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Trump Budget Shortchanges Energy Innovation

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DOE's clean energy RD&D portfolio is essential to the U.S. energy innovation ecosystem. Instead of slashing it, as the administration has proposed, Congress should elevate energy innovation as a national priority and continue to expand it.

KEY TAKEAWAYS

- The administration has proposed massive cuts to energy RD&D, which would jeopardize the pace of energy innovation and impede progress toward national goals in economic competitiveness, energy security, and environmental stewardship.
- The president's proposal is based on two flawed rationales: that the private sector will do most of the energy RD&D we need, and that emerging technologies such as wind and solar are now cheap enough that they don't need additional federal support.
- DOE's RD&D portfolio is essential to the U.S. energy innovation ecosystem, so Congress should reject this budget proposal, elevate energy innovation as a national priority, and continue to expand federal funding for DOE's energy RD&D programs.

OVERVIEW

The Trump administration has again proposed a federal budget with massive cuts to energy research, development, and demonstration (RD&D), which would jeopardize the pace of energy innovation and impede progress toward national goals in economic competitiveness, energy security, and environmental stewardship.[1] Congress should reject the proposed budget and instead elevate innovation in clean energy as a national priority.

The president's budget request for fiscal year 2020 would slash federal investments in the Department of Energy's applied energy programs—including energy efficiency, renewable energy, fossil energy, nuclear energy, and grid modernization—by more than 56 percent, from $4.7 billion in FY 2019 to $2.1 billion in FY 2020. The DOE Office of Science, which includes programs in fusion energy and basic energy sciences, would receive a 16 percent cut, from $6.6 billion in FY 2019 to $5.5 billion under the proposed budget. If enacted, this would be the largest single-year cut to energy RD&D investments in the history of the department, bringing federal energy RD&D to its lowest level since 2006.[2]

Even more troubling, the proposed cuts come as the clean energy transition is slowing down. U.S. carbon pollution increased in 2018 after three straight years of decline; fossil fuels remain the cheapest source of energy in most cases; and patent applications in clean energy have been declining in recent years.[3] Research by ITIF has also identified significant gaps in the federal energy RD&D portfolio, particularly from harder-to-abate sources of carbon pollution.[4] Clean energy technologies simply are not developing fast enough or at sufficient scale to address the magnitude of the climate challenge.

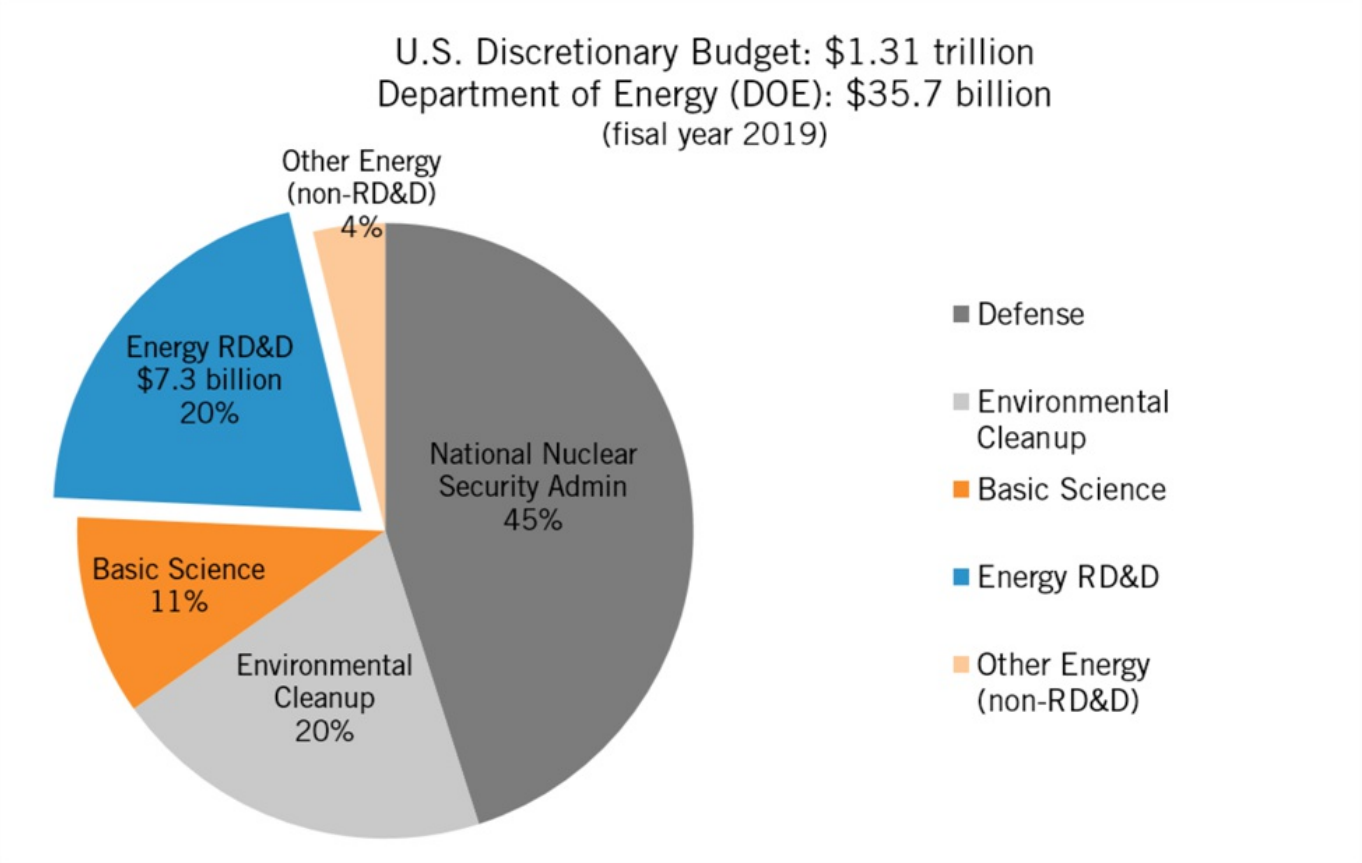
Federal investment in RD&D is essential to inducing the innovation needed to address the climate, security, and competitiveness challenges of the 21st century. The Trump administration's budget asserts that the private sector is best-positioned to fund later-stage energy research. But the private sector cannot by itself afford to invest in high-risk, long-time-horizon, high-capital-cost RD&D that can enable truly transformative changes. Nor can private industry justify the pre-competitive, pre-commercial R&D that underpins the development of new industries and addresses national challenges.

Lawmakers do not have to accept the administration's budget proposal. Indeed, Congress has rejected the same draconian proposals in the last two budget cycles, instead boosting energy RD&D programs by 14 percent in FY2018 and 5 percent in FY2019.[5] Congress has realized that investing in clean energy innovation can be a win-win-win-win: It can lower energy costs for U.S. consumers and businesses, increase the competitiveness of U.S. clean-tech businesses in the global clean-energy industry, improve U.S. energy security and resilience, and reduce pollution, including greenhouse gas emissions that cause climate change.

HISTORIC CUTS ARE BASED ON A FAULTY PREMISE

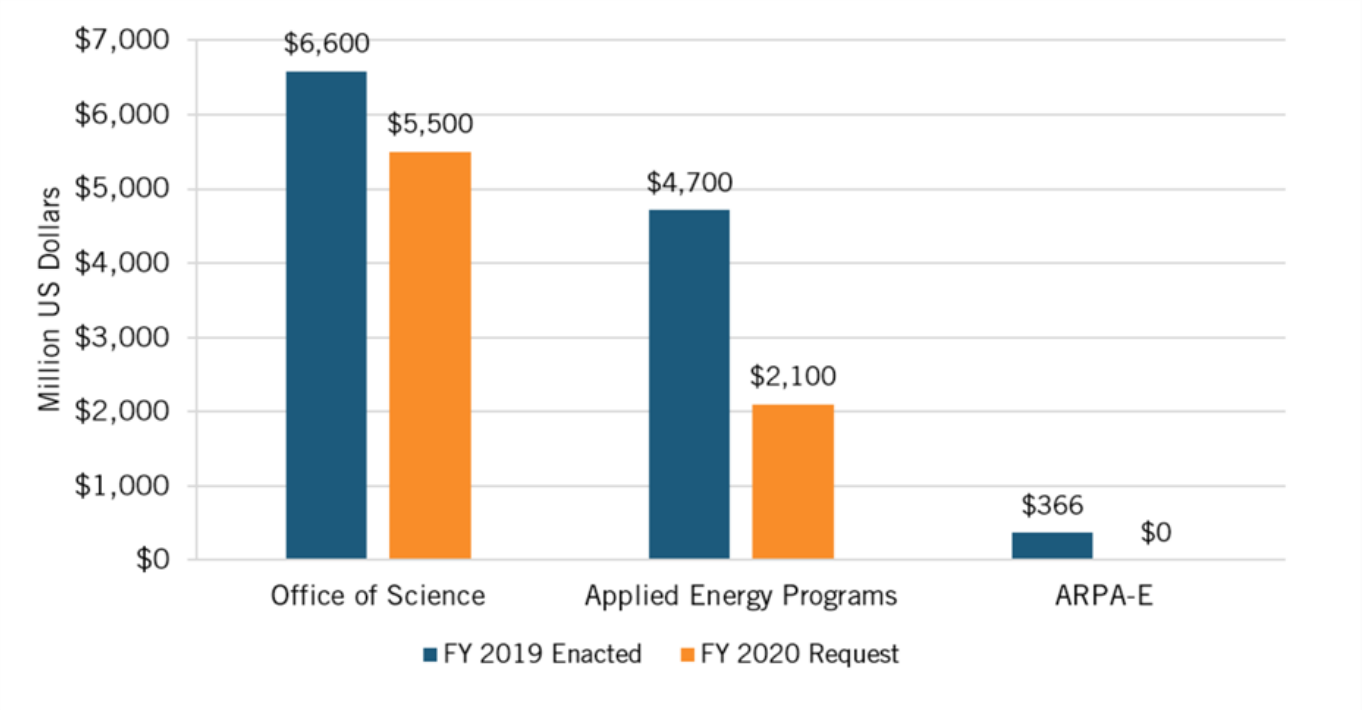
Out of a total discretionary budget of more than $1.3 trillion, the federal government funded the Department of Energy (DOE) at $35.7 billion in FY2019.[6] But only $7.3 billion, or about 20 percent of DOE's budget, supports innovation in renewable energy, nuclear energy, and carbon capture and storage as well as grid modernization and basic energy-related sciences. Nearly two-thirds of DOE's budget goes to defense or environmental cleanup. Another 11 percent funds non-energy-focused basic science research (figure 1).

Figure 1: Total DOE Budget by Major Function, FY2019 [7]



DOE's energy RD&D investments span the entire energy innovation cycle, from basic energy-related science and engineering research, to applied research and development, to demonstration and early deployment of emerging energy technologies.[8] In FY 2019, DOE's Office of Science (SC) funded nearly $6.6 billion of research. The Departments five applied energy five offices—Energy Efficiency and Renewable Energy (EERE); Fossil Energy (FE); Nuclear Energy (NE); Electricity (OE); and Cybersecurity, Energy Security, and Emergency Response (CESER)—together received $4.7 billion in FY 2019.[9] Meanwhile, the Advanced Research Projects Agency for Energy (ARPA-E) invested $366 million in high-risk, high-impact energy RD&D.

Figure 2: Current and Proposed Investments in RD&D Programs at DOE



The administration's proposed budget would dramatically reduce federal investment in energy innovation. ARPA-E would be completely eliminated. Total funding for the applied energy programs would be cut by 56 percent, to $2.1 billion, with cuts ranging from 86 percent for the Office of Energy Efficiency and Renewable Energy to 24 percent for the Office of Fossil Energy (table 1). The Office of Science would receive a 16 percent cut (figure 2). In addition, the Loan Programs Office, which provides loan guarantees for first-of-a-kind projects for innovative energy technologies, would also be eliminated.

Table 1: President Trump's FY 2020 Budget Request for DOE, in millions [10]

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 WH Request	% Change
DOE Total Budget	$34,520	$35,685	$31,700	-11%
Defense	15,509	16,089	16,500	-3%
Environmental Management	7,126	7,175	6,800	-5%
Other Non-RD&D Programs	770	749	831	11%
Office of Science	6,260	6,585	5,500	-16%
ARPA-E	353	366	0	-100%
Applied Energy Programs	4,502	4,721	2,069	-56%
Energy Efficiency & Renewable Energy	2,322	2,379	343	-86%
Fossil Energy R&D	727	740	562	-32%
Nuclear Energy	1,205	1,326	824	-38%
Electricity	248	156	183	17%
Cybersecurity		120	157	31%

This would come as the United States, by many measures, is already significantly underinvesting in energy innovation. For example, adjusted for inflation, DOE's energy RD&D funding for FY2019 remains 29 percent below what it was when the department was first funded in 1978 (figure 3). As a share of the economy, DOE's energy RD&D is down more than 75 percent over the same period.[11] Eleven other countries—including China—invest more in energy RD&D as a percentage of GDP than does the United States.[12] And energy RD&D investment is far below comparable federal spending for space, health, and defense.[13]

This underinvestment is out of step with large majorities of voters across the political spectrum who support increased funding for research into clean energy technologies. According to recent polling, 88 percent of registered voters support funding more research into clean energy sources.[14]

The Flawed Rationales of the Trump Budget

The president's proposal is based on two flawed rationales: first, that the private sector will do most of the energy RD&D that is needed, and second, that emerging technologies (such as wind and solar) have already seen dramatic price reductions and no longer need additional federal support.

In fact, public and private investment play complementary roles along the pathway to commercialization for new energy technologies. The federal government tends to fund pre-competitive RD&D and make high-risk, long-term investments that the private sector is simply unwilling to fund. Additionally, the federal government has a strong "public goods" rationale for investing in national priorities like accelerating clean-energy innovation to address climate change.

ITIF has found that federal investment frequently serves as a catalyst for industry, as government RD&D tends to provide incentives for additional private RD&D dollars rather than crowding them out.[15]

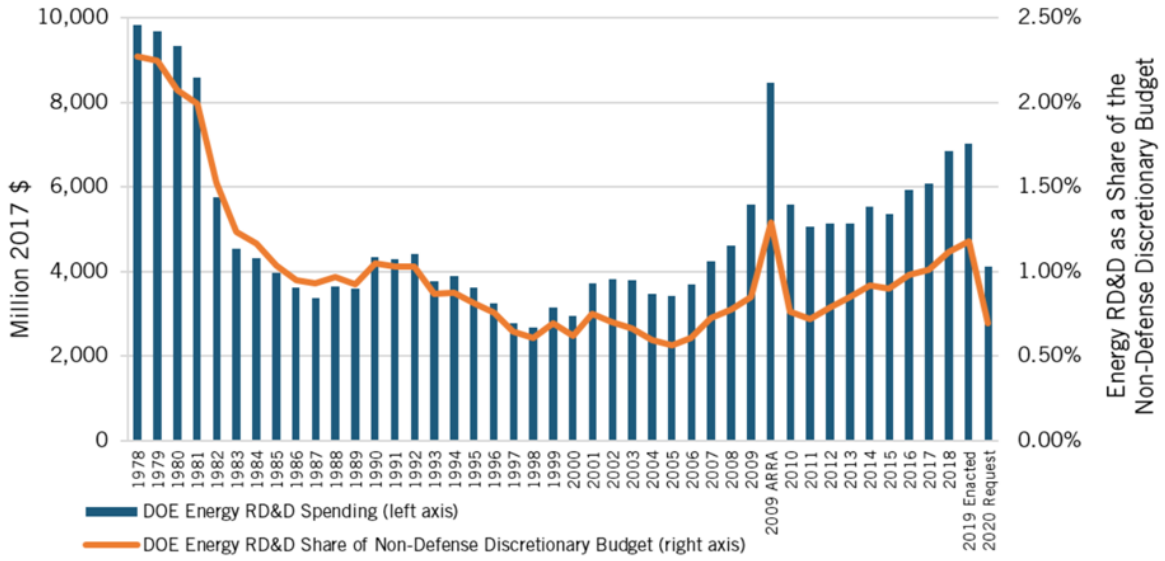
Secretary Perry and other DOE officials have pointed to the success that DOE programs in wind and solar energy have had in driving down costs as reasons these programs are no longer needed.[16] But while (onshore) wind and solar have seen dramatic and rapid cost reductions in recent years, they are still not yet competitive with natural gas in most parts of the country.[17] And other emerging technologies—including offshore wind, marine and hydrokinetic power, battery electric vehicles, algal biofuels, advanced small modular reactors, and many other clean technologies—are still far from matching the reliability and cost of conventional fossil fuel-based incumbent technologies.

ENERGY RD&D AT DOE: A HISTORICAL PERSPECTIVE

DOE was created in the late 1970s—a time when energy demand was increasing rapidly, energy prices were high, and OPEC was flexing its muscles in global oil markets. Energy innovation and the development of domestic clean energy were viewed as matters of economic and national security. In 1978, Congress invested more than 2 percent of non-defense discretionary spending in energy research at DOE ($10 billion in 2017 dollars). But as energy prices declined, energy innovation receded as a national priority, and funding for energy RD&D has not kept pace. Total funding hovered below $4 billion for most of the mid-1980s through the early 2000s.

In 2007, the National Academies released its groundbreaking report Rising Above the Gathering Storm, examining U.S. leadership and competitiveness in science and technology. The report concluded that the United States risked falling behind other nations—particularly in clean energy innovation—without increased RD&D investments. In response, Congress passed the America COMPETES Act of 2007, which authorized a doubling of RD&D funding at DOE and other agencies. The doubling goal was reaffirmed in the 2010 reauthorization of COMPETES, and again at the launch of Mission Innovation in 2015. However, actual appropriations have not matched these funding targets, and the United States remains far short of its original doubling goal. As a result, America's rank in international innovation indices has declined, and U.S. competitiveness in the growing clean energy economy is at risk.

Figure 3: DOE Energy RD&D Spending, FY 1978 – FY 2020 Request (2017 $)



* *The 2009 American Reinvestment and Recovery Act (ARRA) provided a one-time boost in energy RD&D outside regular appropriations, primarily to clean energy demonstration and deployment programs.*

ENERGY RD&D INVESTMENT GENERATES BIG RETURNS FOR AMERICAN TAXPAYERS

DOE-funded RD&D has already generated a significant return on investment, and many of the technologies that now make major contributions to both the U.S. and global energy systems were created through federal investments and public-private cooperation.

Perhaps the most striking example is the rapid emergence of shale gas. Federal support for shale-gas resource characterization and direction drilling in the 1970s and 80s—in tandem with industry-matched applied research and a federal production tax credit—led to the dramatic rise of shale gas production from 2 percent of domestic production in 2001 to 70 percent in 2018.[18]

Many other examples spring to mind. Federal investments at DOE in high-efficiency diesel engines used in medium- and heavy-duty trucks—totaling $931 million between 1986 and 2007—resulted in improved fuel economy and fuel savings of $34.5 billion.[19] Research into heating, ventilation, and air conditioning (HVAC), along with lighting, windows, and appliances resulted in the successful commercialization of 27 technologies between 2010 and 2015.[20] An external review of energy efficiency and renewable energy RD&D at DOE found that a total taxpayer investment of $12 billion between 1975 and 2015 yielded more than $388 billion in net economic benefits, a remarkable return of over $32 for every federal dollar invested.[21]

WHAT'S AT STAKE: THE POTENTIAL BENEFITS OF DOE'S RESEARCH PROGRAMS

Going forward, how will DOE's energy RD&D portfolio benefit Americans, and what is at risk if funding is cut per the Trump administration's budget request? An examination of DOE's energy technology targets provides insights.

For each of its applied energy programs, DOE establishes long-term technology cost and performance targets to guide its RD&D investments, and these targets are generally based on the assumption that current funding levels will be maintained in the future. Perhaps the most well-known example is DOE's Sunshot goals, a set of ambitious cost targets for solar energy technologies that were chosen to make solar energy "among the least expensive options for new power generation and [to] lower than the cost of most fossil fuel-powered generators."[22] A partial list of DOE's technology targets includes:[23]

- Reducing the nationwide average unsubsidized cost of utility-scale solar photovoltaics (PV) to 3 cents per kilowatt-hour (kWh) by 2030;
- Reducing the cost of batteries for electric vehicles to $100/kWh by 2028;
- Lowering the cost of grid-scale energy storage technologies to $100/kWh by 2025;
- Reducing the cost of carbon capture to under $30 per metric ton by 2030; and
- Improving the energy efficiency of all U.S. buildings by 50 percent from 2010 levels.

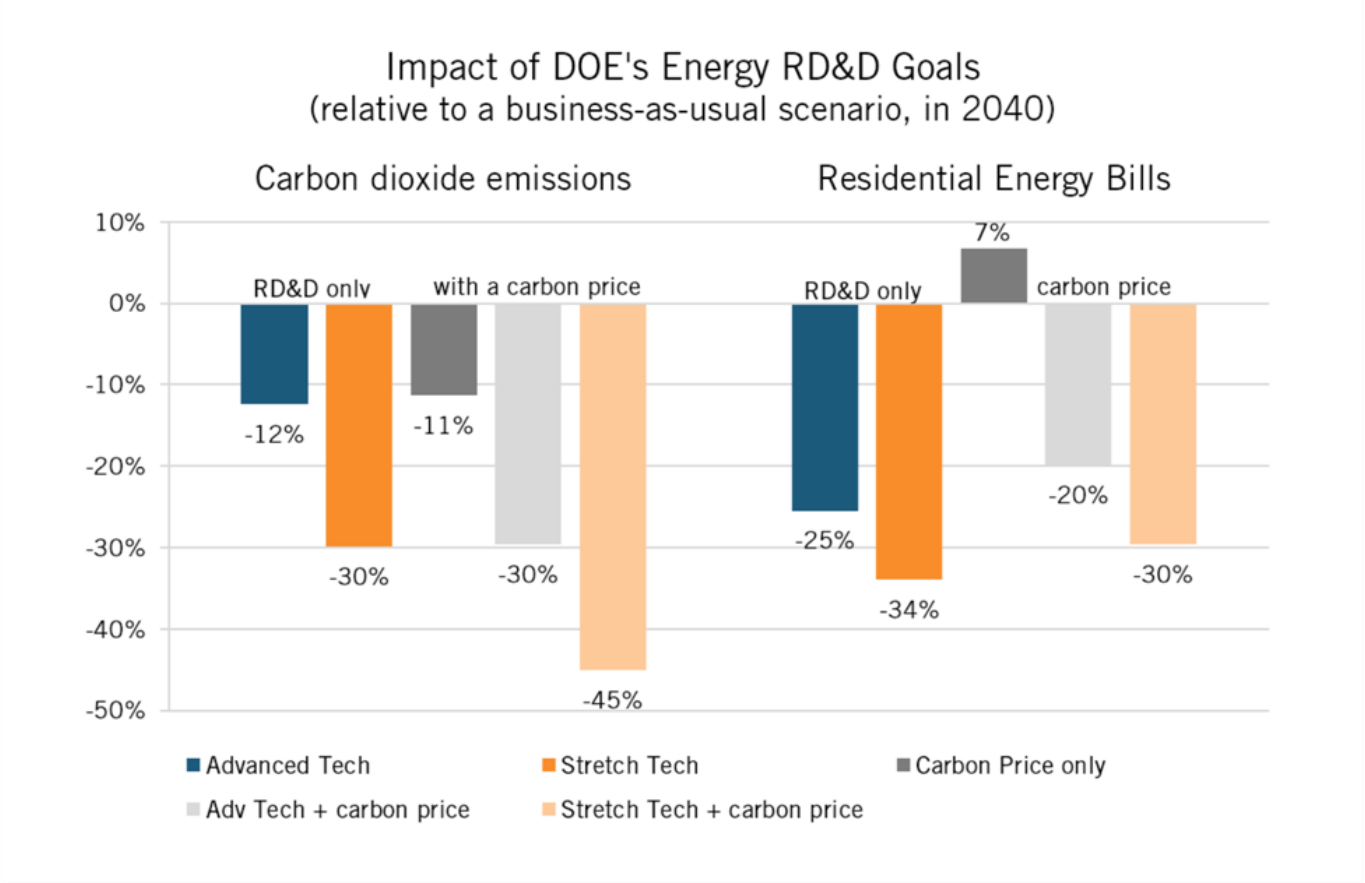
Achieving these targets would provide multiple public benefits to consumers, including lower energy bills and better health and environmental outcomes. They also advance national priorities in economic competitiveness and energy security and resilience. Lower energy costs have been an important driver of "reshoring" manufacturing to the United States over the past decade as well.[24] And as the nation's single largest consumer of energy, the U.S. Department of Defense (DOD) views energy as both an essential enabler and a source of vulnerability.[25] The CNA Military Advisory Board—a think tank of retired generals—identified advanced clean energy technologies as critical to securing energy independence and improving U.S. geopolitical security.[26]

The Climate and Energy Benefits of DOE's Clean Energy RD&D Programs

In its 2017 Quadrennial Energy Review (QER), DOE provided a more detailed assessment of these benefits by incorporating its energy technology cost and performance targets into the energy-economic model used to produce the Energy Information Administration's *Annual Energy Outlook*. The analysis included three technology scenarios: a business-as-usual scenario that applies standard technology learning curves but does not account for DOE's energy programs; an "Advanced Technology" scenario that incorporates DOE's energy technology targets; and a "Stretch Technology" scenario that assumes more aggressive targets conditioned on a doubling of funding for DOE's energy programs. The modeling also examined the impact of a carbon price—starting at $10 per metric ton of CO and increasing 5 percent annually—in combination with each of the three technology scenarios. Among the key findings:[27.]

- Sustaining DOE's energy RD&D programs at current budget levels (see the Advanced Tech case in blue on figure 4) would reduce CO emissions by 12 percent below a business-as-usual scenario and result in 25 percent lower residential energy bills in 2040.
- Doubling funding for energy RD&D (see the Stretch Tech case in orange), which would achieve more ambitious technology targets, while reducing CO emissions by 30 percent and energy bills by 34 percent.
- Combining a modest carbon price and energy RD&D would drive greater emissions reductions than either approach on its own. Yet, even the most aggressive scenario considered—doubling the energy RD&D budget and adding a carbon price (Stretch Tech + carbon price in light orange)—would be insufficient to cut emissions by 80 percent as envisioned by the Paris climate accords.

Figure 4: DOE's Energy RD&D Programs Drive Down Emissions and Reduce Energy Bills



CONCLUSION

DOE's clean energy RD&D portfolio plays an essential role in the U.S. energy innovation ecosystem and has the potential to accelerate the clean energy transition and reduce carbon pollution while

also lowering energy costs for U.S. businesses and consumers. But the Trump administration's budget request would slash funding for these programs and severely hamper U.S. innovation and competitiveness at a time when a number of indicators—including rising carbon emissions and declining clean energy patents—all point to the fact that the United States is significantly underinvesting in clean energy innovation. Congress should reject the Trump budget proposal, elevate energy innovation as a national priority, and continue to expand federal funding for DOE's energy RD&D programs.

ENDNOTES

1. The White House, "President's Budget FY 2020," (Office of Management and Budget, March 11, 2019), https://www.whitehouse.gov/omb/budget/.

2. David M. Hart and Colin Cunliff, "Federal Energy RD&D: Building on Momentum in Fiscal Year 2019," (Information Technology and Innovation Foundation, April 2018), https://itif.org/publications/2018/04/23/federal-energy-rdd-building-momentum-fiscal-year-2019.

3. Colin Cunliff, "Omission Innovation: The Missing Element in Most Countries' Response to Climate Change," (Information Technology and Innovation Foundation, December 2018), https://itif.org/publications/2018/12/10/omission-innovation-missing-element-most-countries-response-climate-change; Rhodium Group, "Preliminary US Emissions Estimates for 2018," figure 2, (Rhodium Group, January 2019), https://rhg.com/research/preliminary-us-emissions-estimates-for-2018/.

4. Colin Cunliff, "An Innovation Agenda for Deep Decarbonization: Bridging Gaps in the Federal Energy RD&D Portfolio" (Information Technology and Innovation Foundation, November 2018), https://itif.org/publications/2018/11/28/innovation-agenda-deep-decarbonization-bridging-gaps-federal-energy-rdd.

5. Colin Cunliff, "Department of Energy RD&D Appropriations, Fiscal Year 2019," (Information Technology and Innovation Foundation, 2018), https://itif.org/publications/2018/06/26/department-energy-rdd-appropriations-fiscal-year-2019. Percent increases refer to nominal dollar amounts and have not been adjusted for inflation.

6. Total discretionary spending includes $647 billion for discretionary defense spending, $69 billion to fund operations in Iraq and Afghanistan, and $597 billion for non-defense discretionary spending. Seamus P. Daniels and Todd Harrison, "Making Sense of the Bipartisan Budget Act of 2018 and What It Means for Defense," (Center for Strategic and International Studies, February 20, 2018), https://www.csis.org/analysis/making-sense-bipartisan-budget-act-2018-and-what-it-means-defense; Matt Hourihan and David Parkes, "Congressional Budget Deal Would Raise Spending Caps," (American Association for the Advancement of Science, February 8, 2018), https://www.aaas.org/news/congressional-budget-deal-would-raise-spending-caps.

7. Defense includes the National Nuclear Security Administration and Other Defense Activities accounts. Environmental Management includes Defense Environmental Cleanup, Non-Defense Environmental Cleanup, and Uranium Enrichment Decontamination and Decommissioning Fund. Basic Science Research includes the Office of Science (SC) minus Basic Energy Sciences (BES), Fusion Energy Sciences (FES), and the portion of Biological and Environmental Research (BER) that supported the bioenergy research centers ($100 million). Energy RD&D funding is estimated as the sum of following: EERE R&D programs minus Weatherization and Intergovernmental Programs (WIP), Federal Energy Management Programs (FEMP), and the portion of the Building Technologies Office (BTO) that supports energy efficiency standards for appliances and equipment; OE and CESER R&D programs minus the Transmission Permitting and Technical Assistance (TPTA) and Infrastructure Security and Emergency Response (ISER); the office of Nuclear Energy (NE) less safeguards and security; the office of Fossil Energy R&D (FE); ARPA-E; SC-BES; SC-FES, and $100 million from SC-BER that supports the bioenergy research centers.

8. American Energy Innovation Council (AEIC), "Energy Innovation: Fueling America's Economic Engine," (Bipartisan Policy Center and AEIC, November 2018), http://americanenergyinnovation.org/2018/11/energy-innovation-fueling-americas-economic-engine/.

9. Total funding includes non-RD&D programs, such as the Weatherization and Intergovernmental Programs (WIP) office in EERE, and the safeguards and security funding within NE. ITIF estimates that $4.1 billion went to RD&D, facilities (such as labs) that support RD&D, or program management of RD&D.

10. .Department of Energy, "FY 2019 Congressional Budget Request: Budget in Brief," (DOE Chief Financial Officer, March 2018), DOE/CF-0144.

11. U.S. Bureau of Economic Analysis, "Table 1.1.6. Real Gross Domestic Product," (accessed March 29, 2018), https://www.bea.gov/iTable/index_nipa.cfm; and K.S. Gallagher and L.D. Anadon, "DOE Budget Authority for Energy Research, Development, and Demonstration Database" (The Fletcher School, Tufts University; Department of Land Economy, University of Cambridge; and Belfer Center for Science and International Affairs, Harvard Kennedy School, June 27, 2017), https://www.belfercenter.org/publication/database-us-department-energy-doe-budgets-energy-researchdevelopment-demonstration.

12. International Energy Agency (IEA), "Energy Technology RD&D Budget Database," https://www.iea.org/statistics/rdd/, (accessed March 29, 2018); Simon Bennett and Remi Gigoux, "Commentary: Declining energy research budgets are a cause for concern," (IEA, 2017), https://www.iea.org/newsroom/news/2017/october/commentary-declining-energy-research-budgets-are-a-cause-for-concern.html.

13. For comparison, the federal government spent $34.38 billion in health R&D and $10.22 billion in space R&D in 2017. American Association for the Advancement of Science, "Historical Trends in Federal R&D," By Function: Nondefense Only, https://www.aaas.org/programs/r-d-budget-and-policy/historical-trends-federal-rd. Accessed February 15, 2019.

14. A. Leiserowitz, *et al.*, "Politics & Global Warming, December 2018" (New Haven, CT: Yale Program on Climate Change Communication, December 2018) 6, http://www.climatechangecommunication.org/wp-content/uploads/2019/02/Global-Warming-Policy-Politics-December-2018.pdf.

15. David M. Hart and Michael Kearney, "ARPA-E: Versatile Catalyst of U.S. Energy Innovation" (Washington, D.C.: Information Technology and Innovation Foundation, 2017); Varun Sivaram et al., "Energy Innovation Policy: Priorities for the Trump Administration and Congress" (Washington, D.C.: Information Technology and Innovation Foundation, December 2016). See also Matt Hourihan, "If Government Scales Back Technology Research, Should We Expect Industry to Step In?" (Washington, D.C.: American Association for the Advancement of Science, October 2017), https://www.aaas.org/news/new-brief-could-industry-fill-gaps-following-federal-rd-cuts.

16. For example, the cost of utility-scale solar photovoltaic (PV) achieved DOE's cost target for 2020—6 cents per kilowatt-hour—three years early, in 2017. However, the unsubsidized, nationwide average cost of solar is still far from DOE's 2030 target of 3 cents per kilowatt-hour.

17. Natural gas accounted for 166 billion kilowatt-hours of new generation from January to October 2018, while wind and solar accounted for only 22 and 18 billion kilowatt-hours, respectively. https://rhg.com/research/preliminary-us-emissions-estimates-for-2018/, figure 2.

18. The shale-gas boom did not occur overnight but resulted from decades of public and private sector RD&D, including: federal support for shale-gas resource characterization and directional drilling beginning in the late 70s; industry-matched applied research from the Gas Research Institute through the early 90s; a time-limited federal production tax credit; public subsidization of demonstration projects in West Virginia and Texas in the 80s and 90s. See A. Trembath,

J. Jenkins, T. Nordhaus, and M. Schellenberger, "Where the Shale Gas Revolution Came From," (Breakthrough Institute, Oakland, CA, 2012). https://thebreakthrough.org/issues/energy/where-the-shale-gas-revolution-came-from; and U.S. Energy Information Administration (EIA), "Today in Energy: EIA adds new play production data to shale gas and tight oil reports," (DOE-EIA, February 15, 2019), https://www.eia.gov/todayinenergy/detail.php?id=38372.

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20. Energetics Inc., "R&D to Market Success: BTO-Supported Technologies Commercialized from 2010-2015," (U.S. Department of Energy, Building Technologies Office, April 2017), https://www.energy.gov/sites/prod/files/2017/06/f34/BTO_Commercial_Technology_Report_April%202017.pdf.

21. Michael Gallaher *et al.*, *Benefit-Cost Evaluation of U.S. Department of Energy Investment in HVAC, Water Heating, and Appliance Technologies*, (U.S. Department of Energy Building Technologies Office, September 2017), https://www.energy.gov/sites/prod/files/2017/09/f36/DOE-EERE-BTO-HVAC_Water%20Heating_Appliances%202017%20Impact%20Evaluation%20Final.pdf.

22. "The SunShot Initiative," Energy.gov, accessed February 8, 2019, https://www.energy.gov/eere/solar/sunshot-initiative.

23. U.S. Department of Energy (DOE), *Fiscal Year 2017 Annual Performance Report / Fiscal Year 2019 Annual Performance Plan*," (DOE Chief Financial Officer) DOE/CF-0147, https://www.energy.gov/cfo/downloads/fy-2017-doe-annual-performance-report-fy-2019-annual-performance-plan; Building Technologies Office (BTO), *Building Technologies Office Multi-Year Program Plan: Fiscal Years 2016 – 2020*, (Washington, D.C.: DOE Energy Efficiency and Renewable Energy, February 2016), 4, https://www.energy.gov/eere/buildings/downloads/multi-year-program-plan. Though not a formal GPRA target, BTO's overarching long-term goal provides a framing for all of the individual technology targets that are aimed at reducing end-use energy consumption.

24. Stephen Ezell, Robert Atkinson, and David M. Hart, "ITIF Comments Responding to Administration RFI for National Strategic Plan for Advanced Manufacturing," (Information Technology and Innovation Foundation, 2018), http://www2.itif.org/2018-comments-national-strategic-plan-advanced-manufacturing.pdf.

25. Dorothy Robyn and Jeffrey Marqusee, "Taking the Fight to Clean Energy: The U.S. Military's Investment in Energy Technology for the Warfighter and What it Means for the Rest of Us," (Information Technology and Innovation Foundation, 2019), https://itif.org/events/2019/03/05/taking-fight-energy-innovation-what-military-investment-energy-innovation.

26. CNA Military Advisory Board, "Advanced Energy and U.S. National Security," (CNA Military Advisory Board, 2017), https://www.cna.org/CNA_files/PDF/IRM-2017-U-015512.pdf.

27. Department of Energy, *Quadrennial Energy Review: Transforming the Nation's Electricity System,* (DOE Office of Energy Policy and Systems Analysis, January 2017), https://energy.gov/qer; Department of Energy, "Energy CO2 Emissions Impacts of Clean Energy Technology Innovation and Policy," (DOE Office of Energy Policy and Systems Analysis, January 2017), https://www.energy.gov/sites/prod/files/2017/01/f34/Energy%20CO2%20Emissions%20Impacts%20of%20Clean%20Energy%20Technology%20Innovation%20and%20Policy.pdf.