulling back from technologies that do not show the same rate of improvement or promise, or where existing markets are already delivering continued progress.[12]

Second, the federal government should catalyze private-sector competition by providing incentives aligned with strategic goals.

Having identified targeted, strategic investment areas, government should then invest in these areas with the primary goal of *fostering increased competition among energy innovators and technologies*. The goal should be to correct market failures, but to do so by investing in multiple technologies and multiple competing approaches that show real and meaningful potential. This will create competition on multiple levels and maximize the likelihood of ultimate technical success.

Government should also base its investment goals on long-term, strategic — and potentially high-payoff — priorities, recognizing that some short-term technology gains can have significant positive impacts over time. This approach will both stimulate competition and leave room for multiple types of innovation.

To facilitate competition among technology, the federal government should take a portfolio approach to energy innovation investments — one that balances technology pathways and risks. Within its investment portfolio, DOE should also strive to institutionalize the ability to take risks. Incentives to "lowball" goals and metrics for fear of missing a target or losing funding should be minimized; some failure is required to achieve significant technology gains. Moreover, the federal government should be technology-agnostic as long as one or more innovations achieve the price and performance goals required to meet national objectives.

Third, the federal government should use the most cost-efficient actions to facilitate positive outcomes.

In the current restrictive budget environment there will likely be fewer funds for all technology areas, including energy. The federal government should seek maximum leverage in using its resources to achieve public objectives, ideally identifying those interventions where a small government action can significantly increase private market activity.

The most highly leveraged form of government support for innovation often focuses on fostering entrepreneurial activity and reducing barriers to innovation. Common examples include intellectual property protection, sound anti-monopoly policy, immigration policies that attract the best and brightest to the country, and structural market changes. For example, the reorganization of telecom markets in the 1990s led to massive innovation and investment in fiber and wireless networks. Similarly, energy markets could be restructured to encourage more advanced clean energy options.

Where direct government funding is required, federal agencies should strive to make their investments go as far as possible. To that end, they should focus on rigorous peer-review processes and competitive funding options that, when possible, attract private-sector participation and co-investment. As a general rule of thumb, the proportion of private-sector investment should increase as a technology approaches commercialization. DOE currently leverages its funding by requiring private-sector cost sharing but additional mechanisms should be explored and tailored to specific technology needs.[13]

Predictable government regulations also create appropriate long-term incentives for innovation without requiring federal dollars. For instance, many state and national energy efficiency standards have systematically driven technology improvements without direct government funding. As a result of performance-based standards, new refrigerators sold in 2007 use approximately 70 percent less electricity than those sold 30 years earlier.[14] In general, performance-based regulations that set goals or rules and rely on private-sector firms operating in a competitive environment to find the best ways to meet them consistently drive innovation.

In sum, programs and policies that allow the country to make technological progress and meet national objectives with relatively small direct investments should be prioritized, improved and expanded.

RECOMMENDATIONS TO STRENGTHEN U.S. LEADERSHIP IN CLEAN ENERGY INNOVATION

Building on the recommendations we first outlined in *A Business Plan for America's Energy Future*, we have identified a suite of policies and programs that could strengthen our nation's energy innovation capabilities. As we have stated in the past, we strongly recommend making healthy investments in energy innovation activities across the continuum of science, engineering and early commercialization. More specifically, drawing on the three principles described above, the recommendations below are part of an overall approach that we believe is necessary to advance our country's innovation capacity.[15]

RECOMMENDATION 1: Develop and implement a comprehensive, government-wide Quadrennial Energy Review (QER)

As we recommended previously, the nation needs a robust National Energy Plan to serve as a strategic technology and policy roadmap. As we noted then, DOE's strategic planning process and individual technology system roadmaps have only partially addressed the need for strategic clarity.

Importantly, such a plan should pinpoint key market failures and technology chokepoints in order to better orient federal programs and resources.[16] It should be based on rigorous analysis and should incorporate critical stakeholder input. With help from the private sector, the plan should identify critical gaps in the innovation chain and establish goals and effective partnerships to align the capacities of the public and private sectors and move technologies to market.

The President's Council on Science and Technology recently recommended developing a QER to provide a clear, integrated road map with short-, intermediate-, and long-term objectives for federal energy technology programs, along with a structured, time-bound plan to get there.[17] DOE is already implementing a Quadrennial Technology Review (QTR) that, in addition to summarizing the current status of selected energy technologies, aims to describe program goals, engage private-sector stakeholders and identify important RD&D policies and levers. Such a road map has important precedents. In national security, the Quadrennial Defense Review lays out a

Tim Solso

Chairman and CEO, Cummins Inc.

Consistently innovating in energy technology requires pairing top engineering talent with world-class research and development facilities and expertise. Public-private partnerships play an essential role. Well structured partnerships accelerate the development of new and improved technologies, including the clean engines and components built at Cummins.

For instance, Cummins currently is partnering with several private firms — including PACCAR Inc., Eaton Corporation and VanDyne SuperTurbo Inc. — and Oak Ridge National Laboratory and Purdue University — on a project under the Department of Energy's SuperTruck program to significantly improve freight efficiency.

The SuperTruck program combines public and private expertise and resources to advance fuel efficiency technology for Class 8 tractor trailers. The goal is to make significant efficiency gains and provide real fossil-fuel savings by fostering innovative advances in diesel engines, cab and trailer aerodynamics and engine idle management. This will be accomplished through a comprehensive, system-based approach.

Cummins and its partners received a $39 million award from the DOE under this program and are matching these funds dollar for dollar — an example of how public resources attract private sector investment and participation. When the technologies developed under the project are fully deployed, the engine efficiency improvements alone are projected to reduce fuel consumption for on-road heavy trucks by over 20 percent. Over 5 years, the fleet would see a reduction of more than 73 million tons of CO2 — equivalent to converting 13 million passenger cars to zero emissions. This initiative demonstrates how DOE brings public and private entities together and incents them to deliver innovative technology results.

Government and the private sector successfully work together through such thoughtfully crafted public-private partnerships, and these initiatives should be expanded going forward.

long-term strategy that both the public and private sector can plan around. Elements of the QDR's success include providing clarity around long-term outcomes, driving alignment across multiple stakeholder groups, opening up Department of Defense (DOD) technology assumptions to outside scrutiny, and using a portfolio approach to balance investments.

We support DOE's QTR process, which we see as an important and meaningful first step toward developing a national energy strategy consistent with our own call for a National Energy Plan. The federal government should build on the QTR and move quickly toward a government-wide QER.

RECOMMENDATION 2: Support "innovation hubs"

In our 2010 report we called for greater resources to be concentrated at "centers of excellence." We believe this concept has much in common with DOE's effort to establish "innovation hubs" and other collaborative innovation models.

Experience has shown that concentrated research centers can drive technologies down all three phases of the innovation "learning curve" by:

- Funding and organizing R&D projects that can lead to technology breakthroughs;
- Providing equipment and lab space to test the viability and scalability of new energy technologies; and
- Securing partnerships to collaborate and share intellectual property with the aim of bringing new technologies to market.

The geographic concentration of highly technical companies—as occurred in Silicon Valley due to early federal spending on defense and space exploration—encourages concentrated talent, the exchange of ideas, and the creation of new technologies and ventures. To this end, we strongly support the direction of DOE's *Innovation Hubs*, *Bioenergy Research Centers* and *Energy Frontier Research Centers* and believe they should receive full funding.

RECOMMENDATION 3: Support and expand ARPA-E

As we have noted previously, ARPA-E offers a stark contrast to the historic DOE structure in that it brings together experts from across the technology development spectrum. The creation of ARPA-E demonstrates a new commitment to working more flexibly within DOE to achieve technology goals. While it is too early to expect transformative technical successes from embryonic ARPA-E programs, the leadership team at ARPA-E has already marked several milestones:

- Investing in high potential projects;
- Successfully attracting talent from the private sector and academia;
- Creating an "open architecture" organizational design that is well adapted to meeting current program needs; and
- Developing processes that support transparency and enhanced coordination with the private sector.

ARPA-E challenges and empowers innovators across a range of technology pathways. This has made it possible to leverage federal dollars with private-sector exposure and, in many cases, follow-on capital. By nearly all accounts, it appears that ARPA-E is being managed as a highly efficient, risk-taking, results-oriented organization. In short, ARPA-E exemplifies the principles laid out in this report.

We originally called for $1 billion in federal funding to support ARPA-E. We maintain that this funding level should be the goal over the coming decade and resources should move to this level as quickly as they can be efficiently and effectively expended. At a minimum we believe that ARPA-E should receive $300 million per year—its authorized budget—at the expense of other DOE programs, if necessary. Going forward, investments in ARPA-E should be prioritized and increased. We believe this new agency represents one of the best investments the federal government can make.

We believe ARPA-E represents one of the best investments the federal government can make.

Norm Augustine

Former Chairman and CEO, Lockheed Martin

My ten years in government were among the most rewarding of my career — but I must confess that I am not a fan of big government. It was my observation that government is often at its best when it is helping the private sector do those things that the latter can't undertake on its own: pursuits that are clearly in the public interest but where the fruits of those pursuits may not accrue to their underwriters and performers or where those pursuits entail high risks and unduly large investments or extend over a prolonged period of time. In such cases, relatively modest government investments can be used to benefit the citizenry as a whole.

Investors often refer to a "Valley of Death" which new initiatives often have to transit. I tend to think of not one but two such valleys; the first when an idea offers considerable promise yet retains substantial risk of technical failure; and the second when the idea's basic feasibility has been proven but its economic viability at scale is still uncertain. These are the tipping points where constructive government intervention can make all the difference. And these are the points when leaders, government and private sector alike, must think out of the box and persevere in the face of considered risks.

For instance, in the aerospace portion of my career, I observed many of our nation's greatest aerospace inventions — Hubble Space Telescope, Reconnaissance Satellites and Polaris, to name a few — suffer major early failures only to overcome setbacks and ultimately achieve success. In each of these cases cooperation between government and the private sector — to find creative solutions and overcome difficult technical challenges — eventually produced positive outcomes.

Only by creating win-win partnerships between government and the private sector that encourage American ingenuity and perseverance can we hope to solve such societal challenges as providing clean, affordable, sustainable energy, assuring national security, protecting the natural environment, and maintaining a strong economy.

Cooperation between government and the private sector — to find creative solutions and overcome difficult technical challenges — eventually produced positive outcomes.

RECOMMENDATION 4: Make DOE work smarter along the ARPA-E model.

Even with the best policy tools to promote innovation, government programs can fall flat without nimble, high-performing, risk-tolerant federal agencies. DOE has a critical role to play and will need to evolve beyond its current program structure and culture to be maximally effective.

DOE's oversight of energy is currently organized around specific technologies (e.g., renewable energy, fossil energy, nuclear energy) and functional aspects of the system (e.g., electricity delivery and reliability, energy efficiency). The result is a classic "stovepipe" organizational structure that suffers from well-understood challenges in terms of information sharing and internal budget competition. To be maximally effective in the current energy market, the federal government — particularly the national labs and the offices within DOE that fund and direct RD&D — must operate more nimbly and strategically.

DOE is making important strides in this area, but there is more to be done. We argue for "ARPA-izing" a larger portion of DOE and the national labs by expanding some of the new authorities, tools and processes embodied by ARPA-E.

Beyond "ARPA-izing" a larger portion of DOE, a number of steps should be taken to improve the overall effectiveness of the agency:

- **Focus more on overall program success than on individual project success and emphasize the value in calculated risks.** Such an approach would build in greater ability for DOE to accept and manage risks and allow some projects to fail even as others succeed.

- **Focus on the role of program managers.** While various organizational taxonomies could provide alternatives to the existing stovepipe program structure, we contend that talent management is ultimately more important than organizational structure. Outstanding employees can overcome suboptimal organizational arrangements, but even the perfect organizational structure — if it lacks talent — will still underperform. Hence, DOE's talent management system should focus on (a) recruiting world-class program managers from academia and the private sector and (b) establishing first-rate training and mentoring programs for existing employees. DOE should be empowered to implement fast-track hiring procedures and assiduously review both managers' and employees' performance and contribution to programmatic goals. The highest performers should be rewarded with both financial and non-financial incentives; poor performers must be dealt with appropriately and quickly.

- **Align the internal structure.** DOE is beginning to drive much greater alignment across its offices and programs. For instance, DOE's SunShot initiative aims to ensure that all DOE's solar innovation activities — from the Office of Science through ARPA-E, the Office of Energy Efficiency and Renewable Energy (EERE), and the loan guarantee program — are well aligned. While it is too soon to determine if these efforts will be effective, we believe they are directionally correct. DOE should continue to improve the alignment of cross-departmental efforts — from the national labs and Office of Science to the applied and commercialization programs — as a way to eliminate redundant projects and ensure a tight hand-off across the innovation value chain.

- **Employ rigorous and transparent peer reviews.** The need for rigorous program and project reviews may seem obvious, but tricky issues often arise in execution. For example, in an effort to prevent conflicts of interest or the appearance of conflicts, DOE will often exclude all professors from a particular university from participating in the outside review of proposals submitted in response to a DOE funding solicitation if even one professor from that same university has submitted a proposal. Carried to extremes, such policies

To be maximally effective in the current energy market, the federal government must operate more nimbly and strategically.

can unnecessarily narrow the pool of qualified outside experts available to review proposals. While it is important to avoid conflicts of interest, that goal must be weighed against the benefits of seeking the most qualified individuals to participate in peer review. We believe rigorous disclosure and transparency requirements can provide adequate safeguards against potential conflicts of interest in most cases.

- **Cancel non-performing projects.** Projects that receive federal support must be continually monitored to assure that goals and deadlines are being met and that failing projects are not allowed to linger. Although DOE currently employs stage-gate assessments and has the ability to terminate projects, it has encountered difficulty in canceling failing projects. DOE must empower managers and provide the necessary leadership to make these critical decisions. Though it may be difficult to admit that a selected project is not going to succeed, doing so and then taking action to stop funding so that resources can be re-directed to more promising alternatives is critical, particularly given the current fiscal imperative to accomplish more with less.

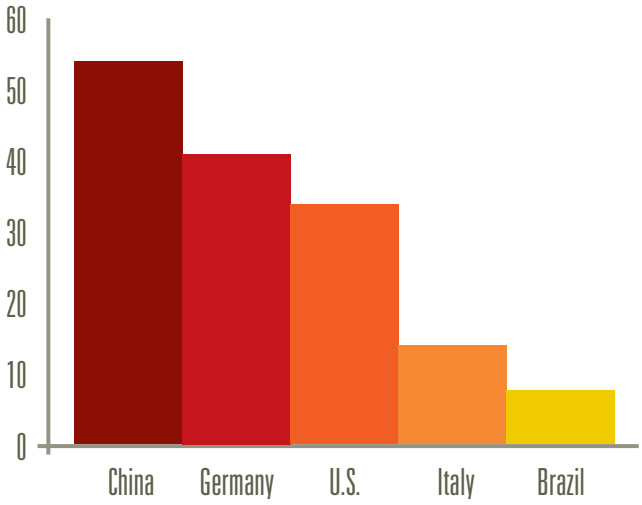
RECOMMENDATION 5:
Develop a first-of-a-kind technology commercialization engine along the lines of the proposed Clean Energy Development Administration (CEDA).

Our previous report called for a new government-backed institution dedicated to overcoming financing hurdles for advanced energy technologies. Its specific mission would be to mobilize significant private-sector capital to buy down the risks of emerging technologies and fill financing gaps so that these technologies can bridge the transition from demonstration to commercialization (in the relevant literature, that transition is often referred to as the "valley of death"). Currently, our country's energy innovation system still lacks a successful, repeatable, technology-neutral mechanism to finance, build and demonstrate unproven, large-scale energy facilities.

To effectively accelerate the demonstration and subsequent deployment of competitive new technologies, a new government-backed financing institution should build off the successful elements of DOE's loan guarantee program and be carefully structured around the following principles and design features:

Figure 6

Top 5 Countries in Clean Energy Financing, 2010



Note: Data includes the following investments: venture capital/private equity, public markets, asset finance, and small distributed capacity. Private and public investment in R&D is excluded.

- **Independence.** The kinds of projects that will require financing support will typically involve complex technology and span multi-year construction periods, both of which increase project financing risks and costs. This means the new institution must have sufficient autonomy to take calculated risks, without political interference. Creating a culture that tolerates risk, and even some failures, is essential.

- **Private-sector co-investment.** Substantial private-sector participation is required to reduce the institution's capital requirements and help ensure that new technologies eventually meet the test of competing in real-world markets.

- **Strong public- and private-sector expertise.** The financing institution should have the authority to use scientific experts from government agencies to provide technical evaluation while seeking advice from business experts in the private sector concerning the commercial aspects of potential investments. Similarly, the financing

institution should adopt flexible hiring practices to attract highly-skilled technical experts, investment professionals, and scientists.

- **Flexibility to offer financing products based on market gaps.** The institution should have broad flexibility in the types and terms of financial instruments it employs to address the specific market failures that apply to each target investment. It should also have strict, short deadlines for conditional acceptances or rejections to speed development and reduce bureaucracy so that its financial products are attractive to the private sector.

- **Governance and oversight.** A diverse board of directors should provide guidance on priorities and best practices, while ensuring that the institution adheres to its organizational mission, operating principles, and strategic objectives.

- **Self-funded.** The new institution should strive to be self-funding after an initial public capitalization, meaning that on an ongoing basis it should be funded to the extent possible by financing fees and by returns on profitable investments.

- **Portfolio investment approach.** The institution should strive to create a diversified investment portfolio, focused primarily on clean energy technologies with breakthrough potential. Additionally, the Office of Management and Budget (OMB) and the new institution should jointly develop a methodology to score investments at the portfolio level.[18] This would allow the new institution to operate more nimbly and be evaluated on the overall performance of its investments—in contrast to DOE's Loan Guarantee Program, which is scored on a project-by-project basis.

- **Transparency.** Decision processes, selection criteria, and investment results should be published to provide feedback to the private sector and reduce the perception that projects are being selected on the basis of partisanship or favoritism.

A number of recent proposals have been introduced in Congress to create a "green bank" along these lines. Currently, there is some momentum in the Senate behind legislation to establish a new energy financing institution called the Clean Energy Deployment Agency (CEDA). We believe the CEDA legislation aligns with our original recommendation to create an institution to finance and build at-scale, advanced energy technologies and could be implemented in a way that encompasses the design elements enumerated above. We believe greater success in this area could have profound implications for energy markets over the coming decade and for U.S. competitiveness in the global market.

THE NEED FOR SMART FEDERAL PROGRAMS

We believe it is critical that the United States pursue a strong strategy to lead in the global race to develop new energy technologies. With China and other trading competitors poised to build more energy infrastructure in the next 15 years than the United States has built in the last 100, our nation faces a significant challenge in maintaining a place at the forefront of a multi-trillion dollar effort to transform the world's energy systems and develop new, high-value industries. Meeting this challenge will require smart government intervention to overcome specific technology hurdles and close specific market gaps.

While we continue to believe that the situation requires increased federal investment in energy RD&D, ramped up over an appropriate period of time and offset by spending cuts elsewhere in the federal budget, we understand that DOE and the rest of the federal government will need to demonstrate improved performance to justify a greater commitment of public resources. We are confident that applying the principles and recommendations outlined in this report will help establish credibility with Congress, the marketplace, and the public and earn the additional resources needed to advance the energy innovation enterprise.

Chad Holliday

Chairman, Bank of America
Former Chairman and CEO, Dupont

In order to bring down the costs of clean energy technologies and create robust domestic supply chains that generate economic growth and new jobs, the country needs to scale clean energy technologies here at home. Achieving rapid growth in clean energy will require constructive partnerships that enable the public and private sectors to work together effectively and leverage the unique strengths of each. At Bank of America, we recently worked with two other companies — Prologis and NRG Energy — and the U.S. Department of Energy to put together a first-of-a-kind deal called Project Amp that will do exactly this.

Project Amp is a large-scale distributed solar generation project that will finance approximately $2.6 billion of commercial rooftop solar installations, producing 733 megawatts (MW) in 28 states across the country. More than sheer size, this deal is unique in several ways — it will be the first distributed solar deal to:

- **Sell all of its power back to the grid through local utilities;**
- **Receive a credit rating and raise long-term debt; and**
- **Use a new, repeatable financing structure developed by Bank of America that can foster subsequent 'gigawatt-scale' solar projects.**

Taken together, these "firsts" are bringing down technology costs and changing the way the market views solar power.

But none of this would have been possible without the help of the federal government. By backing the deal with a partial loan guarantee — which lowered the project's overall financial risks — the government enabled us to put this transformative deal together in what has been a fragmented and underserved segment of the energy market. Moreover, with the government's help, we were able to finance the project almost exclusively with private sector capital. Each $1 set aside by the DOE to cover the guarantee will support roughly $20 in private investment in clean energy development.

Although there were some challenges early in the process, this project demonstrates how small actions by the public sector can catalyze significant private-sector investment.

This project demonstrates how small actions by the public sector can catalyze significant private-sector investment.

Chapter Three:

How can the U.S. Government pay for energy innovation in a new era of fiscal austerity?

Here we turn to the third question and explain how the federal government could pay for a robust energy innovation enterprise, especially in light of America's current budgetary dilemma.

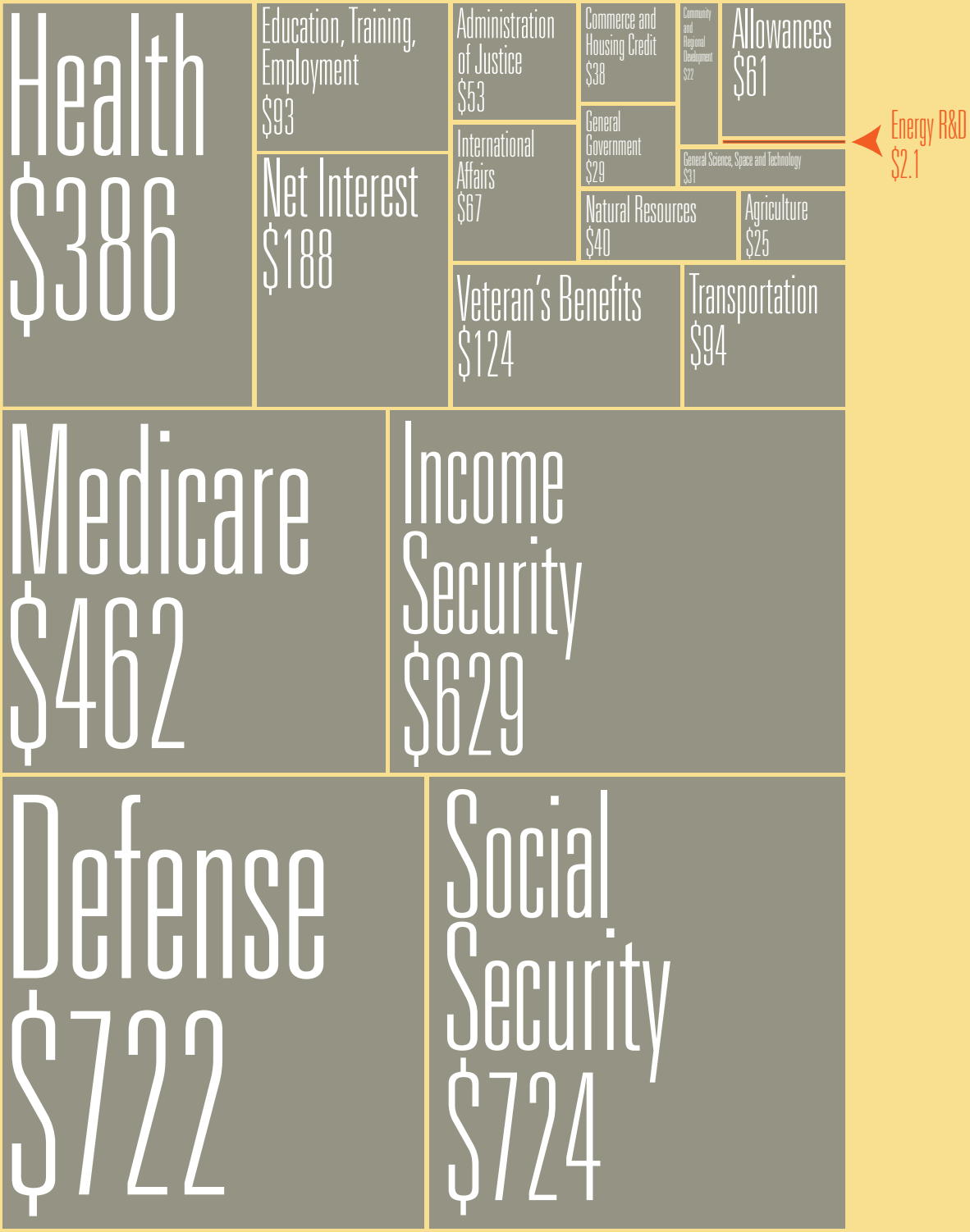
PAYING FOR AN ESSENTIAL INVESTMENT

The previous two chapters make the case for a critical federal role in supporting energy innovation and suggest ways to organize government efforts more effectively. Here we turn to the question of how the federal government could pay for a robust energy innovation enterprise, especially in light of America's current budgetary dilemma.

Previously, we argued that meaningful progress in developing new energy technologies—and capturing a significant portion of the $5 trillion global energy market—would require substantially increased investment in energy innovation. Indeed, there is no way to make the progress this country requires without increasing federal support for energy innovation across the entire innovation continuum. Levels of clean energy RD&D investment must be brought closer to the levels typical of other technologically-intensive sectors and must relate to the size of the U.S. energy market and its importance in driving the U.S. economy.

Figure 7

2010 Federal Budget
$3.60 Trillion (in billions)



In our original report, we called for a three-fold increase in annual energy innovation investments, spanning early stage R&D to early commercialization of large-scale advanced energy facilities. Numerous organizations — from both ends of the political spectrum — have studied energy innovation spending and all agree that significant increases in funding are necessary to fill the pipeline with science, material, and systems gains that can lead to the clean energy technologies of tomorrow.[19]

To be sure, the situation demands a combination of public and private resources and money is not the only solution. But without bringing energy investments to a level that is commensurate with the scale of the industry and with the scale of the national priorities that are at stake, we are unlikely to make the progress our country needs.

We maintain that significantly increased investments in energy innovation should be our country's target over the next decade.

At the same time, the AEIC fully understands the gravity of the nation's current fiscal situation. Serious concerns about the mounting federal debt and budgetary deficits have led to a legitimate and urgent focus on our country's long-term fiscal health. The current estimate of the federal budget deficit for 2011 is $1.3 trillion, and by the end of this fiscal year the Congressional Budget Office (CBO) has projected that debt owned by the public will be more than $10 trillion.[20] While some progress may be made on identifying further deficit-reduction measures in the coming months, few expect that the country will quickly put its fiscal house in order. Pressures to reduce government spending will continue to be a strong influence on policymakers.

However, even in these challenging fiscal times, we believe underfunding energy innovation would be a grave mistake. U.S. consumers continue to send close to $1 billion overseas every day to feed our country's oil appetite, yet both the private and public sectors continue to shortchange the very RD&D investments that offer the best path toward reducing these outflows. The country can't afford to only spend its resources on consumption; it must make smart investments in activities that collectively will result in significant returns in the future.

Today, as lawmakers debate how to bring our nation's debt under control, we believe it is critical to support energy innovation budgets. To be clear, supporting innovation budgets is an investment, not a cost. The country needs to bolster its energy innovation infrastructure to attract and support the best scientific talent and drive competitive growth. As one AEIC member puts it: "In a time of austerity, the last thing one should do is under-fund R&D and high technology priorities…to do so is the equivalent of removing an engine from an overloaded aircraft in order to reduce its weight."

As business leaders, we have all faced tough budgetary decisions throughout our careers. In lean times, each of us has been tasked with cutting back and reorienting investments. These decisions are never easy, but we have always critically assessed and targeted funding cuts, being especially careful to preserve, and in some cases even increase, funding for activities that have the potential to drive future growth. Across the board reductions rarely make sense. Although innovation-based investments often will not show immediate returns — in fact, many take years to pay off — history has shown that the payoffs to successful investments are usually large.

In short, we see an urgent need for a new energy innovation funding regime that accounts for current budgetary realities, but still ensures that our nation makes targeted investments in its energy future. This will be no easy task. Creating a dedicated, consistent stream of federal dollars that is not beholden to the volatility and uncertainty of the annual appropriations process is a common but elusive goal for many interests. For too long,

federal energy innovation investments have been plagued by unpredictable funding patterns. Uncertain annual appropriations, short-term tax credits, and one-time spending injections are all unsuited to creating the sustained, predictable funding stream needed to bolster the country's innovation infrastructure.

Going forward, in general and when possible, we believe federal energy innovation investments should originate from revenues from the energy sector itself rather than from general federal revenues. We believe this step is essential to modernize the nation's energy systems and to attend to the long-term national security and environmental vulnerabilities we face.

While the political obstacles are daunting, **a variety of mechanisms could be employed to generate the needed revenue from within the energy sector**. Options include diverting a portion of royalties on domestic resource production, reducing or eliminating current subsidies to well-established energy industries (and redirecting the savings), collecting a charge on sales of electricity, levying fees on other energy or pollution sources, and streamlining DOE. While we don't advocate for any specific option, based on our assessments, these options could provide funding offsets to support investments in energy innovation commensurate with our original recommendations.

DOMESTIC ENERGY PRODUCTION

The U.S. has an abundance of natural resources, including sizable oil and natural gas reserves. The energy sector is an enormous revenue generator for the government, which collects a variety of taxes and fees from the many companies that produce, refine, and deliver energy to consumers and businesses. Going forward, any expansion of domestic production offers an opportunity to reevaluate the revenue sharing associated with the extraction of U.S. natural resources.

With continued, and likely expanded, off-shore oil and gas exploration, shale gas production on federal lands, and enhanced oil recovery in the coming years, reorienting a portion of the current suite of domestic energy production

Bill Gates

Chairman and former CEO, Microsoft

America is the world leader in pharmaceutical and medical innovation. It's easy to see why.

Over the last 100 years, the U.S. National Institutes of Health (NIH) has funded groundbreaking medical research leading to discoveries that have dramatically increased the lifespan of Americans, reduced the death rate from cancer and heart attacks, and proven the value of preventive health care.

We can and should play a similar role in new energy technologies.

We are in critical need of a government commitment to research into new energy technologies that can free us from our dependence on foreign oil, create affordable clean-energy alternatives, and slow the rate of global warming.

Yet, today, the U.S. government spends only one-sixth as much on energy innovation as it does on medical research.

At Microsoft, we saw R&D investment as fundamental to our success. Throughout the high-tech sector, R&D investment represents a sizeable percentage of operating budgets. It is essential to fueling innovation and remaining competitive.

Understandably, people ask why the private sector can't fund the necessary research into energy alternatives. Fundamentally, we can't rely on the marketplace alone to address a critical national interest. No matter how well intentioned, utility companies and other private investors simply are not going to invest deeply in the kind of R&D needed to create scalable, low-carbon energy innovations.

We have seen time and again the catalyzing role the federal government can play in technological breakthroughs — GPS, the Internet, and commercial aviation to name a few — with important societal and economic benefits. Today, there is no more important issue deserving of increased government research funding than clean energy.

fees — including royalty payments, lease sales, bonus bids and other charges — presents a real opportunity to raise new revenue for the federal government that could fund innovation in new energy technologies.

Former Senators Trent Lott and Byron Dorgan, co-chairmen of the Bipartisan Policy Center's Energy Project, recently proposed using a small portion of the revenues from expanded oil and natural gas production to fund alternative energy investments. Other recent proposals in Congress have suggested expanding domestic production and putting some of the revenue generated in a trust fund that would be used to support clean energy development.

Currently, a dedicated portion of oil and gas royalties support innovation activity in the oil and gas industry. The Energy Policy Act of 2005 established a Royalty Trust Fund that receives a small share of federal oil and gas royalties for research on advanced exploration and production technologies and environmental protection. Research is managed by a nonprofit public-private consortium that operates with DOE's approval. Similar fund and research structures could be established for clean energy innovation.

Because future royalties and other fees depend, to a large extent, on actual production from new areas, predicting the revenue impacts of new production is speculative. However, over the past ten years, oil and gas royalties have generated approximately $11 billion per year, 60 percent of which goes directly to the Treasury. Going forward, a portion of revenues from domestic resource extraction could be dedicated to clean energy technologies.

Federal revenues from domestic oil and gas production could generate on the order of $1–$5 billion dollars per year.[21]

REDIRECTED ENERGY INDUSTRY SUBSIDIES

Numerous state and federal programs have evolved over the years that subsidize particular energy sources or technologies. Energy subsidies come in a wide variety of forms — direct expenditures, tax expenditures and controls, among others — and are estimated to cost the government tens of billions of dollars each year. A recent conservative estimate by the Energy Information Administration is that oil, gas and coal — all mature industries — received over $4.2 billion in subsidies in 2010.[22] Tax credits for ethanol — also a mature technology that simultaneously benefits from a mandatory production requirement — cost taxpayers an estimated $5.7 billion in 2010. Similarly, renewable electricity technologies received over $6 billion in public support last year (including R&D, although R&D activity constituted only a small portion — $632 million — of this support). Nearly every energy industry is subsidized in one form or another. The time has come to rethink where these subsidies go and how they are delivered.

Moreover, in the context of broader fiscal reform, the elimination of long-standing federal subsidies to well-established commercial technologies or industries appears to be gaining bipartisan political support. In both the House and Senate there have been proposals to eliminate a number of energy subsidies — including those for oil, gas and ethanol.[23] We applaud efforts to critically examine the current suite of energy subsidies, which should be used in a targeted fashion and only for a limited period of time to allow new technologies to scale up while driving down costs.

To this end, subsidies to incumbent industries and mature technologies should be reduced or reformed. The market provides ample incentives for these players to deploy

We see an urgent need for a new energy innovation funding regime that accounts for current budgetary realities, but still ensures that our nation makes targeted investments in its energy future.

technology without public support. For other technologies that are still in the earlier and more risk-prone stages of commercialization, the federal government should begin to explore a greater number of competitive subsidies, like reverse auctions, that could squeeze the most value out of every public dollar dedicated to these issues.[24] Going forward, a portion of revenues liberated by eliminating, reducing or reforming energy subsidies should be directed to clean energy innovation.

Reducing or eliminating subsidies and tax breaks for mature industries has the potential to raise on the order of $5–$10 billion per year.[25]

CHARGE ON ELECTRICITY

The term "wires charge" (also sometimes referred to as a "public goods charge") refers to a small fee imposed on each kilowatt-hour of electricity delivered to consumers. It is a fairly common levy at the state level where it is typically used to promote energy efficiency, fund research and development, or pursue other public purposes. The fee is collected by electricity suppliers and is generally kept fairly small — less than one-tenth of one cent per kilowatt-hour, for example. This limits the impact on individual consumers, but because of the large volume of electricity sold, generates significant revenue. For instance, if a 0.1 cent-per-kilowatt-hour wires charge had been applied to all retail electricity sales in 2010, a total of 3,749,985 million kilowatt hours sold nationwide — it would have raised more than $3.7 billion last year alone. Moreover, the impact on the average residential electricity consumer would have amounted to about $1 per month.[26]

Additionally, there are various ways to adjust the wires charge formula. For example, the charge could be imposed only on electricity generated using incumbent fossil energy sources such as coal, natural gas, and oil. A nationwide "wires charge" was proposed in 2008 and 2009 as a method of funding a "Carbon Storage Research Corporation" to accelerate the commercial availability of carbon dioxide capture and storage technologies and methods.[27, 28] This proposal enjoyed bipartisan support and was projected to raise approximately $1 billion per year to fund the early deployment of carbon capture and storage (CCS) technologies.

Innovation investments must relate to the size of the U.S. energy market and its importance in driving the U.S. economy.

Moreover, similar fees to promote R&D have been authorized in the past. For example, the Gas Research Institute, prior to 2004, was funded through mandatory surcharges on interstate pipeline customers. Total funding over the lifetime of the surcharge was more than $3 billion.[29] Similarly, the Propane Education and Research Council is funded through an assessment on each gallon of retail propane at the point it is odorized or imported into the United States.

There are a number of ways to structure a wires charge. Substantial revenues could be raised to fund energy innovation programs with fairly modest consumer impacts.

A wires charge on electricity sales has the potential to raise on the order of $1–$4 billion per year.[30]

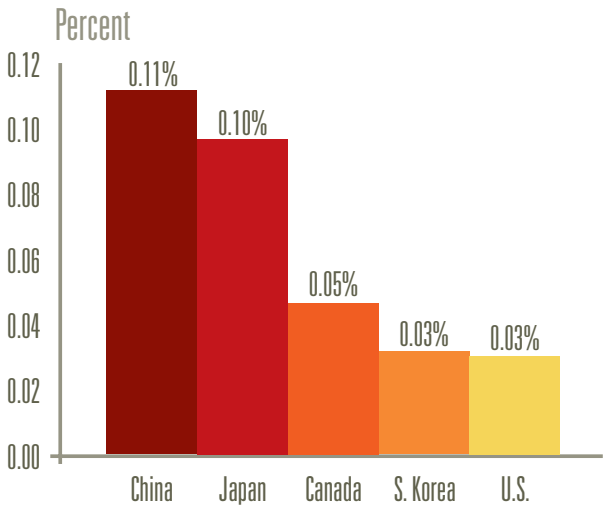
ENERGY FEES

Beyond a wires charge, there are a number of ways to levy a small fee on various energy sources that could generate significant revenues to fund new technology development. A gas tax, oil import fees, energy export fees, and even perhaps a carbon dioxide (CO2) fee are all options that could be considered.

For instance, increasing the gasoline tax would be a simple and transparent, albeit politically challenging, way to generate new revenues. The federal gasoline tax currently stands at 18.4 cents per gallon.[31] Revenues from the gas tax go to the Highway Trust Fund, which is used to maintain and expand roads and other transportation infrastructure. As a revenue-generating mechanism, the gasoline tax has multiple positive attributes: it creates incentives for

Figure 8

Public Energy RD&D Spending as a Share of GDP, 2008



Advancing new clean energy technologies is so important that federal funding for this effort should rise to the top of our national priorities.

reduced oil consumption and vehicle technology innovation, and it can generate large sums because it is extremely broad-based (roughly speaking, each penny-per-gallon of tax generates approximately $1 billion per year in revenue). Although past experience (and consistent polling) suggests that the American public is strongly averse to this type of tax, conversations about increasing the gas tax persist. The President's Commission on Fiscal Responsibility and Reform included a gas tax increase, for example. While we do not want to create competition with the Highway Trust Fund, which should continue to devote much-needed resources to our nation's aging transportation infrastructure, the addition of a few cents to the gas tax could raise billions for both infrastructure and clean energy innovation activities.[32]

Similarly, another old idea that is worth considering is the notion of imposing a fee on imported oil. Like a gas tax, an oil import fee could accomplish two national goals: reducing dependence on foreign oil, and raising revenue for the federal government, a portion of which could fund innovation.[33]

Furthermore, as U.S. domestic production increases, the country could see energy exports, particularly for natural gas, grow as well. Charging a small fee on exports could generate federal revenue while limiting impacts on domestic consumers and deserves further consideration.

Additionally, over the long-term, a fee on CO2 emissions should be considered. Although previous Congressional attempts to price CO2 and other greenhouse gas emissions failed to gain widespread support and are unlikely to gain political traction in the near-term, there are a number of ways to structure a fee for CO2 emissions that could generate significant federal revenue in the future.[34] This revenue could then be used for a variety of public purposes—reducing income taxes, paying down the debt, and funding energy innovation, to highlight a few. Moreover, compared to taxing labor or savings, charging a fee for carbon emissions has significant advantages because it creates a market incentive to reduce pollution and improve the energy efficiency of our economy. While the majority of any of the revenue generated

by a new CO2 fee should be devoted to bringing our national debt under control and to lowering other consumer taxes, a small, dedicated portion could also be used to fund federal energy innovation initiatives.

Energy and emissions fees together have the potential to raise more than $80 billion per year.

STREAMLINE THE DEPARTMENT OF ENERGY (DOE)

Although we are advocating for significantly increased investments in energy technology programs, many of which are currently housed at DOE, we recognize that the country is in a fiscal era that demands hard choices and difficult trade-offs. Policymakers will need to explore ways to streamline, and perhaps even cut, DOE programs that are non-essential in order to free up funding for technology investments that have significant potential. Numerous deficit reduction reports—including reports issued by the CBO, the Domenici-Rivlin Debt Reduction Task Force, and the President's Fiscal Commission—have highlighted options to reduce spending at DOE that were supported by previous Administrations of both political parties. We reiterate that we strongly support increased investments in DOE's energy innovation programs, but policymakers should examine options to trim other high-dollar programs in order to fund the country's energy innovation activities.

Streamlining and trimming DOE programs has the potential to save on the order of $1–$2 billion over the coming years.[35]

A TOP NATIONAL PRIORITY

Recognizing that some of the revenue options discussed in this paper are already in place and are being used to fund a variety of state and federal programs, and also appreciating that the U.S. faces an urgent need to reduce the federal debt, we understand that our leaders face hard choices about revenue and spending priorities. Nevertheless, the AEIC strongly believes that advancing new clean energy technologies is so important that federal funding for this effort should rise to the top of our national priorities. The AEIC does not advocate for one revenue option over another; the only unacceptable option is to fail to make these investments.

It would be detrimental to our country's economy and long-term competitiveness to neglect energy innovation investments.

The Administration and Congressional leaders recently reached a political compromise to address the national debt ceiling that includes steep cuts in federal spending. We understand that major federal spending reductions are needed. However, we urge Congress to cut strategically, as we do in the private sector. While belt tightening is appropriate, it is also important to support growth—protecting investments in technology innovation is critical to the nation's future.

Innovation investments must relate to the size of the U.S. energy market and its importance in driving the U.S. economy. It would be detrimental to our country's economy and long-term competitiveness to neglect these investments. In that context, increasing federal spending in energy innovation would have only a modest impact on the overall budget, but could have very large implications for our nation's future prosperity. Wise investments in a new generation of energy technologies are not only justified, but vital to our future.

Previously, AEIC called for a three-fold increase in annual energy innovation investments. We understand that this level of funding cannot be provided overnight. However, we maintain that investments of this magnitude should be our country's target over the next decade.

We have shown here that the resources to support this endeavor are available. We encourage our political leaders to secure those resources and direct them appropriately.

The Conclusion

If the U.S. successfully innovates in energy, our country stands to reap enormous benefits. Indeed, no sector is more important, economically, strategically, and environmentally, than the energy sector. If, however, the United States fails to invent new technologies and create new markets and jobs that will drive the transformation and revitalization of the $5 trillion global energy industry, we will have lost an opportunity to lead in what is arguably the largest and most pervasive technology sector in the world. Moreover we will cede the stature, the jobs and the economic strength that would accompany such leadership.

As CEOs we have direct experience with developing and implementing strategies to transform markets at national and global scales. Creating transformations in the realm of energy can be done but it will require the leadership of the federal government, partnering with the private sector.

In sum, we know the federal government has a vital role to play in energy innovation. We know the federal energy innovation system can be structured effectively to achieve real results. And we know there are several ways to pay for public investments in this domain. There are no excuses. As a country, it is time to put aside partisan differences and embark on a clear path to achieving our clean energy goals.

We call on Congress and the President to act.

ENDNOTES

1. Joseph E. Stiglitz, "Informaton and the Change in the Paradigm in Economics," *American Economic Review* 92, no. 3 (2002): 486.

Figure 1.

National Science Foundation. Federal research and development obligations, budget authority, and budget authority for basic research, by budget function: FY 1955–2011 (adjusted to 2005 USD). Arlington, VA: NSF, October 2010. Table 37. http://www.nsf.gov/statistics/nsf10323/content.cfm?pub_id=4083&id=2

2. Constitution of the United States of America, Article I, Section 8.

3. Many of us were involved in the National Academies of Science report *Rising above the Gathering Storm* which assessed the role of federal R&D in considerably more detail. That study, like many others, found that federal investments in R&D have achieved demonstrably high rates of return: "estimates of return on investment (ROI) for publicly funded R&D range from 20% to 67%." [National Academies of Science. *Rising above the gathering storm: energizing and employing America for a brighter economic future*. Washington, DC: National Academies Press, 2007.] Other, more targeted, studies have shown that federal energy innovation programs have resulted in real benefits: National Research Council, Energy Research at DOE: Was it Worth it? (Washington, DC: National Academies Press, 2001).

Figure 2.

Notes: 2007 last year available. Company spending only; does not include federal R&D, nor R&D funded by the company but contracted to outside organizations, including non-profits and research institutions. The Electric Power Research Institute (EPRI), for example, is a non-profit company that performs RD&D in the electricity sector. EPRI is funded by its members, who represent 90% of the U.S. electricity generated and delivered in the U.S. EPRI funding ranged from 333-377 million 2008 dollars from 2004–2007. Data through 1999 for SIC (Standard Industrial Classification) 49, Electric, gas, & sanitary services, then NAICS (North American Industry Classification System) 22, Utilities. Power companies predominate in the larger utility industry, accounting for about three-quarters of employment.
Sources: (1) National Science Foundation. Survey of Industrial R&D, various years.
(2) Electric Power Research Institute. Annual Report, various years.

4. National Science Foundation. *Science and Engineering Indicators 2010*. Arlington, VA: NSF, 2010. Chapter 4, Table 4-14. http://www.nsf.gov/statistics/seind10/c4/c4s3.htm

5. National Science Foundation, *Research and Development in Industry: 2006-07* (Arlington, VA: National Science Foundation, 2011), 191. Table 51. http://www.nsf.gov/statistics/nsf11301/pdf/nsf11301.pdf

6. Ibid., 130-131, Table 31 and 261. Table 68.

7. Product differentiation does, of course, drive innovation in energy end-use technologies. For example, a new car could be marketed on the basis of its fuel economy performance in addition to other attributes. The evidence suggests, however, that consumers have historically ranked energy consumption well below other attributes when making purchasing decisions.

8. Appliances are somewhat different but still face investment challenges. Energy efficient appliances, such as space heating, air conditioners, water heaters, lighting and refrigeration, typically last between 10 and 20 years, do not require large up-front investments and have payback times that are usually less than three years. Still, there is significant inertia by consumers to make these investments.

Figure 3.

Note: Includes data for latest year available — 2005 for Energy; 2010 for Pharmaceuticals; 2007 for others.
Sources: (1) National Science Foundation. Federal research and development obligations, budget authority, and budget authority for basic research, by budget function: FY 1955–2011. Arlington, VA: NSF, October 2010. Table 37. http://www.nsf.gov/statistics/nsf10323/content.cfm?pub_id=4083&id=2
(2) National Science Foundation. Science and Engineering Indicators 2010. Arlington, VA: NSF, 2010. www.nsf.gov/statistics/seind10/pdf/c04.pdf
(3) Dooley, JJ. The Rise and Decline of U.S. Private Sector Investments in Energy R&D since the Arab Oil Embargo of 1973. Pacific Northwest National Laboratory, November 2010. http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19958.pdf
(4) Pharmaceutical Research and Manufacturers of America. Pharmaceutical Industry Profile 2011. Washington, DC: PhRMA, 2011. http://www.phrma.org/sites/default/files/159/phrma_profile_2011_final.pdf
(5) Energy Information Administration. Annual Energy Review 2007. Washington, DC: EIA, 2007. Table 3.5.

9. A particularly influential voice at this time was that of Vannevar Bush, who directed the Office of Scientific Research and Development in the early 1940s and whose influential 1945 report Science, the Endless Frontier argued that basic research was the "pacemaker of technological progress." Bush's proposals eventually led to the creation of the National Science Foundation in 1950.

10. In addition to the innovations listed above, a number of innovative developments with broad societal benefits have stemmed from NASA's activities, including breathing apparatuses, school bus chasses, and robotic surgical devices, among others. This activity is documented in Douglas A. Comstock and Daniel Lockney's 2007 report: *NASA's Legacy of Technology Transfer and Prospects for Future Benefits*. <http://www.sti.nasa.gov/tto/hist_techtransfer.pdf>.

11. The Federal government has long supported energy research, development and demonstration. During the late 1970s the government invested more than $7 billion per year (2005$) in energy RD&D. From the 1980s through the mid-200s federal investment hovered around $3 billion annually. Since then, federal energy RD&D has increased slowly, excluding the one-time jump in stimulus funding.
Source: Gallagher, Kelly, and Anadon, Lauren. "DOE Budget Authority for Energy Research, Development, and Demonstration Database." Cambridge, MA: John F. Kennedy School of Government, Harvard University, 2009. http://belfercenter.ksg.harvard.edu/publication/19119/doe_budget_authority_for_energy_research_development_demonstration_database.html

Figure 4.

Source: National Science Foundation. Federal research and development obligations, budget authority, and budget authority for basic research, by budget function: FY 1955–2011 (adjusted to 2005 USD). Arlington, VA: NSF, October 2010. Table 37.

Figure 5.

Technology innovation involves a complex network of linked activities from scientific research, engineering development, and prototype demonstration to commercialization. In the past, industry participated strongly in all stages of innovation, including in the early research stages. Industrial laboratories such as Bell Labs, which invented the first workable photovoltaic solar cell in 1954, were legendary for their contributions to basic science. Structural changes in the global economy and investor requirements for return on capital have shifted the focus of most private companies to later-stage engineering and commercial-stage technologies.

12. The appropriate level of taxpayer support for existing commercial energy technologies, whether clean or conventional, is currently a matter of intense debate. While a detailed examination of energy production incentives is beyond the scope of our efforts, we are heartened that our colleagues at the Bipartisan Policy Center are engaged in such an examination.

13. For early stage R&D grants, DOE typically provides 80 percent of project funding. For project demonstrations, DOE typically provides 50:50 public-private cost sharing.

14. National Academy of Science. *Real Prospects of Energy Efficiency in the US*. Washington, DC: National Academies Press, 2010. http://www.nap.edu/openbook.php?record_id=12621&page=R1

15. In addition to the undertakings we cite in this report, we also believe that the government must continue to improve its ability to deliver on its clearly recognized responsibility to provide a strong foundation for innovative activities. These responsibilities include providing public schools that successfully educate our youth (particularly in science, mathematics and engineering), protecting intellectual capital, and attracting needed foreign talent to our country. For a more detailed discussion of ways to improve these responsibilities please see the report: *"Rising above the Gathering Storm."*

16. Specifically, we encourage the QER to coordinate robust technology linkages between the DOE and DOD to build on the strengths of each organization and avoid programmatic duplication.

17. Executive Office of the President, President's Council of Advisors on Science and Technology. *Report to the President on Accelerating the Pace of Change in Energy Technologies through an Integrated Federal Energy Policy*. Washington, DC: GPO, 2010. http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-energy-tech-report.pdf

Figure 6.

Source: Pew Charitable Trusts. Who's Winning the Clean Energy Race? 2010 Edition. March 2011. http://www.pewenvironment.org/uploadedFiles/PEG/Publications/Report/G-20Report-LOWRes-FINAL.pdf

18. OMB "scoring" is the mechanism used to assess a program's likely impact on the federal budget.

Figure 7.

Sources: (1) Executive Office of the President of the United States. *Budget of the United States Government: Detailed Functional Tables Fiscal Year 2011*. Washington, DC: GPO, 2011. Table 32-1. http://www.gpoaccess.gov/usbudget/fy11/fct.html
(2) National Science Foundation. Federal research and development obligations, budget authority, and budget authority for basic research, by budget function: FY 1955–2011 (adjusted to 2005 USD). Arlington, VA: NSF, October 2010. Table 37.

19. Sources: (1) Ogden, Peter, et al. *A New Strategy to Spur Energy Innovation.* Center for American Progress, January 2008. http://www.americanprogress.org/issues/2008/01/energy_innovation.html
(2) Hayward, Steven, et al. *Post Partisan Power: How a limited and direct approach to energy innovation can deliver clean, cheap energy, economic productivity and national prosperity* (American Enterprise Institute, Brookings Institution, and Breakthrough Institute, 2010). http://www.aei.org/docLib/Post-Partisan-Power-Hayward-101310.pdf

Endnotes

20. Congressional Budget Office. *The Budget and Economic Outlook:An Update*. Washington, DC: CBO, August 2011. http://www.cbo.gov/ftpdocs/123xx/doc12316/Update_SummaryforWeb.pdf

21. From 2001 to 2010, federal oil and gas royalty revenues have averaged just more than $11 billion per year. Excluding 2008, which saw a significant increase in federal royalties due to the release of millions of acres of new leases in Gulf waters, federal oil and gas royalties have averaged more than $9.5 billion per year. Source: Department of the Interior's Office of Natural Resources Revenue.

22. Energy Information Administration. Federal Financial Interventions and Subsidies in Energy Markets in Fiscal Year 2010. Washington, DC: EIA, July 2011. http://www.eia.gov/analysis/requests/subsidy/pdf/subsidy.pdf. This study includes the American Recovery and Reinvestment Act of 2009 and other legislation that provided an increase in federal spending, particularly for conservation and renewables programs, and appropriately caveats the findings: "Focusing on a single year's data also does not capture the imbedded effects of subsidies that may have occurred over many years across all energy fuels and technologies."

23. Senators Coburn and Feinstein have introduced a bill to eliminate the Volumetric Ethanol Excise Tax Credit (VEETC) and repeal the import tariff on foreign ethanol. The Ethanol Subsidy and Tariff Repeal Act was introduced in the form of an amendment to a small business bill in the Senate (Amendment #309, S. 493). Congressman Lance introduced bipartisan legislation, H.R. 1188, to eliminate the ethanol tax credit. A new proposal, H.R. 2307, offered by Congressman Herger, would achieve similar ends. Senator Menendez has introduced S. 940, the Close Big Oil Tax Loopholes Act, a bill that would eliminate five tax expenditures benefitting oil companies.

24. Reverse auctions are a mechanism for competitively distributing government contracts and subsidies to private entities. Reverse auctions require private firms to submit bids that stipulate the minimum price or subsidy level they would accept for a specified output.

25. Oil, gas, coal and ethanol subsidies together totaled just shy of $10 billion in 2010. Creating competitive subsidies for relatively mature technologies like wind could potentially free even more federal resources.

26. Assuming average household electricity consumption of 1,000 kWh per month.

27. H.R. 6258, June 12, 2008.

28. H.R. 1689, March 24, 2009.

29. Massachusetts Institute of Technology. The Future of Natural Gas: An Interdisciplinary MIT Study. Cambridge, MA: MIT, June 2011. http://web.mit.edu/mitei/research/studies/natural-gas-2011.shtml

30. If a 0.03 cent-per-kilowatt-hour wires charge had been applied to all retail electricity sales in 2010, 3,749,985 million kilowatt hours, it would have raised more than $1.1 billion. If a 0.1 cent-per-kilowatt-hour wires charge had been applied, it would have raised more than $3.7 billion.

31. However, its fate is currently uncertain because 4.3 cents-per-gallon of the federal gasoline tax and the current Surface Transportation Reauthorization extension are both set to expire on Sept. 30, 2011 unless Congress acts.

32. For instance, total U.S. gasoline consumption in 2010 was nearly 138 billion gallons (Source: EIA). Increasing the federal gasoline tax by 1 cent per gallon would generate approximately $1.4 billion in revenue per year. Increasing the tax by 5 cents per gallon would generate nearly $7 billion annually.

33. A fee on imports of crude and refined petroleum products at a rate of $4.00 and $5.00 per barrel, respectively, could generate approximately $7 billion annually. It should also be noted that an oil import fee would likely be challenged under the free-trade rules of the World Trade Organization (WTO). However, WTO rules allow some tariffs and fees if those are expressly designed to protect national security, public health, or the environment.

34. The CBO has estimated that a carbon dioxide tax starting at $20/ton in 2012 and increasing slowly over time would raise nearly $1.2 trillion by 2022. [Congressional Budget Office. Reducing the Deficit: Spending and Revenue Options. Washington, DC: CBO, March 2011. http://www.cbo.gov/ftpdocs/120xx/doc12085/03-10-ReducingTheDeficit.pdf]

35. For instance, CBO estimates that reducing the size of the Strategic Petroleum Reserve could save $6,200 in outlays from 2012–2016.

Figure 8.

Sources: (1) All GDP data are from: Alan Heston, Robert Summers, and Bettina Aten. *Penn World Table Version 7.0*. Philadelphia, PA: Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, May 2011. http://pwt.econ.upenn.edu/php_site/pwt_index.php
(2) Japan, Canada, South Korea, and U.S. RD&D data are from: International Energy Agency. *Energy Technology RD&D 2011 Edition*. http://wds.iea.org/WDS/ReportFolders/ReportFolders.aspx
(3) China's RD&D data are derived from: State and Science Technology Commission, *China Statistical Yearbook on Science and Technology* (2009), as cited in: Gallagher, K.S., et al. Trends in investments in global energy research, development, and demonstration. Wiley Interdisciplinary Reviews: Climate Change, Volume 2, Issue 3, pages 373–396, May/June 2011.

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