American Energy Innovation Council

ENERGY INNOVATION: SUPPORTING THE FULL INNOVATION LIFECYCLE

February 2020

Bipartisan Policy Center

THE AMERICAN ENERGY INNOVATION COUNCIL

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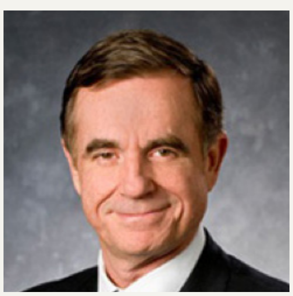

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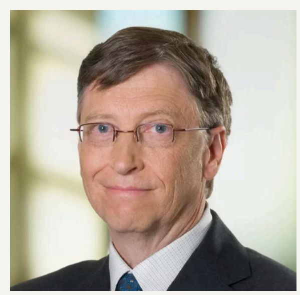

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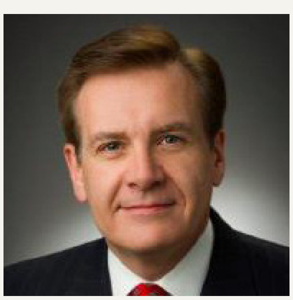

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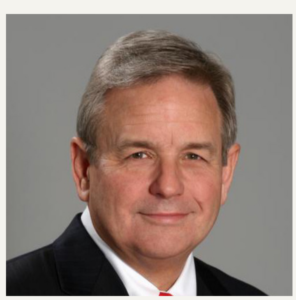

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*Ursula Burns, CEO of Xerox; Jeff Immelt, chairman and CEO of GE; and Tom Linebarger, chairman and CEO of Cummins Inc., were founding members and serve in emeritus status.

THE AMERICAN ENERGY INNOVATION COUNCIL

American Energy Innovation Council

WHO WE ARE

The American Energy Innovation Council, originally formed in 2010, is a group of 11 corporate leaders who share a common interest in increasing U.S. commitment to energy innovation. We speak as executives with broad-based success in innovation. In the course of our careers we have been called upon to overcome obstacles, seize opportunities, and make difficult decisions, all in the pursuit of building great American companies.

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 AEIC is a project of the Bipartisan Policy Center.

Bipartisan Policy Center

ABOUT THE BIPARTISAN POLICY CENTER

The Bipartisan Policy Center is a non-profit organization that combines the best ideas from both parties to promote health, security, and opportunity for all Americans. BPC drives principled and politically viable policy solutions through the power of rigorous analysis, painstaking negotiation, and aggressive advocacy.

As the only Washington, DC-based think tank that actively promotes bipartisanship, BPC works to address the key challenges facing the nation. Our policy solutions are the product of informed deliberations by former elected and appointed officials, business and labor leaders, and academics and advocates who represent both ends of the political spectrum. We are currently focused on health, energy, the economy, housing, immigration, infrastructure, and governance.

BPC's experts work tirelessly to find consensus and common ground, but the effort doesn't stop there. Bipartisan Policy Center Action, our (c)(4) affiliate, is committed to seeing bipartisan policy solutions enacted into law. As such, BPC Action engages in aggressive advocacy and strategic outreach to unite Republicans and Democrats on polarizing issues.

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LETTER FROM THE PRINCIPALS

The American Energy Innovation Council was formed around a shared understanding that robust federal investments in energy innovation are crucial to America's national security, international competitiveness, environmental stewardship, and long-term economic prosperity. In the ten years since AEIC was formed, the political, economic, and energy landscape has changed significantly at home and around the world. New and enhanced technologies and processes—such as large-scale energy storage, advanced nuclear reactors, hydrogen fuel cells for transportation, off-shore wind, and others—are emerging and have the potential to transform how we produce and consume energy while upending traditional business models in the energy sector and beyond. These developments present exciting technical and economic opportunities by enabling continued innovation in the energy sector and beyond, as well as creating additional global markets in which United States-based innovators and manufacturers can compete.

In our last report, Energy Innovation: Fueling America's Economic Engine, we focused on the status of energy innovation in the United States and explored the effectiveness of the Department of Energy's energy innovation programs, both in terms of nurturing new technologies and investing taxpayer dollars. We found that America continues to be a global leader in energy technology innovation and has made major strides in recent years by creating programs such as the Advanced Research Projects Agency-Energy, or ARPA-E, which supports new technologies through the critical transition from lab bench to engineering prototype. Regardless, major challenges remain, particularly with respect to our nation's ability to compete successfully in manufacturing and deploying new energy technologies at scale. Over time we have concluded the United States must become more adept at facilitating the scale-up and demonstration phases of the innovation cycle and at aligning incentives to accelerate new technology deployment.

In recent years, bipartisan recognition that we urgently need to develop and commercialize low- and zero-emission technologies to respond to market demands and address climate change has been growing. We appreciate the need for solutions and note an increased interest in bringing legislative solutions forward in Congress. For example, 28 bipartisan, technology-focused energy innovation bills have been approved in the Senate Energy and Natural Resources Committee so far during the current Congress, along with a number of bipartisan bills in the House Science, Space and Technology's Subcommittee on Energy. We applaud this enthusiasm and hope this report can be used as a blueprint to further an emerging bipartisan, bicameral agenda.

As business leaders, we have first-hand experience with the difficulties of bringing new technologies to market and making them profitable. We believe the federal government fills a critical gap by helping to de-risk technologies in which the private sector cannot or will not invest. This report focuses on how lawmakers can continue to support energy innovation R&D while also thinking ahead toward the need for more effective incentives and strategies for commercial-scale demonstration and deployment.

INTRODUCTION

There is a growing urgency to address critical challenges facing the United States, including climate change and global economic competitiveness. It is abundantly clear a robust energy innovation agenda must be at the heart of tackling these challenges. Bipartisan momentum is gathering around a technology-forward innovation agenda that addresses climate risks. A meaningful innovation strategy must have details around resources and how to allocate them. The AEIC is preparing for a new moment that marries the desire to act with concrete and credible suggestions for effectively scaling innovation. For the United States to respond to climate change and maintain our position of global economic leadership, we must triple down on the full energy innovation lifecycle, from increasing support for basic science to creating effective institutional and financial structures to support the scale-up and demonstration of low- and zero-emission energy technologies for deployment here and export abroad.

One often cited concern with tripling our innovation budget is: Where will this money go? Our answer is demonstration and deployment projects.

Previous AEIC reports have made the case for public and private investment in technology innovation as a way to improve productivity across existing industries and create entirely new ones. Innovation is a proven driver of long-term economic growth[1] and stability; indeed, researchers have estimated at least 50%[2] of U.S. annual GDP growth can be traced back to investments in innovation. Energy innovation, in particular, deserves additional consideration, given the importance of secure, reliable, and affordable access to energy to the U.S. economy as a whole and given the growing urgency of developing and implementing solutions for addressing global climate change.

Recognizing the critical importance of energy innovation—from multiple perspectives, including economic competitiveness, national security, and environmental sustainability—we formed the AEIC in 2010 to advocate for a more robust and effective federal role in this area. Since that time, the Council has published numerous reports, white papers, and case studies, and has regularly put forward recommendations aimed at maintaining and strengthening U.S. leadership in energy technology development.

At the same time, it has become increasingly clear that an exclusive focus on early-stage R&D is insufficient. The path from the lab bench to wide-scale deployment of new energy technologies is long and arduous and can require decades of effort and hundreds of millions, or even billions, of investment dollars. A more comprehensive approach to the full innovation lifecycle—encompassing not only research and development, but also demonstration and deployment—can help ensure the United States remains home, not only to the inventors of tomorrow's critical energy technologies, but also to the companies that build, manufacture, and export those technologies to the world.

INTRODUCTION

Building on core recommendations from previous AEIC work, such as our call for a **tripling of the federal energy innovation budget**, this report reviews the current state of U.S. and global R&D investments in energy innovation and discusses specific options for more effectively supporting the later phases of the energy innovation cycle.

One often cited concern with tripling our innovation budget is: Where will this money go? Our answer is demonstration and deployment projects. However, these projects are not easily financed today. As in previous years, we close with a set of proposals for consideration in this vital policy area.

SUMMARY OF AEIC RECOMMENDATIONS FOR 2020: A POLICY MENU FOR THE FULL INNOVATION LIFECYCLE

FOR RESEARCH AND DEVELOPMENT

1. Congress should expand federal appropriations for DOE's Advanced Research Projects Agency-Energy to $1 billion per year.
2. Congress should authorize and appropriate $20 million per year for DOE's Lab-Embedded Entrepreneurship Program.
3. Congress should authorize and appropriate $16 million per year for the Office of Technology Transitions. In addition, OTT should be given its own authorization, and the head of OTT should report to the Secretary of Energy.

FOR DEMONSTRATION AND DEPLOYMENT

4. Congress should consider strengthening and enhancing DOE's Loan Programs Office.
5. Congress should consider additional institutional mechanisms to support early-stage commercial projects like the Clean Energy Deployment Administration.
6. Congress should consider energy tax provisions focused on supporting the early commercial deployment of new technologies.
7. Innovation multipliers should be considered as a potentially powerful tool to incentivize innovation within energy standards.
8. Public procurement programs should be used to establish early market demand for innovative technologies.
9. Infrastructure financing should be designed to support and incorporate innovative technologies.

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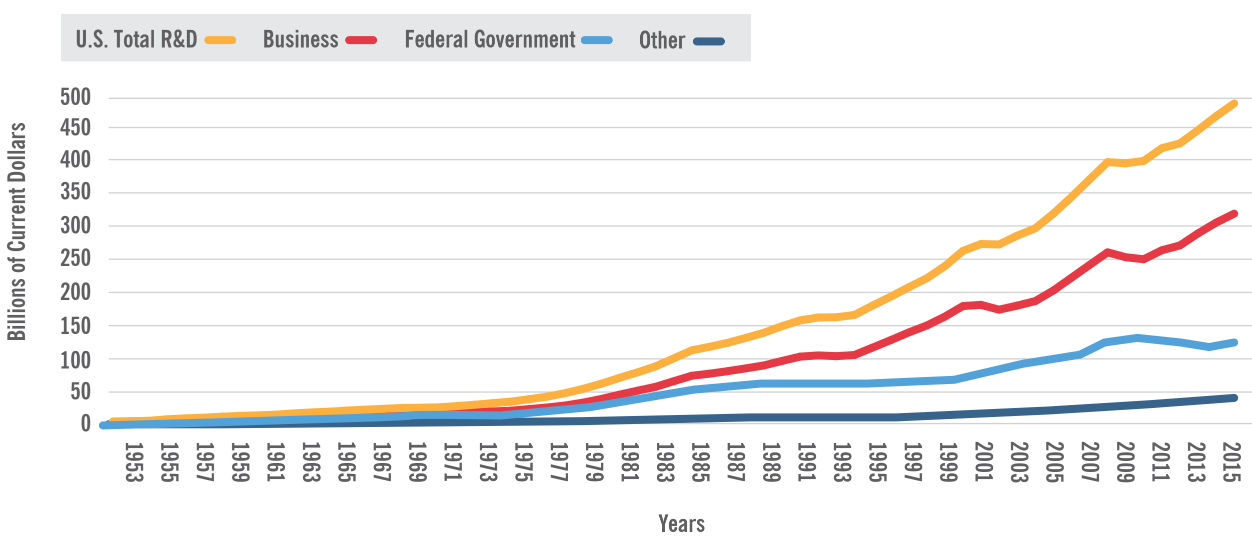
Decades of public and private investment in innovation have facilitated the technological leadership and economic success the United States enjoys today. The federal government's commitment to scientific discovery and technology advancement has long been a core feature of the American experiment and one that played a pivotal role in many of our nation's proudest achievements, from putting a man on the moon to launching the Internet and sequencing the human genome. In many ways, however, today's most successful technology companies are reaping rewards from research investments made decades ago. More recently, U.S. research investments have not kept pace with economic growth, and the relative fraction of this funding has shifted noticeably from the public to the private sector.

As a result, U.S. research intensity—measured as the ratio of investments in R&D relative to overall GDP—has stagnated[3] and now lags behind that of major trading partners such as Germany, Japan, South Korea, and Taiwan. Although U.S. research funding has increased in absolute terms in recent years—for example, federal R&D obligations increased by 2.7% between FY2017 and FY2018[4] —and America remains the largest global investor in R&D, as measured by total dollars spent, China is now close to surpassing the United States along both those metrics.[5] Further, China's R&D intensity, which tripled between 1995 and 2019—a period during which U.S. research intensity, relative to GDP, declined—continues to grow at a faster rate than America's.[6,7] China appears able to focus resources to both quickly scale projects beyond basic R&D and purchase and scale U.S. technologies. Figures 1 through 3 illustrate these trends, which should concern all Americans who recognize how important technology leadership is for the overall health of our economy, specifically in terms of the quality of job opportunities available to future generations.

FIGURE 1. U.S. R&D EXPENDITURES BY SOURCE OF FUNDS, 1953-2015



Source: National Science Board. 2018. Science and Engineering Indicators 2018. NSB-2018-1. Alexandria, VA: National Science Foundation. Available at: https://www.nsf.gov/statistics/2018/nsb20181/assets/nsb20181.pdf

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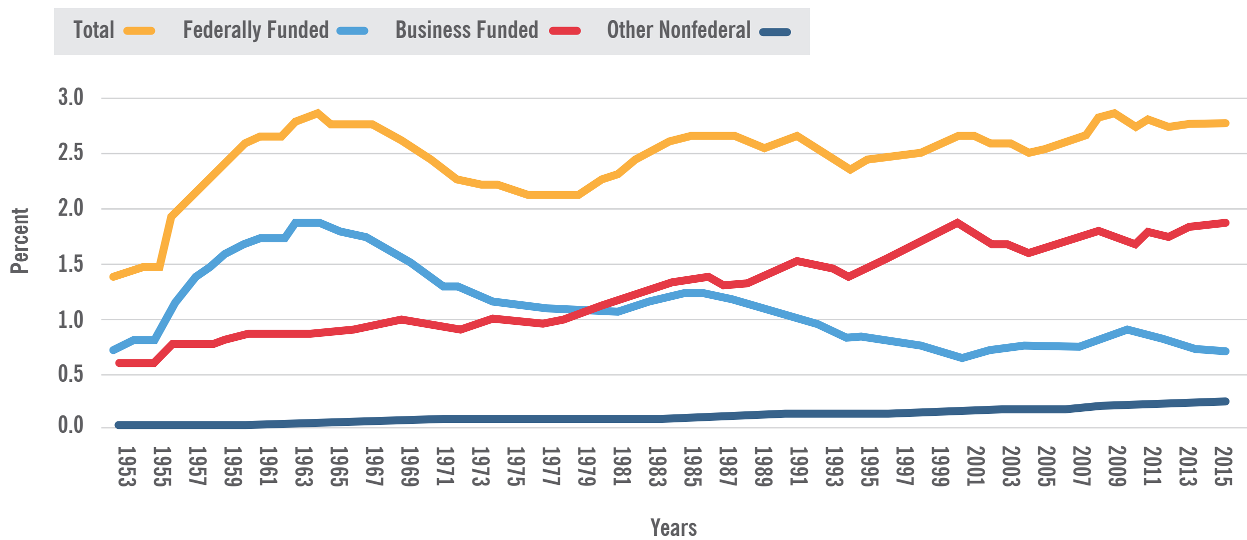
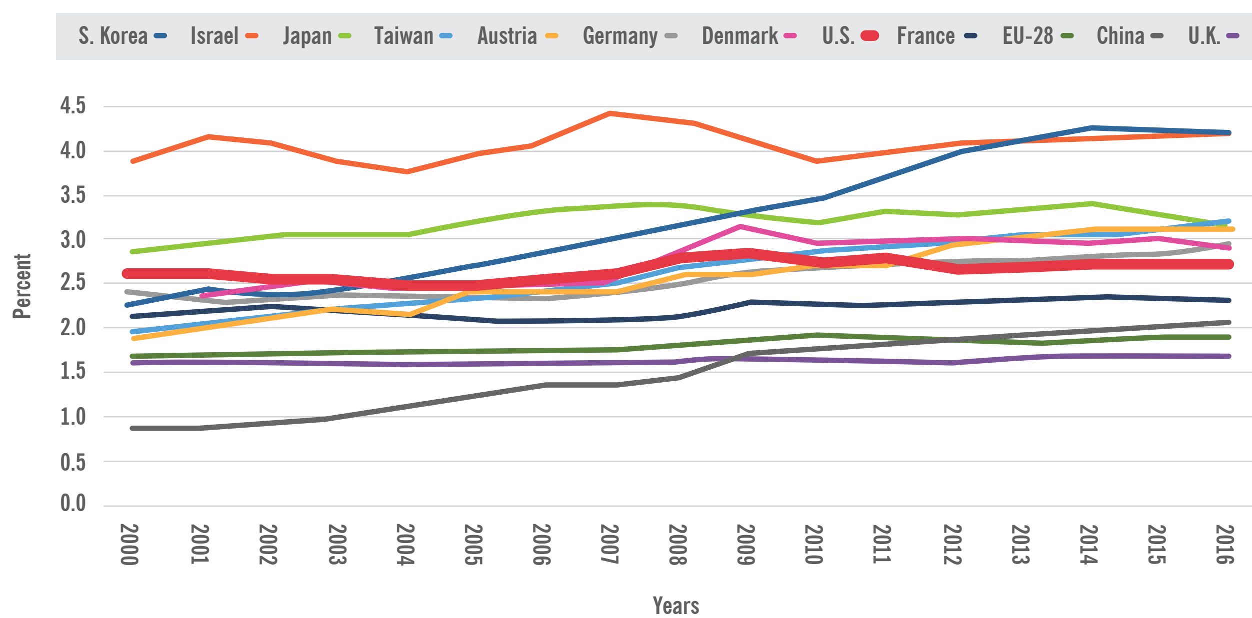
FIGURE 2. U.S. R&D INTENSITY, 1953-2015



Source: National Science Board. 2018. Science and Engineering Indicators 2018. NSB-2018-1. Alexandria, VA: National Science Foundation.
Available at: https://www.nsf.gov/statistics/2018/nsb20181/assets/nsb20181.pdf

FIGURE 3. INTERNATIONAL R&D INTENSITY, 2000-2016



Source: Source: American Association for the Advancement of Science. “Historical Trends in Federal R&D.” 2019.
Available at: https://www.aaas.org/programs/r-d-budget-and-policy/historical-trends-federal-rd

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Figure 2 shows, despite increasing sharply from 1953 to 1965, overall U.S. R&D intensity has largely held between 2% and 2.75% of GDP since the late 1950s, with federal investment declining over much of the last half century. In 2015, federal funding for R&D slid to its lowest point as a percent of GDP since recordkeeping began in 1953. Private spending has largely offset this decline, but the retreat of public investment remains troubling for reasons that have to do with the different constraints and drivers that influence privately-funded versus publicly-funded R&D.

In general, industry investments tend to favor short-term applied R&D activities rather than frontier research due to the pressure companies face to report positive quarterly earnings and show near-term returns on investment. This makes many companies unwilling or unable to sustain long-term investments, particularly in early-stage research or basic science where there is less guarantee that useful knowledge gained through these investments can be kept from competitors and translated into profitable products.[8] There have always been exceptions to this general rule, as exemplified by Bell Labs' storied history of incubating transformative technologies such as lasers, modern transistors, and silicon solar cells.[9] However, the decline of Bell Labs itself, along with the relative dearth of comparable private research organizations today that might play the same role, suggests the central tendency of corporate culture has evolved toward greater "short-termism" rather than less.[10,11] While there certainly are companies supporting long-term, high-risk, high-reward research in the United States today, those investments alone are unlikely to sustain the global technology leadership America enjoyed during the post-World War II era of the last century.[12]

The growing gap between private and public technology investment in the United States is even more pronounced when one focuses on the later stages of the innovation cycle—often called the development, demonstration, and deployment stages. The appropriate role for government support at these stages has long been more controversial than the government role in funding basic science, where there is less of a commercial interest to drive investment and the public benefits of knowledge creation are larger and inherently difficult for private entities to appropriate.[a] Nonetheless, historical experience shows government can play a vital role in supporting breakthrough technologies that deliver substantial economic benefits. An example is public funding for the development and demonstration of advanced drill bits and microseismic mapping in the 1970s. These technologies helped unlock vast natural gas reserves, enabling the United States to become a net exporter of natural gas for the first time in 2017,[13] lowering energy prices for consumers and creating millions of jobs in the process.[14] This was a case where the federal government partnered with industry to advance technologies that helped transform America's energy landscape and eventually delivered enormous benefits, though it involved upfront costs and timelines the private sector generally cannot or will not tolerate on its own.

[a] While support for government funding of basic science and fundamental research is generally broad and bipartisan, tracing all the way back to Vannevar Bush's landmark 1945 report Science the Endless Frontier, the United States barely places in the top ten countries globally in terms of public funding for basic research as a share of GDP. Between FY2017 and FY2018, federal spending on basic research increased only slightly, by 1.3%.

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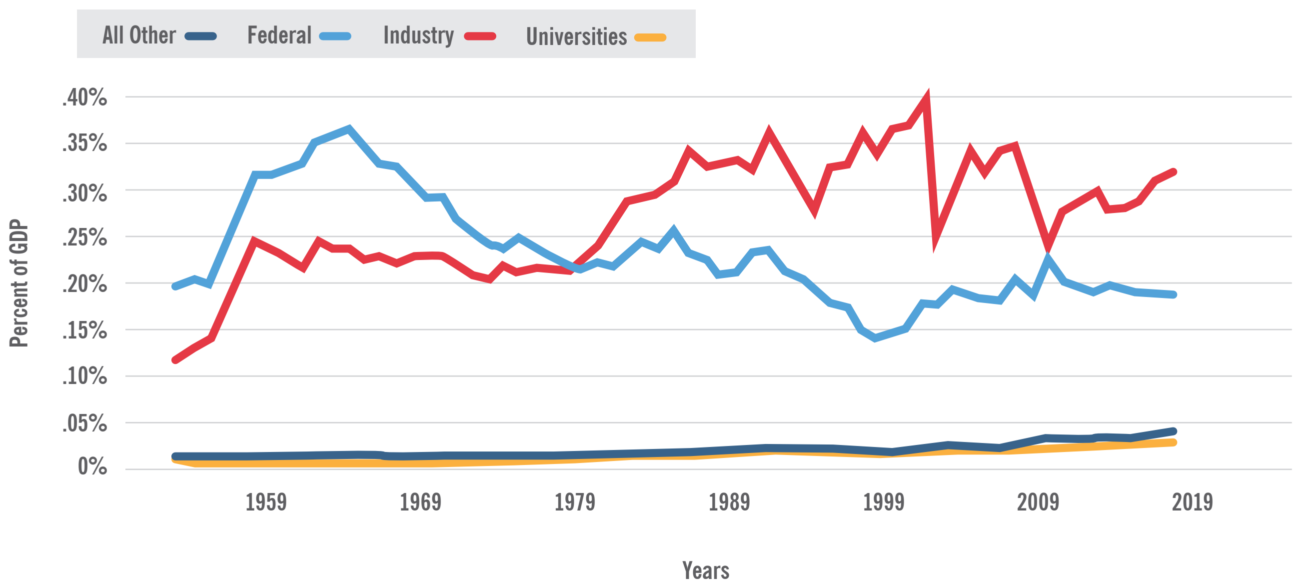
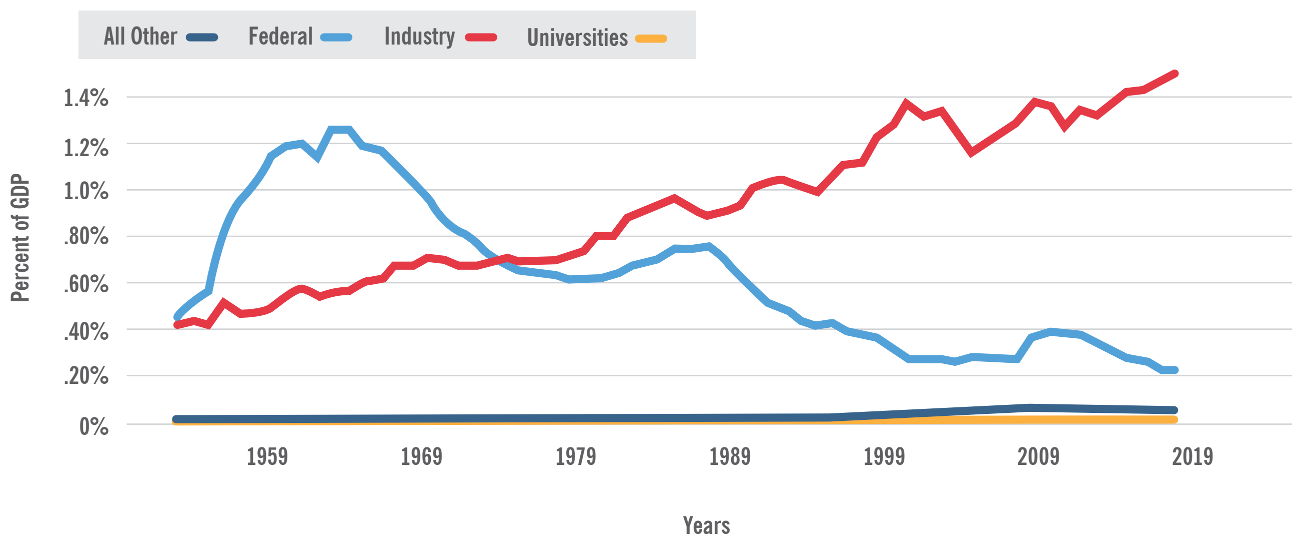
FIGURE 4. US EXPENDITURES ON APPLIED R&D AS A SHARE OF GDP, 1953-2015



Source: American Association for the Advancement of Science. "Federal R&D Budget Dashboard." June 2018. Available at: https://www.aaas.org/page/federal-rd-budget-dashboard

FIGURE 5. U.S. EXPENDITURES ON DEVELOPMENT AS A SHARE OF GDP, 1953-2015



Source: American Association for the Advancement of Science. "Federal R&D Budget Dashboard." June 2018. Available at: https://www.aaas.org/page/federal-rd-budget-dashboard

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In this context, a 3.2% increase in federal FY2019 funding for applied research and development (compared to FY2018) might be taken as an encouraging sign, but it must be noted that this uptick occurred because Congress agreed on a short-term deal to raise the Budget Control Act budget caps for two years.[15,16] It is currently unclear whether these recent increases reflect a long-term commitment or a short-term opportunity. The United States needs a galvanizing clean energy innovation agenda with a strong long-term signal. Evidence that America is in danger of losing the competition for global dominance in energy technology consistently elicits expressions of alarm by politicians on both sides of the aisle. Congress has taken initial steps, including passing and subsequently renewing the bipartisan America COMPETES Act along with technology-specific legislation such as the Nuclear Energy Innovation Capabilities Act. But federal appropriations for scientific research have consistently fallen short of pledges, including the government's Mission Innovation pledge to roughly double funding for key federal science agencies.[17,18]

The United States needs a galvanizing clean energy innovation agenda with a strong long-term signal.

In contrast, other countries, notably China, are increasing their public investments in applied R&D. In fact, China devotes a greater share of its R&D budget to applied research than most other countries.[19] If these trends continue, the United States risks a situation where other countries with a clearer focus on energy technology commercialization and deployment will reap the greater share of benefits from whatever knowledge creation flows from U.S. investments in basic science.

THE STATE OF ENERGY INNOVATION INVESTMENT IN AMERICA TODAY

The government's role in filling gaps where the private sector either cannot invest or underinvests throughout all stages of the innovation cycle is especially important in the energy sector. This is because the energy sector faces unique hurdles in attracting private research investment—from discovery through technology transfer—due to high capital costs, long lead times, regulatory uncertainty, disincentives due to current regulatory structures, and limited opportunities for product differentiation (energy is generally valued and priced as a commodity).[20] A 2018 survey illustrates that even among the top 1,000 global corporate spenders on R&D, businesses invested a disproportionately small share in energy R&D compared to other sectors (Figure 6). This is not a new development, as surveys from past years demonstrate (Figure 7). Moreover, those major companies that are active in the energy space generally devote less than one-tenth to one-third of their total research budget to new technologies; most of their research budget goes to incremental production improvements and product development, rather than breakthrough technologies.[21] Without robust government funding to de-risk new technology, it is unlikely the United States would have developed nuclear energy, modern solar cells, electric vehicle technology, gas turbines, hydraulic fracturing technology, or the advanced electronic and data capabilities needed to manage increasingly complex and sophisticated energy delivery systems.

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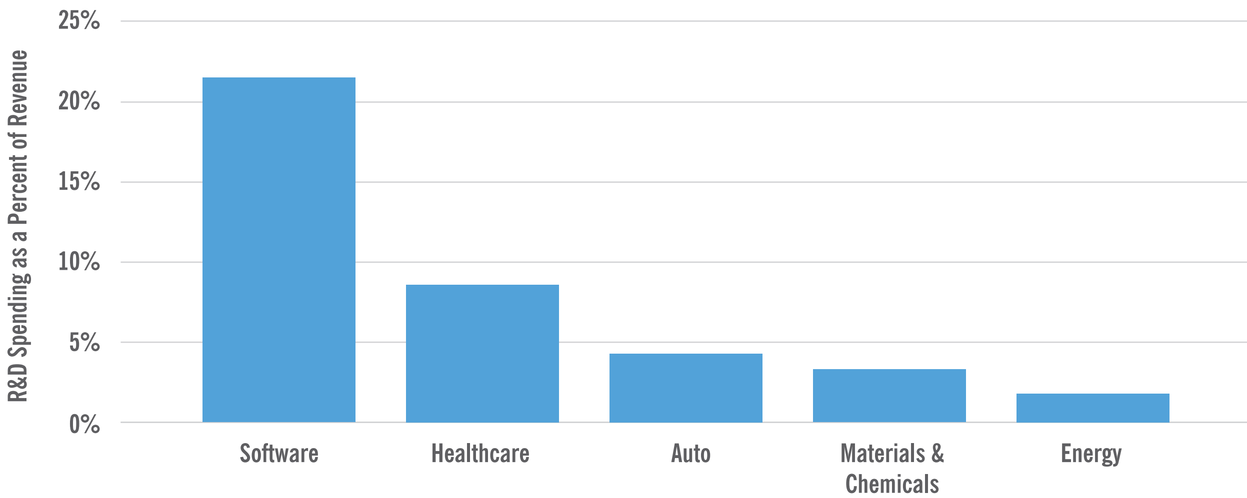
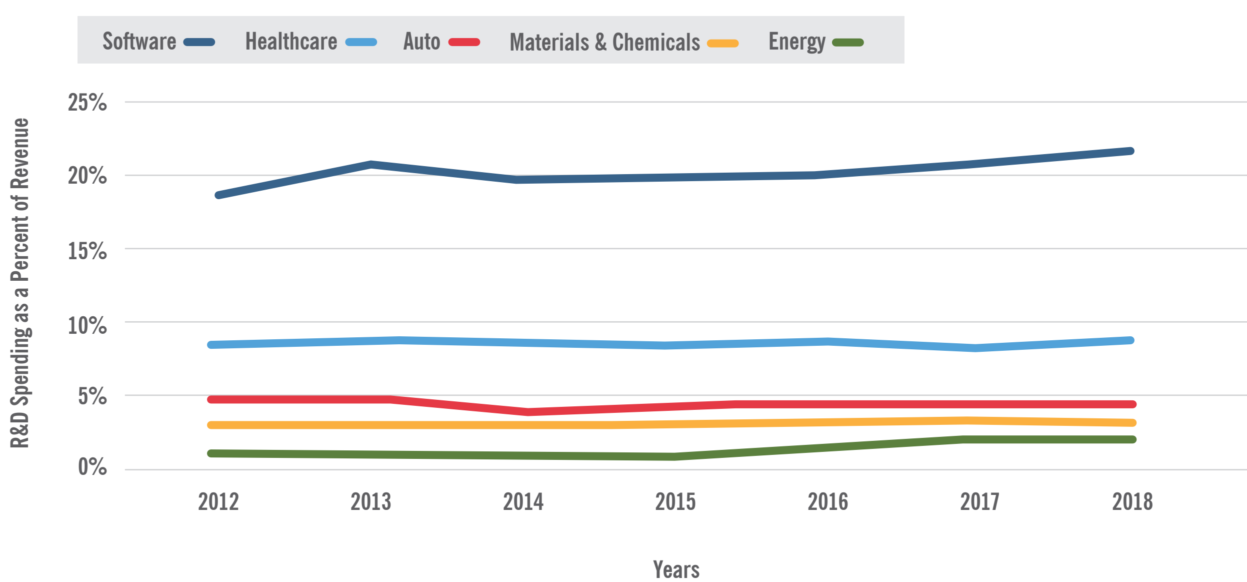
FIGURE 6. R&D INTENSITY OF TOP 1,000 CORPORATE R&D SPENDERS, BY INDUSTRY, 2018



Source: PwC. "The 2018 Global Innovation 1000 Study." October 2018.
Available at: https://www.strategyand.pwc.com/innovation1000

FIGURE 7. R&D INTENSITY OF TOP 1,000 CORPORATE R&D SPENDERS, BY INDUSTRY, 2012-2018



Source: PwC. "The 2018 Global Innovation 1000 Study." October 2018.
Available at: https://www.strategyand.pwc.com/innovation1000

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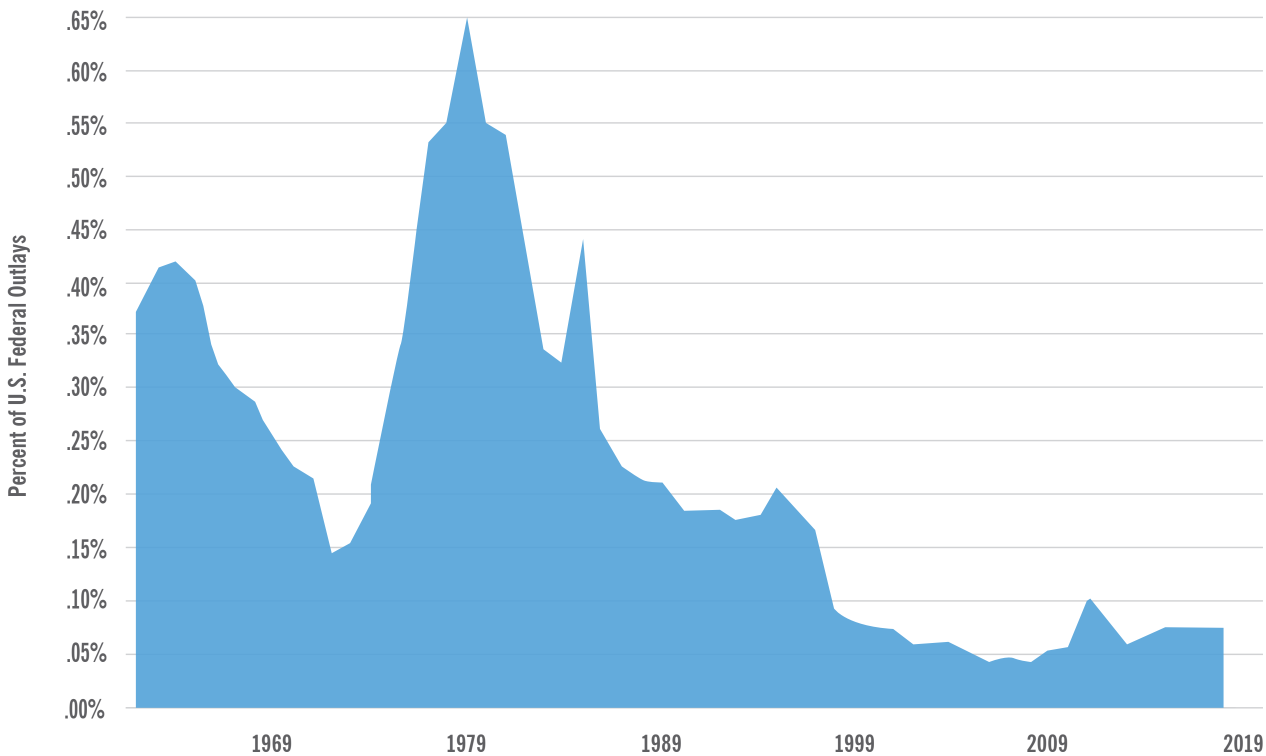
Unfortunately, the trajectory of public funding for energy research in the United States remains far off-track for reaching the level of commitment that AEIC and others have recommended based on the scale and importance of the environmental, geopolitical, and economic challenges and opportunities we face in transforming the global energy system this century.[22] DOE did see sizeable plus-ups in its FY2018 research budget, but this rate of budget growth was not sustained in FY2019. Despite recent short-term increases, it remains the case that only one-third of DOE's budget is dedicated to truly innovative energy research. Most DOE funds are spent on defense and environmental cleanup.[23]

FIGURE 8. ENERGY R&D AS A PERCENT OF U.S. FEDERAL OUTLAYS



Source: American Association for the Advancement of Science. "Federal R&D Budget Dashboard." July 2019. Available at: https://www.aaas.org/programs/r-d-budget-and-policy/federal-rd-budget-dashboard

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In sum, inadequate federal support for energy R&D is a concern because the U.S. government has long been a driving force in generating scientific breakthroughs, as well as a key partner to industry in funding technologies that have become central to modern life and the productive functioning of an advanced economy. This isn't to diminish the importance of industry research, but rather to acknowledge innovative technologies often emerge from the cross-pollination of ideas supported by both government and industry. As we have already noted, the public and private sector have unique strengths and differences in risk tolerance, and each plays a crucial and interdependent role across the innovation cycle.

GLOBAL TRENDS IN ENERGY R&D

Both public and private spending on energy R&D increased globally in 2017 and 2018. This increase followed four years of decline with investment concentrated primarily in low-carbon energy technologies. Corporations remain the largest source of energy research funding in terms of total dollars, but government spending also plays a major role in this sector worldwide. From 2017 to 2018, global spending on energy innovation by corporations and governments increased, in both cases by approximately 4%.[24] The global increase in public funding for energy research was driven by China and the United States; however, it did not keep pace with growth in global GDP.[25]

The United States fell from 13th to 14th place in terms of public energy R&D spending relative to national GDP between 2015 and 2017 (Figure 9).[26,27] As we have already noted, the 12% increase in federal U.S. energy spending from 2017 to 2018 did not continue in 2019, when budget growth slowed in most areas.[28] Relative to most other developed economies, the U.S. government dedicates a smaller share of its research budget to energy and other industrial technologies, including technologies for making heavy-industry manufacturing processes cleaner and more efficient (Figure 10). China, by contrast, has continued to expand its lead in public energy RD&D spending as a share of GDP (Figure 11). Substantial public spending, along with government subsidies and supportive policies, explain why China was the world's largest market for energy investment in 2018, even as Chinese companies were expanding their share of new markets for clean energy technologies such as electric vehicles.[29]

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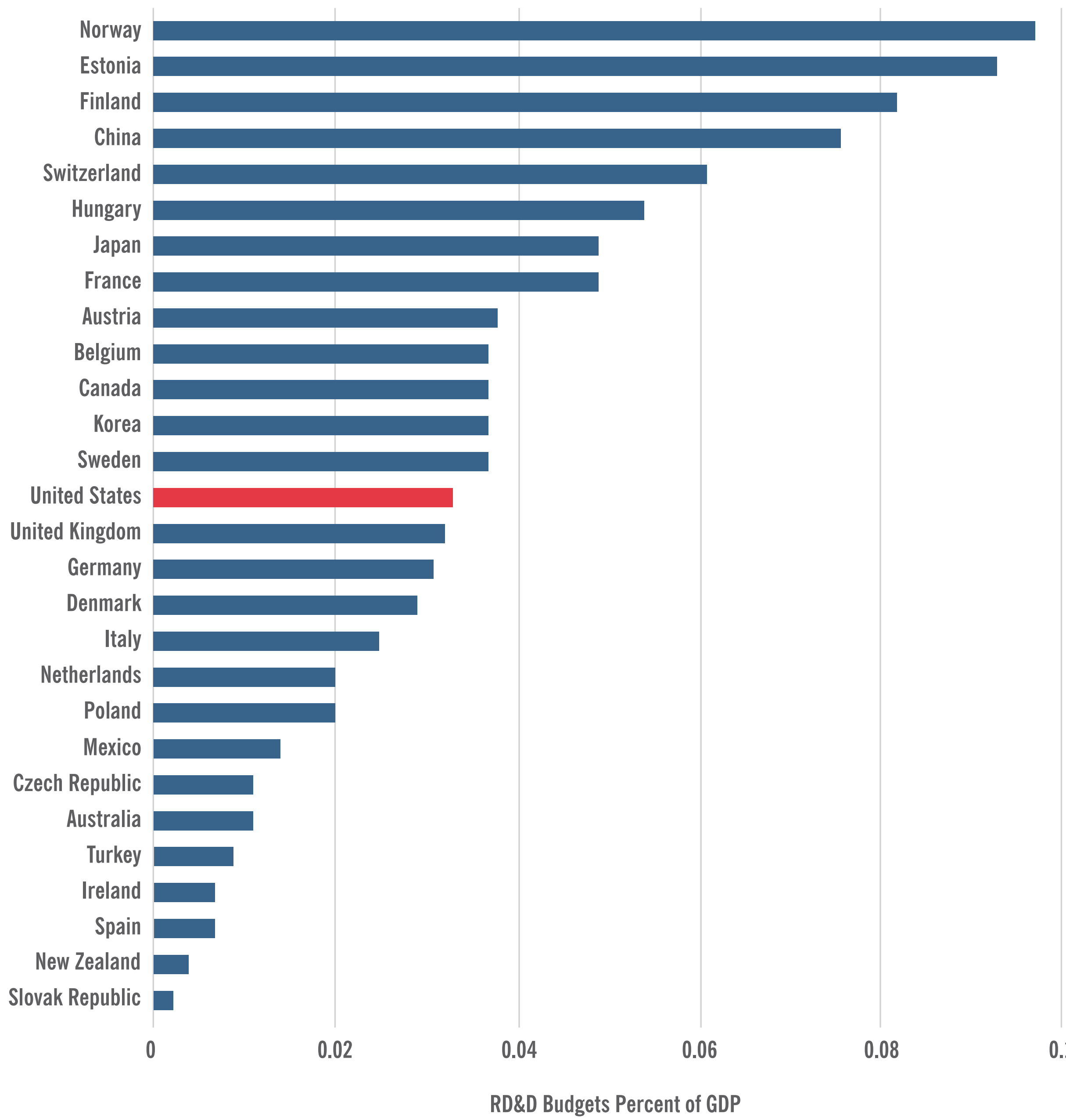
FIGURE 9. TOTAL PUBLIC ENERGY RD&D BUDGET AS A PERCENT OF GDP, 2017



Source: International Energy Agency. "Energy Technology RD&D Budgets: Overview." May 2019.
Available at: http://wds.iea.org/WDS/tableviewer/document.aspx?FileId=1649
Note: Chinese public energy R&D investment includes spending by the government and by state-owned enterprises.

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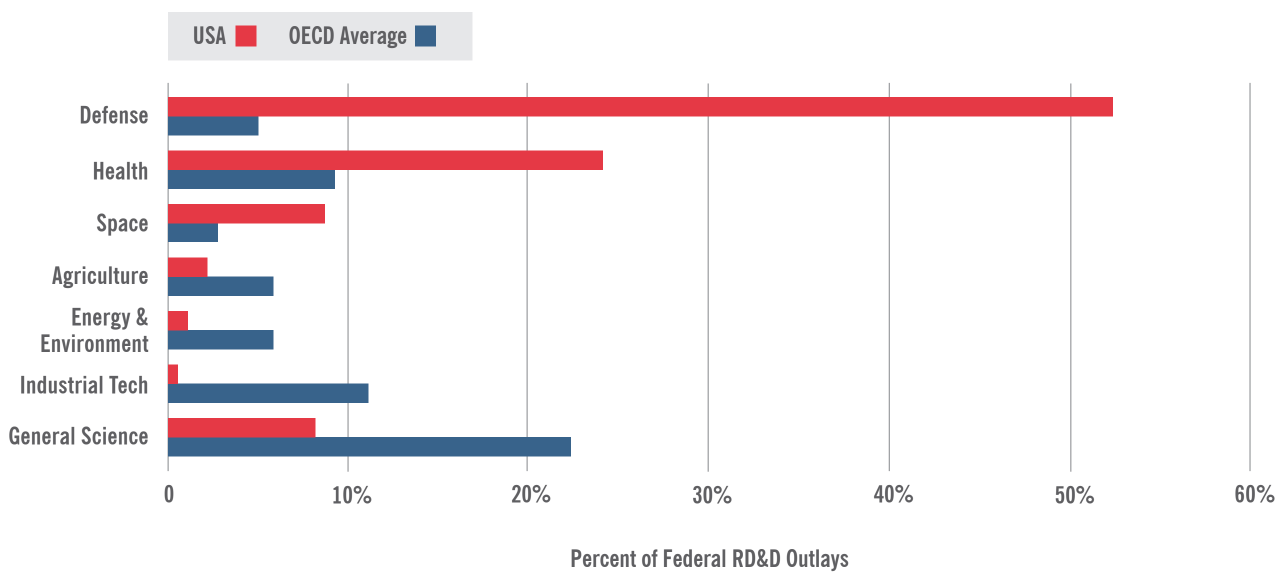
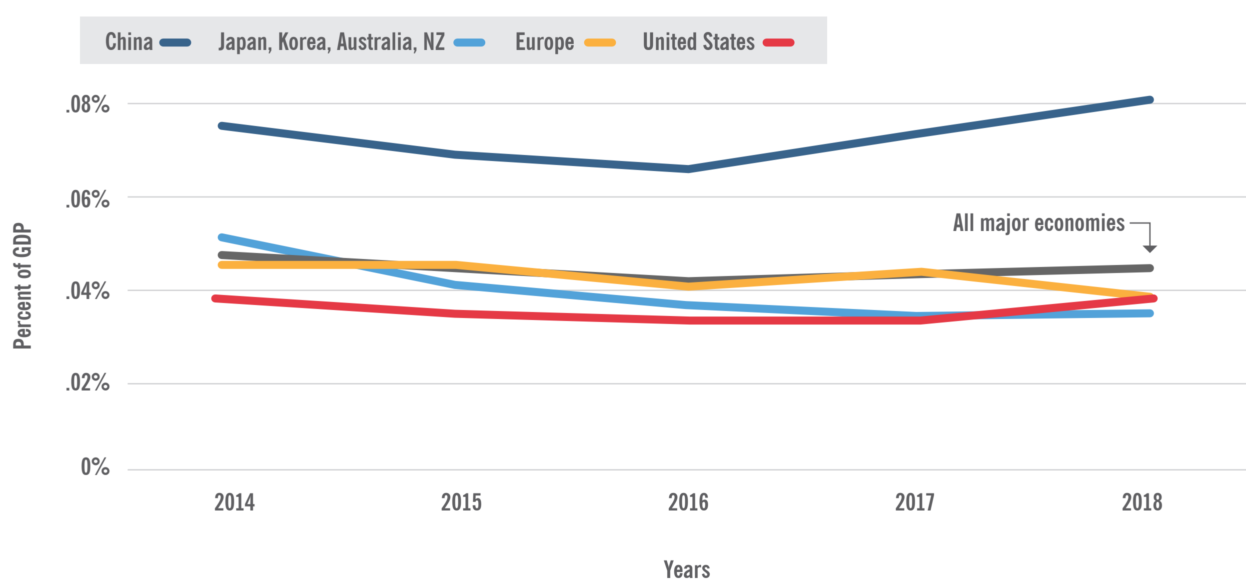
FIGURE 10. R&D BY SOCIOECONOMIC OBJECTIVE, 2016



Source: American Association for the Advancement of Science. "Federal RD&D Budget Trends: A Short Summary." January 2019. Available at: https://www.aaas.org/sites/default/files/2019-01/AAAS%20R%26D%20Primer%202019.pdf

FIGURE 11. GOVERNMENT ENERGY RD&D SPENDING AS A SHARE OF GDP, 2014-2018



Source: International Energy Agency. "World Energy Investment 2019." May 2019. Available at: https://webstore.iea.org/world-energy-investment-2019

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In terms of global spending on energy R&D by corporations, the 4% increase between 2017 and 2018 was driven largely by automaker investments in energy efficiency and electric vehicles.[30] Two related facts are worth noting. First, automakers typically have much higher R&D budgets than other types of manufacturers, thus their R&D spending doesn't necessarily reflect larger trends in corporate R&D spending on energy-related technologies.[31] Second, recent automaker investments have been driven, in part, by national policies that are designed to promote energy efficiency and electric vehicles (EVs) and by growing competition for market share in the EV space. U.S. automakers were part of this upward surge and increased their energy R&D spending 7% on average in 2018, but their investments were nonetheless dwarfed by those of Chinese automakers, which increased their R&D spending by 20% on average.[32] China is the largest single market for future EV sales, and Chinese automakers are projected to command over half of the global EV market by 2030 if current trends continue.[33]

Excluding transportation, two-thirds of global corporate energy R&D investments in 2018 went to low-carbon technologies. Thus, R&D budgets increased for companies active in energy storage, nuclear, and combustion technologies, and corporate interest in carbon capture, utilization, and storage and hydrogen fuel cells was also heightened. Several U.S. companies were among the top corporate spenders on energy R&D globally, including General Electric; another four of the top ten were Chinese companies.[34]

Increased corporate investment in energy R&D was matched by overall revenue growth in the advanced energy industry[b] in 2018, which was valued at $1.6 trillion.[35] China remains the largest destination for energy investment overall, though the United States saw a $25 billion uptick in this space, led by investments in advanced transportation, building efficiency, and advanced fuel production. Revenues in America's advanced transportation sector grew 34% and reached $18 billion in 2018, driven by companies involved in plug-in EV technology.[36] Venture capital investment in energy also grew in 2018, with most of this investment directed at clean energy startup companies as opposed to R&D projects. The vast majority was in the transportation sector, consistent with recent overall growth in automakers' energy-related R&D investments.[37]

Hydrogen fuel cells are a high-opportunity area for investment, given this technology's potential to generate electricity for a wide variety of applications, including in buildings, industry, and non-road and heavy-duty modes of transportation, and as another low-carbon alternative to battery-electric passenger vehicles.[38] There was an uptick in corporate interest in fuel cell technology in 2018, along with an 8% increase in public energy research budgets in this area.[39] Having witnessed remarkable success in expanding its battery technology and EV capabilities, China is

[b] Advanced energy has been defined as "a broad range of technologies, products, and services that constitute the best available technologies for meeting energy needs today and tomorrow." Advanced energy can be further divided into seven segments: building efficiency, electricity delivery and management, advanced transportation, advanced fuel production, advanced industry, advanced fuel delivery, and advanced electricity generation.[35]

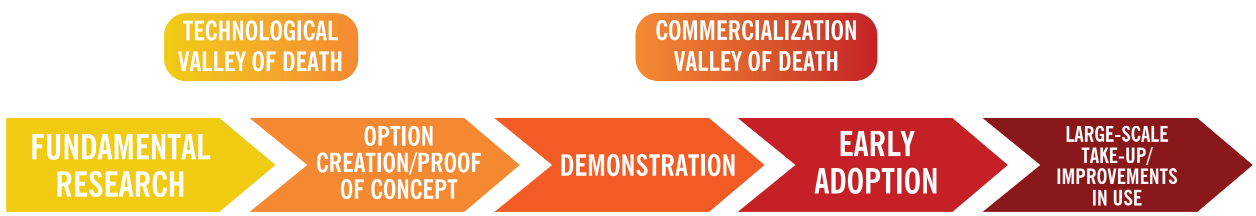
committing to hydrogen fuel cell infrastructure and technology.[40] Japan already leads the way and had the largest public budget for hydrogen research funded in 2018 through its Ministry of Economy, Trade, and Industry and New Energy Industrial Technology Development Organization, which is similar in function to ARPA-E in the United States.[41] This activity was matched by active private-sector research ventures in Japan.[42] Toyota, for example, recently partnered with the Dutch Institute for Fundamental Energy Research to develop advances in hydrogen fuel cell technology and last year teamed up with Paccar to unveil a prototype of a hydrogen fuel cell powered truck.[43]

These developments reflect the important interplay of public and private investment in driving advances in innovative energy technologies and the results that can be achieved by combining investment in both early and late-stage research with enabling national policies to facilitate technology development and deployment. The U.S. government is playing a growing role in this space. It made notable carve-outs for hydrogen and alternative vehicle technologies research in the 2018 budget and recently announced coordinated research with Japan to promote advances in hydrogen production and fuel cell technology.[44,45] This partnership has the potential to help U.S. companies capture market share for advanced technology vehicles, but only if innovation activities and the funding needed to support it are sustained for the period of time needed to reach deployment.

THE INNOVATION LIFECYCLE

To understand the role of public and private investment in technology innovation, it is useful to distinguish the different stages of the innovation process. Though the path from lab bench discovery to commercial product is rarely straightforward or linear, scholars often depict innovation as a kind of pipeline that begins with early scientific discovery and proceeds through basic research, applied research, development activities, small- and large-scale demonstration, and eventual commercial deployment (Figure 12).

FIGURE 12. STAGES OF THE INNOVATION PIPELINE



• Inadequate funding	• Lack of market pull for prototyping/proof of concept • Lack of public/ private co-funding for translation R&D	• Complexity of demonstration project siting • Few vehicles for financing precompetitive pilot/demonstration projects • Barriers to utility R&D investment and cost allocation for pilots • Gaps in private financing mechanism between venture equity risk and project debt models • Lack of adequate standards for accelerating scale-up and demonstration	• Unpredictability and lack of alignment between federal and state standards • Utility and public utility commission innovation risk aversion and institutional barriers • Lack of early adoption incentives for major customers	• Absence of real time pricing • Lack of full life-cycling costs, including carbon and other externalties • Barriers to competitive markets providing adequate risk-adjusted investment returns on long-term scale-up and continuous improvements

Source: Adapted from National Academies of Sciences, Engineering, and Medicine. "The Power of change: Innovation for Development and Deployment of Increasingly Clean Electric Power Technologies." 2016.
Available at: https://www.nap.edu/read/21712/chapter/5

THE INNOVATION LIFECYCLE

In reality, the innovation process is more often iterative and multi-directional rather than linear, and the divide between basic and applied research and demonstration is not as rigid as the conventional pipeline model suggests.[46] As has been rightly pointed out, "often technology is the inspiration of science rather than the other way around."[47] The invention of the steam engine, for example, improved our understanding of the underlying science of thermodynamics and illustrates a not-uncommon scenario in which applications-driven, late-stage development activities reveal further questions or yield new discoveries in the realm of fundamental research.

Venture capital funds are often lauded as innovative and entrepreneurial despite having a relatively low success rate, while government programs are criticized as wasteful or dysfunctional when even a small number of research projects fail compared to total investments. While policymakers have an obvious obligation to ensure that taxpayer dollars are spent wisely and judiciously, failure is to be expected in a healthy innovation portfolio.

The iterative nature of innovation and the interrelatedness of early- and late-stage research are important to keep in mind when considering the role of government in funding science and technology. We have long argued that government's proper role is filling research gaps where the private sector underinvests; in other words, when the risk of not receiving an adequate return on a research investment is too high to motivate investments by the private sector, despite the potential value the research could provide for society or the economy. Though the linear pipeline model has limitations, it illustrates key points, sometimes called "valleys of death," where the innovation process often fails and where government can fill crucial gaps. These "valleys" occur early and late in the technology development cycle. Moreover, features of the energy sector often make them especially difficult to overcome.

It is becoming increasingly evident that industry has become more reluctant to invest in longer-range demonstration activities. These activities are indispensable for bringing new technology to the market, but often require significant investments with highly uncertain returns. However, it is not clear the federal government is the best substitute financer for these investments. Rather, they are often best undertaken by companies with intimate knowledge of the specific markets. Accordingly, it might be very fruitful for the federal government, and DOE in

THE INNOVATION LIFECYCLE

particular, to substantially increase its investments in high-cost, uncertain-return, longer-range development work to be done by industry. Further, it should use its flexibility in setting cost-share requirements accordingly—i.e. higher percentages for technologies approaching commercialization, but much lower rates for long-term critical technology development. An example might be radiation-hard metals for the manufacture of next-generation fission reactors, which may take decades to prove out with no revenue model available to the private entities that are engaged in the research.

Those who argue government should primarily focus on funding basic research are rightly concerned about the potential misuse or inefficient use of taxpayer funds. To the extent that industry is capable of and willing to invest in applied research and development, it is arguably unnecessary and duplicative for the government to play a role here. However, this perspective fails to recognize the degree of risk aversion common to many corporations when confronted with potentially transformational advances in technology, even later in the innovation cycle. It also does not capture some of the unique risks inherent in energy research projects that work against private-sector investment, such as long development cycles, system risks, and high capital costs. Recent advances in small modular nuclear reactors, for example, occurred precisely because government was willing to help de-risk the technology and work constructively with the private sector to promote deployment.[48,49]

While there is no shortage of examples of game-changing innovations that have their origins in publicly funded early- and late-stage research, it is important to keep in mind that failure is inherent to the innovation process.[50] Most venture capitalists expect the majority of their investments to fail and consider just a few successes adequate to justify their entire investment portfolio. By contrast, government investment is often held to a different standard. Venture capital funds are often lauded as innovative and entrepreneurial despite having a relatively low success rate, while government programs are criticized as wasteful or dysfunctional when even a small number of research projects fail compared to total investments. While policymakers have an obvious obligation to ensure that taxpayer dollars are spent wisely and judiciously, failure is to be expected in a healthy innovation portfolio.

This isn't to suggest the U.S. government should blindly fund any and all research ventures without considering how to design programs that effectively manage risk, achieve the most impact per dollar invested, and maximize the likelihood of success. Spending by itself is also not a complete measure of technology leadership. A systematic approach is needed. The good news is that DOE has worked to develop better research arrangements within the past two decades that effectively address critical research gaps while also managing risk and accelerating the pace of energy technology development and deployment.

POLICIES TO SUPPORT THE FULL ENERGY INNOVATION LIFECYCLE

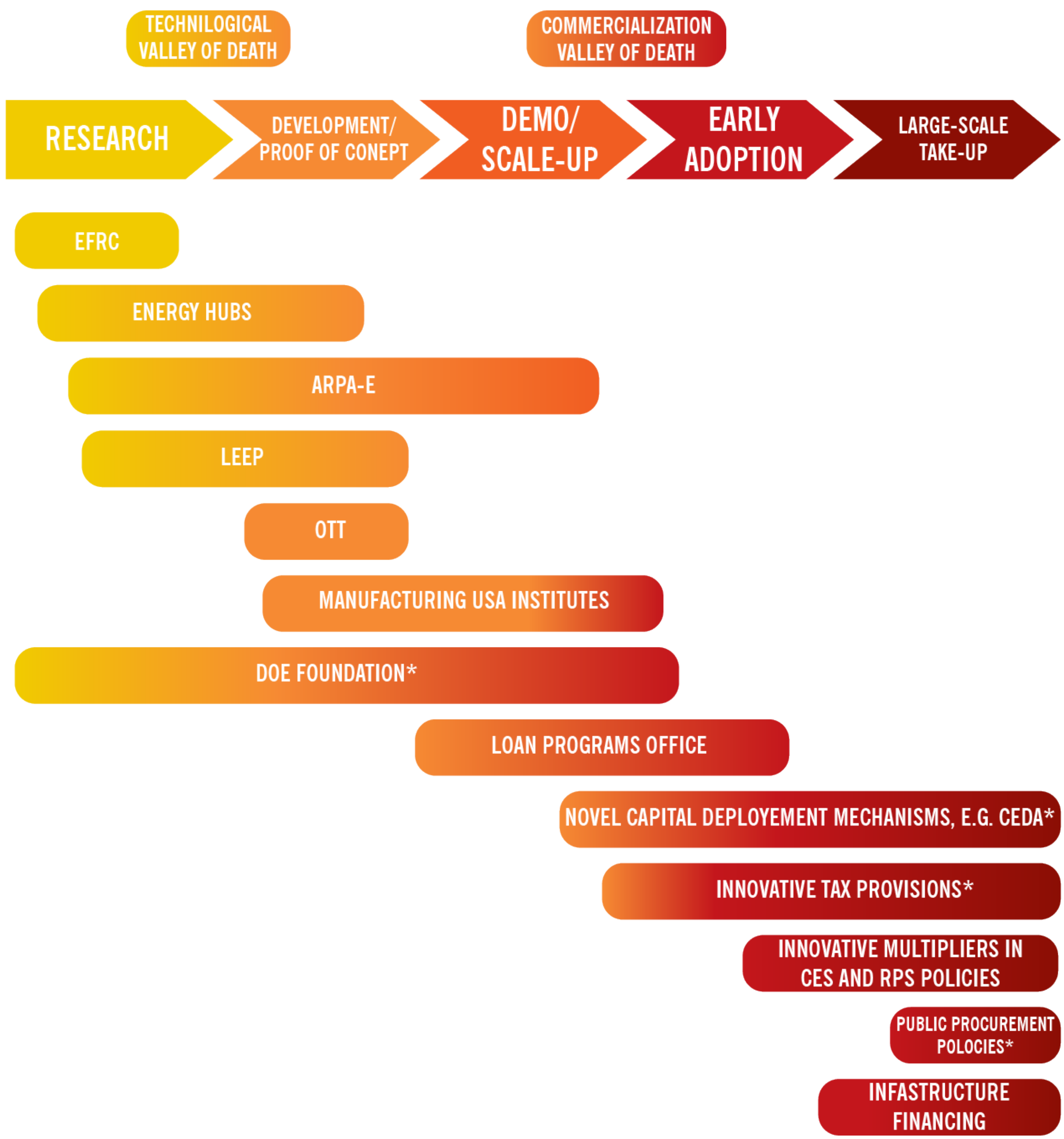
This section highlights several concrete steps Congress and the Administration should explore to bolster the energy innovation ecosystem beyond support for basic research. The ideas expressed in the following pages are not necessarily new or overly controversial. We believe they provide a basis for an invigorated and more effective government role in energy innovation over the critical decades ahead.

In the coming year, the AEIC will continue to investigate institutional, financial, and policy mechanisms to better support later-stage energy innovation, with a focus on technical and commercial demonstration projects and policies to help incentivize the deployment of advanced energy technologies. The recommendations below are not a comprehensive list of proposals. Rather they represent a set of ideas to start the government on such a path.

POLICIES TO SUPPORT THE FULL ENERGY INNOVATION LIFECYCLE

FIGURE 13. FOCUS STAGES OF INNOVATIVE INSTITUTIONS AND POLICIES TO SUPPORT THE WHOLE ENERGY INNOVATION LIFECYCLE

(Items with a * are proposals and currently don't exist or are currently limited in scope like procurement policies)



Source: AEIC Generated

POLICIES TO SUPPORT THE FULL ENERGY INNOVATION LIFECYCLE

RESEARCH & DEVELOPMENT

After an initial discovery of a new physical, chemical, or biological phenomenon, the next step in the innovation process typically involves building a lab-scale prototype to demonstrate technical and potential economic viability through small-scale experiments and techno-economic modeling of potential scaled-up systems. Here the goal is to usher technologies "out of the lab" into the hands of entrepreneurial scientists and engineers who are leading cutting-edge start-up companies. The federal government has made great strides increasing support for this stage of the energy innovation lifecycle, through the creation of the ARPA-E, its Lab-Embedded Entrepreneurship Program, and its Office of Technology Transitions. Congress and the Administration should consider expanding support for these programs as described below. Further, we believe the concept of a non-profit DOE "foundation" is worth exploring.[c] Also, DOE should strive for greater flexibility in cost-share requirements for private-sector partners that actively engage in basic and applied research and long-term development projects, such as nuclear technology, given the low probabilities of success and high spillover effects inherent in early-stage R&D.

RECOMMENDATION: Congress should expand federal appropriations for DOE's Advanced Research Projects Agency-Energy to $1 billion per year.

ARPA-E is a highly effective and successful agency that fills critical funding gaps to help promising innovations advance through technological and commercial valleys of death. Modeled on the well-regarded Defense Advanced Research Projects Agency, ARPA-E benefits from nimble institutional structures including special hiring authority, active program management, and empowered program directors with investment authority. It has succeeded in attracting more than $2.9 billion in private-sector follow-on funding for 145 of more than 437 projects completed in its 10-year history. Of these projects, 76 have led to the formation of new companies.[51] Selected through a competitive application process, every project team receives funding and guidance to meet ambitious project milestones within a limited timeframe. Teams that fail to demonstrate success or meet milestones are terminated, ensuring funds are used efficiently and are focused on the most promising projects. A recent National Academies study of ARPA-E revealed the agency was not only funding "off-roadmap" projects no one else was funding, but was also acting as an agent of change within DOE, spurring the adoption of best practices that make the Department work better.[52] Further, ARPA-E's Technology-to-Market program, which places technology scale-up experts on project development teams to accelerate the pace of commercialization, has been so successful it has also been incorporated into DARPA's organizational structure.

By growing ARPA-E's authorization level, the agency would be able to expand activities to include addressing the scale-up challenges of key clean energy technologies, such as dispatchable zero-emission generation technologies that will be

[c] The National Institutes of Health, the U.S. Department of Agriculture, and the Veterans Administration, among other federal agencies, benefit from non-profit foundations that complement their respective R&D activities. Through public-private partnerships, these foundations pursue innovative projects and initiatives that neither the private sector nor the public sector could implement independently. AEIC's 2017 report made the case for creating a similar foundation to complement DOE's R&D activities. As that report noted, the foundation model would allow DOE to "leverage a small amount of federal funds to attract significant private capital."

POLICIES TO SUPPORT THE FULL ENERGY INNOVATION LIFECYCLE

critical for the electricity grid of the future. ARPA-E's authorization already allows the agency to direct up to half of its funds to demonstration projects. Increased appropriations will permit it to support these types of projects while still maintaining a broad off-roadmap portfolio of early-stage, high-risk, high-reward R&D projects.

The director of ARPA-E can initiate positive change, as well. ARPA-E was given broad authority by Congress to experiment with structures that work to best support high-risk, high-reward R&D. However, over the past decade the vast majority of ARPA-E programs have fallen into one model: three-year, $30 million programs that fund 10 to 12 projects with fixed cost-share rates for different organization types. Yet there is no reason all of the agency's programs need to be designed this way. ARPA-E has the authority to experiment and urgently needs to do so for the good of the country's energy innovation ecosystem.

We recommend ARPA-E make full use of its authorities, including using its broad contracting authority, to be more flexible with cost-share and internal R&D requirements for particularly risky work being undertaken by private industry. Further, given ARPA-E's special hiring authority and freedom to design its own organizational structure, the director should pursue a flatter, more nimble structure. The goal should be to have key leadership roles—director, deputy director of technology, deputy director for operations, deputy director for commercialization—be seen as term-limited, internationally-recognized prestigious positions for which the most qualified individuals are recruited from all over the country. As an organization, ARPA-E should not look like other technology offices in DOE or the federal government, perhaps with the exception of DARPA.

AEIC's recommendation to fund ARPA-E at $1 billion per year dates to 2010[53] and is consistent with our long-standing support for a tripling of federal expenditures on energy R&D. This recommendation is also supported by the National Academies' 2007 *Rising Above the Gathering Storm* report, which recommended funding ARPA-E at $300 million in the first year and growing the program to $1 billion per year over five to six years.[54] ARPA-E has already demonstrated its effectiveness as a research model, but increased funding is needed to allow it to fulfill its congressionally-authorized mission of transforming the energy system. Recently, a bipartisan compromise has emerged in the House and the Senate to reauthorize ARPA-E and increase its budget authorization to $750 million in 2024. This is a major step in the right direction.

RECOMMENDATION: Congress should authorize and appropriate $20 million per year for DOE's Lab-Embedded Entrepreneurship Program.

LEEP places top entrepreneurial scientists within DOE's national labs to conduct R&D and be mentored in advancing and commercializing promising technologies. The program effectively expands access to the vast network of expertise and sophisticated resources that exist at the national labs and provides a research home to entrepreneurial scientists and

POLICIES TO SUPPORT THE FULL ENERGY INNOVATION LIFECYCLE

engineers from across the country. It aims to bridge the gap between early-stage energy research and commercial outcomes and to connect entrepreneurs with tools they otherwise wouldn't have access to for testing the viability of their innovations.

Cyclotron Road, established in 2014, provided a template for the program, having pioneered the concept of entrepreneurial research fellowships at Lawrence Berkeley National Lab. Through a competitive application process, Cyclotron Road supports awardees with a two-year fellowship, access to lab and office space, seed research funds, advisory support and mentorship, and connections to potential commercial partners and investors. The first cohorts that emerged from Cyclotron Road were so promising that two other national labs established similar programs over the past few years: Chain Reaction Innovations at Argonne National Lab and Innovation Crossroads at Oak Ridge National Lab. Fellows are now supported at all three programs by DOE's Advanced Manufacturing Office under the LEEP framework. Meanwhile, the entrepreneurial research fellowship model is also gaining traction outside of DOE. For example, DARPA now funds fellows at Cyclotron Road, and private philanthropies support a similar entrepreneurial fellowship program at Cornell Tech in New York. Further, the independent nonprofit Activation Energy, led by the founder of Cyclotron Road, is planning to expand this model.[55] To guarantee the long-term viability of these programs and secure a steady stream of funding, Congress should authorize and provide direct appropriations for LEEP within DOE to grow this partnership with Activation Energy.

RECOMMENDATION: Congress should authorize and appropriate $16 million per year for the Office of Technology Transitions. In addition, OTT should be given its own authorization, and the head of OTT should report to the Secretary of Energy.

The goal of OTT is to advance the economic, energy, and national security interests of the United States by commercializing the DOE R&D portfolio. OTT coordinates a Lab Partnering Service to increase access to experts, technology, and facilities in national labs. In addition, OTT directly funds commercialization activities within the labs. In creating the position of DOE Chief Commercialization Officer in 2018, DOE signaled it recognizes the need to better facilitate commercialization activities across the department. One step in that direction would be to permanently re-name the statutory position of "technology transfer coordinator" to "chief commercialization officer." The chief commercialization officer would report directly to the Secretary of Energy and would oversee all DOE's technology transition activities.

Additionally, to ensure OTT has the resources it needs, OTT should be formally authorized, taken out of the Department's administration budget, and given its own $9 million budget line. Legislation authorizing OTT should include the current duties of the coordinator and define the Office's functions. A major step in this direction, S.2688, the Technology Transitions Act of 2019, was recently introduced in the Senate by Sens. Bill Cassidy (R-LA) and Sheldon Whitehouse (D-RI).

POLICIES TO SUPPORT THE FULL ENERGY INNOVATION LIFECYCLE

DEMONSTRATION

The demonstration stage of the innovation cycle comes after a technology has been developed at lab-scale and shown to be technically and commercially feasible, though not proven. At this point, the next key step is to demonstrate the technology at scale to prove its commercial viability and mitigate the associated technology risks for further investments. In the case of most energy technologies, significant engineering challenges exist between the lab scale (typically about one kilowatt of electricity generating capacity or the equivalent) and commercial scale (typically hundreds of megawatts of electric generating capacity equivalent). Scaling up new technologies, often by as much as five orders of magnitude, can reveal complexities that are unforeseen at the lab scale. This critical stage of energy innovation is one of the most difficult to fund and would be best addressed by programs in which the federal government partners with private industry to defray demonstration costs and reduce technology risk. Unfortunately, there are also few successful models for such programs. The existing DOE Loan Programs Office could be leveraged and improved, and other mechanisms for supporting public-private commercial-scale demonstration projects should be explored.

RECOMMENDATION: Congress should consider strengthening and enhancing DOE's Loan Programs Office.

The DOE LPO administers three distinct programs: the Tribal Energy Loan Guarantee Program, Advanced Technology Vehicles Manufacturing, and the Title XVII program. TELGP is meant to spur energy projects on tribal land and thereby support economic growth in these communities. Tribes or tribal entities can apply for loans for projects related to mining, fossil energy production, renewable energy development, energy storage facilities, and transmission infrastructure, among others. The ATVM program is focused on automobile manufacturing capabilities, particularly to promote fuel efficiency. Finally, the Title XVII program is meant to support innovation in different energy technology areas, including advanced nuclear, advanced fossil fuels, renewables, energy storage, transmission, bioenergy, and many others. Title XVII projects must illustrate the use of a new or improved technology; reduce, avoid, or sequester greenhouse gases; and meet commercial feasibility assessments. Direct loans and full or partial loan guarantees issued through these three LPO programs have had a pronounced effect on the U.S. energy sector and the U.S. economy, paving the way for some of the most notable recent innovations in energy and vehicle technology.[56]

According to some estimates, LPO projects have saved or created 56,000 jobs across the country, saved 1.7 billion gallons of gasoline, and prevented 34.7 million metric tons of carbon emissions.[57] The Title XVII program has produced several firsts in energy innovation, including the first five utility-scale photovoltaic (PV) solar projects larger than 100 megawatts. Since the launch of these projects, more than 65,000 utility-scale PV installations have become operational or been contracted for. One of the first utility-scale Title

POLICIES TO SUPPORT THE FULL ENERGY INNOVATION LIFECYCLE

XVII solar projects, sited in Arizona, introduced an innovative new inverter technology that helps plants manage larger voltage variations. It enhanced reliability so noticeably that other private solar projects have purchased this technology for their own installations. Tesla, Inc. successfully leveraged its 2009 ATVM loan to build a manufacturing facility for the Tesla Model S, one of the first full-size electric vehicles on the market. This facility created more than 1,500 jobs and put the U.S. electric vehicle industry on the map.[58] Ford and Nissan have also used ATVM loans to expand or establish U.S.-based manufacturing facilities for electric vehicles and engine efficiency technologies.[59]

A key step toward improving the long-term effectiveness of DOE's loan programs would be to make LPO self-sustaining by using returns on loans to pay for its operations. This shift would also signal greater certainty about the resources LPO has on hand to support projects. Additionally, appropriations are available to cover part or all credit subsidy costs for TELGP and ATVM applicants; however, no such support is offered to Title XVII applicants, even though these costs can be a significant part of the applicant's overall cost and prohibitive for some companies. Thus, Congress should consider appropriating funds to more fully cover credit subsidy costs for Title XVII applicants, especially if LPO is not made into a self-sustaining program. (Applicant fees are used to support LPO operations and costs for conducting due diligence.)

Congress should also consider expanding the range of projects that can qualify for DOE loans. For instance, LPO might be more effective if it can fund energy projects and complementary infrastructure projects. Whether the range of LPO-eligible projects is expanded or not, more needs to be done to educate energy companies and stakeholders about the benefits of engaging with this program.[60]

Another issue for Congress to consider is raising LPO's loan loss ratio as a way to increase the risk-tolerance of the portfolio. The loan loss ratio is currently less than 3%. While this low loan loss ratio is a testament to the painstaking work of LPO staff, it may also indicate the current program is too risk-averse. Where taxpayer dollars are involved, there is understandable concern about undue risk exposure and a strong desire to avoid potential losses. But for government programs to have a greater impact, particularly in spurring transformative technology change and innovation, their portfolios will necessarily have to include some riskier projects. **Innovation requires risk**.

DEPLOYMENT

The deployment phase of the innovation cycle comes after a technology has demonstrated its viability at commercial scale. Successful deployment does not follow automatically from successful demonstration. On the contrary, many innovative technologies encounter major headwinds when entering the market and have trouble displacing incumbent technologies, even if the incumbent technologies are inferior. Risk-aversion among investors and customers, lack of familiarity, lack of clear near-term market signals, and lack of a track record of commercial success are typical and often potent barriers.

POLICIES TO SUPPORT THE FULL ENERGY INNOVATION LIFECYCLE

Opportunities to incentivize the deployment of innovative energy technologies exist at both the federal and state levels. Tax-based incentives have been shown to be an effective tool for overcoming some deployment hurdles. Such incentives played a major role, in conjunction with other policies, in spurring the growth of the wind and solar industries in the United States and globally. Further, energy technology mandates (such as renewable portfolio standards), procurement policies, and efficiency (or carbon) standards are other policy options that could accelerate deployment. In general, these programs are most effective when applied in a coordinated fashion.

RECOMMENDATION: Congress should consider additional institutional mechanisms to support early stage commercial projects like the Clean Energy Deployment Administration.

Securing financing for the first set of commercial projects is a common hurdle for many new technologies, especially if the technology is novel and lacks a proven track record and established rate of return. Even if the technology has been successfully demonstrated at scale, costs may still be poorly understood and benefits from learning-by-doing may not be fully realized, creating the potential for cost overruns or higher initial costs. If the company developing the new technology is itself new and considered riskier than mature companies, it may not be able to access financing through traditional capital markets.[61]

In its original 2010 report, the AEIC highlighted this persistent challenge and recommended a "New Energy Challenge Program" that would create an innovative federal program to focus on technology demonstration. An existing proposal to address financing challenges for technology demonstration was included in the Senate American Clean Energy Leadership Act of 2009. Called the Clean Energy Deployment Administration, this proposed new federal entity would have been provided with authority to issue loans, including direct loans, loan guarantees, and other financing options. It also would have had the ability to issue bonds, convertible bonds, and warrants, and would have been allowed to purchase debt securities. An entity of this type could be modeled after other successful federal agencies such as the Export-Import Bank.[62]

RECOMMENDATION: Congress should consider energy tax provisions focused on supporting the early commercial deployment of new technologies.

Tax provisions designed to benefit specific energy technologies or resources have been part of the U.S. tax code for decades, as have debates about the appropriateness of incentivizing certain technologies over others and concerns about fostering an unhealthy dependence on public resources in certain industries.

The federal investment tax credit, or ITC, currently applies to certain capital investments in renewable energy projects for a specified list of technologies.[63]

POLICIES TO SUPPORT THE FULL ENERGY INNOVATION LIFECYCLE

Energy production tax credits, or PTC, are per-kilowatt-hour tax credits for electricity generated using qualified energy resources. These policies have played a critical role in supporting the growth of nascent renewable energy technologies—wind and solar—such that they are now cost-competitive with conventional generation technologies and are beginning to reshape the electricity sector.

Both the ITC and PTC, along with other targeted energy tax credits, have been instrumental in spurring the build-out of clean energy projects, which has led to technology improvements and lower project and electricity costs. Moving forward, energy-related tax policies should be designed in a technology-neutral way with four goals:

1. **Incentivize innovation.**
2. **Scale new technologies.**
3. **Reduce greenhouse gas emissions.**
4. **Reduce costs through expanded deployment.**

Recently there have been attempts to rationalize the ITC and PTC in this way. In the 116th Congress, Sen. Ron Wyden (D-OR) introduced the Clean Energy for America Act, S. 1288, which adopts a technology-neutral approach to simplify and consolidate energy tax credits subject to an overarching emissions reduction objective. In the 116th Congress, Reps. Tom Reed (R-NY) and Jimmy Panetta (D-NY) introduced the bipartisan Energy Sector Innovation Credit Act of 2019, H.R. 5523. It would provide technology-neutral tax credits that phase out with increased market penetration to support energy innovation without locking in continued federal support once a technology is established in the market. Such an approach could compliment S. 1288.

RECOMMENDATION: Innovation multipliers should be considered as a potentially powerful tool to incentivize innovation within energy standards.

States have used renewable portfolio (or energy) standards and clean energy (or electricity) standards[d] since 1983 to spur the deployment of clean energy technologies, such as wind, geothermal, hydro, and solar in the electric power sector. At present, 29 states have adopted portfolio standards of this type and another eight states have adopted specific clean energy goals.[64]

Within the context of the recent expansion of state CES and emerging efforts to develop equivalent national policies like a national CES or RPS, mechanisms to encourage the deployment of new technologies are critically important considerations. Within these standards, multipliers can give "extra credit" to preferred technologies that provide additional value. Multipliers can be designed to incentivize certain types of innovations, such as dispatchable low-carbon generation technologies that may have limited market value today, but could be critical for achieving longer-term policy objectives. Several examples of the multiplier approach can be found in recent legislative proposals.[e] Notably, these types of multipliers can be designed to sunset over a defined period or as a function of market penetration. This feature may be useful as a tool to maintain incentives for continued innovation.

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[d] Although often quite similar, an RPS is usually focused on traditional renewable energy resources, like solar, wind, and possibly hydroelectric power, while CESs tend to be more technology-inclusive, and generally permit advanced nuclear and geothermal, among others, to qualify.

[e] In the 116th Congress the Smith/Lujan CES bill, S. 1359 and H.R. 2597, as well as the Udall RES bill, S. 1974.

POLICIES TO SUPPORT THE FULL ENERGY INNOVATION LIFECYCLE

RECOMMENDATION: Public procurement programs should be used to establish early market demand for innovative technologies.

Well-designed procurement policies can support multiple objectives: modernizing public services, reducing supplier lock-in, cost-effectively supporting innovation, providing local economic benefits, and boosting demand-driven innovation.[65] Such policies can also be a boon for startups seeking to enter the market with an innovative technology, shortening their time-to-market, providing faster access to customers, growing their businesses, and generating international growth opportunities.[66] As one European Commission policy officer noted in a presentation on innovation procurement, "Public buyers can encourage innovation among established market players, but also provide vital opportunities to small and medium enterprises and new innovative companies who may have solutions to unmet needs, but face difficulties in bringing them to the market."[67]

Best practices for innovation procurement address various factors that are important to success, such as intellectual property protections, results tracking, capacity building, and technical assistance.[68] To address this last point, government agencies may consider drawing on the knowledge, skills, and resources of professional bodies and trade associations to develop greater understanding of innovative technologies and processes.[69] According to the European Commission's innovation procurement framework, other issues to consider are whether the procured solution achieves the best added value (in terms of quality, cost-efficiency, environmental, and social impacts) and the contract structure itself and the incentives it creates (for example, whether the contract should be performance-dependent).[70] Regarding contract structure, the World Economic Forum points to "procurement-based reverse auction mechanisms (in which sellers bid for the prices at which they are willing to sell their goods or services)" as a way to support the commercialization of innovative, but as yet untested, technologies.[71]

For some governments and government agencies it may be necessary to address risk aversion and the established procurement culture. Because procurement policies affect the use of taxpayer money, civil servants are likely to be cautious to an extent that hinders innovation and misses associated opportunities and benefits. One option for overcoming this barrier is to establish strong institutional incentives for innovation—for example, by defining a percentage of public purchases that must be dedicated to innovation procurement. Another approach may be to use innovation procurement for smaller projects initially and then scale up. Thoughtful and effective innovation procurement could also be encouraged through performance indicators in job evaluations, promotions, rewards, and prizes. The European Commission framework suggests national innovation procurement prizes.[72]

A related resource that is already available to the U.S. government is the Procurement Innovation Resource Center, which provides guidance and tools to the General Services Administration.[73]

POLICIES TO SUPPORT THE FULL ENERGY INNOVATION LIFECYCLE

RECOMMENDATION: Infrastructure financing should be designed to support and incorporate innovative technologies.

In its 2017 Infrastructure Report Card, the American Society of Civil Engineers gave a grade of D+ to America's infrastructure overall and to America's energy infrastructure, in particular.[74] Investments in modern, well-functioning infrastructure are important for innovators and entrepreneurs as they seek to develop new technologies and build new businesses and as an opportunity to address hurdles to greater market penetration for innovative technologies. For example, before the city of Columbus, Ohio won the Smart City Challenge in 2016, AEP Ohio, one of the state's main utilities, invested a great deal in grid modernization. Due in part to this upgrade, AEP Ohio was able to install more innovative and efficient technologies, such as smart meters, and better support Columbus's bid. As a result, both the utility and the city are in a better position to use new clean energy technologies.

Several notable infrastructure bills have emerged recently. For example, the Financing Our Energy Future Act, S. 1841 and H.R. 3249, from Sens. Chris Coons (D-DE) and Jerry Moran (R-KS) and Reps. Mike Thompson (D-CA) and Ron Estes (R-KS), aims to expand the types of projects that can apply for a master limited partnership. Currently, a master limited partnership must generate at least 90% of its income from qualified resources. The bill would expand the definition of "qualified" to include a broad range of clean energy resources focused on infrastructure projects. This legislation would be the first opportunity for clean energy technologies to permanently utilize a tax financing provision that the fossil energy sector has utilized for more than three decades. Another notable infrastructure financing bill is the Carbon Capture Improvement Act, S. 1763 and H.R. 3861, which is sponsored by Sens. Michael Bennet (D-CO) and Rob Portman (R-OH) and Reps. Tim Burchett (R-TN) and Matt Cartwright (D-PA). This proposed legislation would allow businesses to use private activity bonds issued by state or local governments to finance carbon capture projects.

CONCLUSION

Since its founding, innovation has been key to America's success and will be no less important as nations race to gain a competitive edge in the critical technologies that will shape the global economy of tomorrow. Among citizens and policymakers there is broad support—across the political spectrum—for the proposition that we must continue to strengthen our nation's innovative capacities and grow our investments in the full energy innovation lifecycle to create a strong foundation for continued prosperity and security.

Against this backdrop, increased federal funding for energy R&D in recent years was a welcome step in the right direction. These increases will need to be sustained and expanded, and it is clear that there is a bipartisan desire to do just that. Sustained investments in research and development are extremely important, and robust policy support is equally important for the United States to remain a leader. Additionally, encouraging only early-stage R&D will not be sufficient. Rather, well-targeted public investments and well-designed public policies are needed to scale the next generation of advanced energy technologies. Nowhere is this support more important than in the energy sector, which is both uniquely essential to the functioning of the broader economy and integrally linked to complex and technologically demanding challenges, such as climate change. Because of those challenges, strong growth is expected in global markets for highly efficient, clean, cost-effective, low-carbon energy technologies in the coming decades.

The AEIC will now shift attention to the challenge of scale and examine these issues in greater detail in the year ahead. The ideas advanced here represent a strong down payment toward building the larger and more transformational energy innovation ecosystem our country needs. The investments and policies recommended in this report will help ensure American entrepreneurs, companies, and workers continue to be at the forefront—not only of inventing and developing new energy technologies—but of building and deploying them as well.

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AEIC especially thanks the staff of the Bipartisan Policy Center, listed below, for their contributions to the preparation of this document.

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