American Energy Innovation Council

RESTORING AMERICAN ENERGY INNOVATION LEADERSHIP:

Report Card, Challenges, and Opportunities

February 2015

BIPARTISAN POLICY CENTER

FOREWORD // ENERGY INNOVATION TO MEET A NEW ERA OF CHALLENGES

America's competitive advantage is a tireless dedication to innovation, particularly in energy. U.S. companies are driving an energy boom today—in tight oil and shale gas production, renewable energy, efficiency, and much else—largely because they have significantly benefited from federally funded technology innovation, research and development over the last four decades. These investments, together with critical private-sector innovations and commercialization, have created dozens of technologies vital to America's economic growth, competitiveness, and environment, such as unconventional gas extraction, advanced seismology, efficient clean engines, high-capacity batteries, natural gas turbines, and photovoltaic solar technology, among others.

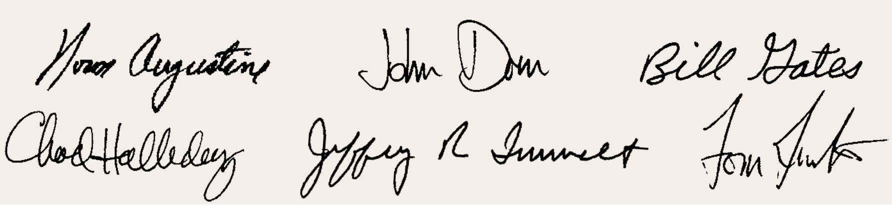
In recent years, however, many Americans and even some policymakers seem to have forgotten this connection. Since 2010, support for government energy research, development, and demonstration has languished, with appropriations remaining depressed when adjusted for inflation. In essence, we have been eating the seed corn of decades past.

This matters because, even amid a surge in domestic production, the country's energy challenges are more critical today than ever: though oil and gas prices have declined recently, affordable energy is out of reach for many households and businesses; oil and gas development requires renewed focus on sustainability; the electric grid is at risk from physical and cyber attacks and faces greater pressures to integrate growing renewable and distributed sources, even as demand growth is flat; global energy market volatility makes diversification from existing sources much harder; and climate change and international competition for energy resources become more threatening with each passing day. The provision of safe, clean, affordable, and sustainable energy is one of the most important missions for the United States. Fortunately, the nation's opportunities are vast—if we invest in them. America can transform its energy landscape, and that of the world, just as profoundly as it has in the past by creating breakthrough technologies and steadily improving existing technologies that fundamentally help solve cost, emissions, and geopolitical problems. From developing large-scale electricity storage to breakthroughs in materials science and efficiency, from next-generation biofuels to low-cost distributed power, from advances in emissions management, renewable energy, and nuclear power to unlocking entirely new energy sources yet to be tapped, the United States can achieve transformative benefits. And U.S. economic competitiveness—both in market share and in job creation—is at stake: other nations, especially emerging powers like China, have made investments to rival or surpass America's in many energy technologies.

This report evaluates policymakers' responses over the last five years to the American Energy Innovation Council's original recommendations, examining both the significant shortcomings and promising signs in America's energy technology research, development, and demonstration (RD&D) policies. The council's fundamental finding is this: the scale of federal energy RD&D investment is still just one-third of what is necessary. Federal funding remains the only viable avenue of support for energy technology research and large-scale demonstration projects. The United States must commit to greater investments in energy technology now to capture its remarkable energy promise and deal with the pressing challenges. And this must be done in a way that ensures each dollar is spent most effectively.

The council is especially eager to work closely with the new Congress, the president, state governments, and other policy leaders to meet the clean, low-cost energy needs of the 21st century. We intend to reach out to presidential candidates, to business and technology leaders, and to many others who can advance this crucial effort and provide the visionary leadership this issue requires.

We hope that readers will assess this work critically and engage the council in an ongoing dialogue on how best to create a clean, low-cost energy future. We firmly believe there are few more important pursuits for the economic strength, security, and well-being of the American people.



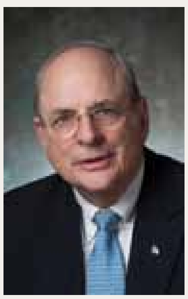
THE AMERICAN ENERGY INNOVATION COUNCIL

American Energy Innovation Council

WHO WE ARE

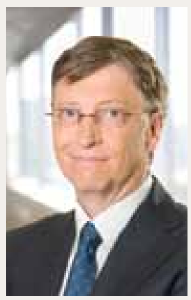
The American Energy Innovation Council is a group of six corporate leaders who came together in 2010 as a result of a common concern over America's insufficient commitment to energy innovation.* We speak as executives with broad-based success in innovation, who, in the course of our careers, have been called upon to overcome obstacles, seize opportunities, and make difficult decisions, all in the pursuit of building great American companies. We seek to share that experience as it relates to meeting the clean energy challenge.

* Ursula Burns, CEO of Xerox, was a founding member and maintains emeritus status.



NORMAN AUGUSTINE
Retired Chairman and CEO, Lockheed Martin

JOHN DOERR
Partner, Kleiner Perkins Caufield & Byers



BILL GATES
Co-Chair, Bill and Melinda Gates Foundation

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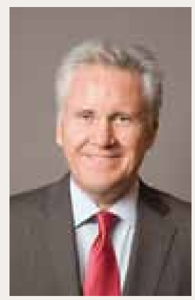
Retired Chairman and CEO, DuPont



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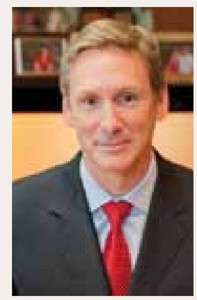
Chairman and CEO, General Electric



TOM LINEBARGER
Chairman and CEO, Cummins

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 and private investments in the development of world-changing energy technologies.

The American Energy Innovation Council is a project of the Bipartisan Policy Center.

ABOUT THE BIPARTISAN POLICY CENTER

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.

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INTRODUCTION // WHAT'S IN THIS REPORT

Energy issues permeate the opportunities and risks facing all nations. The United States demonstrates this duality better than most. After a long period of energy scarcity, and despite continuing excessive reliance on oil imports and exposure to price volatility, the United States has emerged into a new dawn of relative energy abundance and strength. Yet the country has much more to do, both at home and abroad, to sustain its international competitiveness, reinforce its economic security and resiliency, and protect the environment.

In the face of this dual prospect of U.S. abundance and profound challenges, public investments in energy RD&D are crucial. The provision of safe, clean, affordable, and sustainable energy is, by virtually any standard, one of the foremost tests the United States faces—and the current innovation investment and delivery mechanisms are simply not up to the task.

The United States has a historically unmatched record—as the American Energy Innovation Council's (AEIC) recent case studies show—of successful energy RD&D. America's national laboratories, which have no peer in the world, have birthed hundreds of technologies that today dominate the global energy market. U.S. RD&D investments have created the world's best natural gas turbines, the most sophisticated oil-drilling equipment, the world's most efficient solar cells, advanced glass and lighting, and much more. The costs of this RD&D are tiny compared with the benefits. But today's investments are simply too small: they will not offer an expanded range of economic, security, and environmental options in the future.

This report is AEIC's assessment of the changes that have taken place since our original study in 2010. We find that policymakers have a mixed record of progress on our original recommendations. The Department of Energy (DOE) is a better functioning machine now than five years ago, but the scale of energy RD&D is still just one-third of what is necessary for the United States to compete effectively in global energy markets, to diversify away from foreign oil, and to mitigate environmental harms from energy production. The surging growth of both new fossil and new renewable-energy production in the United States, itself stemming from past federal energy innovation investments, has both intensified the need for new energy RD&D support and established a position of strength to undertake it.

We urge Congress to increase federal appropriations for energy RD&D across all low-carbon energy sources, and we support increasing authorizations for DOE energy innovation programs, such as through reauthorization of America COMPETES legislation. We also urge support for large-scale demonstration projects and limited downstream innovation investments, such as through a Clean Energy Deployment Agency (CEDA) or other investment authority, and/or through appropriately targeted tax provisions.

Photo credit: General Motors

The first electric vehicle battery manufacturing facilities in the United States began operations in 2010 and have expanded since.

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.

Chad Holliday
Retired Chairman and CEO of DuPont

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Progress in Implementing the AEIC Recommendations Has Been Uneven.

The AEIC recommended several federal policy actions in 2010 and 2011 to promote energy innovation. The following section summarizes congressional and administration action on these recommendations.

RATINGS KEY

Federal action has moved ahead

Federal action has slowed down

Federal action has stopped

RECOMMENDATION:

Create an independent National Energy Strategy Board charged with developing a National Energy Plan for Congress and the executive branch. Alternatively, develop and implement a comprehensive, government-wide Quadrennial Energy Review that aligns the capacities of the public and private sectors.

In 2011, DOE released its first Quadrennial Technology Review (QTR), which aimed to guide DOE's RD&D priorities.[1] The QTR concluded that DOE had underinvested in transportation energy relative to stationary energy, and identified vehicle efficiency and fuel diversification as priority areas. The QTR also found that DOE has underinvested in grid modernization and building and industrial energy efficiency. Finally, the QTR found that DOE had underinvested in accelerating innovation in existing technologies in the near- to medium-term, relative to its long-term research portfolio. DOE is currently preparing a follow-up Quadrennial Energy Review, whose first report is expected to focus on energy transmission, storage, and distribution infrastructure. We strongly support these efforts, as they contribute to a more effective RD&D portfolio and contain the seeds of a comprehensive national energy strategy.

RECOMMENDATION:

Increase annual investments in clean energy RD&D by $11 billion to $16 billion per year.

The federal commitment to energy RD&D is less than one-half of 1 percent of the annual nationwide energy bill.[2] The United States spends less on energy RD&D than it does on potato and tortilla chips.[3] This is insufficient, and it condemns future generations to fewer options. Since AEIC's initial report, investments have not grown. In

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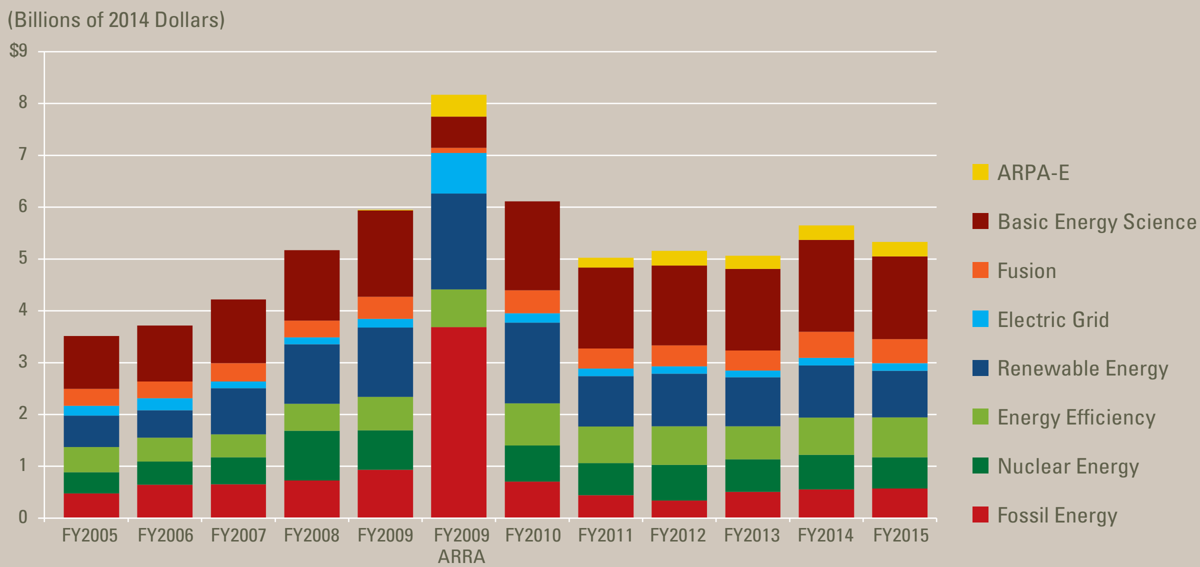
FIGURE 1. APPROPRIATIONS FOR DEPARTMENT OF ENERGY RD&D ACTIVITIES[4]



real terms, the level of U.S. public investment in energy RD&D through DOE has remained largely unchanged. Congressional appropriations for DOE's RD&D activities peaked in FY 2009 and FY 2010—reaching roughly $6 billion (in 2014 dollars) in each of those years, as well as approximately $8 billion (in 2014 dollars) in 2009 stimulus funds—and has since dropped back to the funding levels of previous years, within a range of $5 to $5.7 billion (in 2014 dollars) per year.

While AEIC understands the importance that policymakers have placed on controlling the federal debt, we are disappointed to find that appropriations for DOE's energy RD&D programs have been kept roughly flat. While the annual budget requests have exceeded $2 billion for energy-efficiency and renewable-energy programs, the final appropriations have ranged from $1.8 to $1.9 billion between FY 2011 and FY 2015. Similarly, the final fossil energy program appropriations for FY 2011 through FY 2015 ranged between $347 million and $571 million. U.S. investments through energy-tax expenditures reached roughly $20 billion (in 2014 dollars) annually in 2009 and have remained elevated since; although a number of provisions have been subject to great uncertainty, expiring at the end of 2013, remaining expired through the following year, receiving retroactive extension in December 2014, and expiring again less than a month later.

If the nation is to accelerate research and development and ultimately the commercialization of critical energy technologies, growing and consistent appropriations for these DOE investments are critical. The instability of energy RD&D funding and tax expenditures is as damaging as insufficient RD&D funding, as it prevents businesses and research partners from making effective, multiyear RD&D investment decisions. As discussed later in this report, partnerships between the government and the private sector can make progress on applied RD&D, but they cannot substitute for direct federal investments in fundamental energy science and engineering problems. Growing and consistent appropriations for energy innovation should be a top U.S. priority over the next decade. The budget numbers over the last five years are a major failure in U.S. energy policy.

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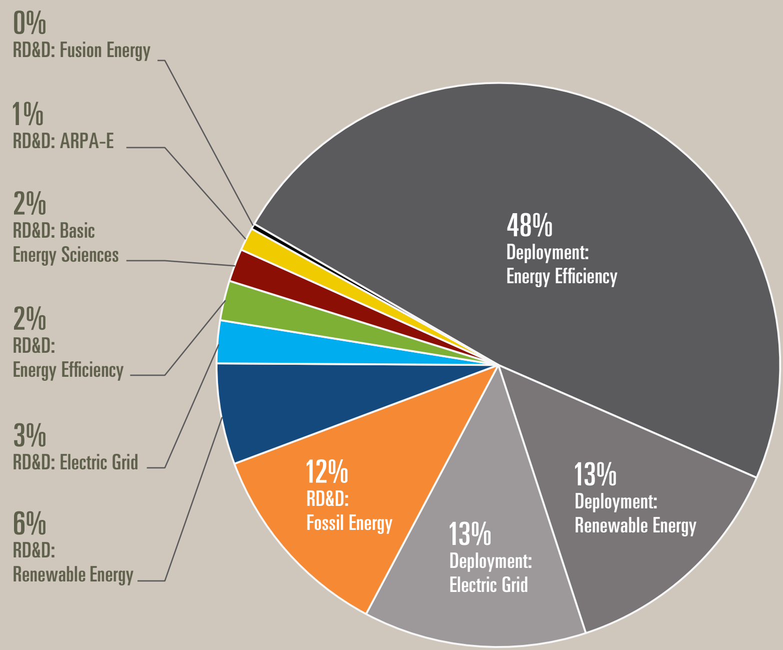
ENERGY RD&D IN THE AMERICAN RECOVERY AND REINVESTMENT ACT

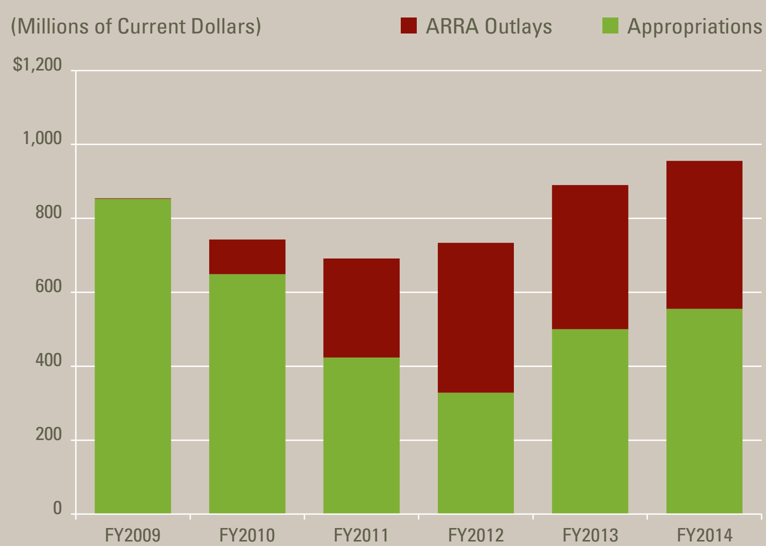
The 2009 American Recovery and Reinvestment Act (ARRA) provided approximately $32 billion (in 2014 dollars) to energy innovation activities at the Department of Energy, of which three-quarters went into deployment activities, such as smart-meter deployments, energy-efficiency rebates, and the like. The amount of the ARRA invested in RD&D was equivalent to 160 percent of average DOE energy RD&D appropriations from FY 2010 to FY 2014.

FIGURE 2. AMERICAN RECOVERY AND REINVESTMENT ACT FUNDS FOR DOE ACTIVITIES[5]



Nearly half of the $8 billion (in 2014 dollars) in ARRA RD&D funds went to fossil energy RD&D, focused almost entirely in carbon-capture technology and advanced coal-combustion technologies; the amount of ARRA funds for fossil RD&D was equivalent to more than seven times the annual appropriation to fossil RD&D and partly offsets some decreases in annual appropriations to fossil energy RD&D. However, the episodic nature of this investment fails to meet fundamental RD&D challenges.

FIGURE 3. FOSSIL ENERGY RD&D APPROPRIATIONS AND OUTLAYS FROM ARRA ACCOUNTS[6]



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RECOMMENDATION:

Create Centers of Excellence in Energy Innovation, with each center receiving annual funding of $150 to $250 million.

DOE Energy Innovation Hubs were created and received appropriations as a part of DOE's Basic Energy Science program starting in FY 2010. This effort is closely aligned with AEIC recommendations. Modeled after Bell Laboratories, the hubs invest in transformational, use-inspired research and development efforts (i.e., basic research linked to initial product development) and are carried out jointly among the personnel of DOE National Labs, universities, and companies. The hubs include the Consortium for Advanced Simulation of Light Water Reactors, the Joint Center for Artificial Photosynthesis (JCAP), the Consortium for Building Energy Innovation, the Joint Center for Energy Storage Research (JCESR), and the Critical Materials Institute. Altogether the hubs have appropriated approximately $480 million since FY 2010.[7] All but one of the hubs continued to receive congressional appropriations in FY 2015.[8] Keeping this effort alive and incorporating lessons learned should be a clear priority for Congress.

In addition to hubs, the Basic Energy Science program at DOE has established 46 Energy Frontier Research Centers (EFRCs). EFRCs bring together researchers at universities, national laboratories, nonprofit organizations, and for-profit firms—singly or in partnerships—to conduct fundamental research focusing on one or more of several "grand challenges" and use-inspired "basic research needs" recently identified in major strategic-planning efforts by the scientific community. EFRCs were selected by scientific peer review and funded at $2 to $5 million per year for a five-year initial award period, with a starting allotment of $377 million (of which $277 million came from ARRA funds and the remaining $100 million from appropriations for Basic Energy Science).[9] Since their establishment in FY 2009, the EFRCs have produced 5,400 peer-reviewed scientific publications and hundreds of inventions at various stages in the patent process.[10] The scientific discoveries, and the early prototypes derived from them, are precisely the kind of basic research and development that the private sector cannot profitably invest in. In FY 2014, DOE allocated another $100 million to a new round of EFRCs, with plans to solicit competitive applications for EFRCs every two years; Congress provided another $100 million appropriation for EFRCs in FY 2015.

In conjunction with the Department of Commerce and Department of Defense, DOE began to establish Institutes for Manufacturing Innovation in 2012. Each institute brings together national labs, universities, and companies in regional clusters to develop and accelerate commercialization of new manufacturing technologies, many of which affect energy-sector equipment and materials. Current institutes include the National Additive Manufacturing Innovation Institute, the Next Generation Power Electronics Manufacturing Innovation Institute, the Digital Manufacturing and Design Innovation Institute, and the Lightweight and Modern Metals Manufacturing Innovation Institute. The federal government has invested $240 million in the four institutes, which is matched more than one-to-one by private investment.[11] For FY 2015, Congress authorized a formal Network of Manufacturing Innovation Institutes program in the Department of Commerce and appropriated $300 million to support the establishment of new institutes.

We applaud both the Energy Frontier Research Centers and the Institutes for Manufacturing Innovation. They can help ensure American leadership on both fronts—but they need steady and expanding funding.

RECOMMENDATION:

Fund ARPA-E at $1 billion per year. At a minimum, ARPA-E should receive at least $300 million per year.

The Advanced Research Projects Agency–Energy (ARPA-E), while authorized in 2007, first received funding of $400 million in the 2009 ARRA and received appropriations starting in FY 2011. ARPA-E was funded at $180 million in FY 2011; $275 million in FY 2012; $250 million in FY 2013; and $280 million in FY 2014 and FY 2015—all below AEIC's recommendation.

We are pleased that, despite across-the-board cuts to nearly all discretionary federal spending, ARPA-E funding has remained somewhat constant, with strong bipartisan backing. Nevertheless, we urge policymakers to better support this work. ARPA-E invests in high-risk, high-reward

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FIGURE 4. APPROPRIATIONS FOR ARPA-E[12]

(Millions of Current Dollars)

energy technology research and development projects to develop prototypes, and it convenes private partners for awardees to facilitate follow-on commercialization investments. From FY 2009 to FY 2015, ARPA-E has appropriated approximately $1.6 billion, and ARPA-E's solicitations have focused primarily on energy storage, alternative fuels, and energy-efficiency technologies.

RECOMMENDATION:

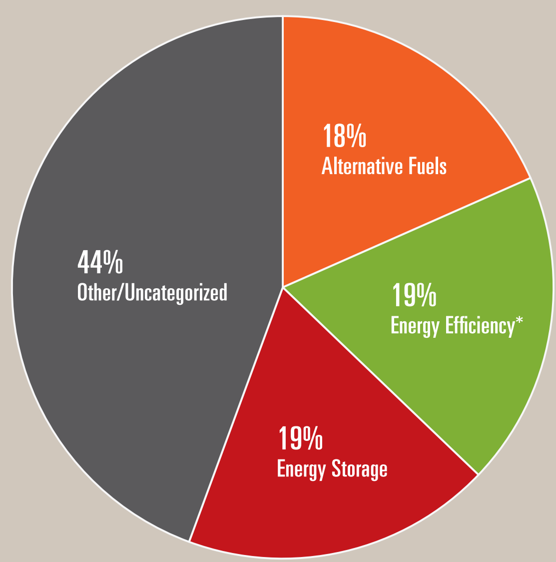
Establish a New Energy Challenge Program for large-scale demonstration projects. Alternatively, develop a first-of-a-kind technology commercialization engine along the lines of a proposed Clean Energy Deployment Administration (CEDA).

Some technologies require serious investments to become commercially viable—because of their sheer scale. Advanced nuclear power and carbon capture and storage will not flourish in America without this sort of commitment, and this recognition was at the heart of the AEIC recommendation for a New Energy Challenge Program. Today, the United States is essentially foreclosing, or at best delaying, those options.

While CEDA legislation was introduced and reported out of committee in 2011, no further congressional action was taken. Most recently, Representative Van Hollen (D-MD) introduced the Green Bank Act of 2014, which follows up on concepts previously introduced in CEDA legislation.

DOE's innovative energy technology loan program could be viewed as representing a small component of what AEIC recommended in the New Energy Challenge Program. DOE's loan program (known as the Section 1703 program) was created in 2005 under President George W. Bush to spur commercial adoption of innovative technologies that avoided, reduced, or permanently stored pollutants. But this approach will not result in the development of generation-IV nuclear power, nor of carbon capture and storage. These are strategically important technologies that are orphaned by current public policy. In 2008, Congress added the advanced technologies vehicle-manufacturing (ATVM) program, which provides direct loans to eligible manufacturers of advanced technology vehicles and components for more fuel-efficient cars. In 2009, Congress created the temporary Section 1705 program (since expired) to

FIGURE 5. ARPA-E INVESTMENTS BY TECHNOLOGY AREA 2009–2014[13]



* Energy efficiency projects range over fossil, renewable, and other energy technlogy areas.

REPORT CARD

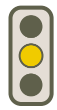
encourage quick deployment of commercial (i.e., not necessarily innovative) renewable-energy and electrical-transmission projects through DOE loan guarantees (i.e., agreeing to repay the borrower's debt obligation in the event of a default). The Section 1705 program became highly controversial when several recipients declared bankruptcy.

To date, DOE has committed loans and loan guarantees with liabilities totaling $32 billion to 31 projects.[14] Notable successes include support for the first all-electric vehicle-manufacturing plants in the United States, the first solar-thermal power plant with molten storage in the United States, and one of the first cellulosic biofuel plants in the United States. Promising projects underway include the first U.S. generation- III+ nuclear reactors and the first U.S. coal-fired power plant with carbon capture and sequestration. Five DOE loan program projects have failed, representing $1.2 billion in liabilities.[15] These failures, though highly visible, represent a 4 percent default rate, only one-eighth the amount Congress anticipated in its authorizing legislation. Recently, DOE has refreshed its loan programs, drafting or issuing solicitations aimed at advanced automotive-component manufacturing (under the ATVM program) and clean fossil energy technologies, nuclear power, and renewable energy (under the Section 1703 program).

A loan guarantee is only one of several tools that a New Energy Challenge Program would use to advance large-scale commercial demonstration projects. Early experience with the Section 1703 program demonstrated that congressional intent could be thwarted by administrative risk-aversion, which resulted in guarantees issued only to projects that just barely missed the criteria for private financing. Loan guarantees can effectively spread the risk of failure, but the risk of failure itself can be mitigated by the use of other tools—cost-sharing, intellectual property allocation, fuel or power-purchase agreements, and tax credits—that actually facilitate successful project completion. In addition to having the flexibility to employ a range of financial tools, the New Energy Challenge Program should prioritize direct equity investments negotiated on a case-specific basis with private-sector partners. These tools, when structured together, would push first-of-a-kind projects forward in a way loan guarantees alone cannot.

RECOMMENDATION:

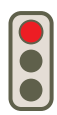
Make DOE work smarter along the ARPA-E model.



Signs of progress are evident. Since 2011, DOE's Office of Energy Efficiency and Renewable Energy instituted ARPA-E-like best practices to better manage their portfolio. Best practices include reorganizing by sectors, not technologies, to break down silos; introducing uniform active project-management practices to give DOE better control over every project; instituting aggressive "go/no-go" milestones; and developing a single corporate database with direct visibility into the status and progress over every project. It is unclear whether DOE's other technology offices have acted to incorporate operational characteristics of the ARPA-E model.

RECOMMENDATION:

Develop a funding regime that is dedicated, consistent, and not beholden to annual appropriations.



Annual appropriations continue to account for almost all energy RD&D funding—which diminishes the consistency of multiyear program planning. **A stable and dedicated funding regime is critical for both effective and efficient energy RD&D decision-making.** One of the only energy RD&D programs to receive dedicated funding was the Research Partnership to Secure Energy for America (RPSEA), a consortium contracted by DOE pursuant to the Energy Policy Act of 2005 to fund ultra-deepwater and unconventional oil and gas RD&D. RPSEA received direct allocations from federal oil and gas royalties, totaling $50 million per year over ten years. In its FY 2014 budget, Congress rescinded further funding for RPSEA.[16]

In 2013, Senator Lisa Murkowski (R-AK) and President Obama released varying proposals to establish a trust fund for energy research and development funded by an annual allocation of federal revenues from energy development on public lands and offshore areas, although no legislation has been introduced.[17]

Photo credit: Southern Company

The Kemper County energy facility in Mississippi, now under construction, will be the first coal-fired power plant in the world to include pre-combustion carbon capture and sequestration technology.

To solve the world's energy and climate challenges we need hundreds of new ideas and hundreds of companies working on them. That is not going to happen without the U.S. government's continued tradition of leadership in R&D. Everyone has a role to play — from the private sector, to philanthropy, to the academy — but we will not be able to find the type of energy miracle we need without investing in the programs that support that innovation.

Bill Gates
Co-Chair, Bill and Melinda Gates Foundation

CHALLENGES AND OPPORTUNITIES

The Scale of the Challenges Facing the United States Demands a Step-Change in Energy Innovation Investment.

WHAT IS ENERGY INNOVATION AND WHY IS IT IMPORTANT?

Effective energy innovation policy hastens the development and market entry of clean energy technologies. By generating new economic possibilities, innovation expands the range of feasible actions available to businesses and consumers.

Technology innovation enables new, expanded possibilities for economic action. Business innovations find new ways to translate those possibilities into sustainable market propositions. Financial innovations find new ways to unlock investments for those businesses and technologies. All these innovations aim at the same goal: to compete with and ultimately supplant the current way of doing things with a better way.

Ultimately, energy innovation policy accomplishes its goal by driving down the unsubsidized cost of clean energy, primarily by speeding the cycles of discovery and invention. Lower costs allow for more competitive pricing, and changing prices signal different choices to energy-market participants. While public policy can modify price signals directly, ultimately clean energy can only meet the challenges of the U.S. energy system if it can out-compete the alternatives on a fair playing field.

Federal RD&D complements regulatory and tax-based approaches to address supply and demand challenges in the energy system. Regulatory approaches shape how energy markets work, establishing rules or standards that affect the choices of energy-market participants as a means of achieving specific outcomes, like energy efficiency or lower air pollution. In contrast, innovation increases the variety and lowers the cost of options for energy-market participants to make different choices and realize desired outcomes. U.S. policymaking includes both innovation- and regulation-oriented approaches: they interact with and reinforce each other's effectiveness. For example, innovations in vehicle technologies have made more robust fuel economy standards economically feasible. Similarly, broadening energy-market resource eligibility has driven innovation in demand-side energy technologies.

Innovation is an indispensable strategy for meeting the competitiveness, security, and environmental challenges of the American energy system.

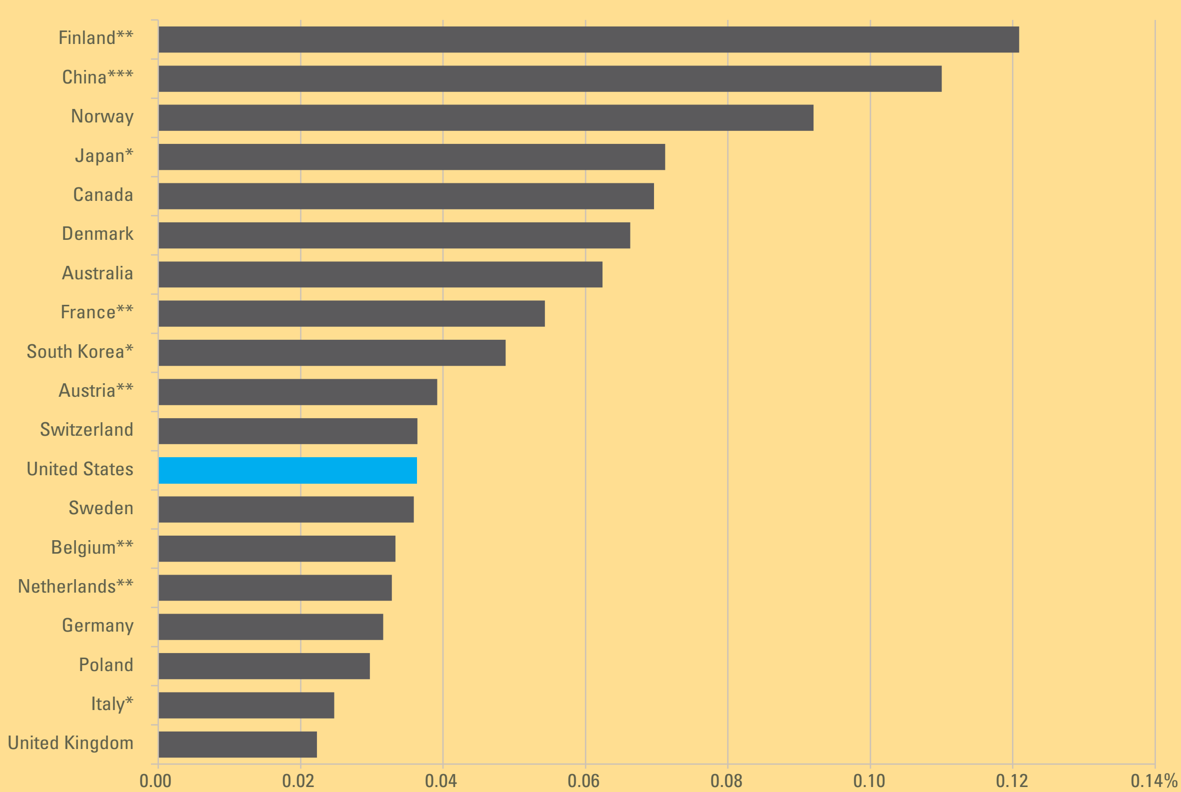
CHALLENGES AND OPPORTUNITIES

Economic Competitiveness

American energy innovation has been critical in unlocking new, affordable energy sources. Competitiveness today often depends on RD&D investments made decades ago. For example, **public RD&D investments during the 1970s and 1980s in unconventional gas exploration and production technologies, as well as in gas turbines, are a significant part of why the United States today is enjoying a resurgence of cheap natural gas production and electricity generation.**[18] Lower-cost natural gas directly reduces energy costs to the economy and enhances the competitiveness of U.S. businesses, especially in manufacturing that uses natural gas as a feedstock. Investments today in clean energy technology innovations will similarly shore up U.S. economic growth and jobs in the future.

Events today threaten America's future competitiveness. While the United States maintains a significant lead in energy technology patenting overall, companies in other countries are jumping into the fray. China, for example, is increasingly rivaling the United States in public RD&D investments, particularly in energy. Germany is dedicating increasing funds to Fraunhofer Institutes, 70 different research institutes, each organized around a strategic area and designed to produce practical technologies, especially energy technologies. **The United States must proactively prepare for a more competitive economic future and scale up innovation investments as other countries increase their own innovation investments.**

FIGURE 6. **GOVERNMENT ENERGY RD&D INVESTMENT AS PERCENT OF GDP, 2013**[19]



* As of 2011 ** As of 2012 *** Estimate of 2008

CHALLENGES AND OPPORTUNITIES

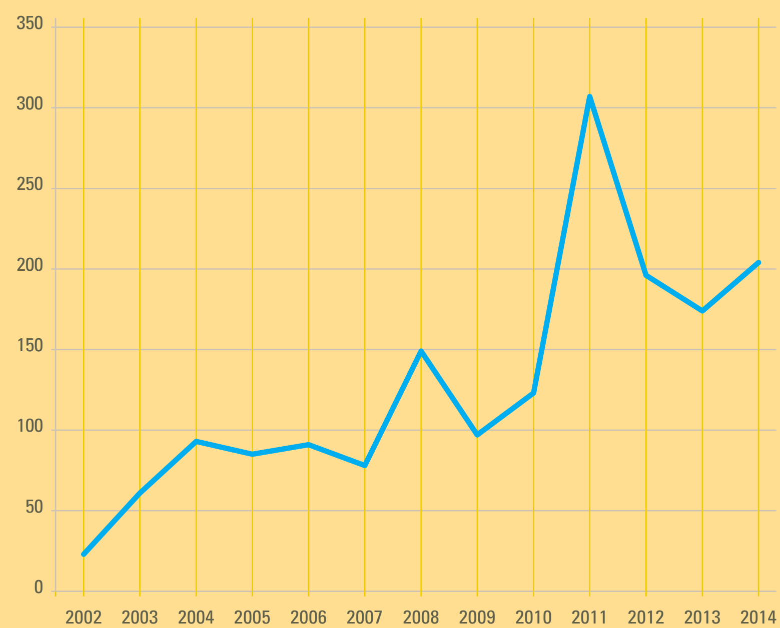
Security and Resiliency

U.S. energy innovation investments are also critical to security and resiliency. **By diversifying the energy technologies businesses and consumers rely on, the United States can reduce its economic vulnerability.** U.S. transportation remains almost entirely dependent on petroleum, the price of which is subject to the vagaries of the global market—which is itself strongly impacted by the decisions of OPEC member states and other state-owned national oil companies. Existing policy and technology have so far left the American consumer vulnerable to forces beyond the country's control. Price volatility remains a threat to U.S. economic wellbeing, and energy technology innovation is critical to diversifying transportation energy and reducing this vulnerability. While alternative fuel and efficiency technologies have entered the market, providing affordable substitutes for oil remains a challenge of enormous scale.

In a similar way, **by increasing the flexibility of its energy system, the United States can reduce its vulnerability to critical infrastructure disruption.** Outages from the U.S. electric system are growing more common over time[21] and cost billions of dollars annually,[22] and innovative energy technologies and infrastructure can promote greater system resilience. Moreover, as the United States diversifies its energy resources to include greater penetration of variable generation from wind and solar, innovative technologies and systems are crucial to the flexibility necessary to integrate these resources cost-effectively.

FIGURE 7. MONTHLY AVERAGE PRICE OF CRUDE OIL[20]

FIGURE 8. MAJOR OUTAGES AND GRID DISTURBANCES IN THE UNITED STATES[23]

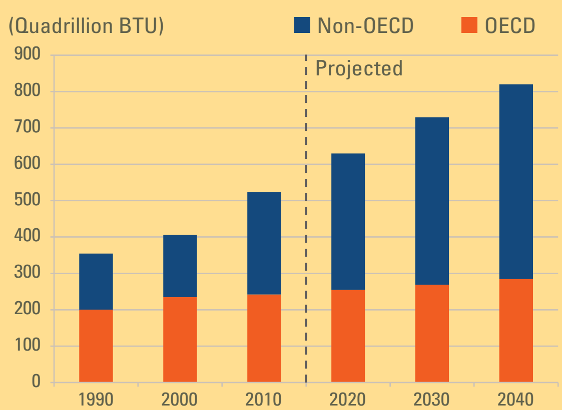


CHALLENGES AND OPPORTUNITIES

Climate Change

Energy innovation is also necessary to mitigate and adapt to global climate change. The United States accounts for approximately 15 percent of global greenhouse-gas pollution from energy consumption,[24] and it would be wise to reduce this threat. More than half of greenhouse-gas emissions come from energy consumption in lower-income countries, whose demand for energy is expected to account for 85 percent of worldwide growth in energy consumption over the next 25 years. **The United States must drive down the cost of clean energy and energy-efficiency technologies as fast as possible, not only to make them viable choices worldwide, but also to ensure American companies lead markets. In that respect, energy innovation is fundamentally a global approach to climate change that is in the best interests of the United States.**

FIGURE 9. **ESTIMATED FUTURE GLOBAL ENERGY DEMAND**[25]



Step-change investment is needed.

The scale of these energy challenges—competitiveness, security, and environment—necessitates a step-change in energy innovation investment. The United States has made incremental progress to address these goals through the existing federal energy innovation budget and investment channels, which AEIC supports. Progress on existing technologies is necessary to get the nation part of the way to a highly competitive, resilient, low-carbon economy. But the council believes that **more cycles of discovery and invention are necessary to produce the solutions that will make a full transformation of energy systems attainable.**

The United States needs next-generation energy storage, solar photovoltaic, nuclear, and carbon-capture technologies that offer performance at a fraction of the cost of existing technologies. The nation must explore untapped hydrokinetic resources in the oceans and geothermal resources currently unreachable deep underground or offshore. It is imperative to accelerate transitions to new transportation energy sources by creating a viable alternative to petroleum.

Public investment is critical to generating the discoveries and inventions that form the basis of disruptive energy technologies. Private companies cannot capture the full economy-wide value of new knowledge and will thus systematically underinvest in research and development relative to the benefits it produces. Moreover, the longer-term the research and development investment, the less likely private companies will choose it when compared with the opportunities presented by shorter-term, incremental investments. For these reasons, government investment in energy science and RD&D is critical.

Public investment is critical to generating the discoveries and inventions that form the basis of disruptive energy technologies.

CHALLENGES AND OPPORTUNITIES

Many first-of-a-kind energy resources require substantial RD&D investments and massive capital expenditures to build. Because the energy sector is dominated by long-lived, capital-intensive projects, turnover is slow — making the reward for new technologies a long-term proposition. At the same time, new projects carry substantial risks of technology failure or of regulatory change during the years a project takes to complete. Such a risk-reward profile will rarely attract necessary investment from the private sector, and therefore many disruptive new technologies won't be brought to demonstration scale. Not only is public investment critical to move new technologies through demonstration, but also such investment must come in large tranches due to the capital-intensive nature of new energy technologies. The large magnitude of viable energy technology investment is unlike most other industries.

All of this argues for a step-change in innovation investment, and now: speed is of the essence. Each new power plant or production facility is a many-decades-long investment that binds the next generation to a limited set of choices. **Every year that clean energy technologies remain undeveloped or uncompetitive represents lost opportunities to build American companies' global market share, create jobs, avoid disruptions to the economy, and reduce climate impacts.** Accelerating energy innovation is critical to make clean energy technology a viable option for every new, long-term investment decision. Some public innovation investments generate breakthroughs that would fail to materialize if left only to private-sector investment — such as nuclear reactors and gas turbines. Other public innovation investments speed up activities that might otherwise happen much more slowly if left to the private sector alone — such as energy-efficient building materials or advanced vehicle technologies. Moving these options forward in time makes an enormous difference; for example, the U.S. recovery from the 2009 financial crisis would have been even more challenging if unconventional oil and gas technologies were ten years behind on the development path that federal innovation investments accelerated.

ENERGY RD&D HAS BIPARTISAN BACKING

In their 2013 report *America's Energy Resurgence: Sustaining Success, Confronting Challenges*, former Senate Majority Leader Trent Lott, former Senator Bryon Dorgan, retired General James L. Jones, and former Environmental Protection Agency Administrator William Reilly led a panel of energy-industry stakeholders to issue bipartisan recommendations on national energy policy. Their recommendations on energy innovation cite those of the AEIC and include:

- Congress should significantly increase federal investments in basic and applied energy research and development.
- Congress and federal agencies should, when appropriate, consider mechanisms to leverage public-sector resources to demonstrate and deploy energy technologies.
- Congress should reauthorize the America COMPETES Act.
- Congress should require a regular, rigorous retrospective review of DOE's energy RD&D portfolio.
- The section 1703 DOE loan-guarantee program should be maintained and reformed.
- Treasury, DOE, and Congress should assess the effectiveness of the tax code in spurring private-sector energy innovation.

Photo credit: Lawrence Berkeley National Laboratory—Roy Kaltschmidt, photographer

Researchers at the federally-funded Joint Center for Artificial Photosynthesis are connecting basic science with applied research and engineering in an effort to use energy from sunlight to produce hydrocarbon fuels.

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.

Norman R. Augustine
Retired Chairman and CEO of Lockheed Martin
Former Undersecretary of the Army

NEW DEVELOPMENTS

Changes in the Energy Landscape Make Energy Innovation Investments More Important.

Since AEIC's first report, many aspects of America's energy system have changed. While the recent growth of new energy resources is a positive story overall—and the result of decades of past energy innovation investments—they bring new challenges with them. The United States has not yet achieved the competitiveness, security, and environmental goals of its energy system.

THE UNITED STATES IS UNDERGOING AN UNPRECEDENTED BOOM IN OIL AND NATURAL GAS PRODUCTION, AND IT IS WITNESSING REMARKABLE PROGRESS IN THE GROWTH OF RENEWABLE ENERGY.

Only a few years ago, the United States was projected to be increasingly dependent on foreign sources of oil, and domestic production was entrenched in a long and slow decline. These trends are in the midst of a dramatic reversal. **After decades of public and private investment in unconventional production technology RD&D, the United States is producing record volumes of crude oil and natural gas.** Horizontal-drilling and hydraulic-fracturing technologies have been applied not only to the production of shale gas, but also to produce crude oil from shale and other formations. The increasing supply of shale gas has driven natural gas prices down and instigated a shift from coal-fired to gas-fired power. The results have been spectacular and were wholly unpredicted: in 2012, U.S. oil production grew more than in any other year since the first commercial well was drilled in 1859,[26] and in October 2013 the United States produced more oil domestically than it imported from foreign sources in a single month for the first time in two decades.[27] Over the next decade, the country is projected to increase its domestic crude-oil production to 9.3 million barrels per day—a level not seen since 1972.[28] While just a few years ago the United States was gearing up to import liquefied natural gas (LNG) to meet domestic needs, companies are now building facilities to export LNG and starting a genuine debate on exporting petroleum.

NEW DEVELOPMENTS

FIGURE 10. U.S. OIL PRODUCTION[29]

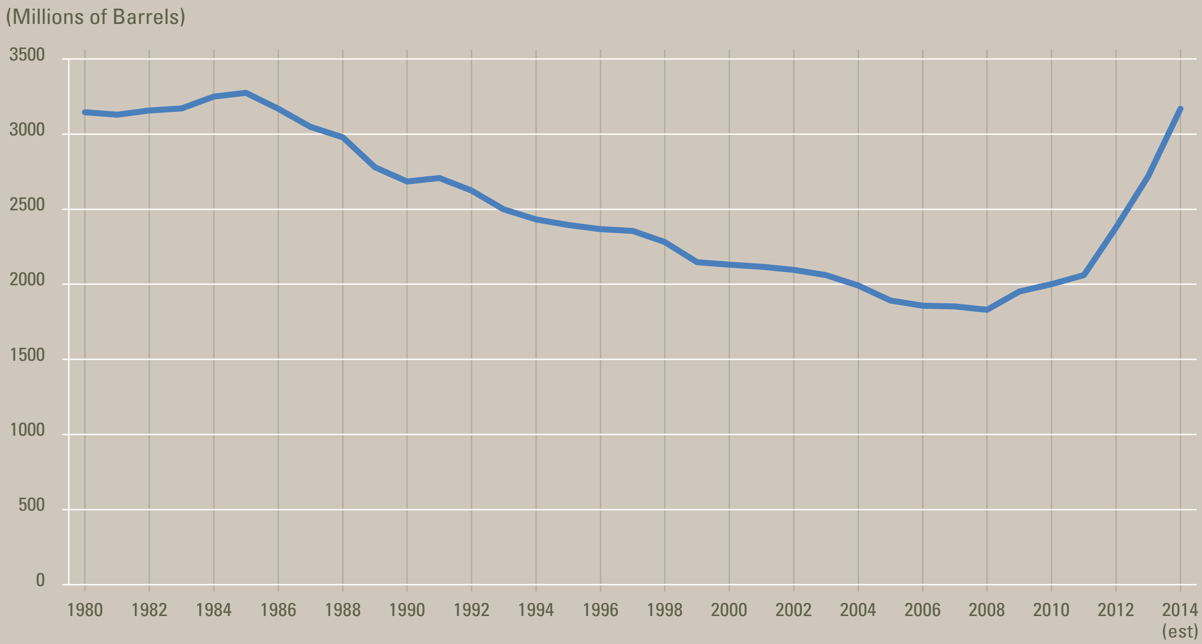
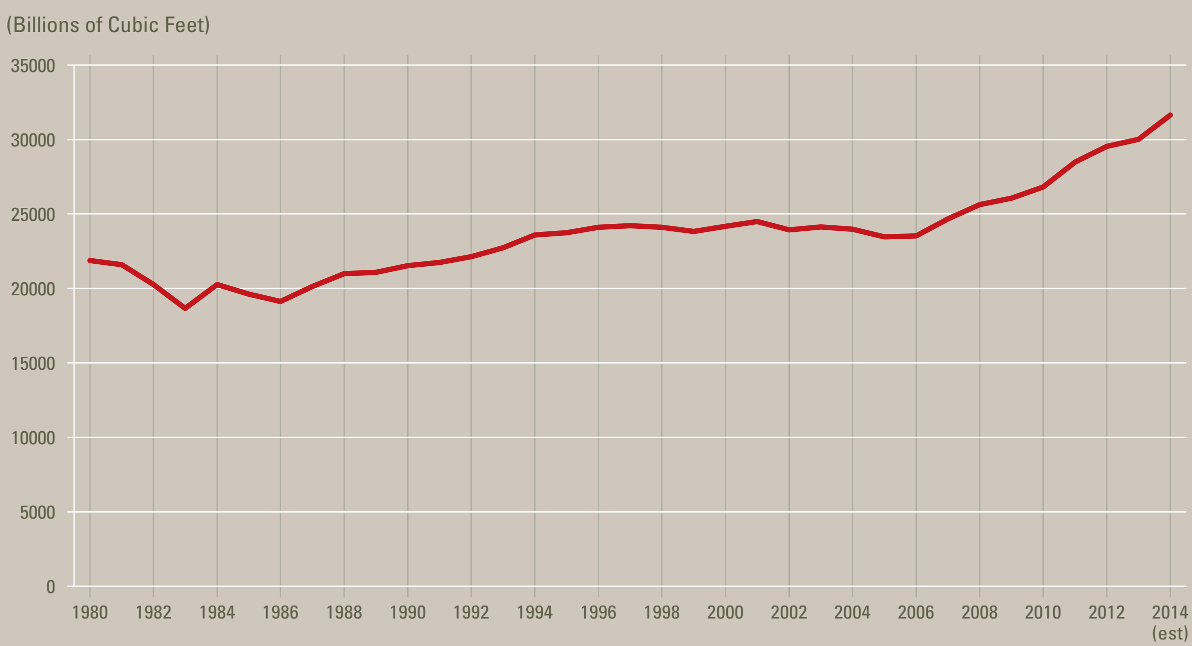


FIGURE 11. U.S. NATURAL GAS PRODUCTION[30]



NEW DEVELOPMENTS

Significant progress has also occurred in renewable energy. Wind, solar, biomass, and other non-hydroelectric renewable-energy technologies have made remarkable gains in a few short years, nearly tripling their contributions to the nation's overall electricity-supply portfolio — from 2.5 percent of generation to almost 7 percent of generation — between 2007 and 2014. The price of many of these technologies has declined significantly in the last several years.

At the same time, U.S. energy consumption is flat, and energy intensity continues to decline as a result of a mix of structural shifts in the economy and investments in energy efficiency.

FIGURE 12. U.S. NON-HYDROELECTRIC RENEWABLE POWER GENERATION[31]

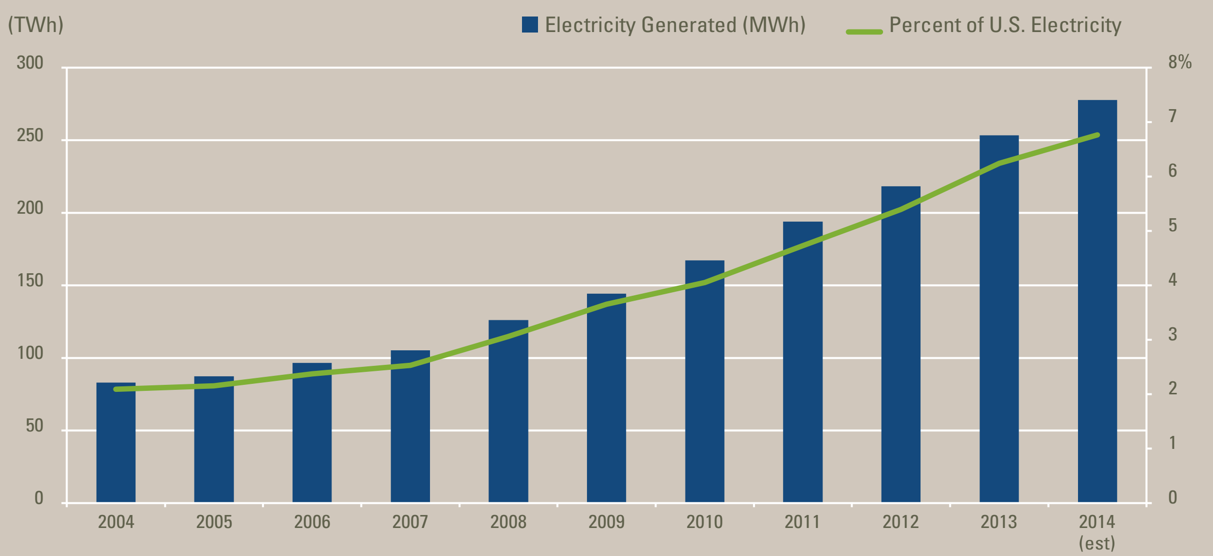
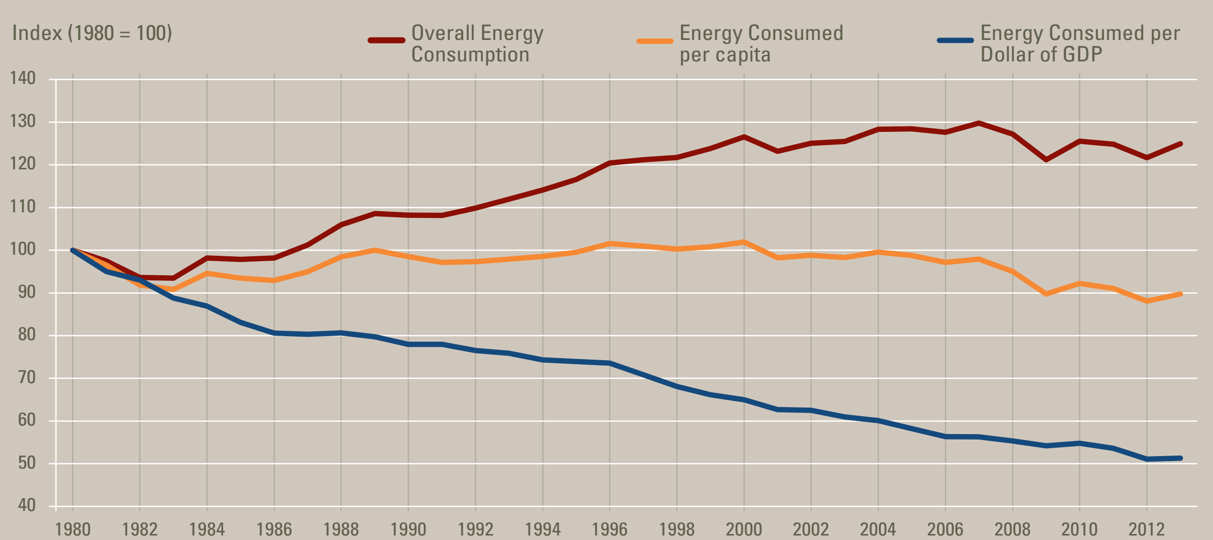


FIGURE 13. U.S. ENERGY CONSUMPTION AND ENERGY INTENSITY[32]



NEW DEVELOPMENTS

AS A RESULT, THE U.S. POWER SECTOR IS TRYING TO RESPOND TO A RANGE OF ECONOMIC, TECHNOLOGICAL, AND REGULATORY FORCES.

The U.S. electric power sector faces a significant transition over the next decade. Sustained progress in energy efficiency, low natural gas prices, modest or no electricity demand growth, increasing distributed generation, and existing and pending environmental regulation will affect generation, transmission, and distribution system planning. In addition, concerns about the reliability of the electric system are growing, and utilities and their regulators are grappling with how to make generation, distribution, and transmission systems less vulnerable to a variety of weather- and security-related events. Electric grids are beginning to support distributed resources and closer integration of grid assets with information and communications technologies, although progress is uneven across utilities and presents new difficulties, such as grid cybersecurity and increasing volatility of loads. New technical capacity on the grid, combined with public policies supportive of new resources and lack of growth in demand, is prompting reconsideration of energy-market rules and utility regulation. Finally, Environmental Protection Agency regulation of power-sector greenhouse gases will require the industry to decarbonize the electric grid while responding to these market transitions and threats to reliability.

FIGURE 14. ADVANCED METERING INFRASTRUCTURE MARKET PENETRATION[33]

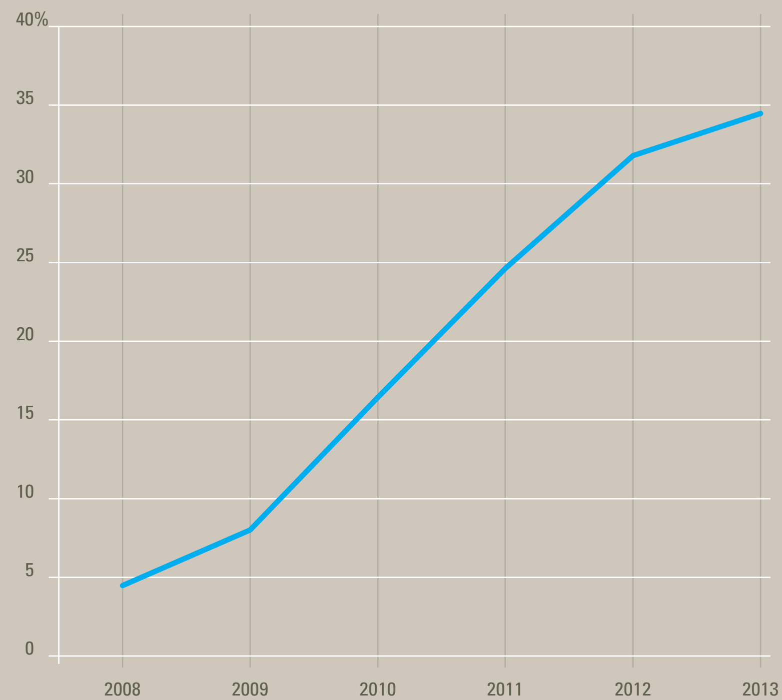
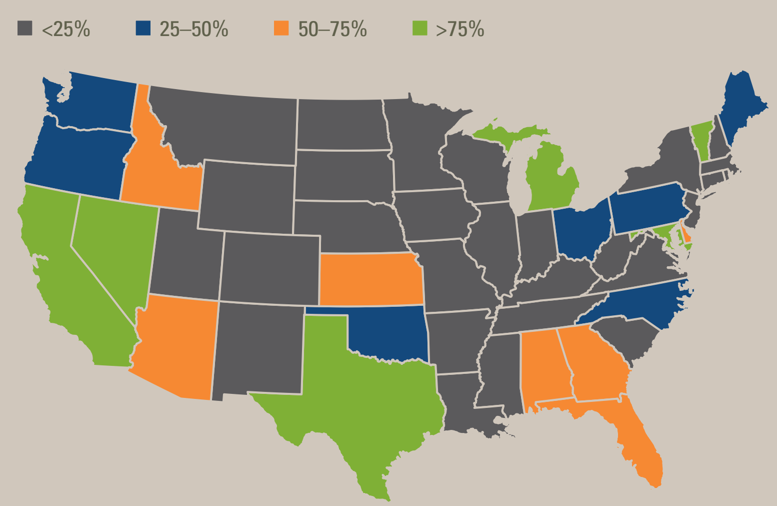


FIGURE 15. ADVANCED METERING INFRASTRUCTURE MARKET PENETRATION IN THE CONTINENTAL UNITED STATES, 2013[34]



NEW DEVELOPMENTS

The electric power sector will be far better prepared to respond to these pressures as energy technologies that increase flexibility and reliability become more affordable and integrate more efficiently with energy infrastructure.

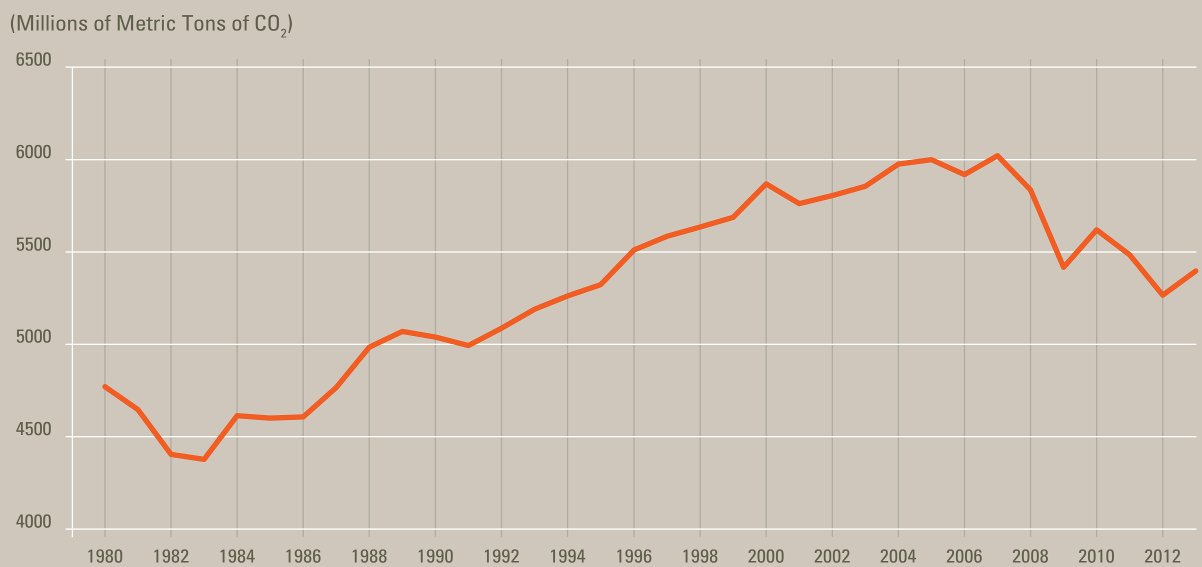
ENVIRONMENTAL CHALLENGES PERSIST, AND NEW CONCERNS HAVE EMERGED WITH THE VARIETY OF NEW ENERGY RESOURCES AVAILABLE.

The United States has made substantial progress addressing a number of energy-related environmental and public-health issues, yet other problems remain. U.S. energy-related emissions of sulfur oxide and nitrogen oxide have continued to decline due to trading programs that cap emission levels. U.S. carbon-dioxide (CO_2) emissions declined 12 percent between 2005 and 2012 due to a recession-related drop in demand, improved energy efficiency, gas replacing coal, and growth in renewable sources. However, U.S. CO_2 increased in 2013 and 2014, owing to an increase in coal-fired generation and increased energy consumption from colder winter weather.[35]

While the Energy Information Administration projects annual U.S. CO_2 emissions to decline slightly in the coming decades, *global* CO_2 emissions continue at a rate that scientific models forecast will incur the more damaging impacts of climate change. **Virtually all energy and climate models indicate that the road to a sustainable future is paved with clean energy technology innovation.**[37]

Additionally, new energy-related environmental issues have emerged. Increased natural gas production and the growing share of natural gas in the power sector have heightened concerns ranging from accidental methane leakage to local water-quality impacts. Recent droughts and other instances of water stress have drawn attention to the mounting water-related impacts associated with a range of energy resources—such as unconventional oil and gas, thermoelectric generation, hydropower, and biofuels—as well as with emerging carbon-capture and sequestration technology. Siting of large utility-scale solar power plants and wind farms have raised new questions regarding land, viewshed, and wildlife impacts. The mass production of new energy-storage technologies may raise concerns over hazardous-waste disposal, and advances in fission-reactor technologies still face long-standing concerns related to waste handling and disposition from nuclear power. Clean energy RD&D is required to deal with all of these sustainability challenges.

FIGURE 16. **CARBON DIOXIDE EMISSIONS FROM U.S. ENERGY**[36]



NEW DEVELOPMENTS

PRODUCTION OF NEW OIL AND GAS RESOURCES IS NOT ONLY CHANGING THE U.S. STRATEGIC POSTURE AND RELATIONSHIPS WITH TRADING PARTNERS AND ALLIES, BUT IT IS ALSO ALTERING THE DEMAND FOR AND SUPPLY OF CLEAN ENERGY.

Ultimately, the production of new fossil energy resources is altering the demand for and supply of clean energy technology in complex ways. For example, cheap natural-gas-fired electricity generation is competing with renewable power sources in the short-run but may support increasing deployment of renewables in the medium- and long-term,[38] and enhanced oil recovery is driving market demand and technology development relevant for carbon capture and sequestration.[39]

Moreover, as similar resources become available in other parts of the world, global supply will expand and diversify, presenting a range of implications associated with commodity prices and global energy consumption. These dynamics are already affecting trade flows; for example, continuing cheap U.S. natural gas production contributed to the doubling of U.S. coal exports between 2009 and 2012,[40] and U.S. oil production has reversed a 20-year trend of steadily increasing oil imports, which dropped by one-quarter between 2007 and 2013.[41]

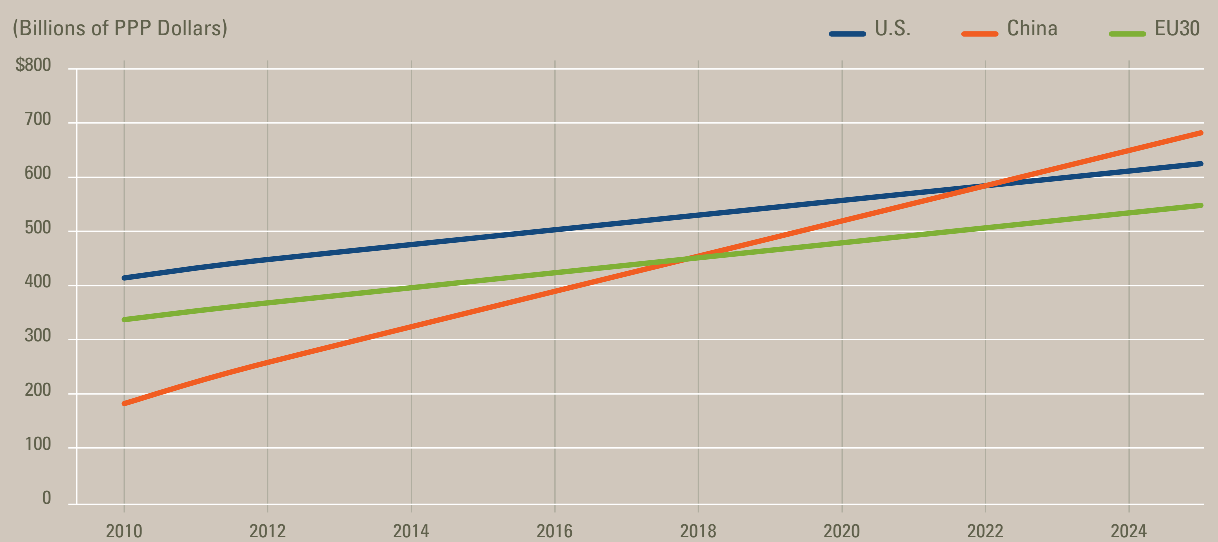
Furthermore, these dynamics will influence the long-term investment decisions of emerging economies' power sectors, particularly as the prices of conventional gas- and coal-fired generation fluctuate relative to clean energy options.

INTERNATIONAL ENERGY TECHNOLOGY COMPETITION IS GROWING.

American public investment in energy RD&D faces increasing competition from other nations. Energy has accounted for 20 percent of the Chinese national research and development budget in recent years,[42] much greater in proportion than the 2 percent of the U.S. federal RD&D budget dedicated to energy. **Chinese research and development investments are increasing rapidly and will exceed America's by 2022 at current growth rates.** While some of these investments will go toward international collaboration, such as the coal-power carbon-capture and sequestration RD&D projects included in the November 2014 U.S.-China energy and climate pledge, the larger share will be dedicated to attaining competitive edge over the United States.

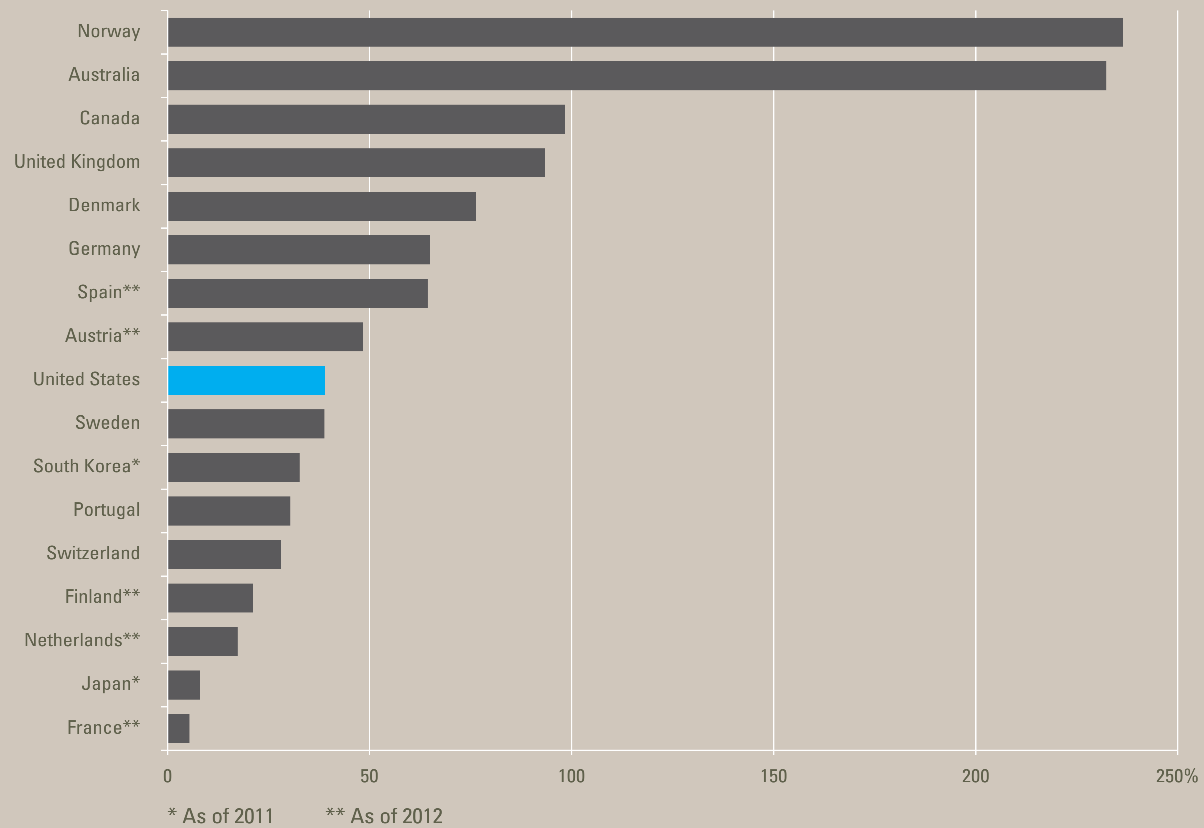
The United States has already fallen behind China in many aspects of energy performance, investment, and speed to take action. In 2014, China both invested more in clean energy than the United States[44] and produced more renewable energy than the United States.[45] China's Electric Power Research Institute

FIGURE 17. PROJECTED GOVERNMENT RESEARCH AND DEVELOPMENT SPENDING[43]



NEW DEVELOPMENTS

FIGURE 18. OECD GOVERNMENT ENERGY RD&D GROWTH 2008–2013[49]



is three times the scale of the U.S. Electric Power Research Institute,[46] and it receives reliable funding from the State Grid Corporation of China, the world's largest utility company and seventh-largest company globally.[47] The lesson is that China is improving its energy infrastructure and increasing its intellectual capital faster than the United States.

Other countries are increasing their energy RD&D budgets as well. For example, Germany's Fraunhofer Institutes have increased budgets by 20 percent since 2010, with about half of funds dedicated to energy RD&D.[48] A number of other Organisation for Economic Co-operation and Development (OECD) countries have expanded their investments in energy RD&D, many at growth rates exceeding that of the United States.

Sustaining U.S. competitiveness requires a continued commitment to innovation. **The United States must build a pipeline of scientific discovery and invention that businesses can translate into globally competitive clean energy products. If these investments are not made, other countries have demonstrated they will step in to sell new technologies in energy production and delivery to the world.**

PROGRESS ON CLEAN ENERGY TECHNOLOGIES REMAINS UNEVEN AND EXPOSED TO POLICY INSTABILITY.

Clean energy today has matured somewhat since 2010. Energy-efficient technologies have improved steadily in cost and performance, driven by standards and relatively short product cycles. For example, LED lighting costs have declined by orders of magnitude in the last decade and are increasing market share rapidly. Wind and solar power generation has grown significantly in the United States, owing largely to state

NEW DEVELOPMENTS

FIGURE 19. WIND ENERGY CONTRACT PRICES IN THE U.S.[50]

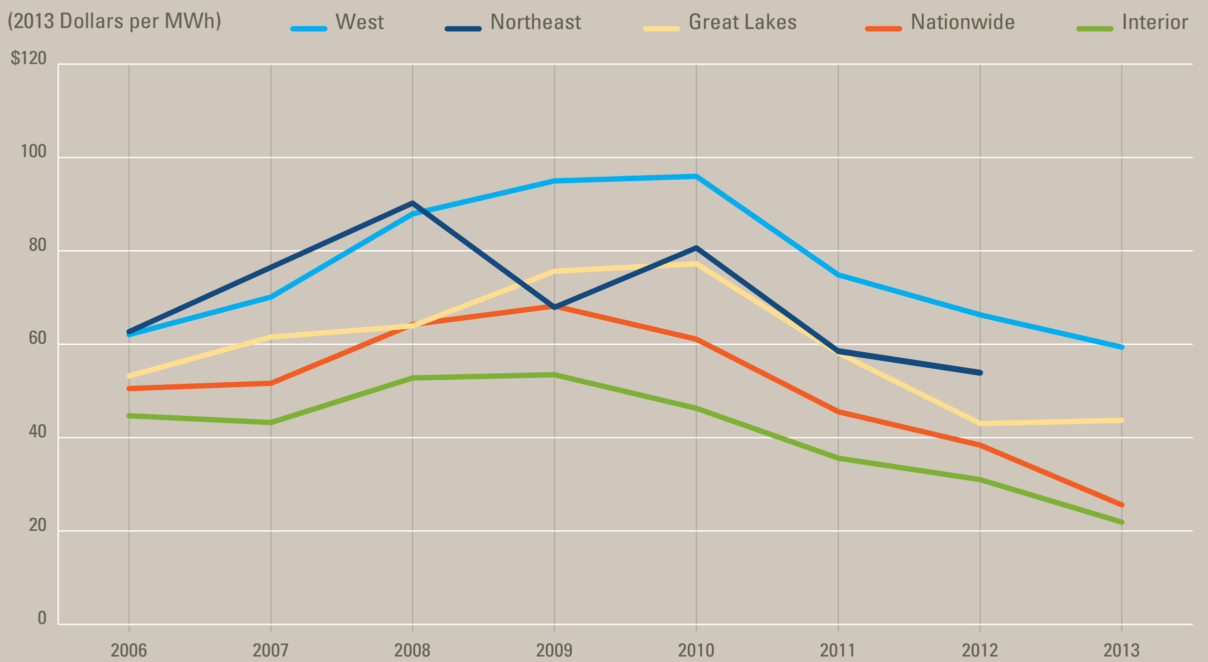
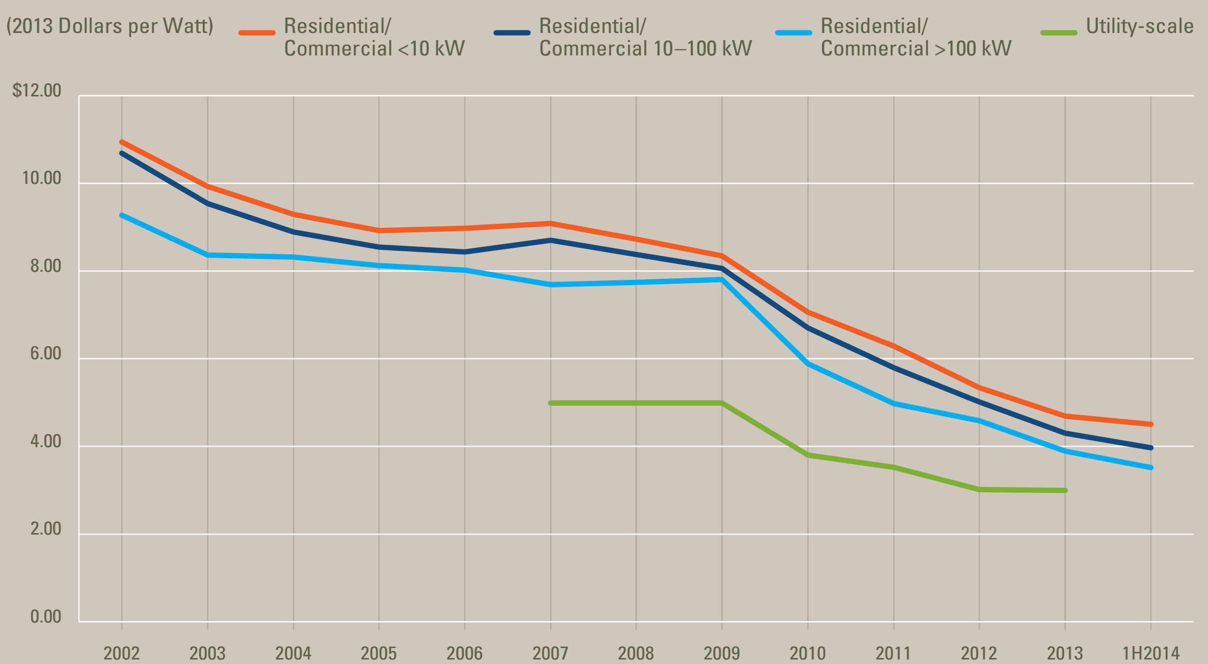
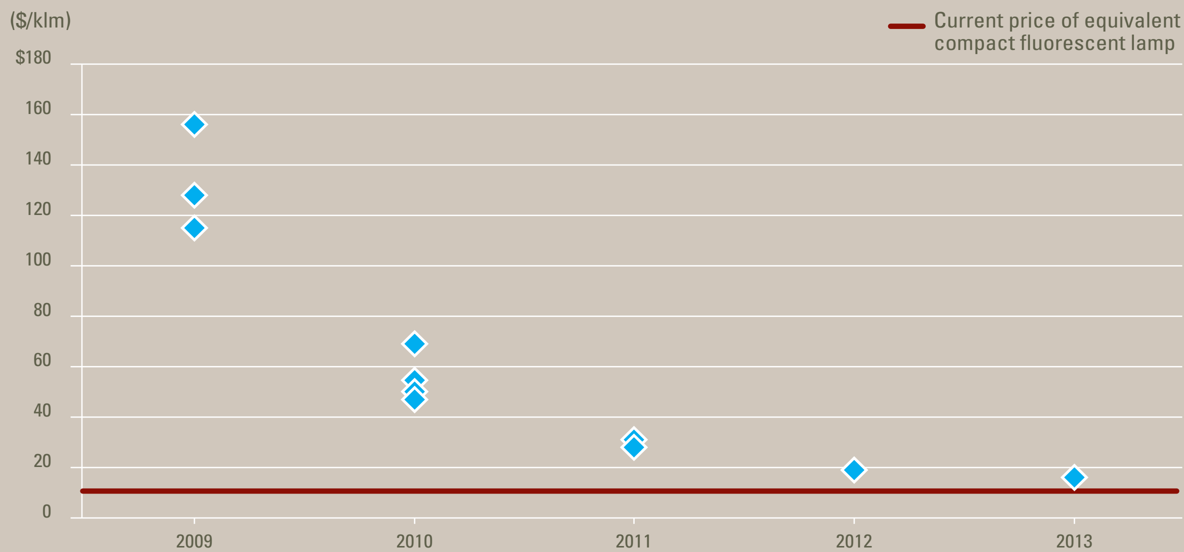


FIGURE 20. INSTALLED PRICE OF SOLAR PV IN THE U.S.[51]



NEW DEVELOPMENTS

FIGURE 21. LED A19 LAMP PRICES[52]



renewable-energy standards and supportive tax credits. Costs of these technologies have also declined significantly, although it is unclear how the expiration of supportive tax credits will affect progress. Moreover, recent setbacks to state clean energy standards threaten to slow progress considerably.

Significant progress is still needed for a variety of clean energy technologies, with some technologies yet to reach first market entry and others yet to mature to the point of no longer requiring significant subsidy to be economically competitive. The first generation-III+ nuclear reactors in the United States, underwritten by DOE loan guarantees, began construction in 2013; following a series of delays, the new reactors are expected to begin operation between 2019 and 2020.[53] The first power-sector carbon-capture and sequestration (CCS) project in the United States, also underwritten by DOE loan guarantees, is under construction; after a series of delays, operations are now planned to begin in 2016.[54] In both cases, the technology development has been badly delayed by insufficient RD&D and commercialization funds.

While commercial-scale production of cellulosic biofuels and mass-market sales of plug-in electric vehicles have started in the United States, significant cost improvements are needed for these technologies to compete successfully for greater market share.

Similarly, while a variety of energy-storage technologies have begun initial deployments, the economics of these technologies must improve significantly to be an affordable resource. An array of breakthrough clean energy technologies—such as marine hydrokinetic energy, deep geothermal energy, generation IV and small modular nuclear reactors, next-generation photovoltaics, and fusion energy—remain in early research and development.

U.S. PRIVATE-SECTOR ENERGY RESEARCH AND DEVELOPMENT INVESTMENT IS DANGEROUSLY LOW, AND VENTURE INVESTMENT IS FLAT.

As public energy innovation investment levels failed to rise, private clean energy innovation investments themselves have remained flat or declining. While data are challenging to compile, it appears that U.S. private clean energy research and development dropped after the 2009 financial crisis, returned to pre-crisis levels by 2011, and declined again in more recent years. Early stage venture capital investments in U.S. clean energy technology companies peaked in 2011 and have declined to levels last seen in 2005; this is out of keeping with venture-capital investment as a whole, which has maintained investment levels at or near the 2011 peak.

NEW DEVELOPMENTS

Federally funded energy RD&D is particularly critical during economic downturns. Businesses must respond in the short-run to outside pressures from markets and shareholders and often cut RD&D during recessions, delaying or canceling innovation investments. Early stage investors become risk averse and reduce or withdraw from venture funding. **As the federal government steps up and invests in RD&D partnerships, these businesses and investors are better able to justify and continue their own research & development and venture investments.**

DOE'S RD&D PORTFOLIO HAS CHANGED MODERATELY ACROSS TECHNOLOGY AREAS.

While DOE has reallocated its portfolio moderately to emphasize different clean energy technology pathways, the absence of a rise in overall funding means some areas have lost funding while others have risen.

Since FY 2008, energy-efficiency RD&D appropriations have increased in share. RD&D appropriations in nuclear power, fusion, and electric grid have remained stable as a share. Appropriations to fossil fuel RD&D, which includes carbon capture and sequestration, have declined in share significantly, and renewables RD&D appropriations, which include biofuels, have declined in share more moderately—although declines in both areas are compensated by significant outlays from ARRA accounts. Regular appropriations to the new office of ARPA-E have begun.

FIGURE 22. ESTIMATED U.S. CORPORATE CLEAN ENERGY RESEARCH AND DEVELOPMENT EXPENDITURE[55]

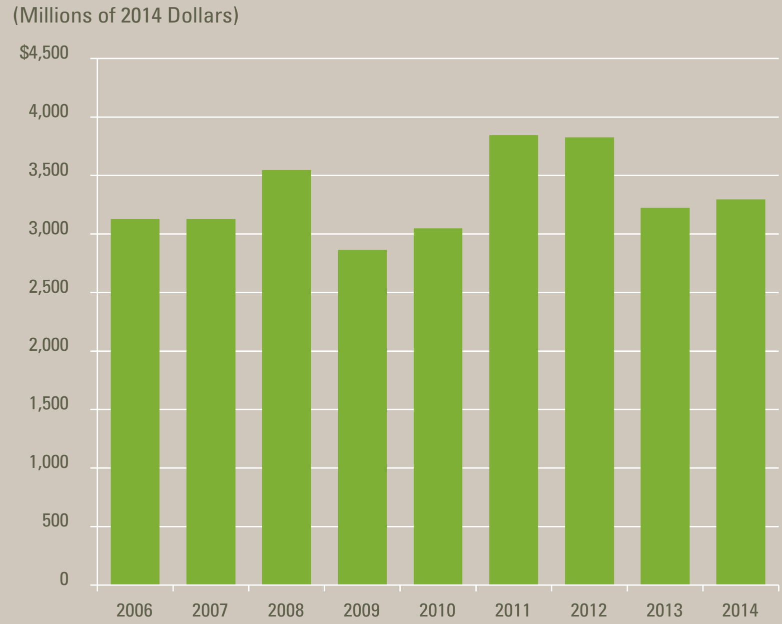
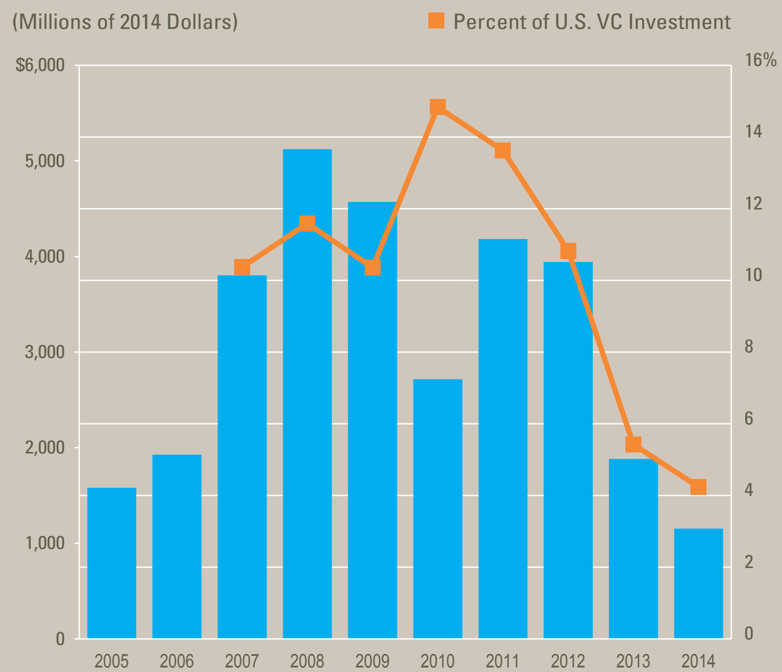


FIGURE 23. U.S. CLEAN ENERGY VENTURE CAPITAL INVESTMENT[56]



NEW DEVELOPMENTS

Congressional appropriations have also shifted RD&D investment allocations within each program. In DOE's energy-efficiency RD&D portfolio, building-technologies and industrial-efficiency RD&D have gained in relative shares, while vehicle technologies have remained stable. In DOE's renewable-energy RD&D portfolio, the share of investment in solar power and bioenergy RD&D has increased significantly, and the share of wind power RD&D has increased moderately. The shares of appropriations to geothermal and hydropower RD&D have remained stable, and hydrogen and fuel-cell RD&D has declined in share. After several years of flux in DOE's fossil fuel RD&D portfolio, relative portfolio shares for coal, oil and gas, and carbon-sequestration technology RD&D have remained stable for several years. Carbon-sequestration technology RD&D has gained the most in share, whereas coal RD&D has declined moderately. (Outlays from ARRA funds increase the total amount invested annually in fossil RD&D by 60 to 100 percent.)

FIGURE 24. **DOE ENERGY RD&D PORTFOLIO BY SHARE OF APPROPRIATIONS**[57]

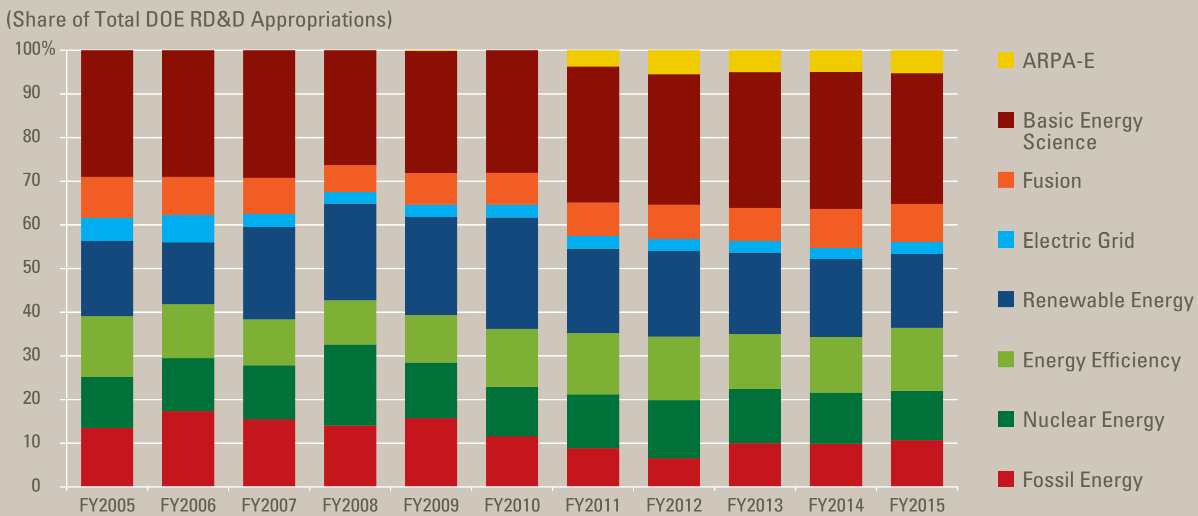
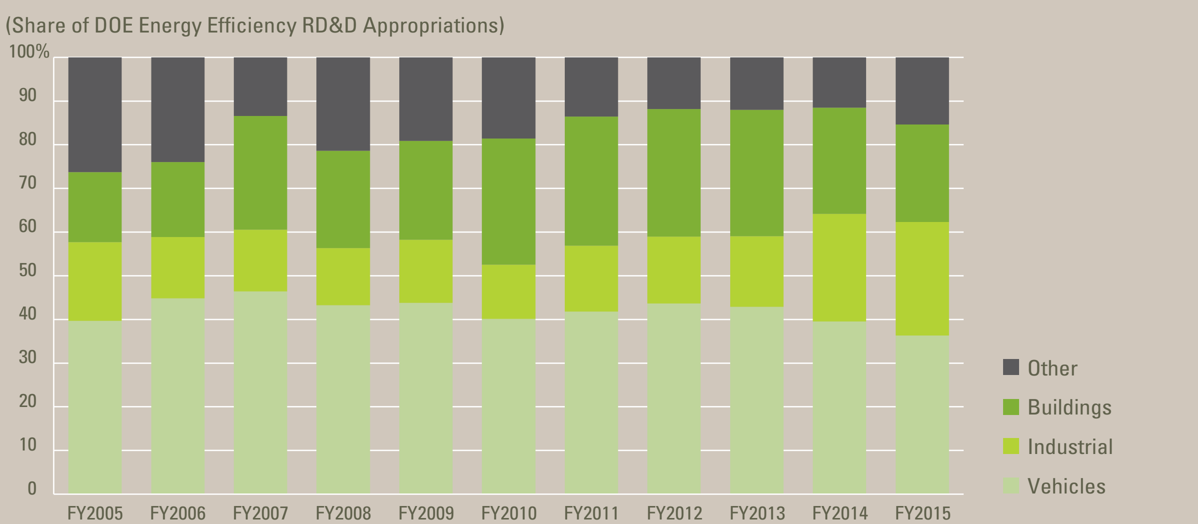


FIGURE 25. **DOE ENERGY EFFICIENCY RD&D PORTFOLIO BY SHARE OF APPROPRIATIONS**[58]



NEW DEVELOPMENTS

FIGURE 26. **DOE RENEWABLE ENERGY RD&D PORTFOLIO BY SHARE OF APPROPRIATIONS**[59]

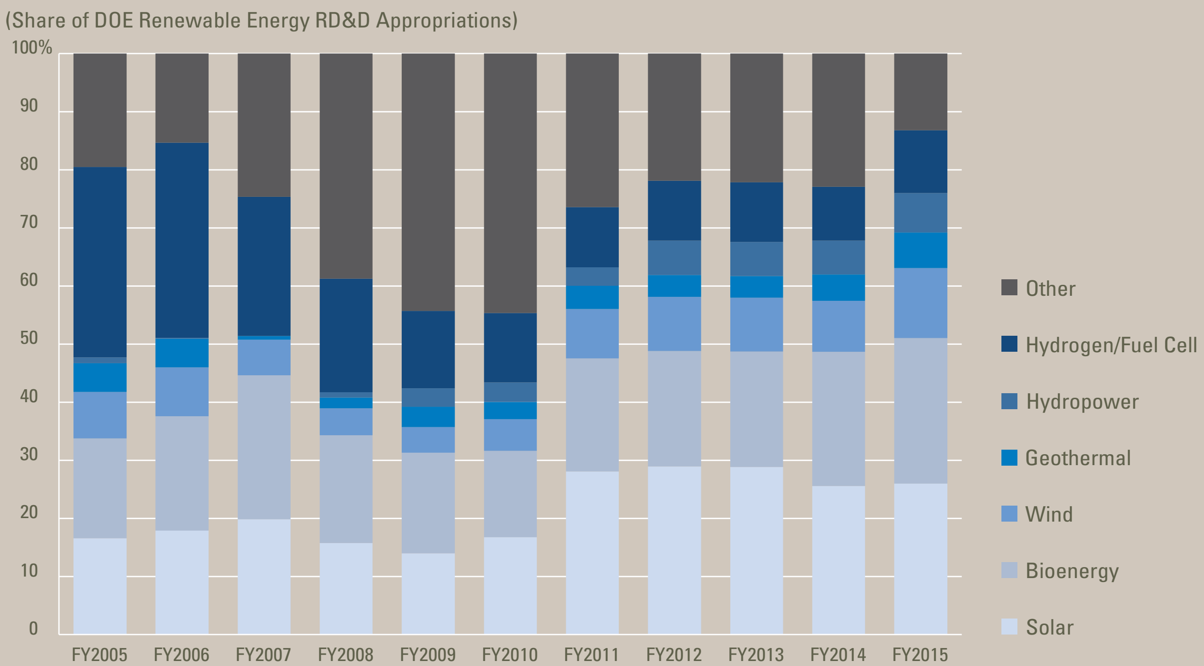
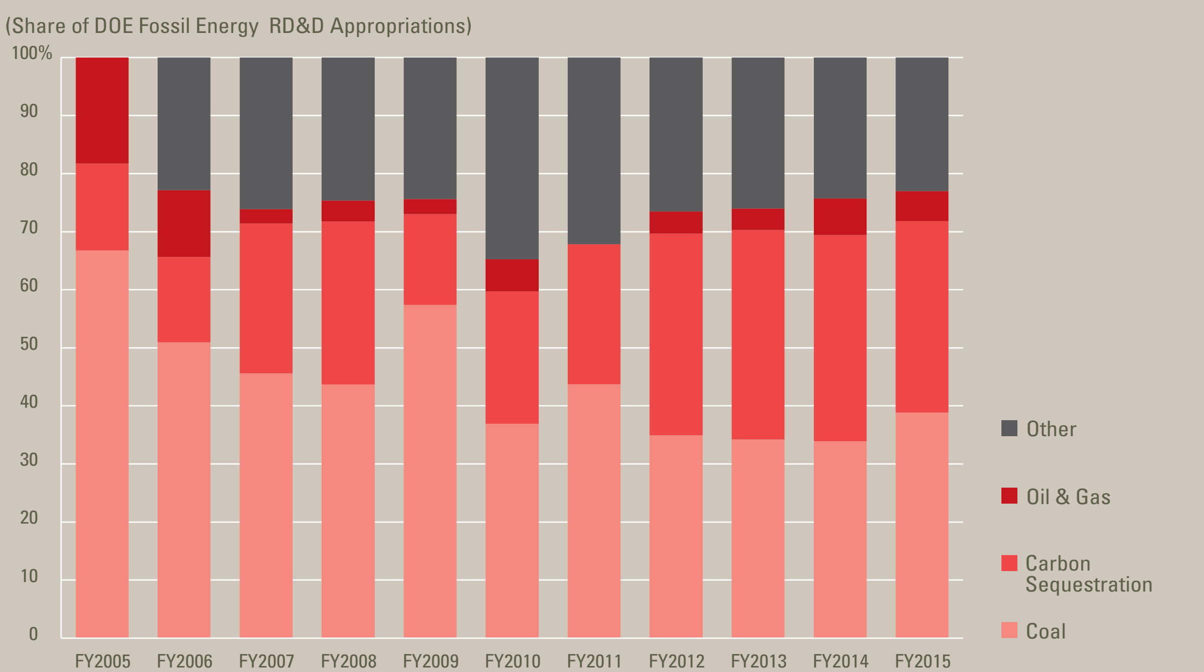
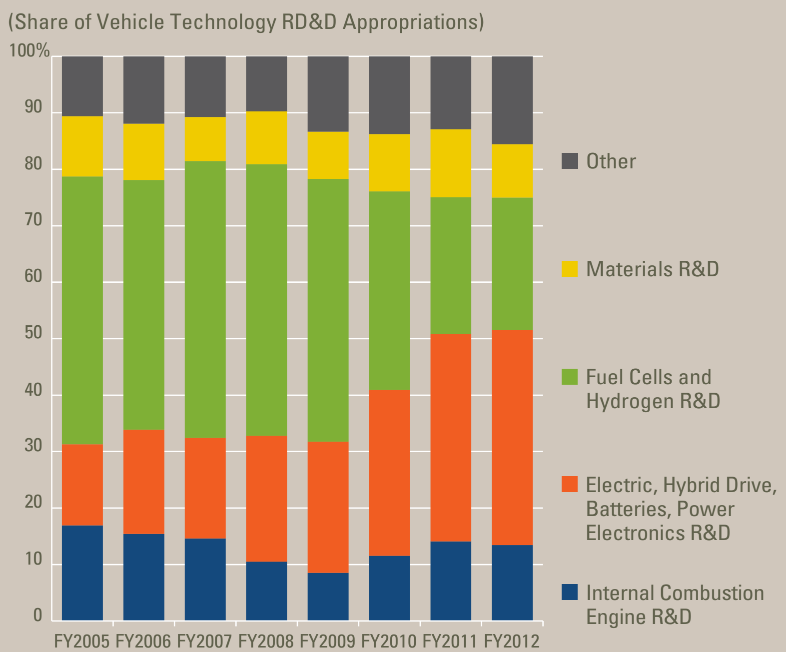


FIGURE 27. **DOE FOSSIL ENERGY RD&D PORTFOLIO BY SHARE OF APPROPRIATIONS**[60]



NEW DEVELOPMENTS

FIGURE 28. DOE VEHICLE RD&D PORTFOLIO BY SHARE OF APPROPRIATIONS[61]



Shifts in RD&D investment allocations have also occurred below the level of congressional control. For example, in DOE's vehicle-technology RD&D portfolio, which is under the larger efficiency RD&D program, electric-vehicle and battery-technology RD&D has expanded significantly, while fuel-cell and hydrogen-fuel RD&D has decreased significantly. Investment shares for materials and internal combustion engine RD&D have remained stable.

While periodic reprioritization of different technology pathways ensures innovation investments meet needs, the overall underinvestment by the federal government in energy innovation simply means different areas are not being funded enough.

FIGURE 29. AEIC FY 2015 RECOMMENDATIONS AND FY 2015 ENERGY RD&D APPROPRIATIONS

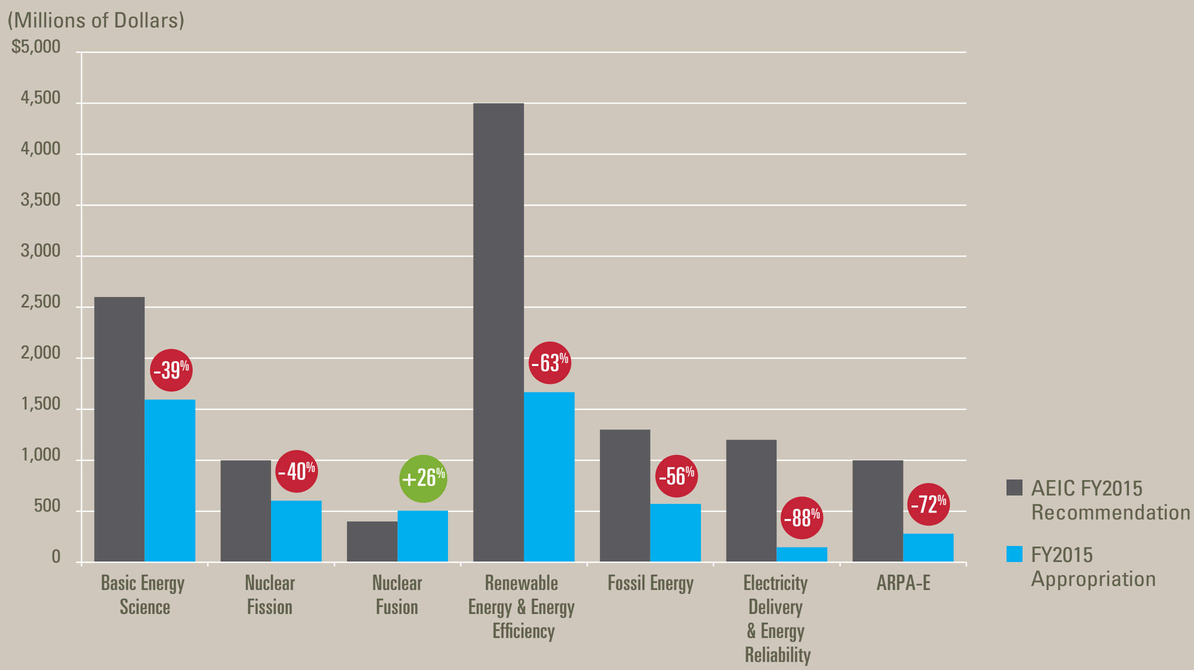


Photo credit: Argonne National Laboratory

While the cost of solar photovoltaic energy has declined dramatically in recent years, a variety of next-generation photovoltaics are progressing through research and development.

The world needs much more investment in and commitment to energy innovation. America must suit up, step up, and get serious about energy RD&D if we're going to be a winner in this race.

John Doerr
Partner, Kleiner Perkins
Caufield & Byers

CONCLUSION // ENSURING TOMORROW'S SECURITY AND COMPETITIVENESS TODAY

America's energy system is buoyed today by abundance, but no student of history can argue that the United States is free from current and future threats. U.S. vehicles still rely almost entirely on oil, exposing us to considerable insecurity from volatile prices. Two-thirds of U.S. electricity generation and nearly all of U.S. transportation emit greenhouse gases, and viable alternatives remain expensive at scale. And the United States struggles to establish clean energy industries as other countries compete for them, increasingly beating us in global markets.

As principals of the American Energy Innovation Council, we urge Congress to increase federal appropriations for energy RD&D across all clean energy sources, in line with our recommendation to triple such investments. We support increasing authorizations for DOE energy innovation programs, such as through reauthorization of America COMPETES legislation, and we welcome related efforts to reform DOE and its National Laboratories to maximize energy innovation investments. Additionally, we urge support for large-scale demonstration projects and limited downstream innovation investments, such as through a CEDA or other investment authority, and/or through appropriately targeted tax provisions.

A step-change in the U.S. commitment to federal energy innovation is critical. America's current energy abundance is in part the product of many years of past energy innovation investments. Future generations should have a rich suite of options to choose from, or they may be swamped by the list of challenges described in this document. Any serious business leader would recognize that the country needs to take advantage of its current strength and act now to create a clean energy future. Only by investing in ingenuity and restlessness will the United States preserve its global leadership and ensure its future prosperity.

ENDNOTES

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