Federal Energy RD&D: Building on Momentum in Fiscal Year 2019

BY DAVID M. HART AND COLIN CUNLIFF | APRIL 2018

Congress should continue on the path it has set, toward an eventual doubling of federal investment in this vital field.

When Congress passed appropriations bills for fiscal years (FY) 2017 and 2018, it wisely rejected extreme cuts to the Department of Energy's (DOE) research, development, and demonstration (RD&D) budget proposed by the Trump administration.[1] Yet, the administration has persisted, making similar proposals again this year. Its FY 2019 budget request reflects a fundamental skepticism about public RD&D investment. If enacted, the administration's proposed cuts would jeopardize U.S. energy innovation, threatening national imperatives in energy security, economic competitiveness and productivity, and environmental stewardship.

Congress should continue on the path it has set, supporting what the Senate Appropriations Committee described as "a comprehensive and real-world strategy that includes medium- and later-stage research and development; deployment and demonstration..."[2] This path leads to a doubling of federal energy RD&D funding, which would fulfill a commitment made by the United States along with 19 other countries to accelerate the global transition to cleaner, more affordable, more reliable energy.[3]

Within this doubling pathway, the Information Technology and Innovation Foundation (ITIF) urges particular attention be paid to these programs, which have been analyzed in prior reports:

- Grow the Advanced Research Projects Agency-Energy (ARPA-E) budget to $1 billion.[4]
- Build a robust, diverse portfolio of technology-demonstration projects.[5]
- Sustain and expand the Clean Energy Manufacturing Innovation Institutes.[6]
- Double the budget of DOE's Energy Innovation hubs.[7]

In this report, we first describe the key role of the federal government in the U.S. energy innovation system. We then provide a high-level overview of both DOE's overall budget and its RD&D budget. The bulk of the report drills down into the programs and subprograms that make up DOE's RD&D budget, detailing what would be put at risk by the administration's proposal, and opportunities that might be realized through its expansion.

THE KEY ROLE OF THE FEDERAL GOVERNMENT IN THE U.S. ENERGY INNOVATION SYSTEM

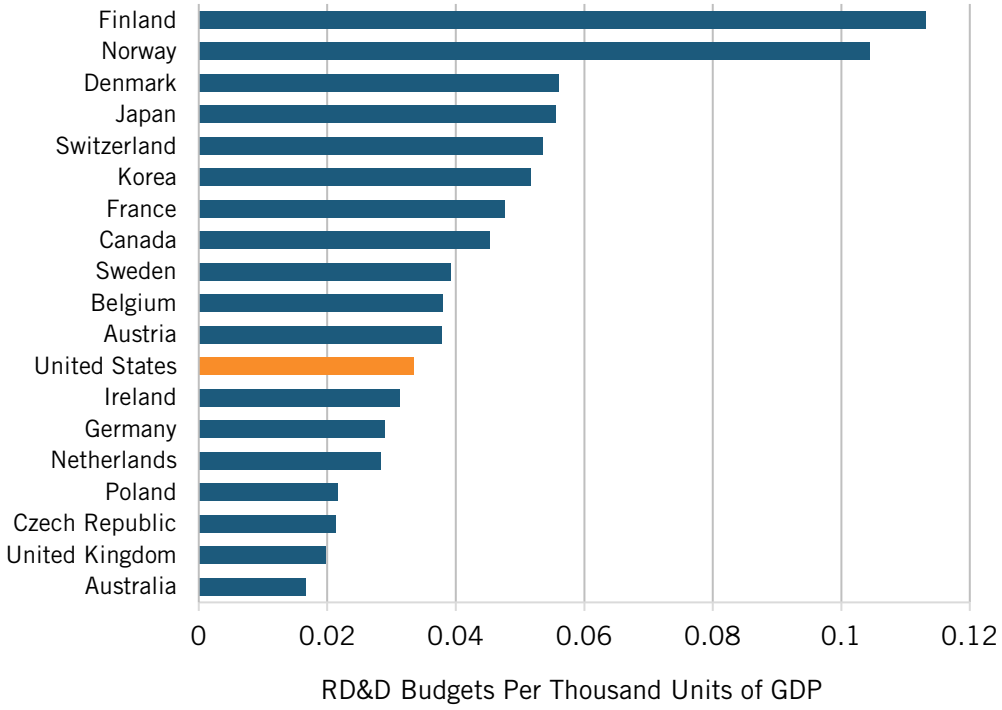
Accelerating the pace of energy innovation is essential to U.S. national security, economic competitiveness and productivity, and environmental stewardship. The Department of Defense is the single largest consumer of energy in the United States and must have reliable and efficient access to energy resources for operations and facilities at home and abroad. Energy is an enormous and vital economic sector, and innovation in this sector is key to reducing volatility and costs in the future. In energy-related manufacturing, the United States has fallen behind key competitors in many market segments that show the greatest growth potential, such as solar panels, batteries, next-generation nuclear power, and technologies to capture carbon. As emissions from the consumption of fossil fuels continue to drive climate change, the fight to avoid potential worst-case scenarios could lead to onerous regulations and taxes that limit consumer choice and reduce living standards—unless energy innovation is accelerated.

The United States has historically been a global energy-innovation leader. Many technologies that now make major contributions to both the U.S. and global energy systems were created through federal investments and public-private cooperation.[8] Federally funded nuclear power RD&D, for instance, led to large-scale private investment in commercial power plants that now account for 20 percent of U.S. electricity generation and 54 percent of zero-carbon power generation.[9] Federal support for shale-gas resource characterization and directional drilling—in tandem with industry-matched applied research and a federal production tax credit—led to the dramatic rise of shale gas production from less than 1 percent of domestic gas production in 2000 to nearly 60 percent in 2016.[10] Decades of federal investment in solar power have culminated in the early achievement of the DOE SunShot Initiative program's 2020 goal of utility-scale solar PV power at six cents per kilowatt-hour ($0.06/kWh).[11]

Despite this record of success, federal investment that supports energy innovation has gyrated up and down over time, reducing the odds of new breakthroughs. Adjusted for inflation, DOE's energy RD&D budget for FY 2018 remains more than 26 percent below what it was when the department was established in 1978. As a share of gross domestic product (GDP), DOE's energy RD&D is down more than 75 percent in the same period.[12] This decline is inconsistent with the view of a large majority of voters across the political spectrum who support increased funding for research into clean energy technologies.[13] Energy RD&D spending is far below comparable federal spending for

space, health, and defense. It also falls short in comparison with other countries around the globe. Eleven other countries invest more in energy RD&D as a percentage of GDP than the United States (figure 1).[14]

Figure 1: Government Energy RD&D Investment as a Percentage of GDP, 2015[15]



Eleven other countries invest more in energy RD&D as a percentage of GDP than the United States.

The shortfall in public energy RD&D investment contributes to a similar shortfall in the private sector. R&D spending as a share of sales in the U.S. energy industry is only 0.4 percent, compared with 8.5 percent in aerospace and defense, 9.8 percent in computers and electronics, and 2.4 percent in the automotive industry.[16] Venture capital and private-equity investment in U.S. renewable energy companies has declined, and only a handful of U.S. companies developing advanced nuclear reactors and carbon capture technologies have raised enough private capital to scale up their innovations. U.S. investors are wary of funding technology scale-up, leading domestic energy entrepreneurs to look overseas for funding, while slow-moving incumbents in this industry tend to support only modest, incremental innovation.[17]

Public investment and private investment play complementary roles along the pathway to commercialization for new energy technologies. Federal investment frequently serves as a catalyst for industry, as government RD&D tends to incent additional private R&D dollars, rather than crowding them out.[18] In fact, ITIF has found that firms funded by federal programs like ARPA-E and Small Business Innovation Research (SBIR) are more likely to receive follow-on private support than comparable firms.[19]

The synergy between public and private investment has motivated the 20 countries that are the largest public investors in energy RD&D, led by the United States, to commit to doubling of their support and inspired a counterpart commitment by private investors led

by Bill Gates to put more than a billion dollars to work behind innovative energy technologies stemming from the increase in public funding.

Research by ITIF has identified gaps in the energy innovation ecosystem that the U.S. government is best-positioned to address and cannot be filled solely by the private sector. While public support is required at varying levels throughout the entire energy innovation process, from full public support for basic research to time-limited, modest subsidies for early deployment, the following gaps are particularly prominent:

- High-risk, high-impact, cross-cutting energy R&D in areas industry alone cannot address;[20]
- Technology demonstration projects for first-of-a-kind technologies that are too risky for private industry to fund;[21]
- Technology transfer and advanced manufacturing programs that partner with industry to infuse innovation into U.S. manufacturing;[22] and
- Interdisciplinary, integrative centers of excellence that bring together researchers from across all sectors to work toward meeting ambitious and targeted technology goals with industry applications in mind.[23]

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Congress has taken important steps to fill these gaps. It created ARPA-E to "sponsor creative, out-of-the-box, transformational, generic energy research."[24] It supported a suite of demonstration projects across a wide range of energy technologies as part of the 2009 economic stimulus package. It established the clean energy manufacturing innovation institutes to foster industry-led innovation and workforce development in key sectors. And it set up energy innovation hubs to focus a critical mass of experts on key long-term challenges.

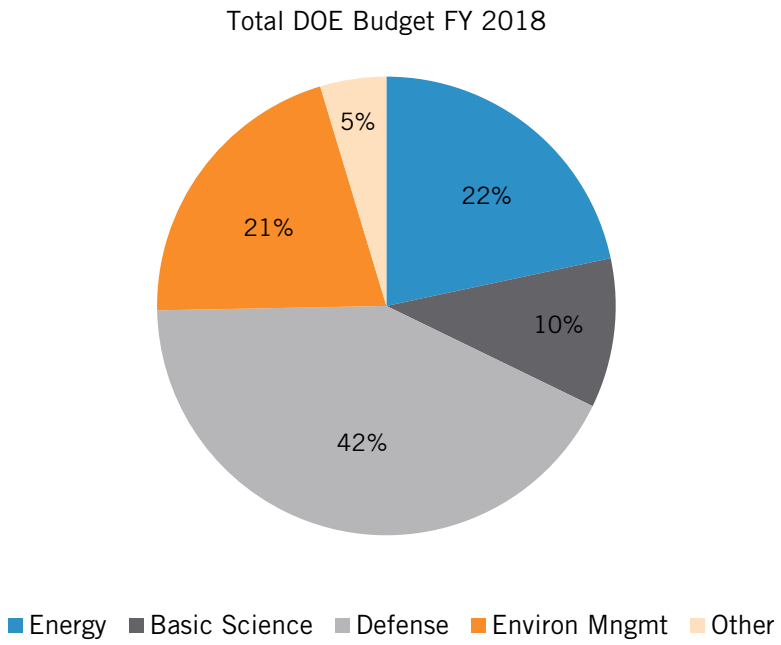
These steps highlight the progress, albeit uneven, that was made under presidents George W. Bush and Barack Obama. But those gains were threatened after the election of President Trump. The new administration proposed cuts to federal energy RD&D that would not merely have undermined efforts to address weaknesses in the U.S. energy innovation system, but would have put the whole system at risk.[25] In its FY 2018 budget, however, Congress definitively and wisely rejected the administration's approach, increasing energy RD&D by 12 percent. Although the administration has once again proposed deep cuts for FY 2019, Congress should now seize the opportunity it has created to sustain the momentum toward an energy-innovation policy that will meet the security, economic, and environmental challenges of the 21st century.

THE DEPARTMENT OF ENERGY... AND LOTS OF OTHER STUFF

The name "Department of Energy" may leave the mistaken perception that DOE's primary function is overseeing and improving the nation's energy system. In fact, as figure 2 shows, when the other activities of DOE—defense, environmental clean-up, and non-energy-focused basic science—are taken into account, only a small minority of its budget

supports energy innovation. Yet, the administration's budget proposal targets this small slice for its largest cuts.

Figure 2: Total DOE Budget Divided by Major Function



Energy programs comprise just 22 percent of the total DOE budget. Defense and Environmental Management together account for nearly two-thirds of the DOE budget.

DOE was assembled in 1977 from previously scattered federal agencies, the biggest of which was the Atomic Energy Commission (AEC), which had managed the military's nuclear-weapons program since just after World War II. DOE's National Nuclear Security Administration (NNSA) carries out such defense responsibilities today. NNSA and other defense programs housed within DOE comprise more than 42 percent of the agency's roughly $30 billion budget. In addition, DOE's Office of Environmental Management (EM) is tasked with cleaning up the massive pollution left behind by the weapons program. EM's budget is more than $6 billion, comprising 21 percent of DOE's budget. Together, these two slices make up almost two-thirds of the department's entire budget pie.

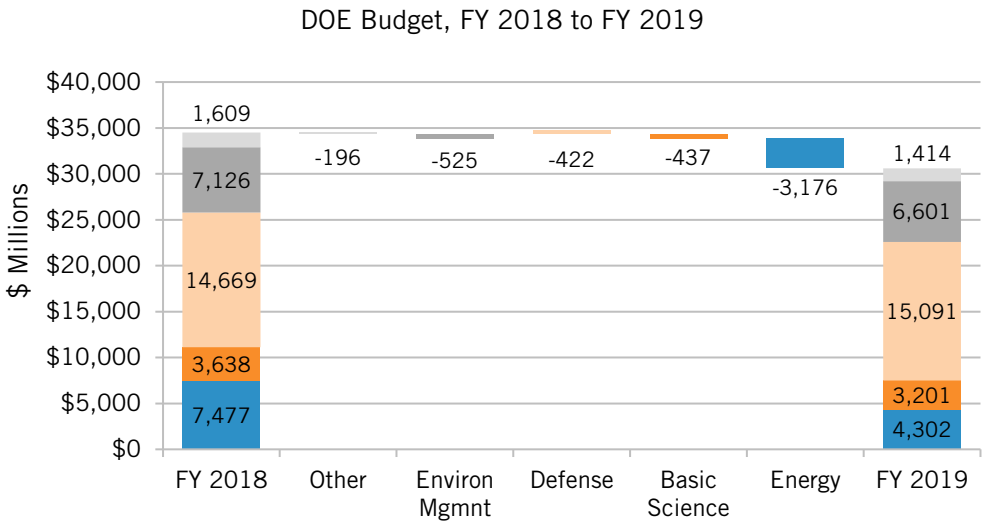
DOE is the third-largest source of federal funding for basic research—surpassing the National Aeronautics and Space Administration (NASA) and the Department of Defense (DOD), and it is the largest source of physical sciences and engineering research funding.[26] Much of this funding flows through the $5 billion budget of DOE's Office of Science (SC), which is a particularly important funding source for high-energy physics, carrying forward a research program that can be traced back to the World War II-era Manhattan Project. Although much of the research that this office funds may ultimately have applications to the energy mission, less than half of its budget, about $2.2 billion for basic energy sciences and fusion, is specifically devoted to advancing that mission.

DOE houses 17 national laboratories, which account for about half of its budget and carry out a significant portion of its science and technology activities. The labs, which include

iconic Manhattan Project installations at places like Los Alamos, New Mexico, and Oak Ridge, Tennessee, are unique concentrations of technical expertise. They also maintain large-scale facilities, such as particle accelerators, that are used by researchers from academia and industry as well as government. The labs receive the vast majority (roughly 80 percent) of their $15 billion annual funding through DOE offices like NNSA, SC, and the applied energy offices described below. Public-private R&D partnerships amount to less than 20 percent of the labs' total funding.

Just 22 percent of DOE's budget encompasses all of the technical areas a reasonable person might infer to be focal points for a department called "Energy": renewables, efficiency, sustainable transportation, advanced fossil energy, nuclear power, grid modernization, ARPA-E, basic energy sciences, and fusion. Figure 3 compares DOE's budget in 2018 to the president's FY 2019 request. The president proposes a slight increase in defense, to over $15 billion, while cutting environmental cleanup by 7 percent and basic science by 12 percent. The budget for energy programs would be cut by 42 percent, from $7.5 billion to $4.3 billion.

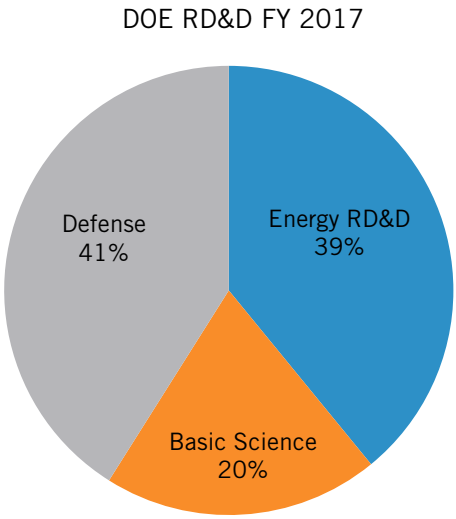
Figure 3: Proposed Changes in Trump's DOE Budget by Major Function



ENERGY RD&D IN THE PRESIDENT'S FY 2019 BUDGET: HISTORIC CUTS

Energy RD&D funding makes up the bulk of DOE's energy programs, so the significant cuts proposed by the administration in these programs for FY 2019 would have substantial impacts on that funding. The cuts would fall hardest on energy RD&D programs that help technologies mature fully so that they can attain sufficient scale to significantly impact the national and global energy systems.

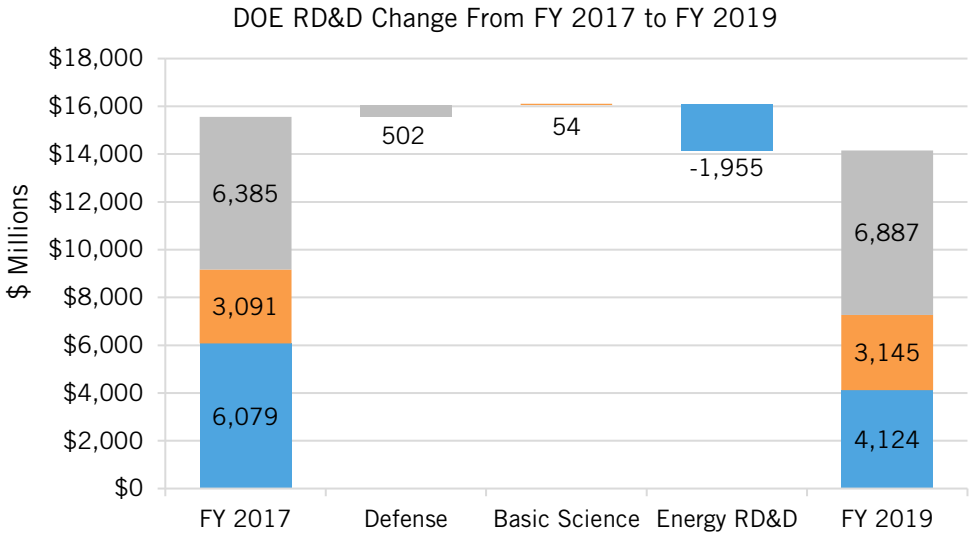
Figure 4: DOE RD&D Budget[27]



Energy RD&D comprises only 39 percent of total DOE RD&D investments, a proportion that would shrink precipitously if the president's budget request were to be approved.

Figure 4 shows energy RD&D programs within DOE's total RD&D budget. (FY 2017 figures are displayed here; FY 2018 figures are not yet available at this level of detail.) Defense RD&D makes up 41 percent of this budget, and non-energy-focused basic science research 20 percent. Energy RD&D is only 39 percent, a proportion that would shrink precipitously if the president's budget request were to be approved, as figure 5 shows.[28]

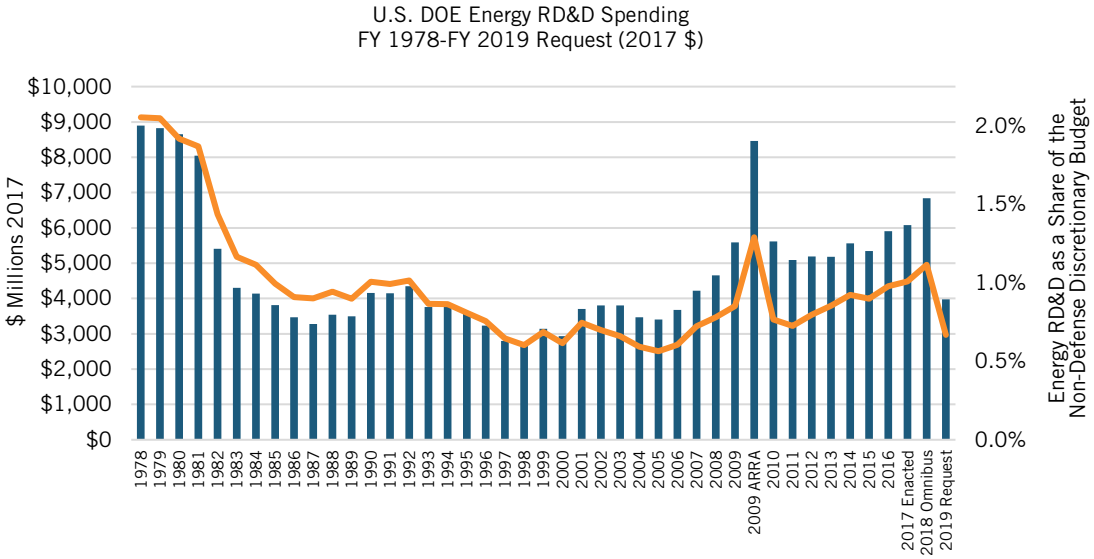
Figure 5: DOE RD&D, President's Proposal Compared to FY 2017



As figure 6 shows, the president has proposed that the energy RD&D budget be reduced to its lowest level (in inflation-adjusted dollars) since it began regaining momentum during the George W. Bush administration. The proposed cut would be the largest single-year decrease (40 percent below FY 2018) in the history of the department, surpassing even the Reagan-era cut of 33 percent in 1982. (The 2009 figure includes funding from the

American Recovery and Reinvestment Act (ARRA) stimulus program, which was separate from and additional to the normal appropriations process.)

Figure 6: Federal Energy R&D Funding, FY 1978 to FY 2019 Request[29]



The proposed cut would be the largest single-year decrease (40 percent below FY 2018) in the history of the department.

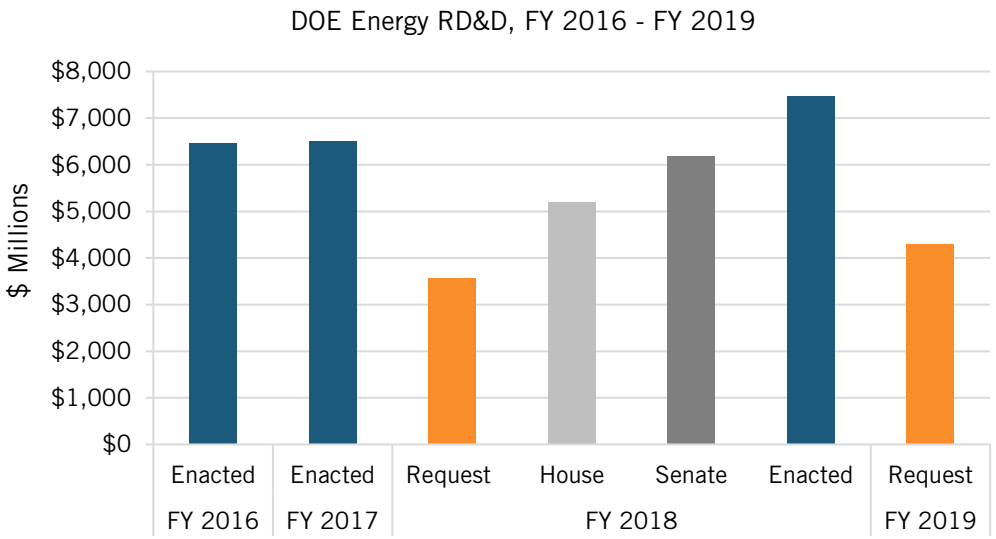
The FY 2019 budget request reflects a fundamental skepticism of federal energy RD&D programs, and a shift away from public investment in energy innovation. The Office of Management and Budget (OMB) has directed agencies to focus RD&D spending on early-stage research and has issued guidance that "federally-funded energy R&D should continue to reflect an increased reliance on the private sector to fund later-stage research, development, and commercialization of energy technologies."[30]

The request therefore falls most heavily on applied research, development, pilot, and demonstration projects as well as tech-to-market, technology transfer, commercialization, and advanced manufacturing programs, as we describe in detail below. These projects and programs seek to address market failures that typically block innovative energy technologies from reaching full maturity.

CONGRESSIONAL PERSPECTIVES ON ENERGY INNOVATION

The president's budget request is only the first step in the appropriations process. Congress makes the final disposition of funds. The House and Senate have had differing perspectives on energy RD&D investment in the recent past. The Senate's view is more supportive of energy innovation—and, fortunately, it has prevailed, as figure 7 shows.

Figure 7: Energy RD&D in the Appropriations Process, FY 2016–2019



"[The president's] approach will not successfully integrate the results of early stage research and development into the U.S. energy system and thus will not adequately deliver innovative energy technologies, practices, and information to American consumers and companies."

House appropriators have taken their lead from OMB, writing that, "The Committee is appreciative of [DOE] efforts to focus on early-stage research and development and begins a gradual approach to achieve this goal."[31]

The Senate Appropriations Committee, by contrast, writes that it

> [B]elieves that [the president's] approach will not successfully integrate the results of early-stage research and development into the U.S. energy system and thus will not adequately deliver innovative energy technologies, practices, and information to American consumers and companies. Notably, this is the case with complex systems and structures such as America's homes, offices and other buildings. The Committee provides funding to support a comprehensive and real-world strategy that includes medium- and later-stage research and development; deployment and demonstration activities… [32]

With respect to grid-modernization R&D, for example, the committee finds that, "Most utilities have limited research and development budgets, primarily due to regulatory constraints designed to keep electricity costs low for consumers. Additionally, utilities are unlikely to implement new concepts because most utilities would need to use their own systems for testing and evaluation, which could impact consumers … The Department [of Energy] plays a vital role, not only in early-stage research, but also in deployment, field testing, and evaluation."[33]

THE ENERGY RD&D PORTFOLIO: WHAT'S AT RISK

The energy RD&D portfolio supports 19 science and technology exploration programs that tackle a diverse set of challenges: mature domains that need to be reenergized, such as building technologies; sectors that are growing rapidly, like solar power; and innovations yet to be commercialized, such as fusion. Two programs, Basic Energy Sciences and ARPA-E, cut across diverse areas of RD&D.

Figure 8: Energy RD&D by Program Office

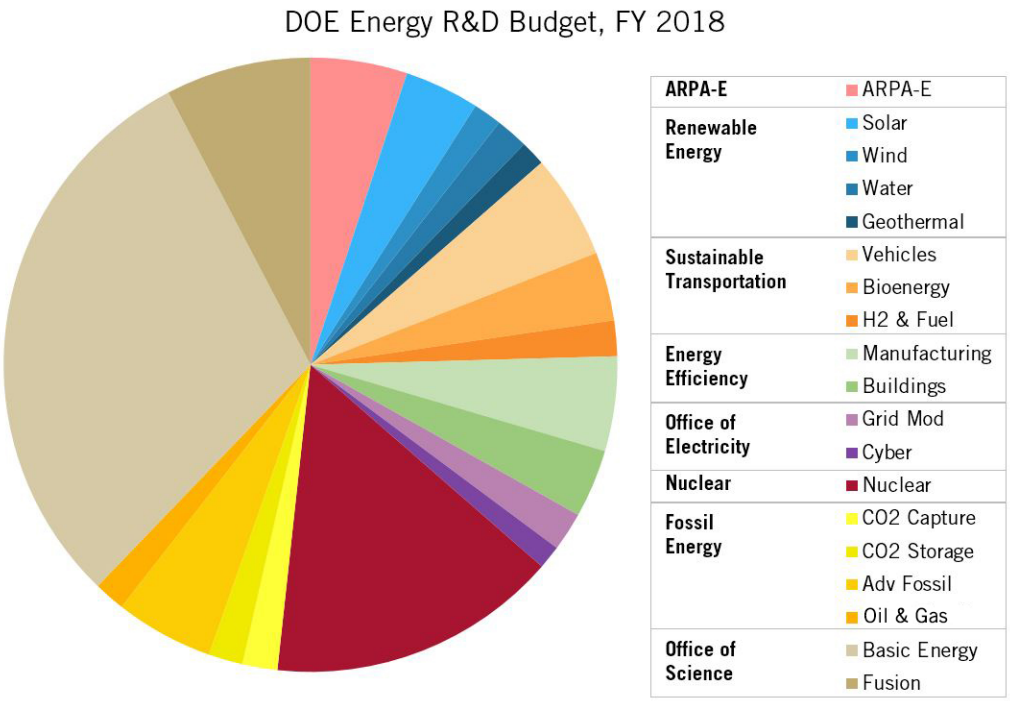


Figure 8 displays the distribution of funds across this portfolio, with programs aggregated into groups according to the DOE office that manages them. The bulk of the funding lies in DOE's applied energy offices: Electricity Delivery and Energy Reliability (OE); Energy Efficiency and Renewable Energy (EERE), with R&D programs organized into renewable energy, sustainable transportation, and energy efficiency; Fossil Energy (FE); and Nuclear Energy (NE). The Trump administration is setting up a new Office of Cybersecurity, Energy Security, and Emergency Response (CESER) as well, which will take over OE's programs in cybersecurity R&D and energy infrastructure emergency response. Fusion and Basic Energy Sciences lie within SC, while ARPA-E is a stand-alone, semiautonomous agency.

Figure 9: Proposed Changes in the DOE Energy Budget

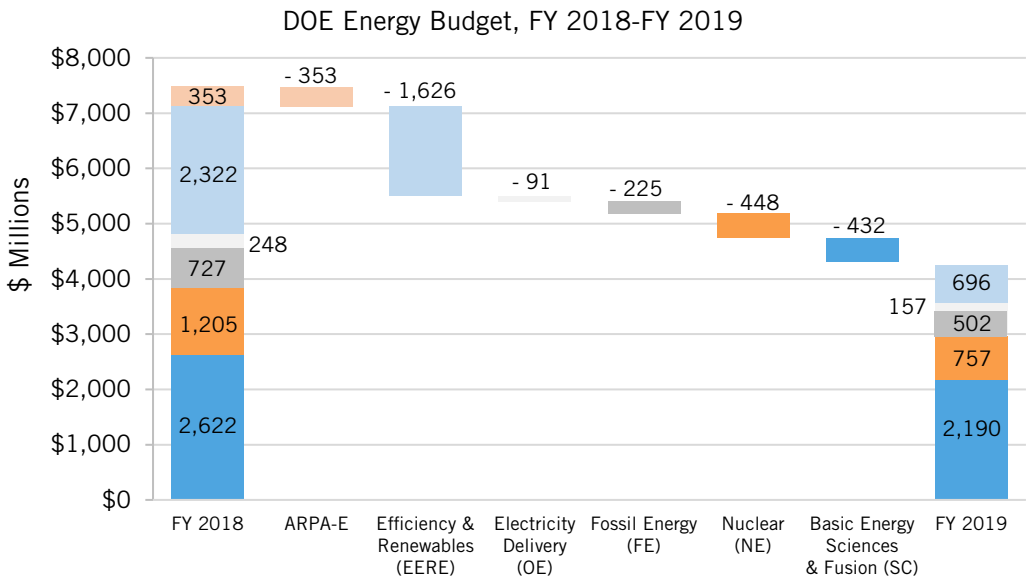


Figure 9 shows how these areas are treated in the FY 2019 budget request. Key proposals illustrated include:

- Elimination of ARPA-E;
- Significant reductions within EERE RD&D, ranging from 49.6 percent (for hydrogen and fuel cells) to 83.3 percent (for bioenergy);
- Scaling back of FE's RD&D on carbon capture, utilization, and storage by 79.9 percent;
- Cutting NE RD&D by 49 percent;
- Reducing OE's RD&D on grid modernization by 71.2 percent;
- Reducing CESER's RD&D on cybersecurity by 7.7 percent; and
- Reducing the Office of Science's energy RD&D (including Basic Energy Sciences and Fusion) by 16.5 percent.

The rest of this report delves deeply into each of the 19 programs.

ENDNOTES

1. The federal budget does not provide a definition or establish a separate category for demonstration; it is encompassed within the definition of "development." However, it is valuable to bear in mind that many energy technologies must be demonstrated at full scale after they have been developed to the point of practical use at bench or pilot scale and before they can be widely deployed and integrated into the energy system. In this report, therefore, we use the term "RD&D" when referring to the overall federal energy innovation investment, but the term "R&D" when discussing specific appropriations that fall within the official budgetary definition of R&D.
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28. Energy RD&D totals include R&D programs in all of the applied offices—EERE, FE, NE, OE, and ARPA-E—as well as the Basic Energy Sciences (BES) and Fusion Sciences (FUS) offices within the DOE Office of Science.
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ACKNOWLEDGMENTS

The authors thank Josh Freed and Spencer Nelson for providing helpful comments, as well as ITIF President Rob Atkinson and the ITIF staff for providing input and support for this report. Any errors or omissions are the authors' alone.

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The Information Technology and Innovation Foundation (ITIF) is a nonprofit, nonpartisan research and educational institute focusing on the intersection of technological innovation and public policy. Recognized as the world's leading science and technology think tank, ITIF's mission is to formulate and promote policy solutions that accelerate innovation and boost productivity to spur growth, opportunity, and progress.

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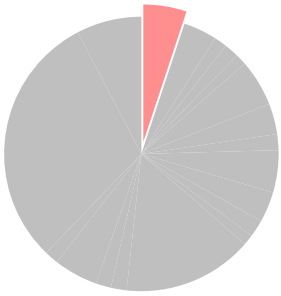
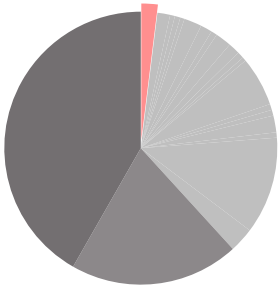
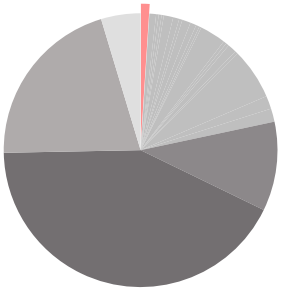


ARPA-E (pink)
Energy R&D (light gray)



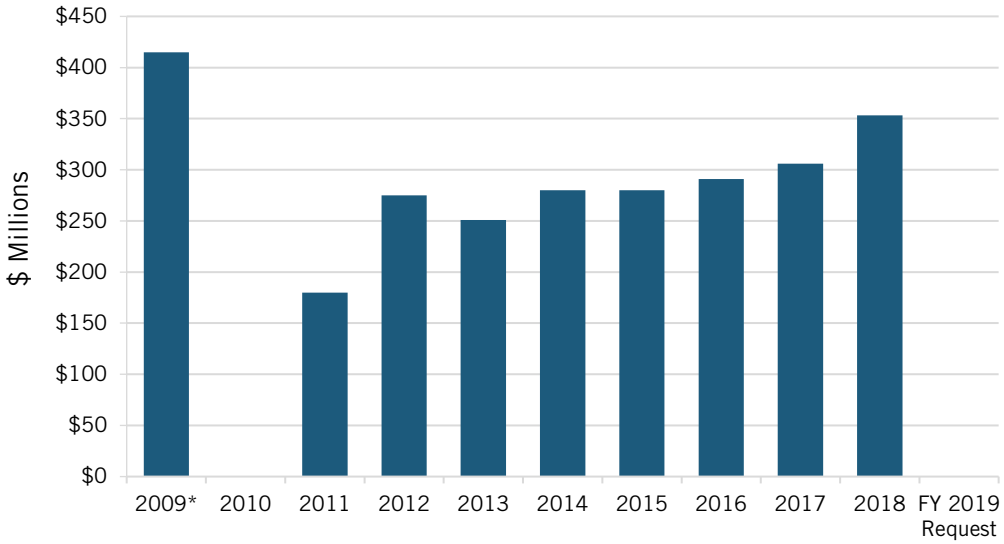
ARPA-E & Energy R&D
Basic Science R&D
Defense R&D



ARPA-E & Energy
Basic Science
Defense
Environ Mngmt
Other

Modeled after the highly successful Defense Advanced Research Projects Agency (DARPA), the Advanced Research Projects Agency-Energy (ARPA-E) advances high-potential, high-impact energy technologies that could radically improve U.S. economic prosperity, national security, and environmental well-being, but are too early for private-sector investment. Its grants help fund energy innovators who are developing technologies to solve critical cross-cutting, real-world problems in transportation, electricity, building, and other sectors.

Figure 1: The FY 2019 Budget Request Would Eliminate Funding for ARPA-E[1]



What's At Risk

Created by Congress in 2007, and funded for the first time in 2009, ARPA-E is an important new institution that has proven to be a valuable and versatile catalyst of energy innovation.[2] Compared with traditional R&D programs, ARPA-E was designed to focus more on the potential impact of the research that it funds. To qualify for ARPA-E funding, each program must explain how its success will change the global energy landscape, identify the key barriers to making such a change, and lay out a set of milestones and metrics for assessing progress.

ARPA-E's high-risk/high-reward ventures are already yielding big returns. As of February 2018, 74 ARPA-E projects had attracted more than $2.6 billion in private-sector follow-on funding; 71 ARPA-E project teams had formed new companies to advance their

technologies; and 109 ARPA-E projects had partnered with other government agencies for further development. Moreover, ARPA-E projects have generated 1,634 peer-reviewed journal articles, along with 248 new patents.[3] According to a recent ITIF analysis, on average, firms funded by ARPA-E raise more private capital than other clean-energy start-up firms.[4] The FY 2019 budget's proposed elimination of ARPA-E would therefore significantly undermine federal efforts to tackle urgent problems of energy supply, management, and use—and eliminate an important source of institutional innovation within DOE.[5]

ARPA-E R&D Programs and Projects

ARPA-E funds are not bound by the technology-specific silos of DOE's applied-energy offices. Rather, ARPA-E's programs are developed by technical experts drawn from industry and academia who, during their three- or four-year terms as program managers, engage intensively with communities of researchers and innovators to create targeted, time-limited programs that seek to fill the "white space" of underexplored but potentially great ideas. In addition, ARPA-E holds open competitions every three years to bring to light promising ideas that might otherwise slip through the cracks between energy R&D programs.

ARPA-E currently funds 270 projects across 32 active programs, which are broadly organized into four areas: electricity generation, efficiency and emissions, transportation and storage, and grid and grid storage.[6] These projects provide a sense of ARPA-E's accomplishments:

- Primus Power is commercializing a zinc-based flow battery that has the potential to provide power to the grid at a such a large scale that it could compete with natural-gas-powered peaker plants. Primus deployed its first system to Marine Corps Air Station Miramar in 2015, and has raised over $100 million in venture funding.[7]

- Foro Energy has developed a unique system for transmitting high-power laser light over long distances via fiber-optic cables for the purpose of ablating or welding materials. Potentially 10 times more economical than conventional hard-rock-drilling technologies, these "laser-assisted drill bits" could provide an effective way to gain access to the U.S. energy resources currently locked under hard-rock formations.[8]

- An ARPA-E-funded research team at the University of Virginia is currently developing a new type of wind-turbine blade. Inspired by palm-tree leaves, the blades are designed to better withstand the intense stresses from operating in windy offshore locations. The group will test a prototype at DOE's testing center in Colorado in the summer of 2018.[9]

Key Elements of the FY 2019 Budget Proposal

The FY 2019 budget request would eliminate ARPA-E.

ENDNOTES

1. In 2009, ARPA-E received $15 million in regular appropriations and $400 million in one-time funding pursuant to the American Recovery and Reinvestment Act.
2. David M. Hart and Michael Kearney, "ARPA-E: Versatile Catalyst for U.S. Energy Innovation" (Washington, D.C.: Information Technology and Innovation Foundation, November 2017).
3. ARPA-E, "The Advanced Research Projects Agency-Energy: Overview," https://www.arpa-e.energy.gov/sites/default/files/ARPA-E-Fact-Sheet-03292018.pdf.
4. Ibid.
5. National Academies of Science, Engineering and Medicine (NASEM), Committee on Evaluation of the Advanced Research Projects Agency-Energy (ARPA-E), Board on Science, Technology, and Economic Policy, "An Assessment of ARPA-E" (Washington, D.C.: National Academies Press, 2017).
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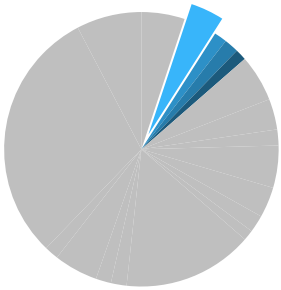
7. David M. Hart and Michael Kearney, "ARPA-E: Versatile Catalyst for U.S. Energy Innovation" (Washington, D.C.: Information Technology and Innovation Foundation, November 2017).
8. National Academies of Science, Engineering and Medicine (NASEM), Committee on Evaluation of the Advanced Research Projects Agency-Energy (ARPA-E), Board on Science, Technology, and Economic Policy, "An Assessment of ARPA-E" (Washington, D.C.: National Academies Press, 2017) C-18.
9. Brad Plumer, "Kelp Farms and Mammoth Windmills Are Just Two of the Government's Long-Shot Energy Bets," *New York Times*, March 16, 2018, https://www.nytimes.com/2018/03/16/climate/arpa-e-summit.html.

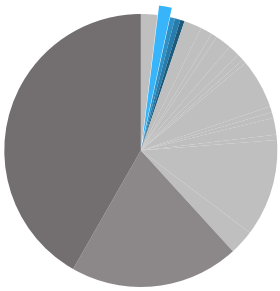
Federal Energy R&D: Solar Energy

BY DAVID M. HART AND COLIN CUNLIFF | APRIL 2018

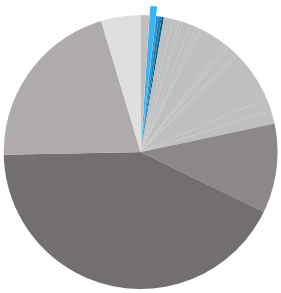
This briefing is part of a series on the U.S. energy budget. See: itif.org/energy-budget.



Solar (light blue)
Other Renewables
Energy R&D (light gray)



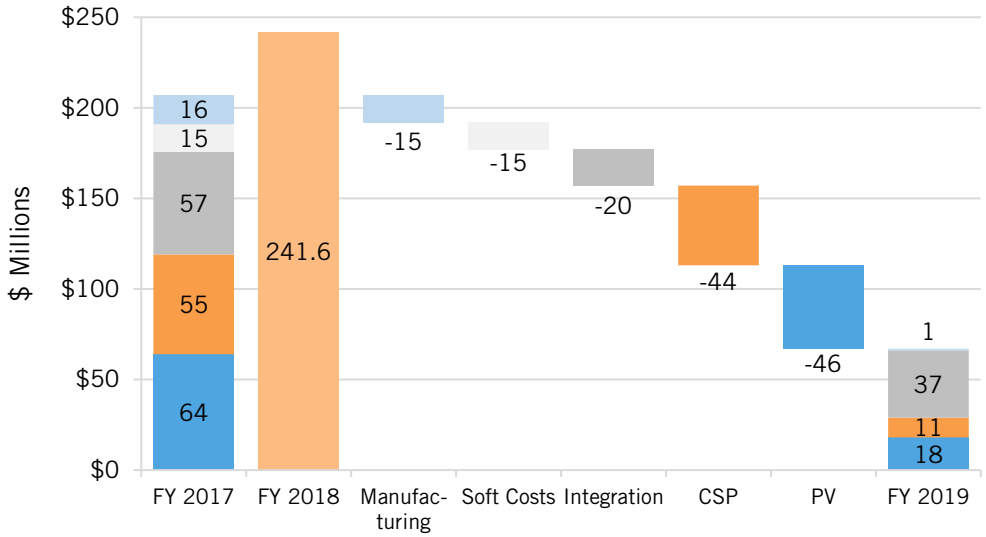
Solar & Energy R&D
Basic Science R&D
Defense R&D



Solar & Energy
Basic Science
Defense
Environ Mngmt
Other DOE

The Department of Energy's (DOE) Solar Energy Program embraces two complementary technologies: photovoltaics (PV), which convert light to electricity via semiconductors, and concentrating solar power (CSP), which converts light to heat that can then be stored and used to generate electricity. The program also works to integrate these electricity-generation technologies more effectively into the transmission and distribution grid, and transfer DOE solar innovations into domestic manufacturing capabilities.[1]

Figure 1: The FY 2019 Budget Request Would Cut Solar Energy R&D by 72 Percent



What's At Risk

DOE's SunShot Initiative program has already achieved its 2020 goal of utility-scale solar PV power at six cents per kilowatt-hour ($0.06/kWh), making it a competitive source for electricity generation in areas with good solar resources and low PV penetration.[2] DOE should build on this success to reduce costs to the point solar PV becomes more competitive for utility, residential, and commercial systems as well—especially when factoring in the costs of integration. SunShot's 2030 goal for utility-scale solar PV is $0.03/kWh, which is 50 percent below today's utility-scale cost. Goals for commercial solar ($0.04/kWh) and residential solar ($0.05/kWh) are even more ambitious, requiring cost reductions of up to 68 percent of today's costs.[3] Achieving these goals would make solar one of the least-expensive sources of electricity generation, costing less than most fossil-fuel-powered sources, thereby contributing to energy affordability while reducing carbon emissions.

The ten CSP systems operating in the United States today have demonstrated solar power's ability to provide 24-hour energy to the grid—although not yet at a competitive cost.[4] DOE's 2030 goal for CSP power is $0.06/kWh, or 71 percent below the 2010 benchmark. These targets are highly competitive with other dispatchable power generators and would enable greater overall penetration of solar electricity into the grid, while also enabling more reliable solar generation and increasing its value to the grid.

Solar Energy R&D Subprograms

R&D in the Solar Energy program is spread across five subprograms:

- **Photovoltaics (PV)** funds research and development to enable higher PV performance, including advanced silicon processes, multijunction solar-cell efficiency, advanced materials science for cadmium-telluride solar cells, and impacts of outdoor soiling, temperature cycling, ultraviolet light, and humidity on PV performance.
- **Concentrating Solar Power (CSP)** focuses on component-level research and development in solar collection, receivers and heat-transfer fluids, power conversion, and thermal-energy storage, as well as integration of subcomponent technologies.
- **Systems Integration** addresses key technical challenges related to the grid integration of solar power, including power variability, voltage regulation, frequency control, unintentional islanding, protection coordination, and two-way power flow.
- **Balance of Systems Soft-Cost Reduction** focuses on reducing non-hardware costs—including financing, customer acquisition, permitting, installation, labor, and inspection—which constitute over half the cost of total system prices for residential, commercial, and community PV systems.
- **Innovations in Manufacturing Competitiveness** funds the development and demonstration of innovative solar manufacturing technologies, as well as technology-to-market programs that support businesses seeking to develop innovations in hardware installation and grid-integration technologies.

Key Elements of the FY 2019 Budget Proposal

- **Elimination of the Soft Costs subprogram**, which threatens to derail progress toward the 2020 and 2030 cost goals for residential and commercial solar, given that soft costs constitute more than half of total system prices for residential, commercial, and community PV systems
- **A 94-percent reduction in the Manufacturing subprogram,** including a discontinuation of funding for the SunShot Incubator program, which provides early-stage assistance to small businesses commercializing innovative solar

technologies. The SolarMAT program—which funds innovative manufacturing technologies and aims to increase the United States' share of the global solar market through the creation of competitive advantages for domestic manufactures—would also be eliminated.

- **Elimination of several R&D activities in the Systems Integration subprogram**, including the Solar Forecasting program, which advances predictive modeling capabilities, and R&D aimed at using solar to improve the resilience of the nations' electrical grid.

ENDNOTES

1. DOE, "FY 2018 Congressional Budget Justification" (Washington, D.C.: DOE/CFO, May 2017) Volume 3, 97.
2. DOE, "2020 Utility-Scale Solar Goal Achieved" (Washington, D.C.: DOE/SETO, September 2017), https://www.energy.gov/eere/solar/articles/2020-utility-scale-solar-goal-achieved.
3. R. Fu et al., "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2016," (NREL Technical Report, September 2016).
4. National Renewable Energy Laboratory, "Concentrating Solar Power Projects in the United States," https://www.nrel.gov/csp/solarpaces/by_country_detail.cfm/country=US.

Federal Energy R&D: Wind Energy

BY DAVID M. HART AND COLIN CUNLIFF | APRIL 2018

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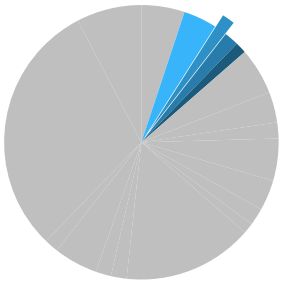
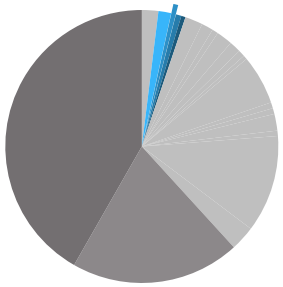
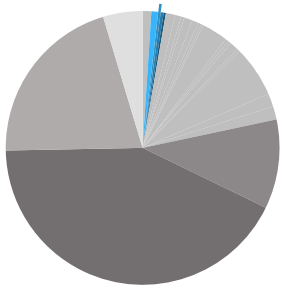


Wind (blue)
Other Renewables (blue)
Energy R&D (light gray)



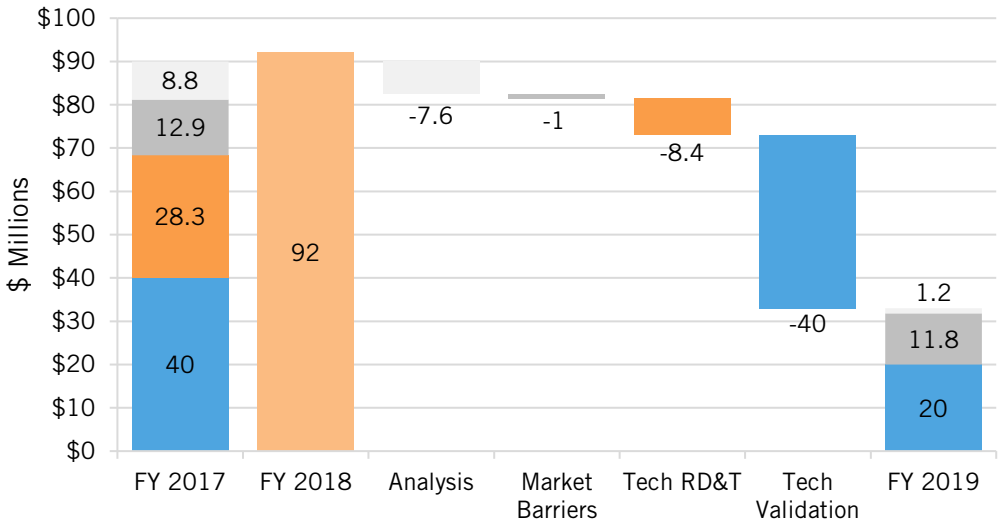
Wind & Energy R&D
Basic Science R&D
Defense R&D



Wind & Energy
Basic Science
Defense
Environ Mngmt
Other DOE

The Department of Energy's (DOE) Wind Energy program targets innovations in onshore, offshore, and distributed wind power to capture the kinetic energy in wind and turn it into electricity via spinning generators. The program also works to integrate wind generation more effectively into the bulk power system, which enables wind farms to provide more-reliable power output and other services to the grid.

Figure 1: The FY 2019 Budget Request Would Cut Wind Energy R&D by 64 Percent



What's At Risk

DOE's Wind Energy program has already achieved substantial cost reductions and technology improvements that have enabled the rapid expansion of land-based wind power. The cost of energy from land-based wind power has decreased from more than 55 cents per kilowatt-hour ($0.55/kWh) in 1980 to a national average of $0.046/kWh in 2015, thus enabling the expansion of wind power to 41 states.[1] DOE should build on this success to improve performance and reduce costs much further until unsubsidized wind power becomes more competitive across more parts of the country. DOE's "Wind Vision" report provides a path to reducing unsubsidized wind-energy costs to $0.023/kWh by 2030, a decrease of 50 percent from today's costs.[2] Achieving this goal could enable up to 200 gigawatts (GW) of total wind capacity by 2030, thereby contributing to energy affordability and security while also reducing carbon emissions.[3]

The first U.S. offshore wind farm, which began operating off the coast of Rhode Island in December 2016, provides encouragement to a nascent domestic offshore wind industry.[4] Offshore wind could present a low-carbon energy alternative for the 28 coastal and Great Lake states, although additional cost reductions will be needed to make it cost competitive with other sources of electricity—as it already is in parts of Europe. Validation and demonstration of new offshore wind technologies will also provide investors with greater confidence in the growing array of energy projects in U.S. waters.[5]

Wind Energy R&D Subprograms

R&D in the Wind Energy program is divided into four subprograms:

- **Technology Research, Development, & Testing (RD&T) and Resource Characterization** focuses on complex aerodynamics, advanced component manufacturing, wind-plant reliability, resource characterization, controls, sensors, and modeling—and manages wind-specific test facilities that enable validation of R&D results.
- **Technology Validation and Market Transformation** conducts high-risk testing and validation of new technologies, including innovative offshore wind pilot projects, and collect and produces public performance and environmental data sets.
- **Mitigate Market Barriers R&D** evaluates technology solutions to address wind-turbine radar interference, and funds other R&D on wind-energy grid integration and grid-infrastructure modernization challenges.
- **Modeling and Analysis** evaluates and prioritizes wind-energy technology-innovation opportunities for land and offshore applications.

Key Elements of the FY 2019 Budget Proposal

- **Elimination of the Technology Validation and Market Transformation subprogram**, which has focused on validation of innovative offshore wind technologies, threatens to derail progress toward the 2030 cost goal for unsubsidized offshore wind energy of $0.14/kWh.
- **A 29-percent reduction in the Technology RD&T and Resource Characterization subprogram**, which houses the Atmosphere to Electrons (A2e) initiative, the Exascale Predictive Wind Plant Flow Physics Modeling project, and the Big Adaptive Rotor (BAR) initiative, provides support to Sandia's Scaled Wind Farm Technology (SWiFT) facility in Texas and National Renewable Energy Laboratory's National Wind Technology Center (NWTC) in Colorado, which hosts testing facilities for industry and academia to test and validate their innovations.

- **An 87-percent reduction to the Modeling and Analysis subprogram**, including reductions to the System Management of Atmospheric Resource through Technology (SMART) activities, which aim to lower costs through enhanced power production, more-efficient material use, lower operation and maintenance costs, and greater grid-integration and reliability features.

- **Elimination of several R&D activities in the Mitigate Market Barriers R&D subprogram,** including the WINDExchange and Wind Energy Regional Resource Centers, which help communities weigh the benefits and impacts of wind energy by providing the best available science to support their decisions.

ENDNOTES

1. DOE, "Wind Energy Technologies Office Accomplishments" (Washington, D.C.: DOE, 2017), https://www.energy.gov/sites/prod/files/2017/05/f34/108630-Wind%20Accomplishments-FactSheet-web150.pdf.
2. Katherine Dykes, et al., "Enabling the SMART Wind Power Plant of the Future Through Science-Based Innovation" (Washington, D.C.: DOE NREL, August 2017) https://www.nrel.gov/docs/fy17osti/68123.pdf.
3. Ibid.
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Federal Energy R&D: Water Power

BY DAVID M. HART AND COLIN CUNLIFF | APRIL 2018

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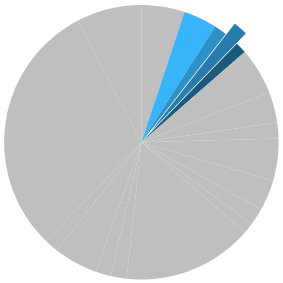
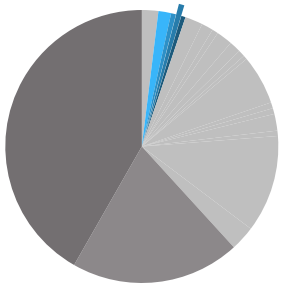
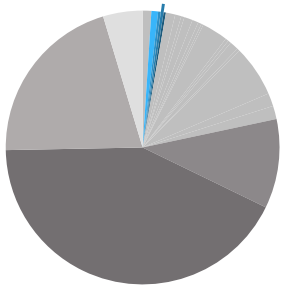


Water (blue)
Other Renewables (blue)
Energy R&D (light gray)



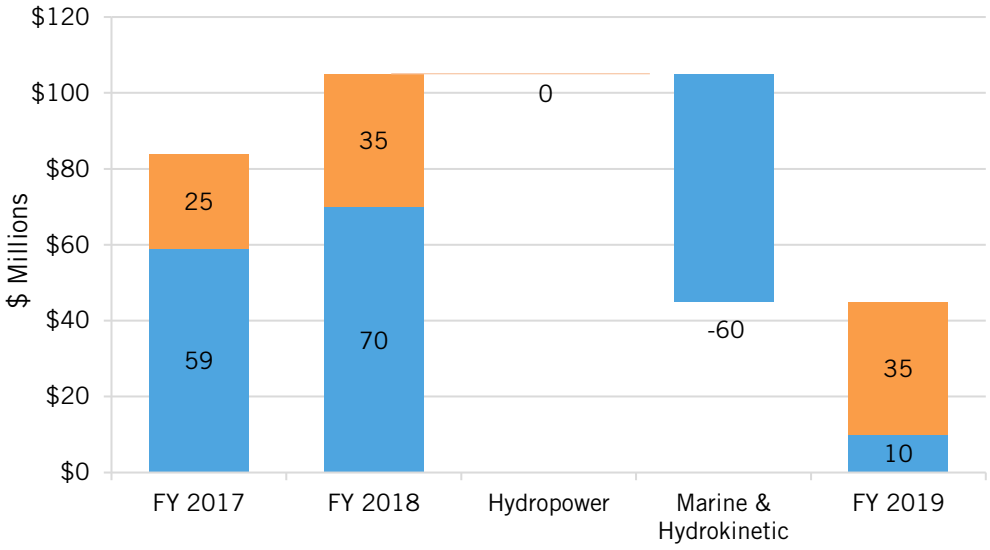
Water & Energy R&D
Basic Science R&D
Defense R&D



Water & Energy
Basic Science
Defense
Environ Mngmt
Other DOE

The Department of Energy's (DOE) Water Power program supports research and development (R&D) of two types of technologies: conventional hydropower (including pumped storage), and marine and hydrokinetic (MHK) energy. Conventional hydropower uses a dam or other structure to convert the kinetic energy of flowing water into electricity, while MHK technologies convert the energy of waves, tides, and currents into electricity.

Figure 1: The FY 2019 Budget Request Would Cut Water Power R&D by 57 Percent



What's At Risk

DOE's 2016 "Hydropower Vision" report identified up to 50 GW of new hydropower capacity that could be gained from upgrading and modernizing the existing fleet, installing generation on non-powered dams, and developing new, small hydropower and pumped-storage technologies.[1] Near-term growth of hydropower generation through 2030 is estimated at 9.4 GW, while approximately 16.2 GW in new pumped-storage hydropower could also become available. However, new technologies and system-design concepts are needed to reduce costs and improve efficiency in order to realize this potential.

National resource assessments have found 1.25–1.85 terawatt-hours per year (TWh/yr) of untapped, technically extractable MHK potential, or the equivalent of 30 percent of the total electricity generated in the United States.[2] MHK technologies are at an early stage of development due to the fundamental scientific and engineering challenges of generating

power from complex low-velocity/high-density dynamics in a corrosive ocean environment. Although they could potentially provide a low-carbon energy alternative for the 28 coastal and Great Lake states, additional cost reductions are needed to make MHK cost competitive with other sources of electricity. The proposed budget cuts threaten to stall the progress currently being made to extract significant energy value from this rich national resource.

Water Power R&D Subprograms

R&D in the Water Energy program is spread across two subprograms:

- **Hydropower R&D** seeks to reduce the site-specific costs of construction, powerhouse design/installation, and environmental mitigation of new hydropower at non-powered dams; develop turbine designs that generate more power at given water flows or increase operational ranges with reduced impacts for existing hydropower facilities; optimize modes of operation for grid stabilization; and develop novel closed-loop pumped-storage designs that can be deployed at a wider range of sites.

- **Marine and Hydrokinetic (MHK) Technologies** focuses on researching controls to maximize power production over a range of ocean conditions; improving and validating modeling tools and methodologies to optimize device and array performance and reliability across operational and extreme conditions; and investigating new approaches to safe and cost-efficient installation, grid integration, operations, maintenance, and decommissioning of MHK projects. MHK is currently developing an open-water wave-energy test facility—to be completed in 2021—that will allow testing and validation of industry-developed MHK energy-conversion components and systems.

Key Elements of the FY 2019 Budget Proposal

- **An 86-percent reduction in the MHK Technologies subprogram**, including a discontinuation of competitive industry-led RD&D of ocean, river, and tidal-energy-conversion components and systems. This subprogram also houses RD&D in advanced materials and structural-health monitoring; a joint DOE/Navy project targeting advanced controls for wave-energy-conversion technologies; and development of wave-classification metrics and site-specific wave-energy characterization.

- **Flat spending on Hydropower RD&D**, including increased funding for pumped-storage hydropower R&D, and R&D into modular hydropower technologies. The proposal would discontinue funding for techno-economic analysis of the value of pumped-storage hydropower coupled to areas with high levels of variable and renewable electricity generation.

ENDNOTES

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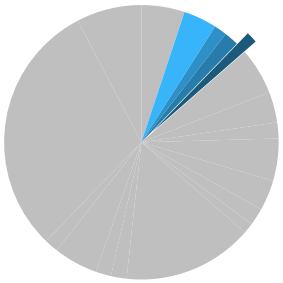
2. DOE, "Quadrennial Technology Review" (Washington, D.C.: DOE, September 2015), https://www.energy.gov/sites/prod/files/2017/03/f34/quadrennial-technology-review-2015_1.pdf.

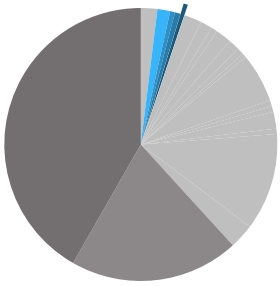
Federal Energy R&D: Geothermal Technologies

BY DAVID M. HART AND COLIN CUNLIFF | APRIL 2018

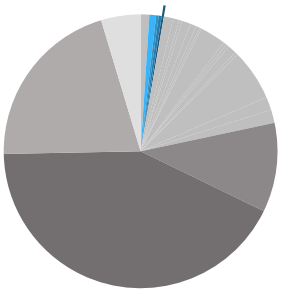
This briefing is part of a series on the U.S. energy budget. See: itif.org/energy-budget.



Geothermal (blue)
Other Renewables (blue)
Energy R&D (light gray)



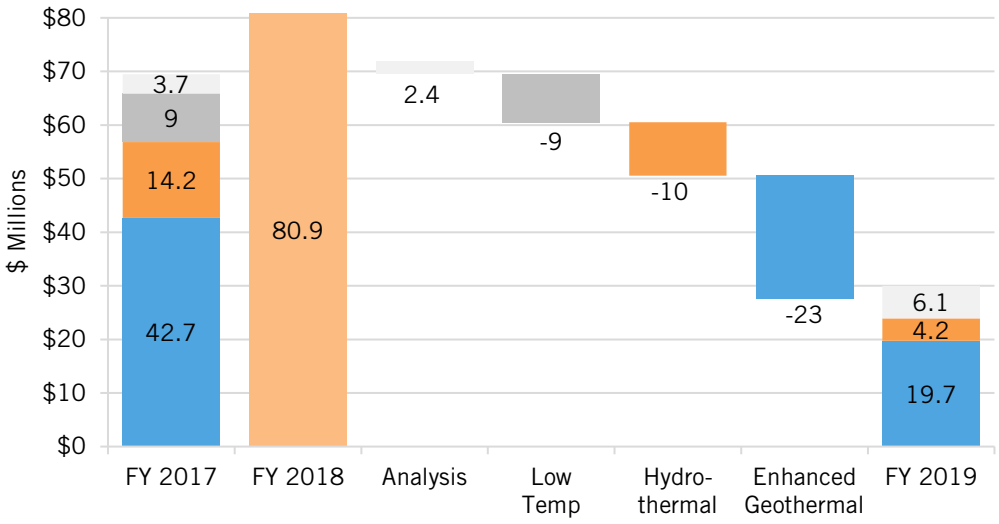
Geothermal & Energy R&D
Basic Science R&D
Defense R&D



Geothermal & Energy
Basic Science
Defense
Environ Mngmt
Other DOE

Geothermal technologies use heat from the earth, either directly for such applications as heating and cooling, or to generate electricity. The Geothermal Technologies program supports research and development of two main types of geothermal technologies: hydrothermal and Enhanced Geothermal Systems (EGS). Hydrothermal resources exist naturally in areas where there is sufficient temperature and permeability in the subsurface for the flow of fluids to generate electricity. EGS, on the other hand, requires rock stimulation for permeability enhancement and fluid injection to allow commercial-scale fluid flow that can be used for electricity generation.[1]

Figure 1: The FY 2019 Budget Request Would Cut Geothermal R&D by 63 Percent



What's At Risk

In addition to the current U.S. installed capacity of geothermal energy of over 3.8 gigawatts (GW), there is a vast source of untapped energy just waiting to be realized: an estimated 30 GW of hydrothermal plus more than 100 GW of geothermal energy through EGS.[2] The geothermal industry operates in a harsh subsurface environment in which unique technical and operational challenges must be overcome to realize this potential. Foremost among these challenges is the resources essentially being "out of sight" at a depth of anywhere from two to five kilometers, thus requiring new exploration technologies and tools to reduce the near-term cost and risk of development. DOE has set an ambitious goal of reducing the cost of electricity from newly developed geothermal systems from 22.4

cents per kilowatt-hour ($0.224/kWh) in 2014 to $0.06/kWh by 2030. Meeting this target (for both hydrothermal and EGS resources) requires R&D to harness lower-temperature resources more effectively, develop improved methods to stimulate new EGS resources, and characterize and model subsurface stress and other reservoir properties. Reductions in R&D funding threaten to delay or even derail the progress DOE has already made toward these targets.

Geothermal Technologies R&D Subprograms

Geothermal R&D is divided among four subprograms:

- **Enhanced Geothermal Systems (EGS)** explores materials and technologies that facilitate characterization of local stress, chemical constituents, and fluid and thermal pathways over time; ensure wellbore integrity over multidecadal time frames; and provide sustainable operation while achieving sufficient power-generation productivity.
- **Hydrothermal** R&D focuses on technologies necessary to find and access "blind" hydrothermal resources (i.e., showing little to no surface expression) by targeting innovative approaches to microhole drilling applications, self-healing cements, and subsurface imaging.
- **Low-Temperature and Coproduced Resources** targets RD&D on technologies applicable to geothermal resources below a temperature of 300 °F (150 °C); direct use of thermal resources for process and space-heating applications; and geothermal-enabling technologies, including thermal desalination processes and hybrid power designs that can be codeveloped with existing well-field infrastructures.
- **Systems Analysis** focuses on identifying and addressing barriers to geothermal adoption, as well as validating and assessing technical progress to inform the direction and prioritization of the portfolio.

Key Elements of the FY 2019 Budget Proposal

- **Elimination of the Low-Temperature and Coproduced Resources subprogram.** Although low-temperature resources have a lower power-conversion efficiency—due to lower temperature fluids—than other geothermal resources, they are abundant and highly accessible. A recent USGS assessment estimated the existence of 46.5 GW thermal of total beneficial heat available from geothermal resources below 90°C; however, further R&D is needed to address technical challenges and bring costs down in order to efficiently utilize this domestic energy resource.
- **A 54-percent reduction in the EGS subprogram,** including to its flagship field laboratory—the Frontier Observatory for Research in Geothermal Energy (FORGE)—which tests novel technologies and techniques that focus on EGS optimization and validation.

- **A 70-percent reduction in the Hydrothermal subprogram**, including discontinuation of the Play Fairways Analysis project, which validates new approaches for identifying blind resources, as well as discontinuation of the hydrothermal lab R&D in microhole drilling, subsurface imaging, and self-healing cements.

- **A $2.4-million increase in the Systems Analysis subprogram**, with new funding going to the cross-cutting Beyond Batteries initiative, which supports improved grid reliability and resilience.

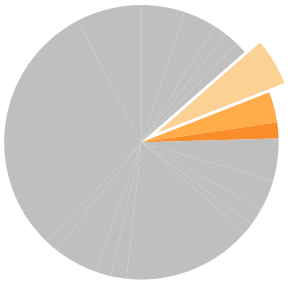
ENDNOTES

1. DOE, "FY 2018 Congressional Budget Justification," (Washington, D.C.: DOE/CFO, 2017) 159.
2. EIA, Form EIA-860, table 3.1, (release date: November 9, 2017). https://www.eia.gov/electricity/data/eia860/; USGS, "Assessment of Moderate- and High-Temperature Geothermal Resources of the United States," (Washington, DC: USGS, 2008), https://pubs.usgs.gov/fs/2008/3082/pdf/fs2008-3082.pdf.

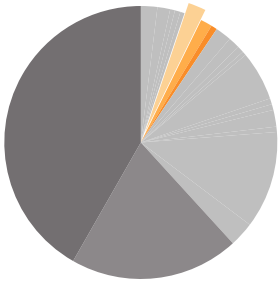
Federal Energy R&D: Vehicle Technologies

BY DAVID M. HART AND COLIN CUNLIFF | APRIL 2018

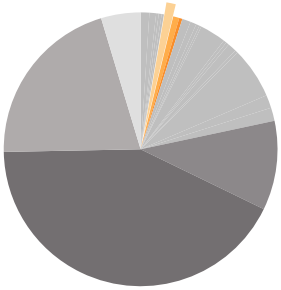
This briefing is part of a series on the U.S. energy budget. See: itif.org/energy-budget.



Vehicles (light orange)
Other Transportation (orange)
Energy R&D (light gray)



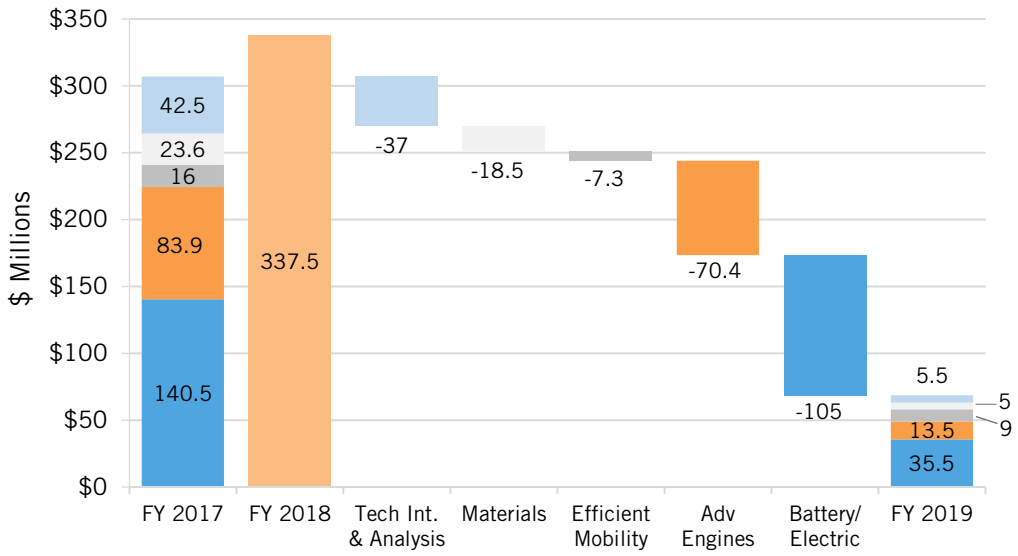
Vehicles & Energy R&D
Basic Science R&D
Defense R&D



Vehicles & Energy
Basic Science
Defense
Environ Mngmt
Other DOE

The transportation sector accounts for 70 percent of petroleum use and 34 percent of all carbon pollution.[1] The average U.S. household spends nearly one-fifth of its total expenditures on transportation, making it the most expensive spending category after housing.[2] With 25 percent of U.S. petroleum consumption coming from imports, U.S. consumers send more than $10 billion per month overseas for crude oil.[3] By investing in R&D to use conventional fuels more efficiently and develop domestically produced alternative-vehicle technologies, the Vehicle Technologies Office (VTO) works to keep prices low for consumers, improve national energy security, and enhance environmental performance.[4]

Figure 1: The FY 2019 Budget Request Would Cut Vehicle Technologies R&D by 80 Percent



What's At Risk

The Vehicle Technologies office has established technology cost and performance targets to help meet national imperatives in energy security, environmental stewardship, and economic growth. Reaching these goals will require new technologies and cost reductions in batteries, efficient engines, lightweight materials, and other enabling technologies. For electric vehicles (EVs), the office has established ambitious targets of reducing the cost of EV batteries by more than half, to $100/kWh, increasing the range to 300 miles, and decreasing charge time to 15 minutes or less by 2028. For conventional light-duty vehicles, the office is working to develop the next generation of engines and fuels capable of

improving passenger-vehicle fuel economy by 35 percent by 2030. The SuperTruck II research activity has set an ambitious target of doubling the freight-hauling efficiency of heavy-duty Class 8 long-haul trucks by 2020. In order to meet consumer expectations regarding cost and performance, each of these goals was chosen to make new technology options more efficient and at least as affordable as conventional technology. However, reductions in R&D funding threaten to delay or even derail current DOE progress toward these targets.

Vehicle Technologies R&D Subprograms

R&D in the Vehicle Technologies program is distributed across six subprograms:

- **Battery and Electrification Technologies** explores new battery chemistry and cell technology to reduce the cost of EV batteries.
- **Energy Efficient Mobility Systems (EEMS)** applies complex modeling and simulation to explore the energy impact of emerging disruptive technologies such as connected and autonomous vehicles, information-based mobility-as-a-service platforms, and advanced powertrain technologies in order to identify opportunities to improve efficiency.
- **Advanced Engine & Fuel Technologies R&D** works to develop advanced combustion engines and co-optimize fuels to improve fuel economy.
- **Materials Technology** supports vehicle lightweighting and improved propulsion (powertrain) efficiency through materials R&D.
- **Technology Integration** maintains the Alternative Fuels Data Center (AFDC) and Fuel Economy Guide, and manages the State & Alternative Fuel Provider Fleet Program.
- **Analysis** provides technology, economic, and interdisciplinary analyses to inform and prioritize the Vehicle Technologies research portfolio.

Key Elements of the FY 2019 Budget Proposal

- **A 75-percent reduction of the Battery and Electrification Technologies subprogram,** including the elimination of battery-safety and thermal-performance research, as well as computer-aided design research to couple crash response with electrochemical response.
- **Elimination of cross-cutting SuperTruck II activities,** which aim to improve freight-hauling efficiency of heavy-duty Class 8 long-haul trucks by 100 percent by 2020. SuperTruck II is a cross-cutting activity funded by multiple R&D subprograms, and whose elimination would result in funding reductions across subprograms.

- **An 84-percent reduction of Advanced Engine & Fuel Technologies R&D,** including the elimination of research on multi-fueled and spark-ignited engines, diesel-engine emissions reduction, and modeling of fluid dynamics in multicylinder engines.

- **A 45-percent reduction in Energy Efficient Mobility Systems,** including the elimination of research on multimodal transportation systems and advanced fueling infrastructure within the SMART Mobility National Laboratory Consortium, as well as work to enhance and update transportation energy models.

- **A 79-percent reduction in Materials Technology R&D**, including the elimination of research on materials for emissions control and reductions, and cuts to research on lightweight and high-temperature materials that could enable greater energy efficiency and engine performance.

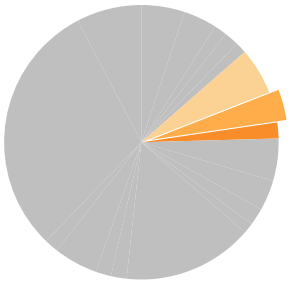
ENDNOTES

1. EPA, DRAFT "Inventory of U.S. Greenhouse Gas Emissions and Sinks," Table ES-2.
2. Bureau of Labor Statistics, "Consumer Expenditure Survey, 2015. Average Annual Expenditures and Characteristics of All Consumer Units, 2013-2015," https://www.bls.gov/cex/2015/standard/multiyr.pdf.
3. Transportation Energy Data Book 34th Edition, Table 1.7 "Imported Crude Oil by Country of Origin 1973-2015"; Table 10.3, "Prices for a Barrel of Crude Oil and a Gallon of Gasoline, 1978-2015" (Oak Ridge National Laboratory, 2015).
4. DOE, "FY 2019 Congressional Budget Justification" (Washington, D.C.: DOE/CFO 2018) 31.

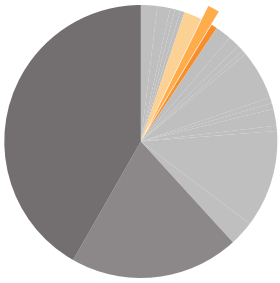
Federal Energy R&D: Bioenergy Technologies

BY DAVID M. HART AND COLIN CUNLIFF | APRIL 2018

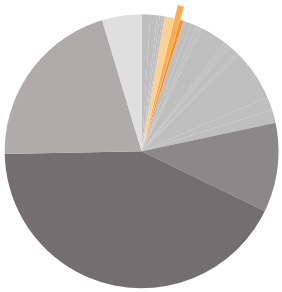
This briefing is part of a series on the U.S. energy budget. See: itif.org/energy-budget.



Bioenergy (orange)
Other Transportation (orange)
Energy R&D (light gray)



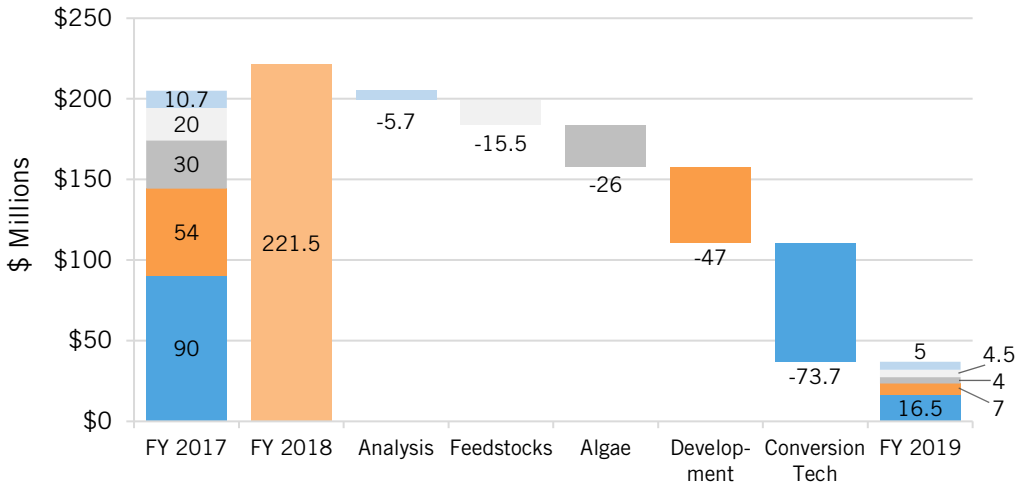
Bioenergy & Energy R&D
Basic Science R&D
Defense R&D



Bioenergy & Energy
Basic Science
Defense
Environ Mngmt
Other DOE

The Department of Energy's (DOE) Bioenergy Technologies Program (BETO) focuses on R&D to develop sustainable bioenergy technologies capable of producing price-competitive biofuels from nonfood sources of biomass such as wastes and agricultural residues, and energy crops like switchgrass and algae. The program's primary focus is on R&D to produce "drop-in" biofuels that are compatible with existing fueling infrastructure and vehicles across a range of transportation modes, including renewable-gasoline, -diesel, and -jet fuels.[1]

Figure 1: The FY 2019 Budget Request Would Cut Bioenergy technologies R&D by 83 Percent



What's At Risk

By 2030, the United States will have the resource potential to sustainably produce 1 billion dry tons of nonfood biomass resources without disrupting agricultural markets for food and animal feed.[2] These resources could produce approximately 50 billion gallons of biofuels (25 percent of U.S. transportation fuels), 50 billion pounds of high-value chemicals and products, and 75 billion kWh of electricity (enough to power 7 million homes).[3] Algal biomass is an important kind of biomass due to its ability to grow quickly, use waste resources, and produce fuel precursors. Algal biofuels could potentially contribute up to 5 billion gallons per year—about 25 percent of the current jet-fuel market—by 2030.[4] Bioenergy with carbon capture, utilization, and storage (CCUS) offers the increasingly essential possibility of net-negative carbon emissions.

Each of the bioenergy production and conversion targets within BETO was chosen to create new technology options that are more efficient than, and at least as affordable as, conventional technology. Achieving these targets will both improve transportation-energy affordability and take the United States one step closer to reaching its national goals in energy security, economic growth, and environmental stewardship. However, reductions in DOE R&D funding threaten to delay or even derail this progress.

Bioenergy Technologies R&D Subprograms

R&D in the Bioenergy program is distributed across these five subprograms:

- **Feedstock Supply and Logistics** develops and improves strategies, technologies, and systems to provide consistent quality feedstock to biorefineries, while focusing on supply and logistics challenges to support further development of advanced biofuels.
- **Advanced Algal Systems** supports R&D of algal-biomass production and logistics systems, with a focus on improving capabilities to predict, breed, and select the best-performing algal strains, harvest algae at high-throughputs, and extract and convert algal biomass components into fuels.
- **Conversion Technologies** R&D focuses on converting biomass feedstocks into transportation fuels and related bioproducts and explores both biological and thermochemical routes to convert biomass into "drop-in" hydrocarbon fuels.
- **Advanced Development and Optimization (ADO)** collaborates with the Vehicle Technologies program on the Co-Optimization of Fuels & Engines (Co-Optima) initiative to develop fuels and engines that are co-optimized to enable higher efficiency and performance.
- **Strategic Analysis and Cross-cutting Sustainability** provides quantitative analysis to inform BETO decisions regarding the future direction and scope of its R&D portfolio.

Key Elements of the FY 2019 Budget Proposal

- **An 87-percent reduction in the Advanced Development and Optimization R&D**, including elimination of biopower R&D, as well as discontinuation of all biorefinery pilot- and demonstration- scale projects.
- **An 87-percent reduction in Advanced Algal Systems**, including discontinuation of R&D on algae harvesting, conversion, and integration studies, such as those previously conducted at the Algae Testbeds.
- **An 82-percent reduction in Conversion Technologies R&D,** including the elimination of public-private cost-shared R&D partnerships between the Agile BioFoundry, industry, and academic partners. R&D on gaseous or wet-feedstock conversion (of biosolids) and advanced anaerobic digestion would also be eliminated.

- **A 78-percent reduction in Feedstock Supply and Logistics R&D,** including for the Fuel Conversion Interface Consortium (FCIC), an organization comprising eight national laboratories whose directive is to solve obstacles encountered by integrated biorefinery projects. R&D on cross-cutting feedstock logistics related to high-moisture feedstocks would be eliminated, and the annual State of Technology on feedstock handling and preprocessing systems would be discontinued.

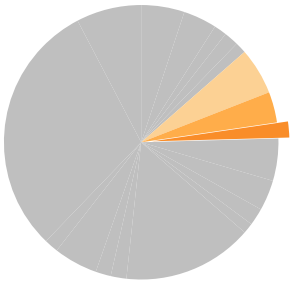
ENDNOTES

1. Department of Energy, "FY 2018 Congressional Budget Justification," volume 3, DOE/CF-0130 (Washington, D.C.: DOE Chief Financial Officer, May 2017) 49, https://www.energy.gov/sites/prod/files/2017/05/f34/FY2018BudgetVolume3_0.pdf
2. DOE, "U.S. Billion Ton Report," (Washington, D.C.: DOE, 2016), https://energy.gov/sites/prod/files/2016/12/f34/2016_billion_ton_report_12.2.16_0.pdf.
3. Department of Energy, "FY 2019 Congressional Budget Justification," volume 3 part 2, DOE/CF-0141 (Washington, D.C.: DOE Chief Financial Officer, March 2018) 61, https://www.energy.gov/sites/prod/files/2018/03/f49/FY-2019-Volume-3-Part-2.pdf.
4. Ryan Davis, et al., "Renewable Diesel from Algal Lipids: An Integrated Baseline for Cost, Emissions, and Resource Potential from a Harmonized Model," Argonne National Laboratory, ANL/ESDA/12-4 (2012), http://greet.es.anl.gov/publication-algae-harmonization-2012.

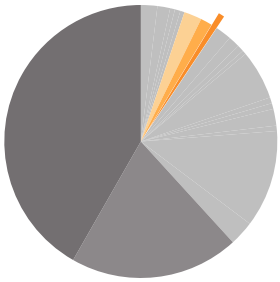
Federal Energy R&D: Hydrogen & Fuel Cells

BY DAVID M. HART AND COLIN CUNLIFF | APRIL 2018

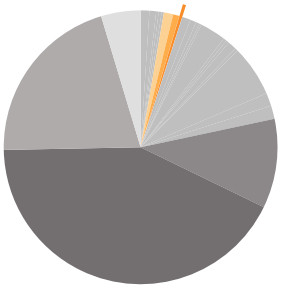
This briefing is part of a series on the U.S. energy budget. See: itif.org/energy-budget.



H2 and Fuels (orange)
Other Transportation (orange)
Energy R&D (light gray)



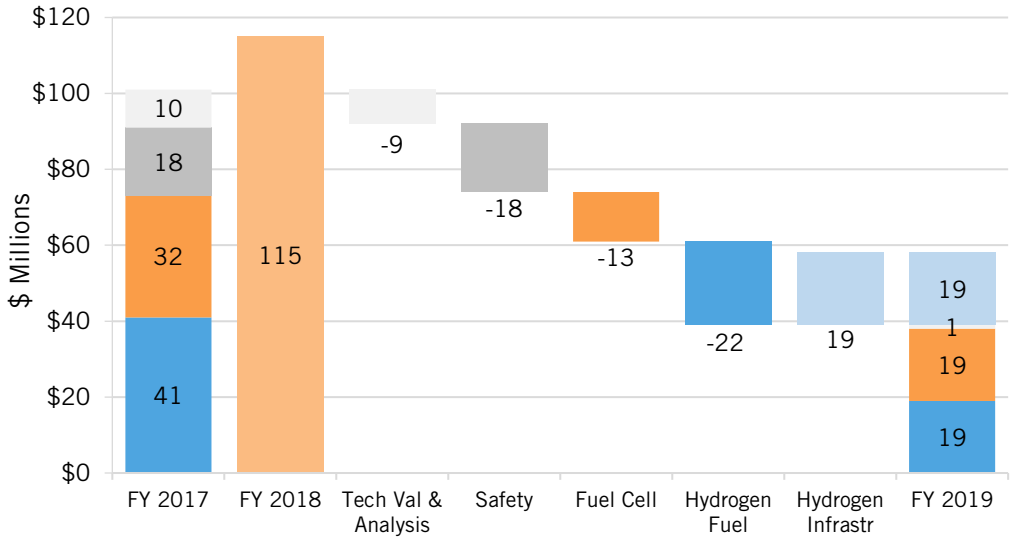
H2 and Fuels & Energy R&D
Basic Science R&D
Defense R&D



H2 and Fuels & Energy
Basic Science
Defense
Environ Mngmt
Other DOE

Fuel cells use the chemical energy of hydrogen or similar fuel to cleanly and efficiently produce electricity. When hydrogen is the fuel, electricity, water, and heat are the only resulting products, with none of the carbon emissions or pollution emitted by conventional internal combustion engines. The Hydrogen & Fuel Cells program conducts R&D on three complementary technologies: low-cost hydrogen production from domestic resources; infrastructure for hydrogen compression, transmission, storage, and delivery; and fuel-cell technologies that can be used in electric vehicles and other applications.

Figure 1: The FY 2019 Budget Request Would Cut Hydrogen and Fuel-cell R&D by 50 Percent



What's At Risk

Innovations resulting from DOE R&D over the past decade have facilitated a more than 50 percent cost reduction in fuel cells. However, further reductions are necessary for fuel cells to become cost-competitive with internal combustion engine vehicles. DOE's goals include decreasing the modeled high-volume cost of automotive fuel cells to $30 per kilowatt ($30/kW) and improving fuel cell durability to 8,000 hours (approximately 240,000 miles of driving) by 2030.[1] While the program's focus is on transportation, its R&D also benefits stationary fuel cells (such as those used to provide backup power), reversible fuel cells, and small-scale cells for tri-generation of fuel, heat, and power that may provide resilience and flexibility to multiple sectors. Reductions in R&D funding threaten to delay DOE progress toward cost-competitive fuel cells.

DOE is also targeting a hydrogen production cost of $2 per gallon gasoline equivalent ($2/gge), with a system-wide cost (hydrogen production plus delivery) of $4/gge in order to be cost competitive with gasoline on a cents-per-mile driven basis.[2] Meeting this target will require continued R&D in different hydrogen production methods.

Hydrogen & Fuel Cells R&D Subprograms

R&D in the Hydrogen & Fuel Cells program is distributed across five subprograms:

- **Fuel Cell** supports R&D to develop technologies that enhance the durability, reduce the cost, and improve the performance of fuel cells, including the discovery and development of catalysts and electrodes that do not use platinum-group metals (i.e., PGM-free catalysts), which could reduce fuel-cell stack costs by up to 40 percent.
- **Hydrogen Fuel R&D** focuses on the development of novel hydrogen production, delivery, and storage technologies, including hydrogen production from domestic sources such as natural gas, oil, coal, and biomass, as well as from nuclear and renewable energy by electrically splitting water.
- **Systems Analysis** performs analytical research that provides a technical basis for informed decision-making for the program's R&D direction and prioritization.
- **Safety, Codes, and Standards** collaborates with government, industry, standards-development organizations, universities, and National Laboratories to harmonize regulations, codes, and standards (RCS), and develop best practices to ensure safety in the operation, handling, and use of hydrogen and fuel-cell technologies.
- **Technology Acceleration** supports technology transition from R&D to commercial viability through validation, evaluation, and testing of advanced hydrogen and fuel-cell technologies under real-world conditions.

Key Elements of the FY 2019 Budget Proposal

- **Elimination of the Safety, Codes, and Standards subprogram**, including R&D to develop domestic supply-chain safety codes and standards for hydrogen and fuel-cell components, as well as education and training programs for first responders and code officials.
- **Elimination of the Technology Acceleration subprogram**, including a first-of-a-kind demonstration of hydrogen-distribution pipelines, field demonstrations of electric parcel-delivery trucks, hydrogen refueling stations, and other activities.
- **A 41-percent reduction in Fuel Cell R&D**, including termination of low platinum-group metal catalyst and electrode R&D, as well as reduced funding for the Fuel Cell Performance and Durability (FC-PAD) consortium, which brings

together multiple national laboratories with industry partners to enhance the performance and durability of polymer electrolyte membrane fuel cells, while also reducing their cost.

- **Splitting the Hydrogen R&D subprogram** into two separate subprograms: one that focuses on hydrogen production, and another that concentrates on hydrogen infrastructure (e.g., storage). Combined funding for the two is 7 percent below 2017 funding levels.

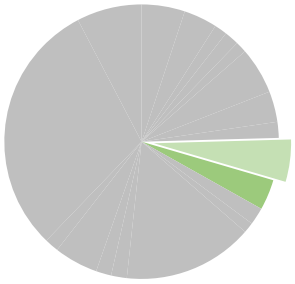
ENDNOTES

1. DOE, "FY 2019 Congressional Budget Justification," volume 3 part 2, DOE/CF-0141 (Washington, D.C.: DOE/CFO, March 2018) https://www.energy.gov/sites/prod/files/2018/03/f49/FY-2019-Volume-3-Part-2.pdf.
2. Ibid.

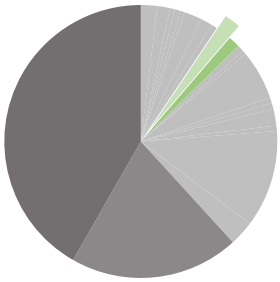
Federal Energy R&D: Advanced Manufacturing

BY DAVID M. HART AND COLIN CUNLIFF | APRIL 2018

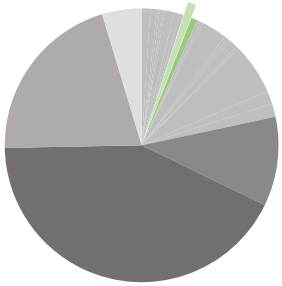
This briefing is part of a series on the U.S. energy budget. See: itif.org/energy-budget.



Manufacturing (light green)
Other Efficiency (green)
Energy R&D (light gray)



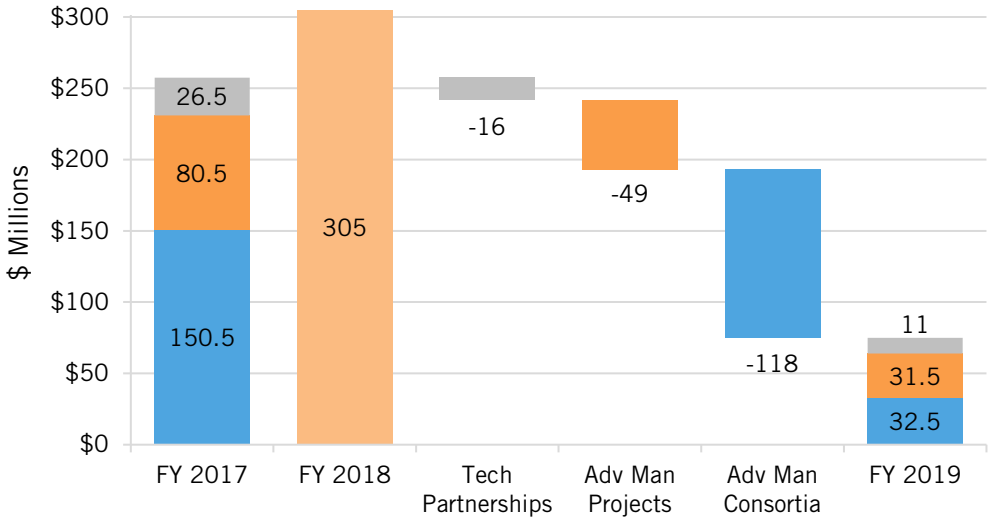
Adv Man & Energy R&D
Basic Science R&D
Defense R&D



Adv Man & Energy
Basic Science
Defense
Environ Mngmt
Other DOE

The Department of Energy's (DOE) Advanced Manufacturing Office (AMO) works to improve the energy efficiency and productivity of U.S. manufacturers by focusing R&D on cross-cutting, platform technologies relevant to manufacturing in multiple fields. A key goal is to ensure new energy technologies invented in the United States are also manufactured in the United States. AMO supports R&D through competitive funding opportunities designed to develop novel manufacturing technologies.

Figure 1: The FY 2019 Budget Request Would Cut Advanced Manufacturing R&D by 75 Percent



What's At Risk

Manufacturing plays an outsize role in the health of the U.S. economy because of both its impact on trade and innovation, and its large multiplier effect on other sectors. Accelerated innovation in both industrial processes that use energy and products used by the energy industry would strengthen U.S. manufacturing and hasten progress toward national economic, workforce, security, and environmental goals. Market failures, however, lead to many gaps in the private-sector response to the manufacturing and energy innovation imperative, and have led to significant supply-chain weaknesses, regional hollowing out, and underinvestment in workforce education and training.

AMO helps address such market failures in several ways, with the goal of improving the energy productivity of U.S. manufacturing, reducing lifecycle energy and resource impacts of manufactured goods, and transition DOE-supported technologies and practices into

U.S. manufacturing. Together, these efforts will assist manufacturers in cutting energy costs, which has already been an important driver in the "reshoring" of manufacturing to the United States over the past decade.

Advanced Manufacturing R&D Subprograms

Current R&D activities in AMO are spread across three subprograms:

- **Advanced Manufacturing R&D Projects** focus on high-impact manufacturing technology and process challenges in areas such as advanced materials manufacturing for energy applications, improved energy-efficient process technologies, high-performance computing for manufacturing, additive manufactured materials, and structures used in extreme environments.

- **Advanced Manufacturing R&D Consortia** brings together manufacturers, research institutions, suppliers, and universities in public-private R&D partnership consortia, each of which focuses on a specific set of challenges at the nexus of manufacturing and energy. Examples include the Manufacturing Demonstration Facility (MDF), which focuses on advanced manufacturing technologies to reduce energy and production costs, and five Manufacturing USA institutes that focus on clean energy technologies.[1]

- **Advanced Manufacturing Technical Partnerships** help small and medium-sized manufacturers improve their energy productivity and reduce waste and water use; demonstrate the viability of improved energy-management approaches; and promote combined heat and power (CHP) and waste heat to power technologies to improve efficiencies and lower energy costs.

Key Elements of the FY 2019 Budget Proposal

- **A 78-percent reduction in the Advanced Manufacturing Consortia,** including termination of the Critical Materials Hub, the Energy/Water Hub, the five existing clean energy Manufacturing USA institutes, and new proposed clean energy Manufacturing USA institute.

- **Reduced funding for public-private R&D projects at the Manufacturing Demonstration Facility (MDF) and the Carbon Fiber Test Facility (CFTC)**, including a shift toward early-stage R&D.

- **A 61-percent reduction in Advanced Manufacturing R&D Projects**, which have previously funded R&D in materials for harsh conditions, energy-conversion materials, materials for energy systems, roll-to-roll materials and processes, innovative computational process modeling in manufacturing, and energy-intensive manufacturing processes.

- **Elimination of the Industrial Assessment Centers (IACs)**, which provide technical assistance to small and medium-sized manufacturers. Overall funding for the Technical Partnerships subprogram would be reduced by 58 percent.

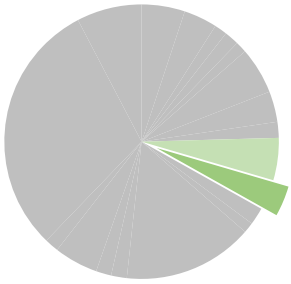
ENDNOTES

1. AMO is currently in the process of establishing a sixth Manufacturing USA institute for clean energy.

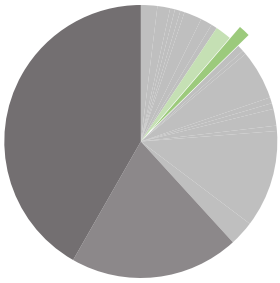
Federal Energy R&D: Building Technologies

BY DAVID M. HART AND COLIN CUNLIFF | APRIL 2018

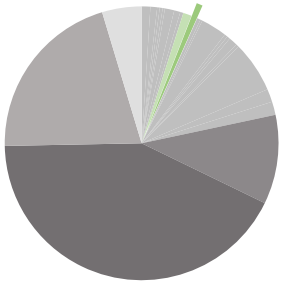
This briefing is part of a series on the U.S. energy budget. See: itif.org/energy-budget.



Buildings (green)
Other Efficiency (green)
Energy R&D (light gray)



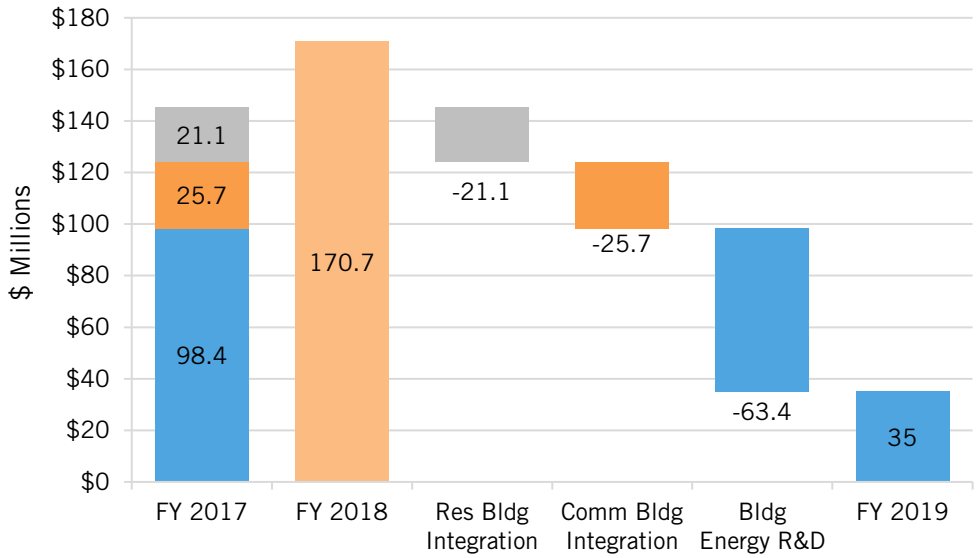
Buildings & Energy R&D
Basic Science R&D
Defense R&D



Buildings & Energy
Basic Science
Defense
Environ Mngmt
Other DOE

The Department of Energy's (DOE) Building Technologies Office (BTO) invests in research and development (R&D) of novel technologies that are designed to improve the efficiency and reduce the energy costs of the nation's residential and commercial buildings—particularly the largest energy users therein: lighting, space conditioning and refrigeration, water heating, appliances, and miscellaneous electric loads (MELs), as well as the building envelopes themselves. BTO also works on improved energy modeling and system controls to predict and manage energy-efficient appliance/equipment, system, and whole-building energy usage.

Figure 1: The FY 2019 Budget Request Would Cut Building Technologies R&D by 76 Percent



What's At Risk

Residential and commercial buildings are the single largest energy-consuming sector in the U.S. economy, accounting for roughly 75 percent of the nation's electricity use and 40 percent of its total energy demand. As a result, Americans spend nearly $400 billion each year to power their homes, offices, schools, hospitals, and other buildings. The Building Technologies program has established the ambitious goal of reducing the average energy use per square foot of commercial buildings by 30 percent by 2030, and that of new single-family homes by 60 percent and existing homes by 40 percent by 2020. In addition to these whole-building targets, the Building Technologies program is pursuing substantial improvements to the efficiency of energy services within buildings, including lighting (65

percent improvement); water heating (35 percent); heating, ventilation, and air conditioning (HVAC) (25 percent); building envelope and windows (35 percent); appliances (30 percent); and sensors and controls (20 percent).[1] Achieving these goals by 2030 would decrease total energy use by 5 quadrillion BTUs, cut carbon emissions by 450 million metric tons, and save consumers over $100 billion annually in energy costs.[2]

Building Technologies R&D Subprograms

BTO R&D activities are divided among three main subprograms:[3]

- **Building Energy R&D (BERD)** sponsors R&D in energy-efficient building technologies: Buildings-to-Grid; heating, ventilation and air-conditioning & refrigeration (HVAC&R); windows & envelope; solid-state lighting; and Building Energy Modeling (BEM).

- **Commercial Buildings Integration (CBI)** conducts R&D and analytical studies of building systems (e.g., lighting, HVAC, envelope, sensors and controls) and whole commercial buildings (e.g., office buildings, schools, hospitals, stores, warehouses, public infrastructure buildings) to assess the interactive effects of combining multiple novel technologies within a commercial building system.

- **Residential Buildings Integration (RBI)** works to innovate new housing construction and home improvement retrofit technologies, and validate the performance of these innovations.

Key Elements of the FY 2019 Budget Proposal

- **Elimination of the Residential Buildings Integration (RBI) subprogram**, including support for the Home Energy Score, which provides energy-use information to homeowners, renters, retrofit contractors, etc. Additionally, the Better Buildings Residential Program Solution Center—which furnishes regional and local partners who implement existing home retrofits with best practices and lessons learned—and the Zero Energy Ready Homes program would be eliminated.

- **Elimination of the Commercial Buildings Integration (CBI) subprogram**, including the Better Buildings Challenge (BBC) and Better Buildings Alliance (BBA) programs, which together have partnered with more than 400 businesses and organizations across the country to develop innovative solutions, share resources, and replicate positive gains in energy efficiency. Additionally, cost-shared technology demonstrations and other technology-to-market activities designed to reduce market barriers for efficiency upgrades for small and medium-sized commercial buildings would be discontinued.

- **A 64-percent reduction in Building Energy R&D**, including termination of campus- and neighborhood-level demonstrations of transactive energy controls,

which enable efficient energy management. Tech-to-market, demonstration and validation programs, and manufacturing R&D activities for emerging technologies such as organic LEDs would also be eliminated. The budget request does, however, provide new funding for Buildings-to-Grid and Beyond Batteries R&D activities.

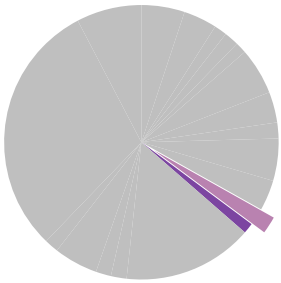
ENDNOTES

1. DOE, "Congressional Budget Justification," http://www.energy.gov/budget.
2. DOE, "Building Technologies Office FY 2017 Budget At-A-Glance" (Washington, D.C.: Department of Energy, Energy Efficiency and Renewable Energy, March 2016), https://www.energy.gov/sites/prod/files/2016/03/f30/At_A_GLANCE%20%28BTO%29.pdf; DOE, "Building Technologies Office Multi-Year Program Plan: Fiscal Years 2016-2020" (Washington, D.C.: DOE/EERE, February 2016), https://www.energy.gov/sites/prod/files/2016/02/f29/BTO%20Multi-Year%20Program%20Plan%20-%20Final.pdf.
3. The Building Technologies Office also houses the Equipment and Building Standards subprogram, a regulatory program which sets energy efficiency standards for appliances, equipment, and processes. Because this program is regulatory in nature, it is not included in our assessment of federal R&D.

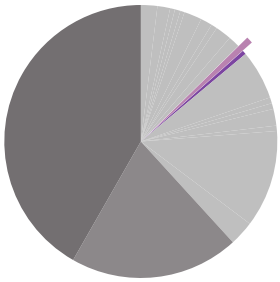
Federal Energy R&D: Grid Modernization

BY DAVID M. HART AND COLIN CUNLIFF | APRIL 2018

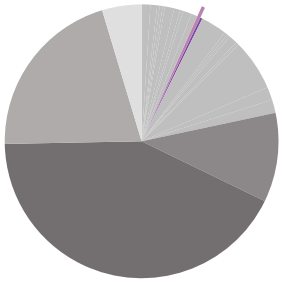
This briefing is part of a series on the U.S. energy budget. See: itif.org/energy-budget.



Grid Mod (lavender)
Office of Electricity
Energy R&D (light gray)



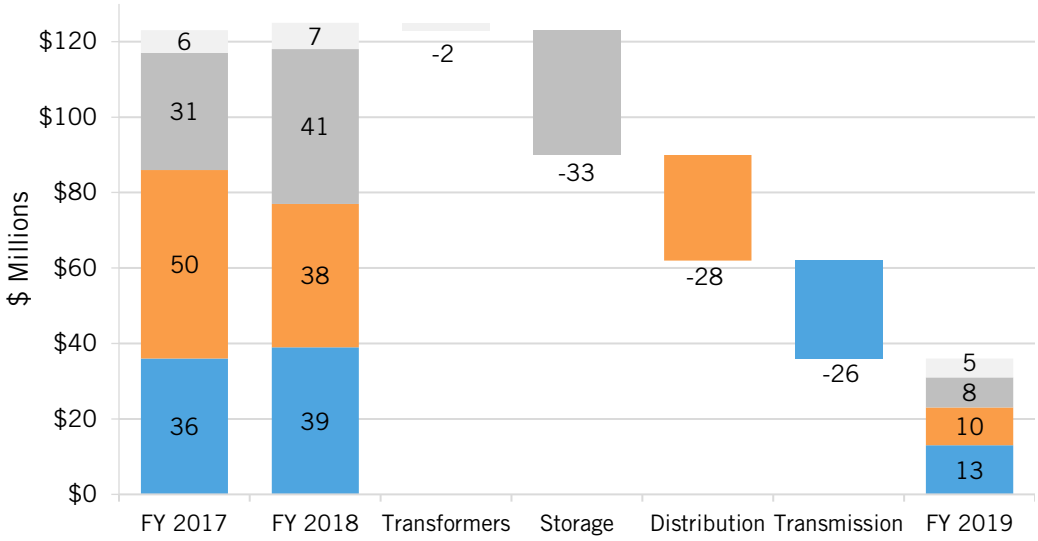
Grid Mod & Energy R&D
Basic Science R&D
Defense R&D



Grid Mod & Energy
Basic Science
Defense
Environ Mngmt
Other DOE

The Grid Modernization program conducts R&D into technologies and tools to improve the reliability and resilience of the electric power grid and its components. It focuses on transmission and distribution systems, large power transformers, and energy-storage technologies—and seeks to provide solutions to market, institutional, and operational failures that go beyond any one utility's ability to solve.[1] The program's work on resilience, threat assessment, risk management, and grid hardening is motivated by natural disasters, such as hurricanes Harvey and Maria and Superstorm Sandy, as well as the 2013–2015 drought and accompanying wildfires in the western United States. The Department of Energy (DOE)-funded R&D into energy-storage technologies aims to enable greater stability, resiliency, and reliability in the electric grid, while also supporting increasing levels of variable renewable energy sources such as wind and solar.

Figure 1: The FY 2019 Budget Request Would Cut Grid Modernization R&D by 71 Percent



What's At Risk

Grid modernization is critical to ensuring reliable and affordable energy delivery, sustaining economic growth, and mitigating risks to the security of the grid and other vital sectors that depend on the grid's services. In collaboration with the utility industry, DOE established the Grid Modernization Initiative to coordinate R&D activities. Through the initiative, a multiyear R&D roadmap outlining six technical areas (devices and integrated systems testing; sensing and measurements; system operations, power flow, and control;

design and planning tools; security and resilience; and institutional support) that industry and government should jointly pursue to establish a resilient, secure, sustainable, and reliable grid was created.[2] For its part, DOE has set aggressive targets and performance measures in reliability and resilience, as well as cost and performance targets for new grid-storage technologies.[3] Reductions in R&D funding threaten to delay or even derail progress toward these goals.

Grid Modernization R&D Subprograms

Grid modernization R&D is made up of four main subprograms:

- **Transmission Reliability and Resilience (TRR)** focuses on ensuring the reliability and resilience of the U.S. electric grid through R&D on measurement and control of the electrical system, and risk assessments to address challenges across integrated energy systems.
- **Resilient Distribution Systems (RDS)** pursues strategic R&D to improve reliability, resiliency, outage recovery, and operational efficiency of the distribution portion of the electricity-delivery system, with a focus on improved resilience against extreme weather and other natural and man-made hazards.
- **Energy Storage** focuses on the development of new materials and device technologies that both improve the cost and performance of utility-scale energy-storage systems and better integrate storage into the grid infrastructure.
- **Transformer Resilience and Advanced Components (TRAC)** supports modernization, hardening, and resilience of grid components, including transformers, power lines, and substation equipment.

Key Elements of the FY 2019 Budget Proposal

- **A 64-percent reduction in Transmission Reliability and Resilience**, including reductions in advanced modeling grid research, which helps system operators and utilities prevent blackouts by expanding wide-area real-time visibility into grid conditions. R&D to develop analytical tools to assess near- and long-term extreme weather risks to energy systems would also be eliminated.
- **An 80-percent reduction in Resilient Distribution Systems**, including termination of R&D activities related to microgrid controller demonstrations; development of Advanced Distribution Management System (ADMS) applications; demonstrations of on-site generation and microgrids; and development of low-cost sensors that measure, analyze, predict, and control the grid.

- **A 74-percent reduction in Energy Storage,** including elimination of grid-scale field-validation efforts with states and utilities, discontinuation of the biannual Safety Forum, and elimination of DOE participation in industry-led safety codes and standards development.

- **A 17-percent reduction in Transformer Resilience and Advanced Components**, which currently conducts research on grid-component vulnerabilities to geomagnetic disturbances (GMD) and electromagnetic pulses (EMP), as well as R&D on improving the resilience of large power transformers—which are one of the most vulnerable components of the grid and would pose a significant risk to the nation in the event of multiple failures.[4]

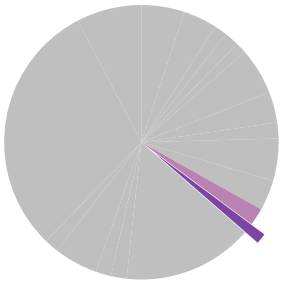
ENDNOTES

1. For example, individual utilities and grid operators lack the wide-area visibility that could have minimized the 2003 Northeast blackout, or the modeling and analytical tools identified as necessary for containing the 2011 Southwest blackout.
2. DOE, "Grid Modernization Multi-Year Program Plan" (Washington, D.C.: November 2015), https://www.energy.gov/sites/prod/files/2016/01/f28/Grid%20Modernization%20Multi-Year%20Program%20Plan.pdf.
3. DOE, "FY 2019 Congressional Budget Justification," Volume 3 Part 1 (Washington, D.C.: March 2018) 20, 26, 32, 36, https://www.energy.gov/sites/prod/files/2018/03/f49/DOE-FY2019-Budget-Volume-3-Part-1_0.pdf.
4. DOE, "Strategic Transformer Reserve Report to Congress" (Washington, D.C.: March 2017), https://www.energy.gov/oe/downloads/strategic-transformer-reserve-report-congress-march-2017.

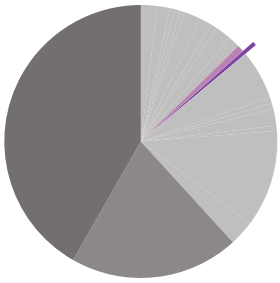
Federal Energy R&D:
Cybersecurity for Energy Systems

BY DAVID M. HART AND COLIN CUNLIFF | APRIL 2018

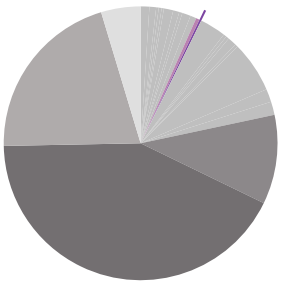
This briefing is part of a series on the U.S. energy budget. See: itif.org/energy-budget.



Cyber (purple)
Office of Electricity
Energy R&D (light gray)



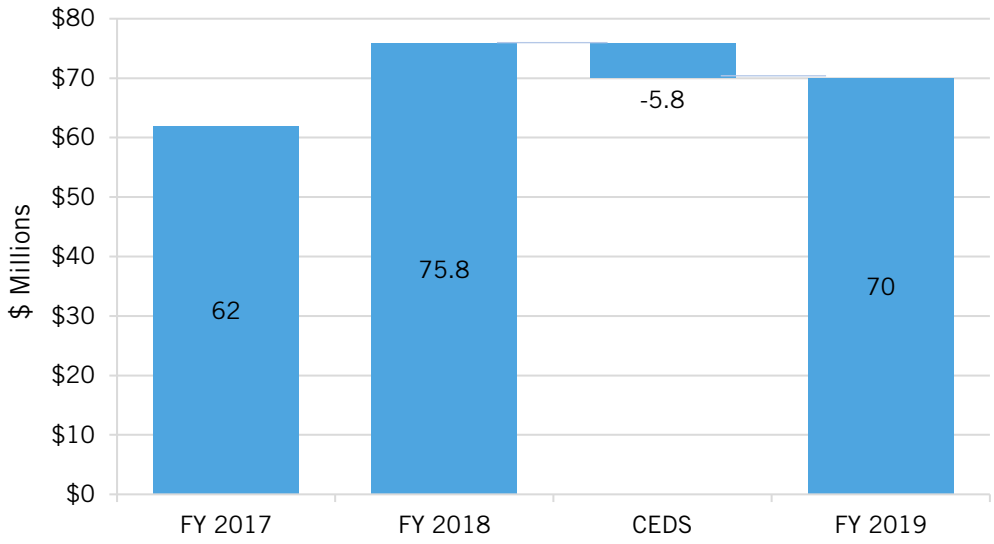
Cyber & Energy R&D
Basic Science R&D
Defense R&D



Cyber & Energy
Basic Science
Defense
Environ Mngmt
Other

The goal of the Cybersecurity for Energy Delivery Systems (CEDS) program is to reduce the risk of energy disruptions from cyber events. Through CEDS, the Department of Energy (DOE) directly collaborates with energy-sector utility owners, operators, and vendors to strengthen the cybersecurity of critical energy infrastructure against current and future threats.

Figure 1: The FY 2019 Budget Request Would Cut Cybersecurity for Energy-delivery Systems R&D by 8 Percent



What's At Risk

The energy sector has been subjected to a dramatic increase in focused cyber probes, data exfiltration, and malware attacks in recent years.[1] Previous rounds of threats have been aimed at information technology (IT) systems (e.g., email and business applications) at energy companies, but a new wave of cyberattacks is targeting operating technologies (OT), including software and hardware that directly control equipment on the grid. The cyberattack on the Ukrainian electricity-distribution system in December 2015 caused the first-ever cyber-linked blackout—and demonstrated the vulnerability of power grids to cyber events.[2]

In March 2018, the Department of Homeland Security (DHS) accused Russian government cyber actors of targeting critical U.S. infrastructure, including the electrical grid and nuclear power plants, highlighting the need for greater cybersecurity.[3] Although the Trump

Administration is proposing an increase in grid cybersecurity R&D over FY 2017 levels, in light of the FY 2018 budget agreement, the administration's proposal would now actually yield a net reduction in this line item. Many legislators believe recent events indicate the need for an even greater effort than that which they supported in FY 2018.[4]

Cybersecurity R&D Activities

CEDS focuses on these key research activities:

- **Cybersecurity Risk Information Sharing Program (CRISP)** develops situational-awareness tools and facilitates the near-real-time sharing of cyber-threat information with energy owners and operators—such that they can promptly analyze the data and receive machine-to-machine mitigation measures.

- **Cyber Analytics Tools and Techniques (CATT)** improves the speed, value, and cost of CRISP analyses, reports, and mitigation, while working to add new threat-detection capabilities to the CRISP platform.

- **Cybersecurity for the Operational Technology Environment (CYOTE)** monitors utility data in the complex OT environment to identify malicious actions. CYOTE is currently piloting two-way OT data sharing and analysis with four electric utilities, while also working to identify pathways hackers could use to compromise utility OT systems.

- **Cybersecurity Capability Maturity Model (C2M2)** works in partnership with utilities to help asset owners and operators assess their capabilities and improve their cybersecurity postures.

Key Elements of the FY 2019 Budget Proposal

The FY 2019 budget request proposes a new program, the Cybersecurity, Energy Security, and Emergency Response (CESER) office, and moves the CEDS research program from the Office of Electricity Delivery and Energy Reliability (OE) into CESER. The budget also moves the Infrastructure Security and Energy Restoration (ISER) program—an energy-sector emergency-support function that does not include R&D activities—into CESER. Elements of CESER's proposed budget include:

- New funding for Advanced Industrial Control Systems Analysis Center to model and assess energy-sector cyber-supply-chain components for vulnerabilities, through a public-private partnership between the National Laboratories and private-sector partners.[5]

- Increased funding for the development of cybersecurity tools, including cyber sensors, for information data sharing and data analytics, including continued support for C2M2.

- Reduced funding for the Virtual Energy Sector Advanced Digital Forensics Analysis Platform, which provides a virtual sandbox for executing untested code and programs. The platform is being developed for transition to the private sector, with the ultimate goal of becoming self-sustaining.

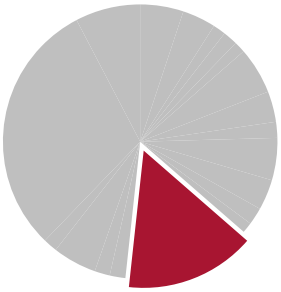
ENDNOTES

1. DOE, "FY 2017 Congressional Budget Justification," Volume 3, p 353 (Washington, D.C.: DOE/CFO, 2016).
2. For a description of the Ukraine hacking and its implications for the U.S. electric sector, see the E&E News Special Report by Peter Behr and Blake Sobczak, "The Hack," (E&E News Special Report, Washington, D.C.: July 2016), https://www.eenews.net/special_reports/the_hack.
3. Department of Homeland Security, "Alert (TA18-074A): Russian Government Cyber Activity Targeting Energy and Other Critical Infrastructure" (Washington, D.C.: March 15, 2018), https://www.us-cert.gov/ncas/alerts/TA18-074A.
4. Jeremy Dillon, "Perry Told to Do More on Grid Cybersecurity After Russian Hacks," *Roll Call* (Washington, D.C.: March 20, 2018), https://www.rollcall.com/news/policy/perry-told-grid-cybersecurity-russian-hacks.
5. DOE, "FY 2019 Congressional Budget Justification," volume 3 part 1, DOE/CF-0140 (Washington, D.C.: DOE/CFO, March 2018) 64 https://www.energy.gov/sites/prod/files/2018/03/f49/DOE-FY2019-Budget-Volume-3-Part-1_0.pdf.

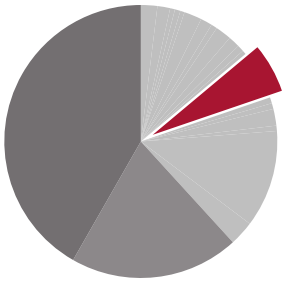
Federal Energy R&D: Nuclear Energy

BY DAVID M. HART AND COLIN CUNLIFF | APRIL 2018

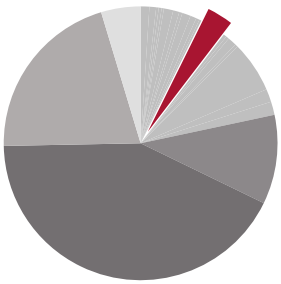
This briefing is part of a series on the U.S. energy budget. See: itif.org/energy-budget.



Nuclear Energy R&D (red)
Energy R&D (gray)



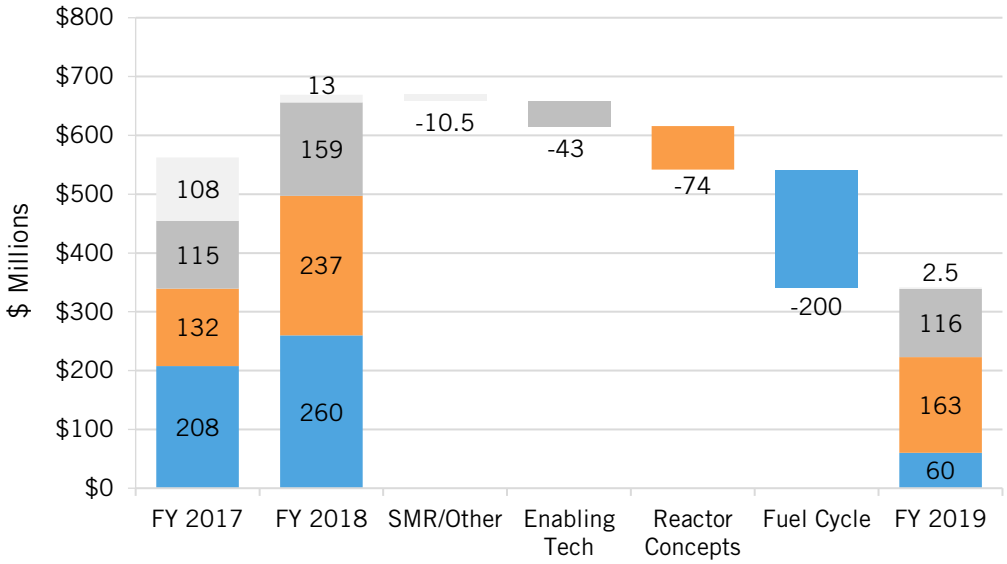
Nuclear Energy & Energy R&D
Basic Science R&D
Defense R&D



Nuclear Energy & Energy
Basic Science
Defense
Enivron Mngmt
Other DOE

Nuclear power accounts for 20 percent of the electricity generated in the United States, and 54 percent of all carbon-free electricity.[1] Despite this success, the existing nuclear fleet is being challenged by low-cost natural gas and renewables, as Russia and China surpass the United States in the development of advanced nuclear reactors. To address these challenges, the Department of Energy's (DOE) nuclear energy (NE) program conducts R&D on technical challenges that may threaten the maintenance of the existing reactor fleet, and on the development of a robust pipeline of advanced reactor designs and supply-chain capabilities.

Figure 1: The FY 2019 Budget Request Would Cut Nuclear Energy R&D by 49 Percent



What's At Risk

Nuclear energy has unique regulatory challenges that limit the ability of the private sector to conduct full-scale R&D on its own. Plus, many of the facilities necessary for R&D are capital-intensive and lie beyond the financial capacity of potential nuclear innovators. DOE has had success working with industry to develop small modular reactors (SMRs) based on current light-water-reactor technologies. The SMR Licensing Technical Support program, for example, addressed first-of-a-kind costs associated with design certification and licensing, resulting in the submission of the first SMR license application to the Nuclear Regulatory Commission in January 2017.[2]

DOE is exploring advanced, non-light-water reactor designs that could operate at higher temperatures (allowing for greater efficiency and provision of other energy services, such as process heating), produce lower volumes of waste, incorporate passive safety features, and reduce proliferation risks. However, DOE has conducted R&D in advanced reactors since the late 1990s, and so far no advanced reactor concepts have progressed to full-scale demonstration, let alone commercialization.[3] The department has established aggressive targets to develop and demonstrate advanced reactors by the early 2030s, but is unlikely to meet this goal without greater levels of sustained funding for R&D.

Nuclear Energy R&D Subprograms

Nuclear energy R&D is conducted in the following subprograms:

- **Reactor Concepts RD&D** develops new and advanced reactor designs and technologies, including advanced SMRs, fast reactors using liquid-metal coolants, high-temperature reactors, and light-water-reactor technologies.
- **Fuel Cycle R&D** studies advanced fuel-cycle technologies that have the potential to enhance safety, improve resource utilization, reduce waste generation, and limit risk of proliferation.
- **Nuclear Energy Enabling Technologies** works to develop cross-cutting technologies in reactor materials; advanced sensors and instrumentation; advanced manufacturing methods; and modeling and simulation—and provides support for nuclear-science user facilities.
- **Other NE R&D** includes contributions to the cross-cutting Supercritical Transformational Electric Power (STEP) program, which develops supercritical carbon dioxide Brayton cycle technologies (which are potentially applicable to nuclear, concentrated-solar, bio-, geothermal, and fossil-fuel power), as well as nuclear-workforce training and education programs.

Key Elements of the FY 2019 Budget Proposal

- **A 77-percent reduction in Fuel Cycle R&D**, including the transfer of used-nuclear-fuel-disposal R&D and integrated waste-management systems to a new Yucca Mountain and Interim Storage Program, as well as reduced funding for advanced nuclear fuels, material recovery and waste-form development, and elimination of systems analysis and integration.
- **A 31-percent reduction in Reactor Concepts R&D**, including reduced funding for light-water-reactor sustainability and advanced-reactor technologies; the proposal includes the creation of a new Advanced Small Modular Reactor program to develop advanced (i.e., non-light-water) SMRs as well as a small increase in funding for the Versatile Advanced Test Reactor.

- **A 27-percent reduction in Nuclear Energy Enabling Technologies**, including elimination of the Energy Innovation Hub for Modeling and Simulation; R&D for cross-cutting technologies—including advanced sensors and instrumentation, advanced manufacturing methods, cooling technologies, and hybrid energy systems—and R&D in advanced modeling and simulation would see modest increases.

- **Elimination of NE participation in STEP and nuclear-workforce development programs.**

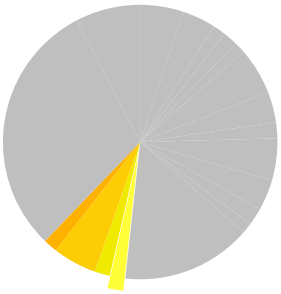
ENDNOTES

1. EIA, "Monthly Energy Review," Table 7.2a, (Washington, D.C.: EIA, 2018), http://www.eia.gov/mer. Accessed April 14, 2018.
2. Karen Thomas, "NuScale files US' first SMR License Application as Suppliers Await Tender," *Nuclear Energy Insider*, January 10, 2017, https://analysis.nuclearenergyinsider.com/nuscale-files-us-first-smr-license-application-suppliers-await-tender.
3. A Abdulla et al., "A Retrospective Analysis of Funding and Focus in US Advanced Fission Innovation," Environmental Research Letters, 084016, 2017, 12, https://doi.org/10.1088/1748-9326/aa7f10.

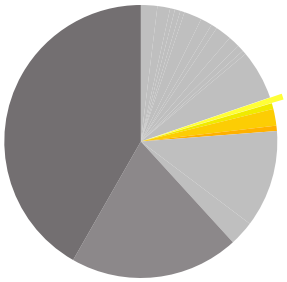
Federal Energy R&D: Carbon Capture

BY DAVID M. HART AND COLIN CUNLIFF | APRIL 2018

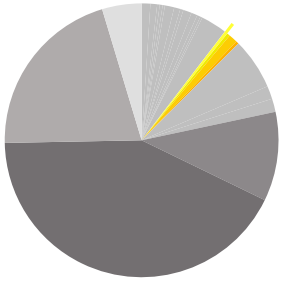
This briefing is part of a series on the U.S. energy budget. See: itif.org/energy-budget.



Carbon Capture (yellow)
Other Fossil (yellow)
Energy R&D (light gray)



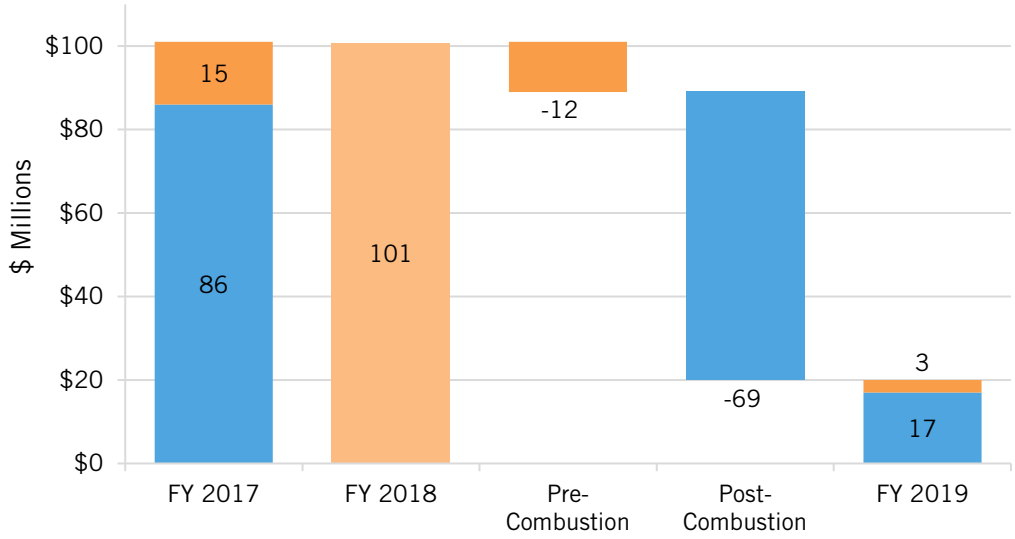
Carbon Capture & Energy R&D
Basic Science R&D
Defense R&D



Carbon Capture & Energy
Basic Science
Defense
Environ Mngmt
Other DOE

Carbon capture, utilization, and storage (CCUS) technologies for fossil-fuel power plants and carbon-emitting industrial sources have the potential to preserve important options—including coal-fired electricity generation—in a carbon-constrained future. Many studies suggest the future costs of achieving massive reductions in carbon pollution would be much higher if CCUS technologies were not available.[1] DOE's carbon-capture RD&D program embraces two complementary technologies: pre-combustion systems, in which coal is gasified to allow for the removal of carbon dioxide (CO_2) prior to combustion or use in fuel cells; and post-combustion capture, which removes CO_2 from flue gas after combustion.

Figure 1: The FY 2019 Budget Request Would Cut Carbon Capture R&D by 80 Percent



What's At Risk

The Department of Energy's (DOE) efforts to advance carbon-capture technologies build on recent progress. For example, in January 2017, the world's largest post-combustion carbon-capture facility came online on a large unit at the Petra Nova power plant near Houston, Texas, successfully removing 90 percent of the CO_2 from its emissions.[2] That success was quickly followed in April 2017, when the first-ever bioenergy with carbon capture and sequestration (BECCS) facility came online at the Archer Daniels Midland ethanol plant in Decatur, Illinois, demonstrating the viability of "negative-emissions" technology.3 Nevertheless, continued improvement and substantial cost reductions must occur before CCUS will be viable for full-scale deployment.

DOE has set the ambitious target of reducing the cost of carbon capture to less than $40 per metric ton of CO_2 by 2025—and under $30 per metric ton by 2035. Achieving these goals will improve the competitiveness of fossil-fuel resources in a carbon-constrained world. However, reductions in R&D funding threaten to delay or even derail current DOE progress toward these targets.

Carbon Capture R&D Activities

R&D in carbon capture is spread across two activities:

- **Post-Combustion Capture Systems** focuses on separating and capturing CO_2 from flue gas after the fuel has been combusted, and can be used to retrofit existing fossil-fuel power plants. Because CO_2 makes up only 5 to 15 percent of flue gas, separation is challenging—and once separated, the pure CO_2 must then be compressed for sequestration. Recent funding has gone to the development of second-generation technologies for these functions, including pilot tests at the National Carbon Capture Center, as well as their integration with advanced power cycles and environmental control technologies for other pollutants.

- **Pre-Combustion Capture Systems** focuses on removing CO_2 from fossil fuels before combustion is complete. For example, coal can be gasified under high pressure to produce a mixture of hydrogen (H_2) and highly concentrated CO_2, with the former used for energy storage and fuel, and CO_2 captured and sequestered. Recent R&D has focused on advanced solvents, sorbents, and membranes to lower the cost of CO_2 separation for pre-combustion systems.

Key Elements of the FY 2019 Budget Proposal

- **An 80-percent reduction in Post-Combustion Capture Systems**, including a discontinuation of all large-scale demonstrations, pilot projects, and similar ventures that address technology scale-up. The budget proposes refocusing on early-stage research and bench-scale development of advanced membranes and metal organic frameworks, in addition to advanced gas-separation technologies with the potential to reduce the cost of CO_2 capture.

- **An 80-percent reduction in Pre-Combustion Capture Systems,** including a discontinuation of all large-scale demonstrations and pilot projects. No funding is requested for activities to scale up pre-combustion technologies beyond bench-scale demonstrations.

- **Discontinuation of all funding for the National Carbon Capture Center (NCCC)**, a research facility in Alabama that is used to conduct small- and large-scale pilot tests of both pre-combustion and post-combustion capture technologies. Managed and operated by Southern Company, the NCCC leverages public funding through partnerships with leaders in the energy industry, and evaluates technologies at various levels of maturity with the aim of accelerating their commercialization.

ENDNOTES

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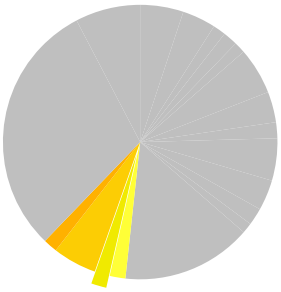
3. "DOE Announces Major Milestone Reached for Illinois Industrial CCS Project," DOE website, accessed April 15, 2018, https://www.energy.gov/fe/articles/doe-announces-major-milestone-reached-illinois-industrial-ccs-project.

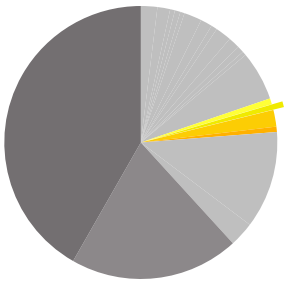
Federal Energy R&D: Carbon Storage and Utilization

BY DAVID M. HART AND COLIN CUNLIFF | APRIL 2018

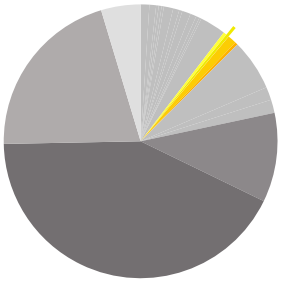
This briefing is part of a series on the U.S. energy budget. See: itif.org/energy-budget.



Carbon Storage (yellow)
Other Fossil (yellow)
Energy R&D (light gray)



Carbon Storage & Energy R&D
Basic Science R&D
Defense R&D



Carbon Storage & Energy
Basic Science
Defense
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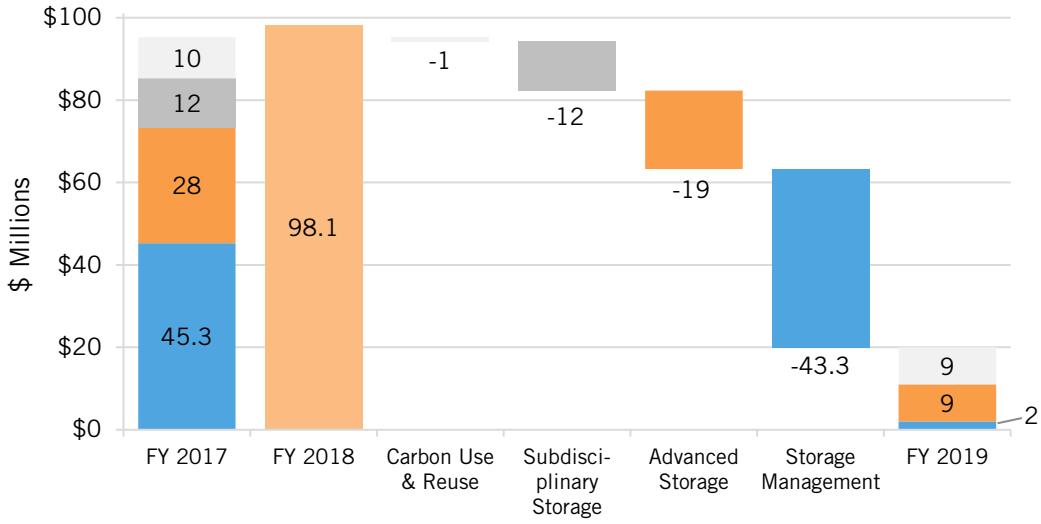
Other DOE

The Carbon Storage and Utilization subprogram is focused on development of technologies for the safe and permanent utilization and storage of captured carbon dioxide (CO_2). It conducts research and development on 5 primary geologic storage media—saline formations, oil and natural gas reservoirs, unmineable coal seams, basalts, and organic shales—and in reservoirs across 11 geologic depositional classes.

Figure 1: The FY 2019 Budget Request Would Cut Carbon Storage and Utilization R&D by 80 Percent



What's At Risk

Preliminary research suggests the United States has enough subsurface capacity to permanently sequester 1.71 trillion metric tons of CO_2, which is the equivalent of 950 years of carbon emissions from power plants at 2016 levels.[1] However, additional cost reductions, validation, safety testing, and mitigation research are necessary to realize this capacity. While the size of many subsurface storage reservoirs has been initially characterized, detailed site-specific work is required to confirm their potential. R&D is also needed to develop tools to map and simulate below-ground fractures and faults with a high degree of resolution and fidelity, devise wellbore materials that can better resist corrosion by CO_2-saturated brine, and improve the ability to monitor and mitigate the risk of induced seismicity from the injection of CO_2 underground.

The launch of the Illinois Industrial Carbon Capture and Storage project in April 2017 provides one of the largest-ever demonstrations of geologic sequestration. The project, which is funded jointly by DOE and private-sector partners, captures CO_2 from an ethanol-production facility—at a rate of up to one million metric tons of CO_2 per year—and stores it underground in a saline reservoir. This large, first-of-a-kind demonstration project is testing and validating technologies, while concurrently endeavoring to reduce future costs. The proposed budget would cut funding substantially for this promising effort.

Carbon Storage and Utilization R&D Activities

Funding for carbon storage and utilization R&D is spread across four activities:

- **Storage Infrastructure R&D** focuses on geologic resource characterization and small- and large-scale field projects to demonstrate permanent geologic storage; validation of injection, simulation/risk assessment, and monitoring strategies; and assessment of the probability, and subsequent mitigation, of potential seismic events.

- **Advanced Storage R&D** is focused on developing and validating storage monitoring, simulation, risk-assessment, and advanced wellbore technologies to detect and mitigate wellbore issues. R&D activities include developing CO_2-resistant construction materials and well-integrity technologies, plus technologies to detect and mitigate potential CO_2 leakage pathways.

- **Carbon Use & Reuse R&D** explores the beneficial reuse of CO_2, including conversion into higher-value products such as chemicals, plastics, and building materials, and accelerated curing for cement. The primary objective is to lower the near-term cost of CCUS through the creation of value-added products via the conversion of CO_2.

- **Sub-Disciplinary Storage R&D** focuses on assessment and validation of subsurface models; participation in the National Risk Assessment Partnership (NRAP), with a focus on storage risk tools; and development of assessment and monitoring capabilities.

Key Elements of the FY 2019 Budget Proposal

- **A 96-percent reduction in Storage Infrastructure R&D,** and discontinuation of all field projects, including the Brine Extraction Storage Tests (BEST), which advances strategies for managing subsurface pressure and fluid flow; all seven Regional Carbon Sequestration Partnerships, which are currently testing large-scale CO_2 injection and storage technologies; and the Carbon Storage Assurance and Facility Enterprise (CarbonSAFE), which funds industry cost-shared R&D projects to characterize and develop commercial-scale (50+ million metric tons of CO_2) storage complexes by 2025.

- **A 78-percent reduction in Advanced Storage R&D** (which would be merged with Sub-Disciplinary Storage R&D). Current activities in this area focus on development of monitoring, verification, accounting, and assessment (MVAA) tools for CO_2 storage; simulation and risk-assessment technologies; and advanced wellbore technologies to detect and mitigate wellbore issues from both short- and long-term exposure to CO_2. It is unclear which activities would be scaled down or discontinued under the proposed budget.

- **A 10-percent reduction in Carbon Use & Reuse R&D,** with remaining funding focused on catalytic conversion of carbon wastes to chemicals and polymers, mineralization to building products, and biological conversion of CO_2 to nutraceuticals, bio plastics, and animal feed.

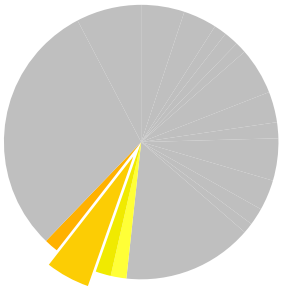
ENDNOTES

1. DOE, "Siting and Regulating Carbon Capture, Utilization, and Storage Infrastructure" (Washington, D.C.: DOE Office of Energy Policy and Systems Analysis and Office of Fossil Energy, January 2017) 14, https://www.energy.gov/sites/prod/files/2017/01/f34/Workshop%20Report--Siting%20and%20Regulating%20Carbon%20Capture%2C%20Utilization%20and%20Storage%20Infrastructure.pdf; EPA Draft, "Inventory of U.S. Greenhouse Gas Emissions and Sinks," Table ES-2, (Washington, D.C.: Environmental Protection Agency, February 2018), https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

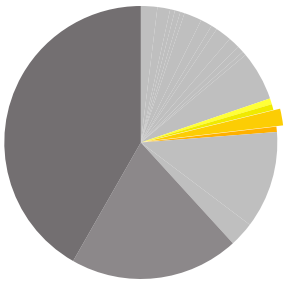
Federal Energy R&D: Advanced Coal Energy Systems

BY DAVID M. HART AND COLIN CUNLIFF | APRIL 2018

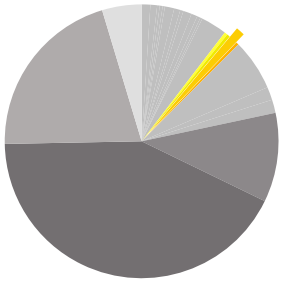
This briefing is part of a series on the U.S. energy budget. See: itif.org/energy-budget.



Adv Coal (orange)
Other Fossil (yellow)
Energy R&D (light gray)



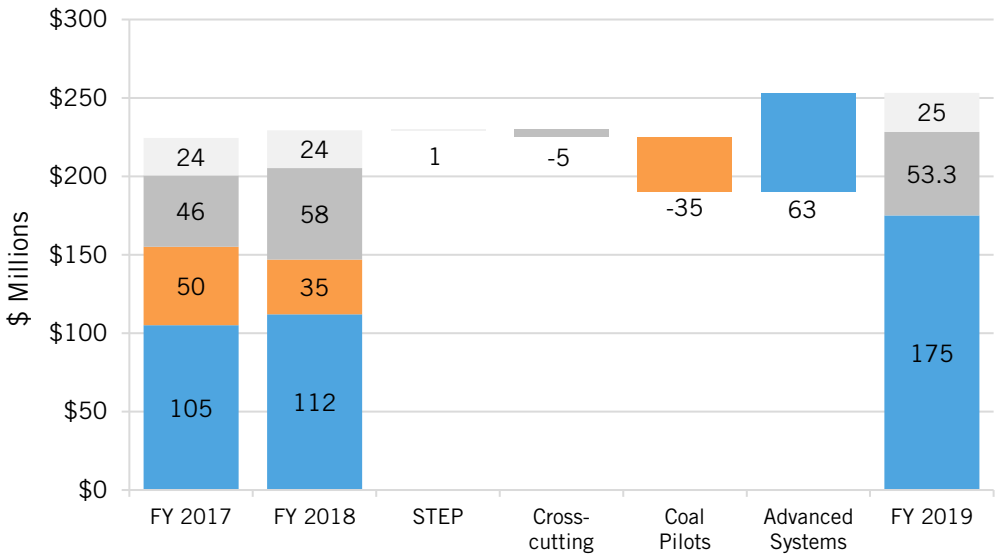
Adv Coal & Energy R&D
Basic Science R&D
Defense R&D



Adv Coal & Energy
Basic Science
Defense
Environ Mngmt
Other DOE

The Department of Energy's (DOE) Advanced Coal Energy Systems R&D program focuses on improving the efficiency of coal-based power systems, developing advanced technologies such as gasification and fuel-cell systems, improving environmental mitigation of coal power, and enhancing the value of coal and coal by-products.

Figure 1: The FY 2019 Budget Request Would Increase Advanced Coal Energy Systems R&D by 7 Percent



What's At Risk

Coal currently accounts for 30 percent of U.S. electricity generation and 69 percent of power-sector carbon emissions.[1] It is projected to remain an important part of the nation's energy mix for decades to come.[2] Coal and other power-generation technologies that convert heat into electricity (including natural gas, nuclear, concentrated solar, and geothermal power systems) require large volumes of water for cooling, accounting for 45 percent of total U.S. water withdrawals—more than all of agriculture.[3] Many Advanced Coal Energy Systems R&D projects seek to maximize the electricity generated from each ton of coal by the existing fleet of power plants while minimizing their water use.

The program also seeks to develop new technologies that would substantially reduce the environmental impacts of coal-based power systems. For example, gasification systems combine coal with oxygen and steam under high pressure to produce synthesis gas, which can be used in fuel cells or combined-cycle power plants. The gasification process also

produces a high-concentration stream of carbon dioxide (CO_2), which can be captured more easily than in conventional coal plants. The first integrated coal gasification combined-cycle power plant in the United States went into operation at the Kemper facility in Mississippi in October 2016.[4] However, due to cost overruns, the facility switched to natural gas in June 2017, indicating more R&D is needed to bring this technology to maturity.[5] Solid oxide fuel cells (SOFCs) are another promising technology that converts gasified coal into electricity without combustion and with fewer emissions than conventional coal plants. Additional R&D is necessary to lower costs and sufficiently improve performance to enable commercial deployment of SOFCs.

Advanced Coal Energy Systems Subprograms

Advanced Coal Energy Systems R&D is spread across four subprograms:

- **Advanced Energy Systems** focuses on improving the efficiency of coal-based power systems and supports research across six areas: gasification, which converts coal into synthesis gas, chemicals, hydrogen, and liquid fuels (and complements pre-combustion carbon capture R&D); solid oxide fuel cells, which can convert synthesis gas and other fuels into electricity without combustion or emissions; advanced turbines; advanced sensors and controls; power-generation efficiency; and advanced energy materials.
- **Transformational Coal Pilots** provides funding for the design, construction, and operational costs of two large-scale pilot projects for transformational coal technologies.
- **Cross-cutting Research** serves as a bridge between basic and applied research by targeting the concepts with the greatest potential for transformational breakthroughs. Current research focuses on recovery of rare-earth elements from coal and coal by-products; improved water management in power plant operations; and modeling, simulation, and analysis of environmental and regulatory impacts.
- **Supercritical Transformational Electric Power (STEP)** works to develop a Brayton cycle energy conversion system to transform heat energy into electricity using supercritical CO_2, rather than the traditional steam/water Rankine cycle, and has applications for nuclear, gas, and concentrating-solar as well as coal power plants.

Key Elements of the FY 2019 Budget Proposal

- **Establishes a goal** of developing two new High-Efficiency (greater than 42 percent), Low-Emission (HELE) small modular coal-plant designs by 2022.
- **A 56-percent increase in Advanced Energy Systems**, including new R&D activities to improve the performance of existing coal plants, develop higher-quality coal, and devise advanced materials for coal-power applications. Funding

for advanced combustion/gasification systems, turbines that can withstand higher temperatures and pressures, and sensors and controls would receive increases as well. Solid oxide fuel cell R&D would be cut by 90 percent.

- **Elimination of the Transformational Coal Pilots program.**

- **A 9-percent decrease in Cross-cutting Research,** including a decrease in modeling, simulation, and analysis of unexpected plant outages, a doubling of funding for critical minerals and rare-earth-element recovery from coal by-products, flat funding for water management R&D, and additional funding for university training and research programs.

- **A 4-percent increase for STEP funding within the Advanced Coal Energy Systems program.** However, the proposed budget for this collaborative program would decrease funding by 14 percent overall, because of a cut in STEP funding from the office of Nuclear Energy.

ENDNOTES

1. EIA, "Monthly Energy Review," Tables 7.1 and 12.6, accessed April 13, 2018, http://www.eia.gov/mer.
2. EIA, "Annual Energy Outlook," Table 1, http://www.eia.gov/aeo. Accessed April 13, 2018.
3. DOE, "Quadrennial Energy Review Second Installment: Transforming the Nation's Electricity System" (Washington, D.C.: DOE, January 2017) 3-57, https://www.energy.gov/policy/downloads/quadrennial-energy-review-second-installment.
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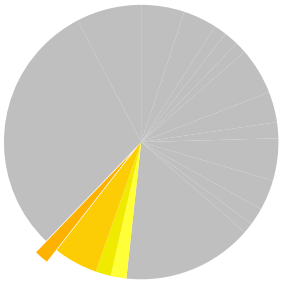
5. DOE website, "Southern Company – Kemper County, Mississippi," accessed April 15, 2018, https://www.energy.gov/fe/southern-company-kemper-county-mississippi.

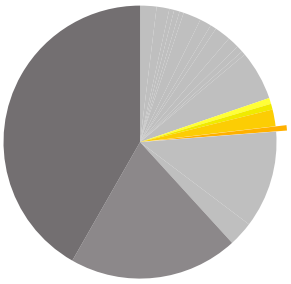
Federal Energy R&D: Oil & Gas

BY DAVID M. HART AND COLIN CUNLIFF | APRIL 2018

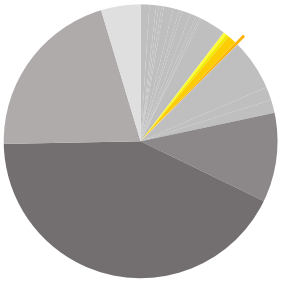
This briefing is part of a series on the U.S. energy budget. See: itif.org/energy-budget.



Oil & Gas (orange)
Other Fossil (yellow)
Energy R&D (light gray)



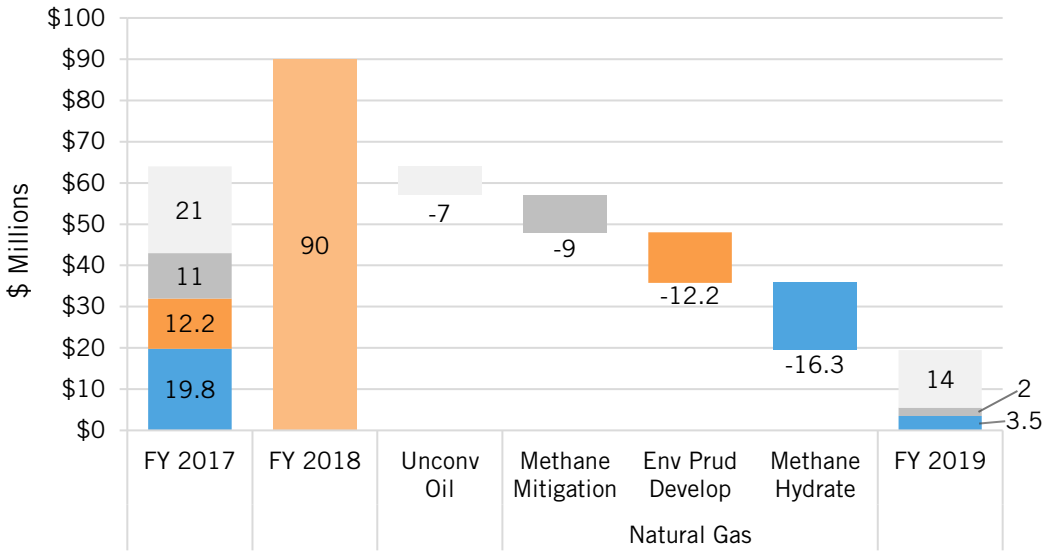
Oil & Gas & Energy R&D
Basic Science R&D
Defense R&D



Oil & Gas & Energy
Basic Science
Defense
Environ Mngmt
Other DOE

The Department of Energy's (DOE) oil and natural gas program supports R&D and policy options that ensure domestic and global supplies of oil and natural gas remain secure. A key focus of this program has been to improve the safety, and mitigate the environmental impacts, of oil and natural-gas energy systems. For example, the program has explored the connection between hydraulic fracturing and induced seismicity, while also seeking to mitigate emissions. In addition, it has funded R&D to reduce the amount of water used in oil and gas production, and to develop technologies to treat brackish water that is co-produced with oil and gas. The program also focuses on the development of new oil and gas resources, including methane hydrates and unconventional oil.

Figure 1: The FY 2019 Budget Request Would Reduce Oil and Gas R&D by 78 Percent



What's At Risk

Domestic production from unconventional reservoirs has enabled the United States to become the world's largest producer of oil and gas over the last few years, keeping energy prices low, and decreasing reliance on imported crude oil. However, current technology allows for recovery of only 7 to 10 percent of the oil found in such reservoirs. More R&D on subsurface flow mechanics is needed to improve these factors. R&D to characterize and evaluate domestic sources of methane hydrate deposits could also lead to large new sources of domestic natural gas in such places as Alaska and the Gulf of Mexico.

Other R&D activities focus on improving the efficiency of natural gas infrastructures—including pipelines and storage facilities—to reduce natural gas leaks and better conserve domestic energy resources, as well as address high-priority challenges to the safe and prudent development of unconventional oil and gas resources. For example, subsurface fluid flow and the causative factors of induced seismicity must be further studied if technologies and practices to reduce seismic risk are to be developed. Reduced funding could inhibit progress toward key public health, safety, and environmental goals.

Oil & Gas R&D Activities

R&D in oil and natural gas is spread among four activities:

- **Unconventional Fossil Energy from Petroleum R&D** supports the development of domestic production from unconventional reservoirs, which requires complicated engineering measures, such as hydraulic fracturing and directional drilling, to improve access and enable commercial production.

- **Methane Emissions Quantification and Mitigation** focuses on technologies that quantify and reduce methane leaks and vented emissions from natural gas systems. Methane, the main component of natural gas, is a powerful greenhouse gas that, on a pound-for-pound basis, is about 30 times more effective at trapping heat than carbon dioxide, although its atmospheric residence time is much shorter.[1] Reducing methane emissions would have the dual effect of improving the environmental performance of natural gas systems and enhancing stewardship of domestic gas resources.

- **Environmentally Prudent Development** conducts research on induced seismicity and wellbore integrity, as well as into water quality, water availability, air quality, and environmental impacts of oil and gas resource development.

- **Gas Hydrates R&D** aims to develop technologies that will enable natural gas production from domestic and arctic offshore methane hydrate deposits. Methane hydrates are methane molecules trapped in ice that turn into natural gas and water when heated or depressurized.

Key Elements of the FY 2019 Budget Proposal

- **A 33-percent reduction in the Unconventional Petroleum program,** including elimination of field laboratories focused on shale geology and fracture dynamics. Research on the relationship between hydraulic fracturing and induced seismicity, treatment and reuse of produced water (i.e., brackish water that is coproduced with oil and gas), and technologies for conversion and utilization of stranded or flared gas will continue.

- **An 82-percent reduction in Methane Emissions Quantification and Mitigation R&D**, including a discontinuation of all emission quantification R&D, which aims to identify and measure leaks and other emissions sources from

the natural gas system. R&D of technologies to reduce methane emissions and improve the efficiency of natural gas systems would be cut by 71 percent.

- **Elimination of all Environmentally Prudent Development research.**
- **An 82-percent reduction in Gas Hydrates R&D,** including termination of field work in the Gulf of Mexico and field tests in Alaska.

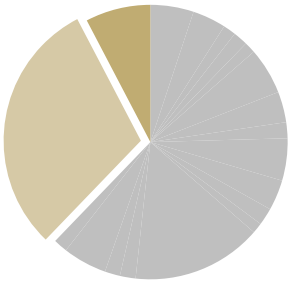
ENDNOTES

1. EPA, "Understanding Global Warming Potentials," accessed April 15, 2018, https://www.epa.gov/ghgemissions/understanding-global-warming-potentials.

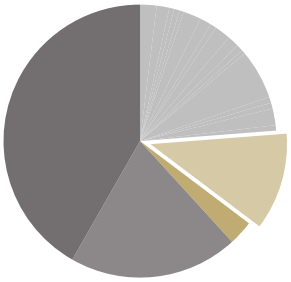
Federal Energy R&D: Basic Energy Sciences

BY DAVID M. HART AND COLIN CUNLIFF | APRIL 2018

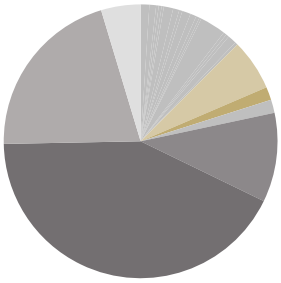
This briefing is part of a series on the U.S. energy budget. See: itif.org/energy-budget.



Basic Energy Sciences (brown)
Energy Science (brown)
Energy R&D (light gray)



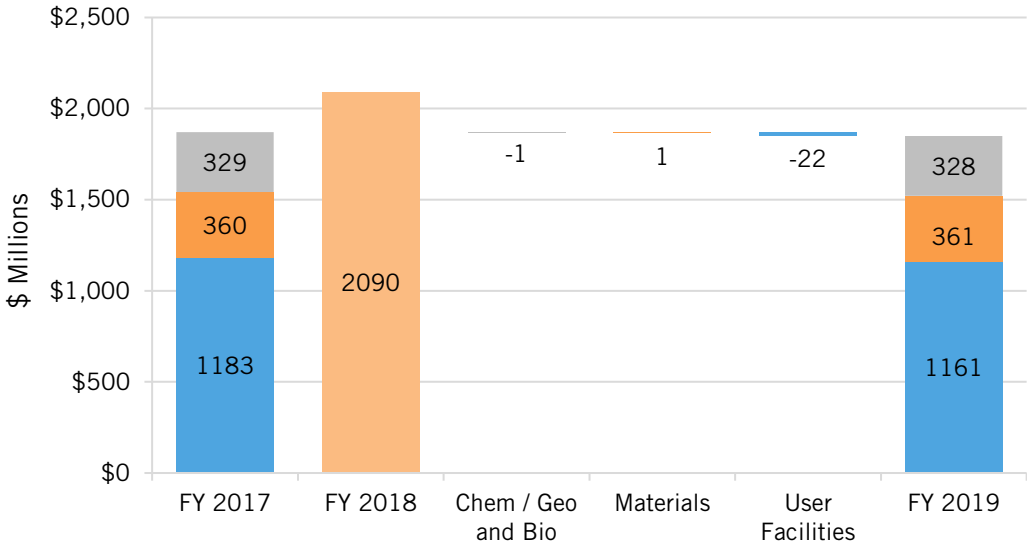
Basic Energy Sciences
Energy R&D
Basic Science R&D
Defense R&D



Basic Energy Sciences,
Energy, Basic Science,
Defense, Environ Mngmt,
Other DOE

Basic Energy Sciences (BES) support fundamental research into understanding and controlling matter and energy, thereby helping to build the foundation for new energy technologies. BES research—in condensed matter and materials physics, chemistry, geosciences, and aspects of biosciences—touches virtually every important facet of energy production, transmission, storage, and waste mitigation. BES also operates open-access scientific user facilities that serve researchers from private industry, national laboratories, and universities.[1]

Figure 1: The FY 2019 Budget Request Would Cut Basic Energy Sciences R&D by 11 Percent



What's At Risk

Research in basic energy sciences is a key component of the energy innovation ecosystem. In response to a bipartisan congressional requests to identify challenges to American competitiveness, the National Academy of Sciences found that "the scientific and technological building blocks critical to our economic leadership are eroding at a time when many other nations are gathering strength," and called for a doubling of basic science research, including basic energy sciences, as a means of addressing those challenges.[2] BES supports 36 Energy Frontier Research Centers, which are partnerships among universities, national laboratories, and industry that integrate the talents and insights of leading scientists and engineers to confront critical energy challenges across sectors.

In addition, DOE set up interdisciplinary, integrative centers of excellence that bring together researchers from across sectors to address "grand energy challenges" and use-inspired basic research needs. BES houses two of these energy innovation hubs: the Fuels from Sunlight Hub, which seeks to generate fuels directly from sunlight, carbon dioxide, and water in a manner similar to natural photosynthesis; and the Batteries and Energy Storage Hub, which researches nanoscale phenomena to develop next-generation, beyond-lithium-ion-energy storage systems. The hubs connect basic research to real-world challenges and enable fast technology transitions from the lab to the market.

Basic Energy Sciences R&D Activities

R&D in basic energy is distributed across three subprograms:

- **Materials Science and Engineering** supports research on materials synthesis, behavior, and performance for a wide range of energy-generation and end-use challenges, with a focus on the origin of macroscopic-material behaviors; their fundamental connections to atomic, molecular, and electronic structures; and their evolution as materials move from nanoscale building blocks to mesoscale systems.

- **Chemical Sciences, Geosciences, and Biosciences** supports research on chemical reactivity and energy conversion, which is the foundation for energy-relevant chemical processes—such as catalysis, synthesis, and light-induced chemical transformation—to achieve a fully predictive understanding of complex chemical, geochemical, and biochemical systems at the same level of detail as simple molecular systems.

- **Scientific User Facilities** supports the operation of a diverse suite of research facilities that provide thousands of researchers from universities, industry, and government laboratories unique tools to advance a wide range of science research. These user facilities are operated on an open-access, competitive merit review basis, enabling public and private researchers from every discipline to take advantage of the facilities' unique capabilities and instrumentation.

Key Elements of the FY 2019 Budget Proposal

- **Near-flat funding for Materials Science and Engineering Research**. Research using x-ray, neutron-scattering, and electron-microscopy techniques focused on superconductivity and organic electronics would be de-emphasized, with a shift in focus to understanding quantum phenomena and materials research. Funding for Energy Frontier Research Centers and the Energy Innovation Hub for Batteries and Energy Storage would remain flat at FY 2017 levels.

- **Near-flat funding for Chemical Sciences, Geosciences, and Biosciences**. Chemical-transformations research will emphasize chemical processes that occur in nuclear environments, with an aim toward better understanding the structure, dynamics, and energetics of molten salt coolants and fuels that can inform the development of advanced nuclear power. Photochemistry and biochemistry

research will de-emphasize efforts in plant cell-wall biosynthesis and light signaling. Funding for Energy Front Research Centers and the Fuels from Sunlight Energy Innovation Hub would remain flat at FY 2017 levels.

- **Modest reductions in funding for research conducted at User Facilities.** This would include discontinuation of research activities for detectors and optics instrumentation. Upgrades to x-ray-light and neutron sources, including the Advanced Light Source (soft x-rays), Advanced Photon Source (hard x-rays), and Linac Coherent Light Source-II (ultrafast x-rays) facilities would remain ongoing.

ENDNOTES

1. DOE, "FY 2019 Congressional Budget Justification," volume 4, DOE/CF-0142 (Washington, D.C.: DOE Chief Financial Officer, February 2018), 149, https://www.energy.gov/sites/prod/files/2018/03/f49/DOE-FY2019-Budget-Volume-4_0.pdf.
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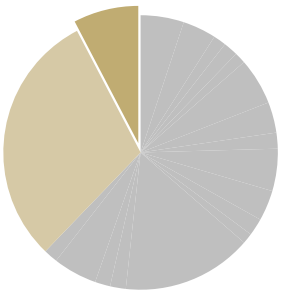
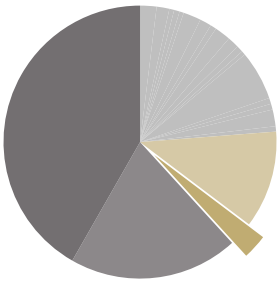
Federal Energy R&D: Fusion Energy Sciences

BY DAVID M. HART AND COLIN CUNLIFF | APRIL 2018

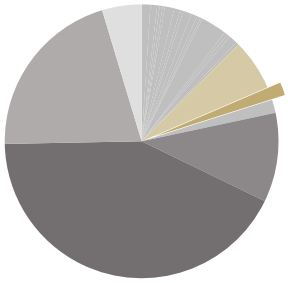
This briefing is part of a series on the U.S. energy budget. See: itif.org/energy-budget.



Fusion Energy (brown)
Basic Energy Science (brown)
Energy R&D (light gray)



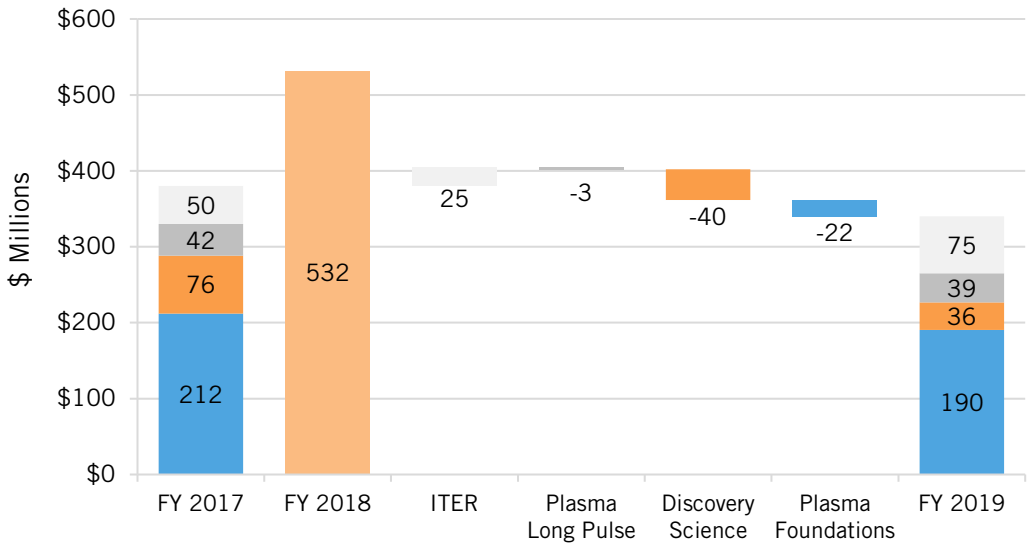
Fusion Energy & Energy R&D
Basic Science R&D
Defense R&D



Fusion Energy Sciences,
Energy, Basic Science,
Defense, Environ Mngmt,
Other DOE

The mission of the Fusion Energy Sciences (FES) program is to help build the scientific foundation needed to develop a fusion energy source by expanding the fundamental understanding of the physics behind plasmas (i.e., matter at very high temperatures and densities).[1] Comprising 99 percent of the visible universe, plasmas are at the heart of the fusion process that powers the stars. The promise of fusion—an energy system that could generate massive amounts of power, using fuel obtained from seawater and earth-abundant materials, with very little pollution—is enormous.

Figure 1: The FY 2019 Budget Request Would Cut Fusion Energy Sciences R&D by 36 Percent



What's At Risk

Fusion RD&D has the potential to contribute to U.S. energy security by making available a robust clean energy technology that relies on widely available and virtually inexhaustible fuel sources. However, the technological advances needed to realize safe, low-cost fusion are still nascent, so basic research into plasma physics—including plasma confinement and plasma-materials interactions—remains essential to advancing toward the goal of fusion energy. Reductions in funding for this program could stall advances in fusion science, while threatening the United States' leadership in this important area.

Because its science is so wide-ranging, plasma research could spin off a number of applications for other technologies. Advances developed in the quest for fusion energy have already led to the creation of other technologies that provide considerable economic and

societal impact, including applications in lighting, semiconductor manufacturing, medical and health science and technology, materials, and waste management.[2] Robust plasma-research funding is therefore necessary to prevent the United States from losing out on future benefits in these and other industries.

Fusion Energy Sciences R&D Activities

R&D in fusion energy is distributed across four subprograms:

- **Burning Plasma Science: Foundations** advances the predictive understanding of plasma confinement, dynamics, and interactions with surrounding materials—and conducts research in advanced tokamak and spherical-tokamak science, as well as small-scale magnetic confinement experiments.
- **Burning Plasma Science: Long Pulse** explores new scientific regimes using long-duration superconducting international machines, and addresses the development of materials and technologies required to withstand and sustain burning plasma.
- **Discovery Plasma Science** explores the fundamental properties and complex behavior of matter in the plasma state to improve the understanding required to control and manipulate plasmas for a broad range of applications.
- **International Thermonuclear Experimental Reactor (ITER)** is an international partnership among seven governments (China, the European Union, India, Japan, the Republic of Korea, the Russian Federation, and the United States) that demonstrates the scientific and technological feasibility of fusion power for electricity generation.

Key Elements of the FY 2019 Budget Proposal

- **A 10-percent reduction in Basic Plasma Science: Foundations**, including reductions in the spherical-tokamak user facility at Princeton, New Jersey, as well as to the theory and simulations program that works to develop the predictive capability needed for sustainable fusion.
- **A 7-percent reduction in Basic Plasma Science: Long Pulse**, including reductions in superconducting stellarators and long-pulse tokamaks, as well as reductions in the fusion nuclear science and materials R&D that seeks to understand how plasmas interact with the materials that might be used in future fusion facilities.
- **A 53-percent reduction in Discovery Plasma Science,** including elimination of R&D in exploratory magnetized plasmas—which is necessary to advance innovative solutions and capabilities for the creation, control, and manipulation of magnetically confined plasmas for terrestrial and space applications—as well as reductions in R&D in general plasma science, which explores low-temperature plasma science and engineering, and high energy density plasma science, which explores the behavior of matter at extreme conditions of temperature, density, and pressure.

- **Increased contribution to the International Thermonuclear Experimental Reactor (ITER).** Although U.S. investment in ITER is less than 10 percent of construction costs, the United States has access to all ITER technology and scientific data, which represents a significant opportunity for U.S. universities, laboratories, and industries to both design and construct parts, and propose and conduct experiments.

ENDNOTES

1. DOE, "FY 2019 Congressional Budget Justification," volume 4, DOE/CF-0142 (Washington, D.C.: DOE Chief Financial Officer, February 2018) 149, https://www.energy.gov/sites/prod/files/2018/03/f49/DOE-FY2019-Budget-Volume-4_0.pdf.
2. Fusion Energy Sciences Advisory Committee, "Applications of Fusion Energy Sciences Research" (Washington, D.C.: DOE, September 2015), https://science.energy.gov/~/media/fes/fesac/pdf/2015/2101507/FINAL_FES_NonFusionAppReport_090215.pdf.