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Federal Energy RD&D: Grid Modernization

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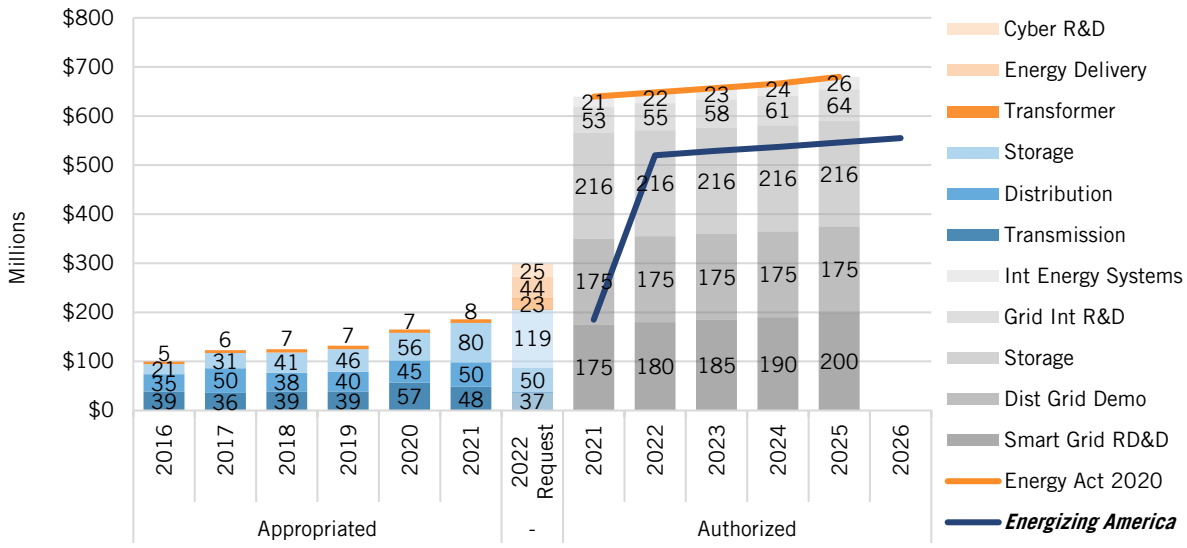
The grid modernization research, development, and demonstration (RD&D) programs in the Office of Electricity (OE) seek to accelerate discovery and innovation in electricity transmission, storage, and distribution technologies so that they incorporate greater levels of distributed and variable energy resources, provide enhanced connectivity between systems and devices, and improve reliability and resilience. OE aspires 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 the 2021 winter storm in Texas. The OE-funded RD&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.[2]

Figure 1: The Energy Act of 2020 proposes new grid modernization RD&D programs, roughly in line with recommendations from *Energizing America*.[3]



What's at Stake

Electricity is fundamental to our daily lives, and also the economy. But the U.S. electricity system faces a number of critical challenges, even as the nation becomes more reliant on electric power: aging infrastructure that needs to be updated; increasing frequency of extreme weather events and billion-dollar disasters; greater proliferation of distributed energy resources, demand-side resources, and two-way power flows; digitization and integration of smart appliances and other connected devices that interact with the grid; and a changing generation profile marked by greater reliance on variable generation.[4] At the same time, the grid must rapidly decarbonize and expand to enable the decarbonization of other key sectors.[5] Grid modernization is key to addressing these challenges and enabling the power system of the future.[6]

In collaboration with the utility industry, the Department of Energy (DOE) in 2015 established the Grid Modernization Initiative to coordinate research and development (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) was created.[7] For its part, DOE set targets and performance measures in reliability and resilience, as well as cost and performance targets for new grid storage technologies, to pursue by 2020.[8] However, DOE has not updated this roadmap since 2015, despite congressional pressure to do so. In March 2021, the National Academies of Sciences, Engineering, and Medicine (NASEM) released *The Future of Electric Power in the United States,* which develops recommendations to DOE, Congress, and state and utility stakeholders to address critical needs for grid modernization.[9]

As electricity from variable wind and solar takes greater shares in the U.S. power grid, the need for flexible energy storage technologies increases. Energy storage can decrease grid variability and help balance electricity supply and demand during periods when the sun is not shining or the wind is not blowing. A report by the Information Technology and Innovation Foundation (ITIF) finds that low-cost, long-duration energy storage technologies at grid scale are needed if renewables are to fully displace carbon-emitting fossil fuels.[10] DOE has been ramping up its work in grid-scale energy storage. On March 10, 2021, DOE announced the construction of the Grid Storage Launchpad at the Pacific Northwest National Laboratory (PNNL) to enable development, testing, and evaluation of batteries and other storage technologies for grid applications.[11] The Grid Storage Launchpad will also support DOE's Energy Storage Grand Challenge, a program to accelerate the development of domestically manufactured energy storage technologies.[12]

Smart grid technologies—e.g., technologies that allow for enhanced sensing and control of grid elements, enable two-way communication between the grid and other infrastructures, use more powerful computer processing, and have finer control systems—can support renewables integration and enable increased energy efficiency, reliability, and security.[13] While DOE's Grid Modernization Initiative roadmap identifies several smart-grid-related artificial intelligence applications, an updated roadmap that includes a smart grid RD&D agenda is needed.

There are currently no active federal programs that support the deployment of smart grid infrastructure. The American Recovery and Reinvestment Act of 2009 included $3.4 billion for the Smart Grid Investment Grant (SGIG) program, which provided funding for the deployment of smart meters, distribution automation systems, advanced sensors known as Phasor Measurement Units (PMUs), and customer systems such as smart applications and building energy management systems.[14] Smart meters, which track and communicate real-time energy usage, have been critical to expanding participation in demand response programs and giving utility customers greater insight and control over their energy consumption.[15] While the first SGIG program nearly doubled the number of smart meters installed, nearly half of U.S. customers still lack smart meters.[16] No similar programs have been established since SGIG ended.

The Energy Act of 2020 includes the Grid Modernization R&D Act, which establishes a smart grid regional demonstration initiative; a program on smart grid modeling, sensing, visualization, architecture development, and advanced operation and control; a program to enhance grid resilience and strengthen emergency response; a program to develop hybrid energy systems; a program for renewable energy, electric vehicles, and buildings integration onto the electric grid; and new programs for technology demonstrations on the distribution grid, micro-grid, and

integrated micro-grid systems. It provides separate authorizations for each program for FY 2021 through FY 2025, as depicted in figure 1.[17] The bill also includes the Better Energy Storage Technology (BEST) Act, which authorizes the creation of a cross-cutting RD&D program within DOE for energy storage technologies across multiple timescales—from hourly and sub-hourly to seasonal. DOE is required to carry out three energy storage demonstration projects, including at least one project for storage technologies that have the capacity to discharge energy for 10 to 100 hours at minimum, or have the capability to address seasonal variations in supply and demand. Moreover, the act establishes a joint long-term demonstration initiative with the Department of Defense (DOD), and an energy storage materials recycling R&D program.[18]

Figure 1 shows historical DOE investment in grid modernization RD&D by subprogram for FY 2016 through FY 2021. The blue line shows recommended funding levels from the *Energizing America* report (see box 1). The orange line shows authorized funding levels from the Energy Act of 2020, which are roughly in line with *Energizing America* recommendations.

Box 1: An Innovation Agenda for Grid Modernization

The *Energizing America* report coauthored by the Information Technology and Innovation Foundation (ITIF) and Columbia University's Center on Global Energy Policy offers several recommendations for grid modernization. Similarly, ITIF's March 2021 report "How Congress and the Biden Administration Could Jumpstart Smart Cities with AI" and November 2018 report "Making 'Beyond Lithium' a Reality: Fostering Innovation in Long-Duration Grid Storage" make recommendations to DOE and Congress to accelerate the adoption of smart grid technologies:

- Congress should appropriate full funding for the grid modernization and energy storage R&D and demonstration projects authorized in the Energy Act of 2020. [19]
- Congress should establish a DOE research program on recycling lithium, cobalt, and other materials used in energy storage in order to reduce supply chain risks and dependence on imports. DOE recently launched a new battery-critical minerals recovery and recycling research initiative under its existing authorities; and Congress should pass authorizing legislation to provide greater direction and long-term budget certainty for the new program.
- Congress should revive the SGIG program to support the deployment of advanced metering infrastructure and other smart grid investments.[20]
- Congress should increase funding for RD&D in high-voltage direct current (HVDC) transmission, including advancing power electronics and converter and conductor technologies, and demonstrating meshed networks of HVDC lines.[21]

- DOE should update its Grid Modernization research plan to include artificial intelligence applications identified in the Grid Modernization Multi-Year Program Plan. DOE has not updated its research plan since 2015, leaving the smart grid research agenda uncoordinated with different technology programs.[22]
- DOE and DOD should launch a joint storage demonstration program to leverage and coordinate research in high-energy-density storage media.[23]

Grid Modernization RD&D Subprograms

Grid modernization RD&D is made up of four main subprograms:[24]

- **Transmission Reliability and Resilience** focuses on ensuring the reliability and resilience of the electric grid through RD&D on measurement and control of the electrical system, and risk assessments to address challenges across integrated energy systems.
- **Resilient Distribution Systems** pursues strategic RD&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** supports modernization, hardening, and resilience of grid components, including transformers, power lines, and substation equipment.

Key Elements of the FY 2022 Budget Proposal[25]

The budget proposal seeks $327 million for grid modernization RD&D activities, a 54 percent boost from FY 2021 enacted levels. Some highlights include:

- **A new $25 million Cyber R&D subprogram,** which focuses specifically on cybersecurity R&D for electricity delivery systems. The Office of Cybersecurity, Energy Security, and Emergency Response retains the lead responsibility for crosscutting cybersecurity issues that go beyond electricity delivery systems.
- **No change to the Resilient Distribution Systems subprogram,** with continued funding for distribution sensors R&D activities; support for a Balance-Centric Grid Funding Opportunity Announcement targeting DERs and storage; funding for competitively selected projects that develop and demonstrate innovative technologies to enhance distribution systems resilience to physical hazards and support decarbonization goals; no new funding for the National Test Bed Laboratory for Coordinated Management of Microgrids and Networked Distributed Energy Resources (COMMANDER) as this was fully funded in FY 2021; and continued funding for the Situational Awareness Network (SAN) activities.

- **A 49 percent increase in the Energy Storage subprogram,** with $24 million to complete funding for the construction and commissioning of the Grid Storage Launchpad facility at PNNL. Funding for other RD&D activities within this subprogram would be increased by $15 million, with a focus on demonstration of next-generation storage technologies (battery and non-battery) for grid applications and the validation and demonstration of long duration (6+ hours) energy storage technologies.
- **A 23 percent decrease in Transmission Reliability and Resilience subprogram,** primarily due to the completion of funding for the North American Energy Resilience Model (NAERM) Phase II development. Funding will now focus on sensor research, data analytics, and software tool development to improve transmission system flexibility and reliability. Funding will also support a new university-based Engineering Research Center, which would focus on fundamental research on the electric power system.
- **A 2 percent increase in Transformer Resilience and Advanced Components,** including an additional $15 million to expand R&D on solid-state power substations (SSPS)—which has the potential of greater standardization and improved resilience of grid components and systems—with a focus on developing modeling and testing capabilities, and establishing a consortium to lead SSPS technology development efforts.
- **A new $44 million Energy Delivery Grid Operations Technology subprogram,** which focuses on bringing technologies from R&D to operation. This subprogram would support the operation and maintenance of the NAERM platform, which has been fully funded by the Transmission Reliability and Resilience subprogram and is ready for operation. It also provides operational support and expansion of SAN transitions from the Resilient Distribution subprogram.

Further Reading

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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.
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