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“A plan to make the United States the world leader in clean energy innovation and rise to an existential challenge—creating exciting new jobs along the way.”

—John F. Kerry, 68th US Secretary of State

ENERGIZING AMERICA

**A Roadmap to Launch a
National Energy Innovation Mission**

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EXECUTIVE SUMMARY

Clean energy innovation is central to the fight against climate change. The dramatic success in lowering the costs of solar panels and wind turbines in the past decade must be replicated across a wide range of other energy technologies. Doing so will open extraordinary economic opportunities.

To rise to this challenge, the United States should launch a National Energy Innovation Mission. Led by the president and authorized by Congress, this mission should harness the nation's unmatched innovative capabilities—at research universities, federal laboratories, and private firms (both large and small), in all regions of the country—to speed the progress of clean energy technologies. To jumpstart this mission and unlock a virtuous cycle of public and private investment, the US federal government should triple its funding for energy research, development, and demonstration (RD&D) over the next five years.

Although a growing bipartisan chorus is calling for more ambitious public investment in clean energy innovation, no detailed roadmap exists for how Congress and federal agencies can most effectively increase funding. This volume aims to fill that gap. We offer policymakers a strategic framework to build a growing RD&D portfolio over the next five years, detailed funding proposals across the full spectrum of critical energy technologies, and recommendations for immediate action. In making these proposals, we have surveyed the scholarly literature, distilled decades of US historical experience,

drawn on dozens of legislative proposals, and assembled the most up-to-date database of federal clean energy RD&D funding to derive lessons for maximizing the return on public investment.

This volume has two parts. Part I makes the case that the federal government should dramatically increase funding for clean energy innovation. Part II provides a detailed roadmap for doing so.

Part I: The need to increase federal investment in clean energy innovation

Leading the world to a clean energy future is in the US national interest. Unchecked climate change endangers our security, economy, and well-being. The devastating hurricanes and wildfires of recent years are a grim foretaste of a warmer future. Although the global slowdown from COVID-19 lowered greenhouse gas emissions, they are already surging back as the world economy recovers. Averting catastrophe will require new and improved clean energy technologies to enable the world to reach net-zero emissions in the coming decades, a herculean task known as “deep decarbonization.”

The United States also stands to prosper by seizing the opportunity to lead the low-carbon industries of the future. Around the world, countries are eagerly investing in clean energy—to cut air pollution, reduce dependence on imported fossil fuels, and fight climate change. Today, China is the world leader in deploying clean energy technologies and invests heavily in clean energy innovation. The United States—with the world’s best and largest innovation system—could lead the world in clean energy innovation in the decades ahead, but not without commitment and effort.

Federal funding is critical to US energy innovation. Emerging clean energy technologies face steep barriers to market success. Risk-averse incumbent firms, byzantine regulations, and the inertia of existing infrastructure and subsidies built around fossil fuels can sink even the most promising ventures. It will take strong and sustained public RD&D investment to stimulate the massive private investment needed for deep decarbonization. Such public funding could complement near-term stimulus measures to help the economy recover from the COVID-19 crisis. RD&D investments should be paired with policies to support the market deployment and export of clean energy

technologies, so that innovative energy industries of the future sustain long-term prosperity and inclusive economic growth.

The National Energy Innovation Mission would open a new chapter in the storied history of US innovation. Federal funding has accelerated the development of life-saving drugs, modernized the military's arsenal, and put a man on the Moon. These past missions have helped make the United States the world's science and technology superpower.




By comparison, the federal government has neglected energy innovation. Prior surges in federal energy RD&D spending have been short-lived, and recent funding increases have been tepid. Today, the federal government invests less than \$9 billion per year on energy innovation, less than a quarter of what it invests in health innovation and less than a tenth of what it invests in defense innovation. The United States remains well short of meeting its international commitment under the 2015 Mission Innovation compact to double public funding for RD&D to \$12.8 billion by 2021.

This should change. The federal government should elevate energy innovation as a core national priority and fund it accordingly. Over the next five years, annual public funding for energy innovation, across a range of federal agencies, should triple to \$25 billion. A wealth of research shows that US research institutions and private firms are capable of absorbing this scale of federal support and translating it into rapid technological progress—delivering economic returns that far outstrip public investments.

Part II: A National Energy Innovation Mission

Federal policymakers should develop a strategy for ramping up federal funding to most effectively invest in clean energy innovation—and take swift action to set this strategy in motion (Figure ES-1). To prioritize funding, they should build RD&D programs around ten technology pillars, each representing a critical challenge for deep decarbonization. In addition, as policymakers design and execute these programs, they should heed six principles that will maximize the effectiveness of federal investments. And following the inauguration in 2021, the next Congress and administration should take three immediate actions to launch the National Energy Innovation Mission.

FIGURE ES-1: Strategic and tactical guidance to the next administration and Congress

Technology Pillars	Strategic Principles	Immediate Actions
<div>1</div> Foundational science & platform technologies	<div>1</div> Match the funding portfolio to critical decarbonization needs	<div></div> <div>1</div> The President should launch the National Energy Innovation Mission
<div>2</div> Clean electricity generation	<div>2</div> Support all stages of the innovation pipeline	
<div>3</div> Advanced transportation systems	<div>3</div> Marshal the full capacity of the federal government	<div></div> <div>2</div> Congress should increase energy RD&D funding by 30% in FY22
<div>4</div> Clean fuels	<div>4</div> Harness the innovative capacity of National Laboratories, universities, and the private sector	
<div>5</div> Modern electric power systems	<div>5</div> Partner with state & local governments to support regional innovation	<div></div> <div>3</div> The United States should reassert international leadership on energy innovation
<div>6</div> Clean and efficient buildings	<div>6</div> Set predictable long-term funding targets, while adapting to new data	
<div>7</div> Industrial decarbonization		
<div>8</div> Carbon capture, use, & sequestration		
<div>9</div> Clean agricultural systems		
<div>10</div> Carbon dioxide removal		

Tripling the federal energy RD&D budget over five years will enable the United States to pursue the full deep decarbonization innovation agenda. The federal government’s current energy RD&D portfolio focuses heavily on clean electricity generation—only one of the ten technology pillars. Organizing the National Energy Innovation Mission around all ten will significantly improve

the prospects for rapid progress on a wide range of technologies. Few of these technologies have yet achieved widespread commercial success anywhere in the world, so the United States has an opportunity to lead in nascent and growing markets including carbon capture and storage, digital energy technologies, long-duration grid energy storage, advanced transportation technologies, and clean fuels such as hydrogen. For each of the pillars, we propose specific federal government initiatives.

In shaping the energy RD&D portfolio as it grows to \$25 billion annually by 2025 (that is, by Fiscal Year 2026, which begins October 1, 2025), policymakers should follow six strategic principles. The first five call for diversification—across topics, stages of innovation, federal agencies, research partners, and regions of the United States. In addition to covering all ten technology pillars, federal energy RD&D investments should cover the entire innovation pipeline from early-stage research to commercial-scale demonstration projects. They should expand beyond the Department of Energy (DOE) and its National Laboratories (Figure ES-2). Although DOE and the Labs will continue to provide core expertise on energy innovation, Congress should also provide growing funding for energy innovation at the Departments of Defense (DOD) and Agriculture (USDA), the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), and other federal agencies. Participating agencies should invest across the innovation ecosystem, from federal labs to universities to private ventures, and partner with local and state governments to build regional clusters of excellence. Finally, the sixth principle recommends a strategy for managing the portfolio over time: Policymakers should adopt long-term funding targets but adapt the portfolio over time as circumstances change and as they learn from experience.

In recent years, bipartisan momentum has grown in support of energy innovation investments, providing a window of opportunity. The 117th Congress and the presidential administration that will be sworn in in 2021 should take immediate action to set the National Energy Innovation Mission in motion by taking three concrete steps.

First, the president should issue a Presidential Policy Directive announcing the National Energy Innovation Mission, establishing energy innovation as a national priority, setting a goal of tripling federal funding for energy innovation in five years, and creating a White House Task Force to coordinate

among agencies and speed implementation. (A draft of a Presidential Policy Directive is included as Appendix A.) Second, the next Congress should pass an ambitious budget for Fiscal Year 2022 (FY22) that sharply increases federal energy RD&D funding—focusing particularly on currently underfunded technology pillars—and sets the United States on a path to tripling the budget by 2025. (Figure ES-3 outlines a specific proposal for the FY22 energy innovation budget, summarizing the line-item recommendations in Table ES-1 to congressional appropriators for funding each agency and office.) Third, the United States should immediately reassert its international leadership by recommitting to Mission Innovation, courting bilateral collaborations to advance energy technologies, and stimulating a competitive race-to-the-top to raise global public funding for clean energy innovation.

FIGURE ES-2: Historical clean energy RD&D funding by federal agency and proposal to ramp up to an annual clean energy innovation budget of \$25 billion by 2025

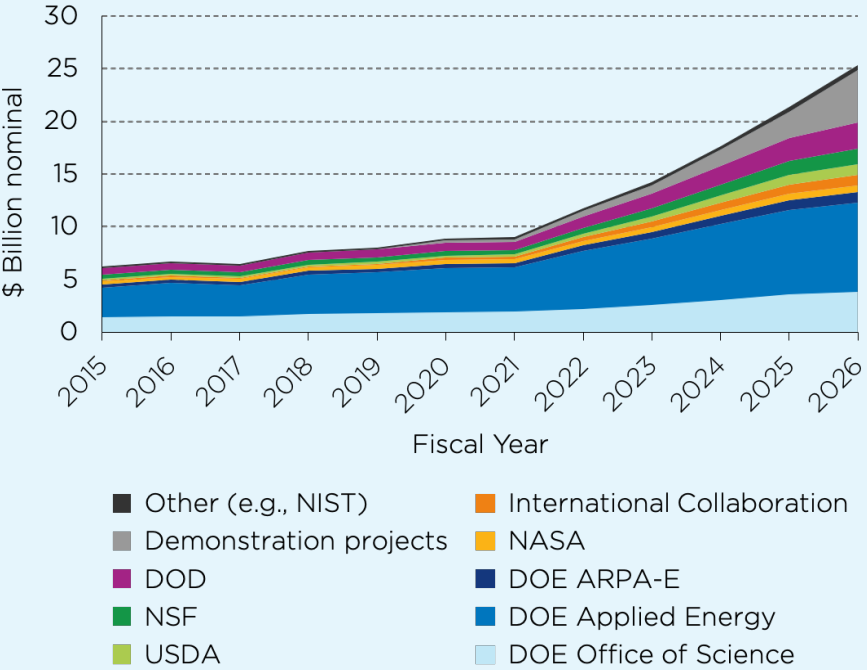
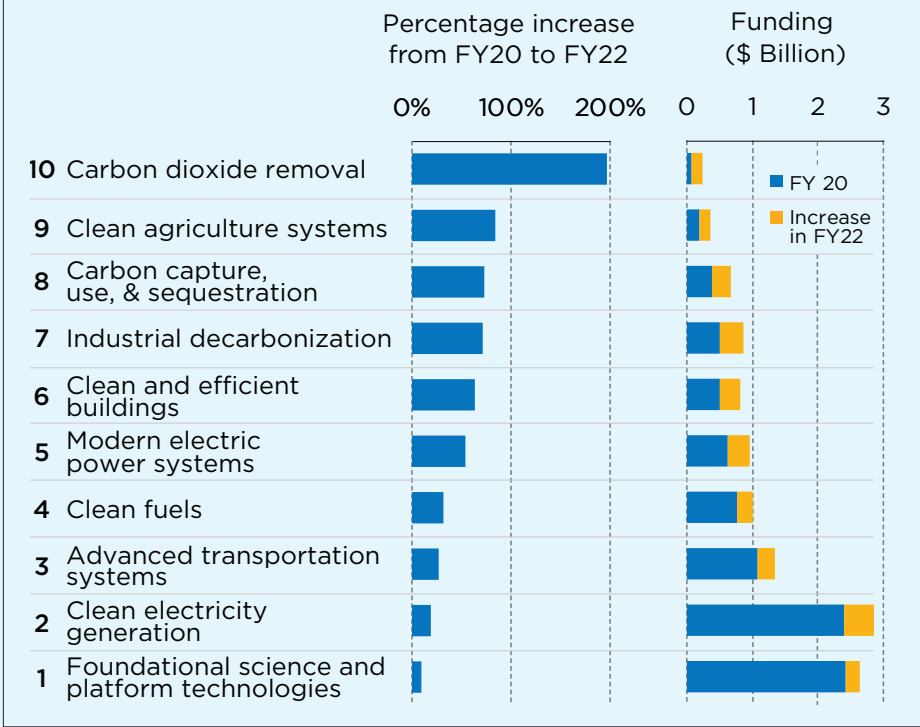


FIGURE ES-3: Proposed FY22 federal energy innovation budget by technology pillar, compared with FY20 levels



These three immediate actions will launch the next national innovation mission. The United States has a proud history of rising to global challenges by unleashing its potential to innovate. If policymakers decisively invest in the clean energy technologies of the future and sustain that investment, history will repeat itself. On the heels of the global coronavirus crisis, the United States will lead the response to an even graver global threat—climate change—and prosper as the world transitions to clean energy.

TABLE ES-1: Proposed FY22 federal energy innovation budget, by agency and office (\$ millions)

Funding Agency	Funding Office/Organization	FY 2020 Est.	FY 2022 Proposed	% change
Dept. of Energy	Energy Efficiency and Renewable Energy (EERE)	2,228	2,682	20%
	Vehicle Technologies Office (EERE/VTO)	396	488	
	Bioenergy Technologies Office (EERE/BETO)	260	320	
	Hydrogen & Fuel Cell Technologies Office (EERE/HFTO)	150	185	
	Solar Energy (EERE/SETO)	280	303	
	Wind Energy (EERE/WETO)	104	113	
	Water Power (EERE/WPTO)	148	160	
	Geothermal Technologies Office (EERE/GTO)	110	170	
	Adv. Manufact. Office (EERE/AMO)	350	432	
	Building Technologies Office (EERE/BTO)	230	301	
	Office of Carbon Management (CM)*	472	812	72%
	Carbon Capture (Power & Industrial)	115	300	
	Carbon Utilization	21	25	
	Carbon Storage	79	120	
	Adv. Energy Systems/Crosscutting	123	150	
	Negative Emissions Technologies (new office)	--	75	
	Methane Leak Detection & Mitigation	18	22	
	Office of Nuclear Energy (NE)	1,493	2,028	36%
	Versatile Test Reactor	65	450	
	Reactor Concepts RD&D	102	163	
	Fuel Cycle R&D	305	255	
	Advanced Reactor Research, Development and Demonstration	330	520	
	Office of Electricity (OE)	190	520	174%
	Office of Science (SC)	2,151	2,572	20%
	Advanced Scientific Computing Research (SC/ASCR)	173	200	

(continued from previous page)

Funding Agency	Funding Office/Organization	FY 2020 Est.	FY 2022 Proposed	% change
Dept. of Energy	Biological and Environmental Research (SC/BER)	451	523	
	Basic Energy Sciences (SC/BES)	661	766	
	Fusion Energy Sciences (SC/FES)	671	740	
	Advanced Research Projects Agency-Energy (ARPA-E)	425	516	21%
	Subtotal, DOE	6,959	9,130	31%
Dept. of Agricult.	Agriculture Advanced Research and Development Authority (AGARDA)		50	
	Agricultural Research Service (ARS)	99	158	
	NIFA Agriculture and Food Research Initiative (NIFA/AFRI)	106	169	
	Subtotal, USDA	205	377	83%
Dept. of Defense	U.S. Army Research Laboratory (ARL)	155	202	
	U.S. Naval Research Laboratory (NRL)	97	127	
	U.S. Air Force	254	332	
	Other (Defense-Wide, DARPA, ESTCP)	298	391	
	Subtotal, DOD	804	1,053	31%
NASA		339	394	16%
National Science Fndn.	Biological Sciences (BIO)	54	75	
	Computer and Information Science and Engineering (CISE)	24	34	
	Engineering (ENG)	156	219	
	Directorate for Mathematical and Physical Sciences (MPS)	162	227	
	Other NSF	21	29	
	Subtotal, NSF	804	1,053	31%
Other (NIST, NOAA, USGS, FHWA, EPA-ORD)		169	221	31%
Total	N/A	8,894	11,758	32%

**This is the proposed new name for the current Office of Fossil Energy
FY 2020 funding levels for non-DOE programs are estimates of the portion of funding that goes to clean energy / clean agriculture. Agency and Office totals include estimates of program direction and RD&D facilities (not shown in the table) and may be greater than the sum of RD&D programs.*

About the Authors

Dr. Varun Sivaram is a Senior Research Scholar at the Center on Global Energy Policy at Columbia University and a faculty affiliate of its Data Science Institute. A physicist, bestselling author, and clean energy technology expert, his experience spans the corporate, public, and academic sectors. Most recently, as Chief Technology Officer of ReNew Power, Dr. Sivaram led research and development for a multibillion-dollar company recognized as India's largest producer of renewable energy as well as its most innovative energy company. His corporate experience also includes consulting for McKinsey & Co., and he serves as senior advisor to Camus Energy and Radia, Inc., and as advisory board member to Glint Solar. Dr. Sivaram has also shaped government policies supportive of innovation as the director of the energy and climate program at the Council on Foreign Relations and as a senior energy advisor to the Los Angeles mayor and New York governor's office. A widely published scientist and innovation scholar, he serves on the boards of Stanford University's energy and environment institutes, as a senior fellow at the Aspen Institute and Information Technology and Innovation Foundation, and previously as professor at Georgetown University where he created the course "Clean Energy Innovation" to train the next generation of energy leaders. He is one of the 25 advisors to the UN COP26 climate conference in 2021 and serves on the World Economic Forum's Global Future Council for the Energy Transition. His books include *Taming the Sun: Innovations to Harness Solar Energy and Power the Planet* (MIT Press, 2018) and *Digital Decarbonization: Promoting Digital Innovations to Advance Clean Energy Systems* (CFR Press, 2018). TIME Magazine named him one of the TIME 100 Next most influential people in the world. A Rhodes and Truman Scholar, he holds a Ph.D. in condensed matter physics from Oxford University and undergraduate degrees from Stanford University.

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The History and Future of the Clean Energy Ministerial (2016). Other works include *Plug-In Electric Vehicles: What Role for Washington?* (2009) (editor), *U.S.-China Cooperation on Climate Change* (2009) (co-author) and *Freedom from Oil* (2008). Mr. Sandalow is a member of the Innovation for Cool Earth Forum (ICEF) Steering Committee and chair of ICEF Innovation Roadmap Project. He serves as a director of Fermata Energy. Mr. Sandalow is a member of the Zayed Future Energy Prize Selection Committee, Global CO₂ Initiative Advisory Board, Electric Drive Transport Association's "Hall of Fame" and Council on Foreign Relations. Mr. Sandalow is a graduate of the University of Michigan Law School and Yale College.

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