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DOE's Office of Electricity Delivery and Energy Reliability (OE): A Primer, with Appropriations for FY2017

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Summary

The nation's energy infrastructure is undergoing a major transformation. For example, new technologies and changes in electricity flows place increasing demands on the electric power grid. These changes include increased use of distributed (mostly renewable energy) resources, Internet-enabled demand response technologies, growing loads from electric vehicle use, continued expansion of natural gas use, and integration of energy storage devices.

The Department of Energy's (DOE's) Office of Electricity Delivery and Energy Reliability (OE) has the lead role in addressing those infrastructure issues. OE is also responsible for the physical security and cybersecurity of all (not just electric power) energy infrastructure. Further, OE has a key role in developing energy storage, supporting the grid integration of renewable energy, and intergovernmental planning for grid emergencies. As an illustration of the breadth of its activities, OE reports that, during FY2014, its programs responded to 24 energy-related emergency events, including physical security events, wildfires, severe storms, fuel shortages, and national security events.

OE manages five types of research and development (R&D) programs, usually conducted in cost-shared partnership with private sector firms. OE also operates two types of deployment programs, conducted mainly with state and tribal governments. Each OE program office has its own set of goals and objectives. OE plays the central role in two of DOE's broad cross-cutting initiatives: grid modernization and cybersecurity. President Obama treated grid modernization as a high priority, stressing its importance to jobs, economic growth, and U.S. manufacturing competitiveness.

Since 2005, the Energy and Water Development (E&W) appropriations bill has funded all DOE programs, including those operated by OE. DOE's FY2017 request for OE sought $262 million, an increase of $56 million (27%) over the FY2016 appropriation of $206 million.

Most congressional action for FY2017 OE funding has taken place through the two E&W appropriations bills, S. 2804 and H.R. 5055. In the Senate, S. 2804 was incorporated into H.R. 2028 as an amendment in the nature of a substitute, and it was approved on the Senate floor. That Senate-passed FY2017 E&W bill included $206 million for OE—the same amount as the FY2016 appropriation. In the House, H.R. 5055 was defeated in House floor action. That bill had included $225 million for OE, which was the amount recommended by the House Appropriations Committee. In late September 2016, a continuing resolution (P.L. 114-223, Division C) set FY2017 funding for OE at the FY2016 level through December 9, 2016. On December 10, 2016, a second continuing resolution (CR) provided funding at the FY2016 level through April 28, 2017.

Most of DOE's requested FY2017 increase for OE aimed to create three new programs: a Grid (Manufacturing Innovation) Institute, a State Distribution Level Reform program, and a state Energy Assurance program. The House Appropriations Committee's report on FY2017 E&W funding does not mention those proposed programs. The Senate Appropriations Committee's report on FY2017 E&W funding expressed support for the regional and state activities that DOE proposed for two of the new programs, but encouraged DOE to support those activities with some of the funding it recommended for the OE Infrastructure Security and Energy Restoration program. Neither the first nor the second CR included funding for any of the proposed new programs.

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Background

The federal government first supported a program for energy storage and electric power system technology during the 1970s, before the establishment of the Department of Energy (DOE).[1] In those early days, the program was focused mainly on energy storage—especially to even out the variable power production from rapidly growing use of wind and solar technologies—but also to support large coal and nuclear power plants. The advancement of computer capacity, miniaturization, and industrial controls has expanded the ability of grid operators to monitor and control electric power flows. The subsequent increase in networking of computerized devices for grid data collection and control advanced the ability of operators to anticipate, avoid, and otherwise mitigate potential power crises, such as blackouts. However, in more recent years, Internet-connected networks have become vulnerable to unwanted computer-driven intrusions and disruptions, revealing a new cybersecurity challenge for electric power systems.

The nation's energy infrastructure is diverse. It includes a variety of transmission and distribution system network structures (electricity, oil, and natural gas), an array of operating models (public and private), and a variety of hardware and software. The energy sector consists of thousands of electricity, oil, and natural gas assets[2] that are dispersed geographically. Thus, interdependency within the sector and across the nation's critical energy infrastructure sectors is significant. Coordinating the security and resilience of energy assets is complicated by the virtually borderless nature of energy use and the reliance on predominantly privately-owned infrastructure.

Key challenges and opportunities facing the electric power industry include a changing power generation mix, replacing aging infrastructure (transmission, storage, distribution, and generation); modernizing and securing communication networks (e.g., analog to digital); accommodating new end-use technologies (for solar and other distributed resources); planning for increased interdependencies of natural gas, water, and electricity systems; and devising business models to manage the challenges while providing reliable and affordable electricity. These activities are constrained by the need for cost control, physical security, cybersecurity, improved system resiliency, and the flexibility to adapt to weather and market uncertainties. Further opportunities arise from growing use of shale gas production and decreasing costs for information technologies which allow improved grid control and more opportunities for customer management of power use.

Office Organization and Strategy

Mission

The DOE Office of Electricity Delivery and Energy Reliability (OE) is charged with a mission to support more economically competitive, environmentally responsible, secure, and resilient U.S. energy infrastructure.[3] To achieve that mission, OE supports electric grid modernization and resiliency through research and development (R&D), demonstration projects, partnerships, facilitation, modeling and analytics, and emergency preparedness and response. OE is the federal government's lead entity for energy sector-specific responses to national energy security

[1] DOE was created by the DOE Organization Act (P.L. 95-91), and began operating in 1978.

[2] The largest assets are energy production facilities, pipelines, and transmission lines.

[3] This mission is cited in Strategic Objective 2 of the DOE Strategic Plan.

emergencies which are due to either hardware (infrastructure) or software (cybersecurity) problems.

OE leads DOE's efforts to strengthen, transform, and improve our energy infrastructure so that consumers have access to reliable, secure, and clean sources of energy. To accomplish this mission, the Office works with a variety of stakeholders, including private industry and federal, state, local, and tribal governments on a variety of initiatives to modernize the electric grid. Grid modernization is needed to address aging infrastructure, achieve public policy objectives, sustain economic growth, support environmental stewardship, and mitigate risks. OE's goal for the future grid is to support economic growth and energy innovation through delivery of reliable, affordable, and clean electricity to consumers where, when, and how they want it.[4]

Activities

The largest share of OE funding (e.g., about 80% of the FY2016 appropriation) goes to R&D on technology development. The remainder of OE funding (e.g., about 20% of the FY2016 appropriation) goes to a variety of planning and other operational areas. OE divides these responsibilities into five general areas:

- R&D and Deployment—pursues technologies to improve grid reliability, efficiency, flexibility, functionality, and security. OE makes investments and sponsors demonstration projects to help bring new and innovative technologies to maturity and to help the technologies transition to market. Much of this activity takes place through partnerships with private firms that provide matching funds.
- Modeling and Analytics—develops core analytic, assessment, and engineering capabilities that can evolve as the technology and policy needs mature to support decisionmaking within DOE and for stakeholders. Also OE supports analyses to explore complex interdependencies among infrastructure systems, such as between electricity and natural gas systems.
- Institutional Support and Technical Assistance—builds capacity in industry and convenes stakeholders to coordinate grid transformation efforts. Also, OE provides technical assistance to states and regions to improve policies, utility incentives, state laws, and programs that facilitate modernization of electric infrastructure.
- Coordination of Federal Transmission Permits—streamlines permits, special use authorizations, and other approvals required under federal law to site electric transmission facilities.
- Emergency Preparedness and Response—pursues enhancements to the reliability, survivability, and resiliency of energy infrastructure, and facilitates faster recovery from disruptions to energy supply.[5]

Organizational Structure

In 2007, DOE established an independent Assistant Secretary for OE and, thereby, elevated the office to an administrative status equal to that for the major energy technologies (nuclear, fossil,

[4] DOE, *FY2016 Budget in Brief*, p. 32.

[5] DOE, *FY2017 Congressional Budget Request (vol. 3)*, pp. 327-328,

renewables).[6] OE currently has five deputy assistant secretaries, each of whom reports to the Assistant Secretary. The corresponding five offices are: Power Systems Engineering R&D, National Electricity Delivery, Infrastructure Security and Energy Restoration, Energy Infrastructure Modeling and Analysis, and Advanced Grid Integration.[7]

Strategy and Planning

OE's mission is guided mainly by two key DOE planning documents: the *Quadrennial Technology Review* and the *Grid Modernization Multi-Year Program Plan*.

DOE Quadrennial Technology Review

DOE's second (2015) Quadrennial Technology Review (QTR) outlined key elements of the department's strategy for grid modernization. The report concluded that:

> Fundamental changes in both supply and demand technologies are placing new requirements on the electric power system... Accompanying these changes is a convergence of digital communications and control systems ("smart grid" technologies) to improve performance and engage consumers... These trends create new technical requirements for a grid that is more flexible and agile, with the ability to dynamically optimize grid operations in near-instant time frames."[8]

Further, from DOE's cross-cutting programs viewpoint, the report stressed the R&D aspects of grid modernization:

> The electric grid is transitioning from a centrally-controlled, predictable system with one-way power flows in distribution to a much more distributed, stochastic, and dynamic system with bi-directional flows in distribution... Grid-related technologies need to evolve with the changing supply and end-use technologies landscape. Simultaneously, the RDD&D [research, development, demonstration, and deployment] associated with technologies that connect to the grid (e.g., renewable power supplies, efficient motor controllers, and smart loads) should consider the evolving interface with the grid. If electricity displaces petroleum and natural gas in electric vehicles and heating applications, respectively, the grid may serve an even more central role in the future energy system.[9]

Grid Modernization Multi-Year Program Plan (MYPP)

DOE's 2015 *Grid Modernization MYPP* describes its vision for "a future electric grid that provides a critical platform for U.S. prosperity, competitiveness, and innovation by delivering reliable, affordable, and clean electricity to consumers where they want it, when they want it, how they want it."[10] To help achieve this vision, DOE aims at three key national targets:

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[6] Prior to that time, OE programs had been managed as a minor program office under the Office of the Secretary and under the Office of Energy Efficiency and Renewable Energy (EERE).

[7] For more details about the OE organizational structure, see DOE, Office of Electricity Delivery and Energy Reliability, Our Organization, http://energy.gov/oe/about-us/our-organization.

[8] DOE, *QTR 2*, Summary and Conclusions, p. 416, http://energy.gov/sites/prod/files/2015/09/f26/Quadrennial-Technology-Review-2015_0.pdf.

[9] *QER 2*, p. 425.

[10] DOE, *Grid Modernization Multi-Year Program Plan (MYPP)*, November 2015 (released January 14, 2016), Executive Summary, p. xi, http://energy.gov/sites/prod/files/2016/01/f28/Grid%20Modernization%20Multi-Year%20Program%20Plan.pdf.

- A 10% reduction in the economic costs of power outages by 2025.
- A 33% decrease in the cost of reserve margins while maintaining reliability by 2025.
- A 50% decrease in the net integration costs of distributed energy resources by 2025.[11]

Progress toward the targets will be assessed by looking at RD&D efforts in individual technical areas and by looking at three integrated demonstrations, referred to in the MYPP as "major technical achievements." They are: (1) a transmission and distribution system operating reliably on a lean reserve margin,[12] (2) resilient distribution feeders[13] with high percentages (50%) of low-carbon distributed energy resources, and (3) an advanced modern grid planning and analytics platform.[14] The MYPP states that multiple demonstrations will be conducted across various regions of the country to underpin these "major technical achievements."[15]

Administration Perspective and Goals

OE programs are aligned with the Obama Administration's priorities, as documented in *A Policy Framework for the 21st Century Grid: Enabling Our Secure Energy Future* (June 2011),[16] the *President's Climate Action Plan* (June 2013),[17] and other DOE efforts to address energy infrastructure needs and challenges. The FY2017 OE request aimed to support the Obama Administration's "all-of-the-above" energy strategy and emphasized priorities that increase electric grid resilience—through managing risks, increasing system flexibility and robustness, increasing visualization and situational awareness, and deploying advanced control capabilities.

OE Funding History

Spending History in Context

Historically, electric systems technology development programs have supported all four major types (nuclear, fossil, renewable, efficiency) of energy technology. For most of DOE's funding history, OE programs received a relatively small portion of funding, compared to the portion provided for the energy technology programs.[18]

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[11] DOE, *Grid Modernization Multi-Year Program Plan*, November 2015, p. 12.

[12] Reserve margin is a measure of available electric power generation capacity over and above the capacity needed to meet normal peak demand levels. Reserve margin and reserve capacity are synonymous. For a producer of energy, it refers to the capacity of a producer to generate more energy than the system normally requires.

[13] A feeder is a power conductor with a high current carrying capacity. A feeder distributes power from a substation to end-use consumers. No circuit tappings are taken from the feeders. The feeder current always remains constant.

[14] DOE, *MYPP, Executive Summary*, pp. xiv-xv.

[15] DOE, *MYPP,* November 2015, Executive Summary, p. xi.

[16] Executive Office of the President (National Science and Technology Council), *A Policy Framework for the 21st Century Grid: Enabling Our Secure Energy Future,* June 2011, https://www.whitehouse.gov/sites/default/files/microsites/ostp/nstc-smart-grid-june2011.pdf.

[17] Executive Office of the President, *The President's Climate Action Plan*, June 2013, https://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf.

[18] From FY1948 through FY1977 the federal government provided an extensive amount of R&D support for fossil energy and nuclear power technologies. The energy crises of the 1970s spurred the federal government to expand its R&D programs to include renewable (wind, solar, biomass, geothermal, hydro) energy and energy efficiency (continued...)

Recovery Act Funding

However, the OE program received a major one-time boost in funding—$4.5 billion—from the American Recovery and Reinvestment Act of 2009 (Recovery Act, P.L. 111-5).[19] The funding was targeted for "grid modernization." Thus, much of it was used to provide grants to the electric utility industry to deploy smart grid technologies to modernize the electric grid. As a part of these programs, independent system operators (ISOs), regional transmission organizations (RTOs), and electric utilities installed about 1,100 synchrophasors[20] and other related technologies in their electric power transmission systems.[21] That deployment of synchrophasors, however, covered only a small portion of the total national grid.

Funding Comparison with Energy Technologies

Figure 1 provides a condensed visual summary of the relative portion of funding for electric systems in three different historical time periods.

(...continued)

technologies. In real (constant dollar) terms, funding support for all four of the main energy technologies skyrocketed during the 1970s to a combined peak in FY1979. Funding then dropped steadily, leveling off during the late 1990s. Since then, funding has increased gradually—except that the Recovery Act provided a one-year spike in FY2009. More details about DOE—and earlier (pre-1978)—spending for energy technologies are available in CRS Report RS22858, *Renewable Energy R&D Funding History: A Comparison with Funding for Nuclear Energy, Fossil Energy, and Energy Efficiency R&D*, by (name redacted)

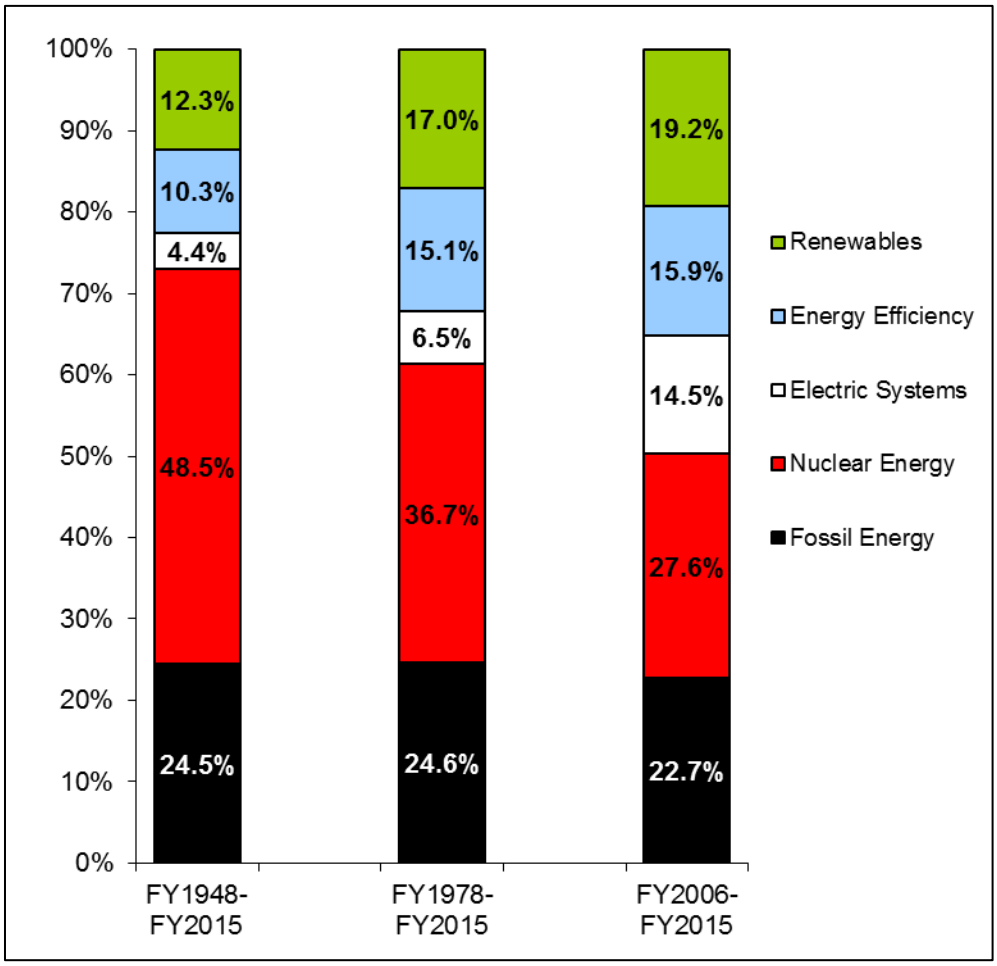
[19] The Recovery Act funding supported smart grid activities that were authorized primarily by Title 13 of the Energy Independence and Security Act of 2007 (EISA, P.L. 110-14).

[20] A synchrophasor is an advanced power monitoring and control device. It is also referred to as a phasor measurement unit (PMU).

[21] DOE, OE, *Synchrophasor Technologies and the Deployment in the Recovery Act Smart Grid Programs*, August 2013, https://www.smartgrid.gov/files/Synchrophasor_Report_08_09_2013_DOE_2_version_0.pdf. For a brief discussion about synchrophasors, see the section below on Clean Energy Transmission and Reliability.

Figure 1. DOE Energy Technology R&D Program Funding Shares: Comparison over Three Time Periods

(Chart taken from CRS Report RS22858)



Source: DOE *Budget Authority History Table by Appropriation*, May 2007; DOE Congressional Budget Requests (several years); DOE (Pacific Northwest Laboratory), *An Analysis of Federal Incentives Used to Stimulate Energy Production*, 1980; DOE Conservation and Renewable Energy Base Table. February 1990. Deflator Source: *The Budget for Fiscal Year 2016*. Historical Tables. Table 10.1.

Notes: Column to far left shows shares for the period FY1948-FY2015; middle column shows shares for period from FY1978-FY2015; and far right column shows shares for period from FY2006-FY2015.

Recent Appropriations History

Since 2005, the Energy and Water Development (E&W) appropriations bill[22] has funded all DOE programs, including those operated by OE.[23] The office mainly conducts R&D, which is often performed in funding partnership with industry. OE administers a wide range of R&D programs, each with its own set of goals and objectives.

[22] For an overview of the FY2017 E&W appropriations process, see CRS Report R44465, *Energy and Water Development: FY2017 Appropriations*, by (name redacted)

[23] Prior to 2005, DOE programs were supported partly by the E&W bill and partly by the Interior appropriations bill.

Since FY2011, DOE has requested sizeable increases in OE spending each year, but Congress did not significantly boost spending until FY2016. DOE's FY2016 request for OE sought $270 million, nearly double the FY2015 level of $147 million. The final appropriation for FY2016 was $206 million.[24] **Table 1**, below, shows the recent pattern of OE requests and final appropriation levels.

Table 1. OE Requests and Final Appropriations, FY2011–FY2017

($ millions, current)

Fiscal Year	Request	Final Appropriation
FY2011	$186	$141
FY2012	$238	$139
FY2013	$143	$132
FY2014	$169	$147
FY2015	$180	$147
FY2016	$270	$206
FY2017	$262	—-

Source: DOE Budget Requests, FY2011 through FY2017; and personal communication with Yulia Korzh, OE, February 8, 2016.

Notes: The FY2016 OE figure was provided in Division D of the Consolidated Appropriations Act, FY2016.

FY2017 Request Highlights

Summary

DOE presented its FY2017 budget request on February 9, 2016.[25] The request for OE sought $262 million, which would have been a $56 million, or 27%, increase over the FY2016 level.[26] As part of that requested increase, DOE proposed to fund three new programs: a Grid Institute, State Distribution-Level Reform, and State Energy Assurance. The two largest increases for existing programs would have gone to the Energy Storage and Transformer Resilience programs. The Cybersecurity program would have gotten the largest cut in funding.

About $44 million (79%) of the requested OE increase would have been spread almost equally across these three new programs. The other large increases are sought for the Energy Storage (up $24 million) and the Infrastructure Security (up nearly $9 million) programs. The Cybersecurity

[24] For more details about the congressional action on FY2016 funding for OE, see CRS Report R44357, *DOE's Office of Electricity Delivery and Energy Reliability (OE): A Primer, with Appropriations for FY2016*, by (name redacted)

[25] A video replay of Secretary Moniz's oral presentation of the DOE request is available at http://energy.gov/articles/energy-department-presents-fy16-budget-request. The portion on energy programs, including EERE, begins at about nine minutes into the video recording. Also, the printed text of the Secretary's oral presentation is available at http://energy.gov/articles/secretary-monizs-remarks-presenting-department-s-fy-2016-budget-request-delivered.

[26] At the same time—to offset a large overall requested increase for DOE funding—the Administration sought a revenue offset derived from a proposal to repeal about $4 billion in fossil fuel tax incentives. For more details about the congressional action on FY2016 funding for OE, see CRS Report R44357, *DOE's Office of Electricity Delivery and Energy Reliability (OE): A Primer, with Appropriations for FY2016*, by (name redacted)

program would have been cut by nearly $17 million. FY2017 request also notes that OE plays the central role in two of DOE's broad cross-cutting initiatives: grid modernization and cybersecurity.

In FY2017, the Budget Request proposed to:

- Issue a funding opportunity for a new institute, focused on grid applications to help transition innovative materials processes and production technologies to industry. This Grid Institute would become part of the National Network for Manufacturing Innovation (NNMI).
- Enable transformational R&D on advanced distribution management systems, synchrophasor applications, and, especially, energy storage technologies to modernize and enhance the resilience of the nation's electric grid backbone.
- Advance cybersecurity technologies and operational capabilities to fortify grid security.
- Launch two new state programs to facilitate reliable and flexible grid modernization by addressing distribution system challenges (State Distribution-Level Reform) and energy assurance planning (State Energy Assurance).

Proposed Funding Changes Ranked by Program

This section presents the key OE-requested program funding changes and describes some highlights for the largest requested changes. DOE sought funding changes for several programs and proposes the creation of three new programs for FY2017. **Table 2** shows all requested program increases in dollar amounts and percentages, relative to the FY2016 levels.

Table 2. OE FY2017 Requested Program Increases and Decreases, in Rank Order

($ millions, FY2017-FY2016 difference)

Program	Dollar Change	Percent Change
Energy Storage	$24.0	117%
State Distribution-Level Reform	$15.0	—
State Energy Assurance	$15.0	—
Grid Institute	$14.0	—
Transformer Resilience (TRAC)	$10.0	200%
Infrastructure Security and Energy Restoration (ISER)	$8.5	94%
National Electricity Delivery (NED)	-$1.0	-13%
Smart Grid R&D	-$5.0	-14%
Clean Energy Transmission and Reliability (CETR)	-$8.7	-22%
Cybersecurity (CEDS)	-$16.5	-27%

Source: DOE, *FY2017 Budget Request (vol. 3)*, pp. 321-402.

Notes: Transformer Resilience was a new program for FY2016. Three new programs requested for FY2017 are: State Distribution-Level Reform, State Energy Assurance, and Grid Institute.

Table 2 shows that the largest requested increases are for Energy Storage and three new programs—State Distribution-Level Reform, State Energy Assurance, and Grid Institute. The

largest requested cuts are sought for Cybersecurity and for Clean Energy Transmission and Reliability.[27] A discussion of the planned FY2017 activities in these areas follows.

Program Descriptions and Proposed Funding Changes

Existing Programs

Clean Energy Transmission and Reliability (CETR)

The CETR program aims to improve energy system decisionmaking by fostering the development of system measurement, modeling, and risk analysis. The program provides tools and analyses needed to assess risks, inform decisions, and improve system performance, planning, and policy. CETR is focused on ensuring the reliability and resiliency of the U.S. electric grid through R&D focused on measurement and control of the electricity system and risk assessment to address challenges across integrated energy systems. It is OE's main program for energy modeling and analysis. CETR also brings together energy stakeholders from government, industry, and academia to generate ideas and develop solutions to the nation's energy infrastructure challenges. CETR activities are organized into three R&D subprograms: Transmission Reliability, Advanced Modeling Grid Research, and Energy Systems Risk and Predictive Capability.[28]

Smart Grid R&D

This program focuses mainly on developing innovative technologies, tools, and techniques to modernize the distribution portion of the electric delivery system. Distribution infrastructure takes power from the transmission system and delivers it to individual businesses and homes. The Smart Grid program aims to improve reliability, operational efficiency, resiliency, and faster outage recovery. It builds on previous and ongoing grid modernization efforts, including the 2009 Recovery Act's Smart Grid Investment Grants and Smart Grid Regional Demonstrations.[29]

The Smart Grid program strengthens distribution system modernization by accommodating greater numbers of distributed energy resources (solar photovoltaics, combined heat and power, energy storage, electric vehicles, etc.), enabling higher levels of demand-side management and control practices, and enhancing reliability and resiliency during both normal operations and extreme weather events.

Information and communication technologies play a key role in Smart Grid goals to address technical challenges such as rising demand and supply variability, two-way power flow, data management and security, interoperability between new and legacy technologies, and the increasing linkages of distribution and transmission operations.

Cybersecurity for Energy Delivery Systems (CEDS)

This program aims to strengthen the energy infrastructure against current and future cyber threats. The energy sector, which includes both the electricity and oil and natural gas sectors, has been

[27] For more about smart grid and cybersecurity issues, see CRS Report R41886, *The Smart Grid and Cybersecurity—Regulatory Policy and Issues*, by (name redacted) .

[28] DOE, *FY2017 Congressional Budget Request (vol. 3)*, pp. 333-343, http://energy.gov/sites/prod/files/2016/02/f29/FY2017BudgetVolume3_2.pdf.

[29] DOE, *FY2017 Congressional Budget Request (vol. 3)*, pp. 345-351.

subjected to a dramatic increase in focused cyber probes,[30] data exfiltration,[31] and malware[32] development for potential attacks in recent years. The sophistication and effectiveness of these intrusions mark the transition to an era of nation-state level threats to the United States.

Reliable and resilient energy infrastructure is essential to the nation's economic vitality, national security, and public health and safety. Energy delivery system cybersecurity is one of the nation's most vital grid modernization and infrastructure security issues. Innovative solutions designed to meet the unique requirements of high-reliability energy delivery systems are needed to ensure the success of grid modernization and transformation of the nation's energy systems to meet future needs for economic growth.

As the energy sector-specific agency (SSA),[33] DOE has the mission and domain expertise to work with industry to mitigate risks resulting from the cyber-physical environment. DOE's long history of collaboration with industry has created integral relationships to activities that expand situational awareness (of activities such as data exfiltration) and information sharing to reduce cyber risk. OE contends that effective solutions must be based on industry best practices, sound risk management processes, and improved situational awareness, and will require multidisciplinary collaborations and shared expertise in power systems engineering, computer science, and cybersecurity.

In meeting the SSA requirement for DOE, the CEDS program supports activities with four key objectives: (1) researching technologies to improve energy reliability and resilience, (2) accelerating information sharing to enhance situational awareness, (3) expanding implementation of the Cybersecurity Capability Maturity Model and Risk Management Process,[34] and (4) developing innovative solutions for reconstitution after a large-scale cyber event.[35]

[30] A probe is an action taken or an object used for the purpose of learning something about the state of the network.

[31] Data exfiltration is the unauthorized transfer of sensitive information from a target's network to a location which a threat actor controls.

[32] Malware is a short-hand term for malicious software. It is any software used to disrupt computer operation, gather sensitive information, or gain access to private computer systems.

[33] The Homeland Security Presidential Directorate-7 (HSPD-7) identified 17 critical infrastructure and key resources (CI/KR) sectors and designated federal government sector-specific agencies (SSAs) for each of the sectors. CI/KR includes physical or virtual assets, systems, and networks so vital to the United States that the incapacity or destruction of such assets, systems, or networks would have a debilitating impact on security, national economic security, public health or safety, or any combination of those matters. SSAs are responsible for working with Department of Homeland Security (DHS) to implement the National Infrastructure Protection Plan (NIPP) sector partnership model and risk management framework, develop protective programs and related requirements, and provide sector-level CI/KR protection guidance in line with the overarching guidance established by DHS pursuant to HSPD-7. Department of Homeland Security, *National Infrastructure Protection Plan: Sector Overview*, https://www.dhs.gov/xlibrary/assets/NIPP_SectorOverview.pdf.

[34] This activity is a public-private partnership effort that was established to improve electricity subsector cybersecurity. It helps organizations—regardless of size, type, or industry—evaluate, prioritize, and improve their cybersecurity capabilities. The model focuses on the implementation and management of cybersecurity practices associated with the operation and use of information technology and operational technology assets and the environments in which they operate. The goal is to support ongoing development and measurement of cybersecurity capabilities within any organization. For more details, see DOE's website at http://energy.gov/oe/services/cybersecurity/cybersecurity-capability-maturity-model-c2m2-program.

[35] DOE, *FY2017 Congressional Budget Request (vol. 3)*, pp. 353-359.

Energy Storage

This program develops and demonstrates new and advanced energy storage technologies (e.g., batteries, pumped hydro, flywheels) that will enable the stability, resiliency, and reliability of the future electric grid. Also, Energy Storage enables increased deployment of variable renewable energy resources such as wind and solar power generation. The Energy Storage program focuses on accelerating the development and deployment of energy storage in the electric grid through directly addressing the four principal challenges identified in the 2013 DOE *Strategic Plan for Grid Energy Storage*: (1) cost competitive energy storage technology, (2) validated reliability and safety, (3) equitable regulatory environment, and (4) industry acceptance.[36] Storage technology still needs to make substantial improvements in safety, cycle life, energy density, and cost before becoming fully competitive.

The Energy Storage program supports technology cost reductions, performance improvements, and reliability and safety validations. The program works toward an equitable regulatory environment and industry acceptance. The FY2017 request sought three to four new highly leveraged, cost-shared demonstrations with states, which were designed to encompass more than 5 megawatts of energy storage assets.[37]

Transformer Resilience and Advanced Components (TRAC)

Transformers, power lines, and substation equipment are often exposed to the elements and are vulnerable to an increasing number of natural and man-made threats. To ensure a reliable and resilient electric power system, next-generation grid hardware needs to be designed and built to withstand and recover from the impact of lightning strikes, extreme terrestrial or space weather events, electrical disturbances, accidents, equipment failures, deliberate attacks, and other as yet unknown threats.

The TRAC program supports modernization and resilience of the grid by addressing the unique challenges facing transformers and other critical components (i.e., grid hardware) that are responsible for carrying and controlling electricity from where it is generated to where it is needed. As the electric power system evolves to enable a more resilient and clean energy future, R&D and testing will be needed to understand the physical impact these changes have on transformers and other vital grid components and to encourage adoption of new technologies and approaches. Development of advanced components aims to provide the physical capabilities required in the future grid and help avoid infrastructure lock-in with outdated technologies that are long-lived and expensive.[38]

TRAC increases investments in the development of technologies and assessments to mitigate system vulnerabilities such as geomagnetic disturbances and electromagnetic pulses. Planned activities would also focus on developing next-generation transformers to fill a critical gap identified in the 2015 *Quadrennial Technology Review*.[39] Research efforts are to address the

[36] DOE, *Grid Energy Storage*, December 2013, http://energy.gov/sites/prod/files/2014/09/f18/Grid%20Energy%20Storage%20December%202013.pdf.

[37] DOE, *FY2017 Congressional Budget Request (vol. 3)*, pp. 361-366.

[38] DOE, *FY2017 Congressional Budget Request (vol. 3)*, pp. 367-369.

[39] DOE, *Quadrennial Technology Review*, September 2015, http://energy.gov/sites/prod/files/2015/09/f26/Quadrennial-Technology-Review-2015_0.pdf.

unique challenges associated with high power levels (voltage and current), high reliability requirements (25 to 40 years in field operation), and high costs of critical components.[40]

National Electricity Delivery (NED)

The National Electricity Delivery (NED) program helps state, regional, and tribal entities to develop, refine, and improve their programs, policies, and laws related to electricity while mitigating market failures. The scope of this activity includes facilitating the development and deployment of reliable and affordable electricity infrastructure, whether generation, transmission, storage, distribution, or demand-side electricity resources. In addition, NED implements a number of legal requirements, such as coordination of transmission permitting by federal agencies, periodic transmission congestion studies, permitting of cross-border transmission lines, and authorization of electricity exports.[41]

Infrastructure Security and Energy Restoration (ISER)

This program leads efforts for securing the U.S. energy infrastructure against all hazards, reducing the impact of disruptive events, and responding to and facilitating recovery from energy disruptions, in collaboration with industry and state and local governments. The three main areas of ISER activities are: (1) executing effective emergency preparedness, response, and restoration operations; (2) providing reliable energy infrastructure tactical analysis (event analysis) and situational awareness to all stakeholders; and (3) encouraging a risk-based approach to energy system assurance.[42]

ISER enables the security and resilience of the nation's energy infrastructure (electricity, petroleum, and natural gas) through implementation of the National Preparedness System to help achieve the National Preparedness Goal: "a secure and resilient nation with the capabilities required across the whole community to prevent, protect against, mitigate, respond to, and recover from the threats and hazards that pose the greatest risk."[43]

ISER is the DOE office responsible for executing DOE's Energy Sector Specific Agency (SSA) role, executing DOE's Emergency Support Function-12 (ESF-12) (Energy) role and providing DOE's support to the Infrastructure Systems Recovery Support Function (IS-RSF). ISER facilitates the creation of a favorable security and resilience environment by delivering analysis, training, data (which includes situational awareness and modeling data), tools, and validation exercises to assist its partners with executing Preparedness activities across the five mission areas specified in *Presidential Policy Directive 8: National Preparedness*.[44]

ISER's development and delivery of these capabilities is informed by coordination with energy infrastructure stakeholders by virtue of its SSA authorities and through active participation with its sister agencies. This allows ISER to serve as a point of entry for energy infrastructure security

[40] For more on this topic see CRS Report R43604, *Physical Security of the U.S. Power Grid: High-Voltage Transformer Substations*, by (name redacted) .

[41] DOE, *FY2017 Congressional Budget Request (vol. 3)*, pp. 375-378.

[42] DOE, *FY2016 Congressional Budget Request (vol. 3)*, p. 387.

[43] Department of Homeland Security, *National Preparedness Goal (Second Edition)*, September 2015, https://www.fema.gov/media-library-data/1443799615171-2aae90be55041740f97e8532fc680d40/National_Preparedness_Goal_2nd_Edition.pdf.

[44] Department of Homeland Security, *Presidential Policy Directive 8: National Preparedness*, https://www.dhs.gov/presidential-policy-directive-8-national-preparedness.

and resilience stakeholders at all levels, including the private sector, to DOE and the federal government.

New Programs Proposed

Grid Institute

The proposed Grid Clean Energy Manufacturing Innovation Institute was designed to focus on projects that help transfer to industry innovative material processes and production technologies for grid infrastructure application. The Institute would have focused on technologies related to critical metals for grid application, and advances would be broadly applicable in multiple industries and markets. The Grid Institute would have become part of the larger multi-agency National Network for Manufacturing Innovation (NNMI).[45] The NNMI implementation model promotes collaboration, complements university research, and supports innovation to increase the competitiveness of U.S. manufacturers. Manufacturing institutes are a partnership among government, industry, and academia, supported with cost-share funding from federal and non-federal sources. Within five years of its launch, the Grid Institute was intended to become financially independent and sustainable using only private sector and other sources without further federal funding.

Industry estimates that about $1.1 trillion will be needed to expand, upgrade, and, as necessary, replace the U.S. electric delivery infrastructure through 2040. The process of modernizing the grid and replacing older assets will create an opportunity to develop and deploy next-generation grid hardware. However, successful commercialization of advanced grid components will require materials with new physical properties and enhanced functionality.[46] Electric power infrastructure (e.g., cables, conductors, transformers) depends heavily on industrial metals such as aluminum, iron, and copper. In particular, the Institute would have aimed to spur grid infrastructure applications of recent advances in metallurgy, nanotechnology, and materials science that have enabled better control and optimization of the various properties of metals.[47]

State Distribution-Level Reform Program

The technical assistance provided by this proposed program would have employed system analysis to ensure that the integration of distribution energy resources[48] with new markets would be accommodated through appropriately designed business and regulatory processes. There is broad recognition that the electricity sector is undergoing a major transformation. Much of this change is occurring at the distribution level, where utilities and other entities are working to offer consumers products and services to help them cut electricity costs and obtain new kinds of

[45] For more about NNMI, see CRS Report R42625, *The Obama Administration's Proposal to Establish a National Network for Manufacturing Innovation*, by (name redacted)

[46] For example, the magnetic core of a solid state transformer will need to operate at higher frequencies and sustain performance at higher temperatures.

[47] DOE, *FY2017 Congressional Budget Request (vol. 3)*, pp. 371-373.

[48] Distributed energy resources (DER) are smaller power sources that can be aggregated to provide power necessary to meet regular demand. As the electricity grid continues to modernize, DER such as storage and advanced renewable technologies can help facilitate the transition to a smarter grid. Deploying DER in a widespread, efficient and cost-effective manner requires complex integration with the existing electricity grid. Research can identify and resolve the challenges of integration, facilitating a smoother transition for the electricity industry and its customers into the next age of electricity infrastructure. Electric Power Research Institute, http://www.epri.com/Our-Work/Pages/Distributed-Electricity-Resources.aspx.

benefits from the use of electricity. Several states have embarked on major efforts to reform the regulatory frameworks for their distribution sectors, leveraging OE support. The common theme among their efforts is the need to "unlock new sources of value" that are latent in the existing framework, while preserving or enhancing traditional values such as reliability and affordability.

Through 5 to 10 competitive awards, this program would have aimed to help states identify and address issues involving structural, policy, and/or regulatory reforms. While OE already provides high-level policy and technical expertise to states, this support would have allowed state officials to utilize DOE's national laboratories, associated academic institutions, and other subject matter experts to develop targeted solutions to specific issues that are too situation specific to be addressed by existing OE programs.[49]

State Energy Assurance

This program was designed to assist state, local, tribal, and territorial stakeholders in planning, training, and exercising in advance of energy emergencies. Specifically, it would have aimed to improve the capacity of states, localities, and tribes to identify the potential for energy disruptions, quantify the impacts of those disruptions, develop comprehensive response plans, and devise plans to mitigate the threat of future disruptions. OE has worked on energy assurance planning across the states and U.S. territories (including the District of Columbia). A key lesson learned is that such plans should be continually updated and exercised annually—in order to reflect changing conditions, identify and address new threats, and maintain staff capacity to implement plans. The proposed program would have provided funds through competitive regional cooperative assistance awards. The funds would have supported continual energy assurance plan improvement, promoted regional and state capabilities to identify potential supply disruptions, and improved training programs for energy planning and emergency response.

OE's goal for state and local energy assurance planning would have been to achieve a robust, secure, and reliable energy infrastructure that is also resilient—better able to withstand catastrophic events, able to restore services rapidly in the event of any disaster, and designed to diminish future vulnerabilities. Through support of state energy assurance planning improvement and regional resilience exercises, the federal government would have partnered with states and local governments—which are ultimately responsible for responding to disasters and disruptions—to build and maintain preparedness and assurance capabilities.[50]

Program Direction

This activity provides for the costs associated with the federal workforce, including salaries, benefits, travel, training, building occupancy, information technology (IT) services, and other related expenses. It also provides for the costs associated with contractor services that, under the direction of the federal workforce, support OE's mission.[51]

Cross-Cutting Initiatives

The FY2017 request also sought to continue crosscutting programs that coordinate across the department and to employ DOE's full ability to address national energy, environmental, and

[49] DOE, *FY2017 Congressional Budget Request (vol. 3)*, pp. 379-382.

[50] DOE, *FY2017 Congressional Budget Request (vol. 3)*, pp. 389-391.

[51] DOE, *FY2017 Congressional Budget Request (vol. 3)*, pp. 393-397.

security challenges. OE serves as the central hub of the Grid Modernization and Cybersecurity crosscutting programs.

Funding Table by Program: FY2017 and Prior Years

OE operates seven program offices[52] and one administrative office (program direction). Each program office has its own set of goals and funding needs. The FY2017 request sought to establish three new programs. **Table 3** shows the funding breakdown for existing and proposed activities by program office. It also shows congressional recommendations for FY2017.

Table 3. Electricity Delivery and Energy Reliability (OE) Appropriations

($ millions)

Program	FY2013 Approp.	FY2014 Approp.	FY2015 Approp.	FY2016 Approp.	FY2017 Request	FY2017 House Approp. Cmte	FY2017 Senate
Existing Programs							
Clean Energy Transmission and Reliability (CETR)	24.1	32.4	34.3	39.0	30.3	36.0	36.0
Smart Grid R&D	20.6	14.6	15.4	35.0	30.0	50.0	35.0
Cybersecurity for Energy Delivery Systems (CEDS)	30.1	43.5	46.0	62.0	45.5	62.0	50.5
Energy Storage	18.9	15.2	12.0	20.5	44.5	31.0	29.5
Transformer Resilience and Advanced Components (TRAC)	—	—	—	5.0	15.0	n.s.	8.5
National Electricity Delivery (NED)	6.6	6.0	6.0	7.5	6.5	n.s.	7.5
Infrastructure Security and Energy Restoration (ISER)	6.1	8.0	6.0	9.0	17.5	n.s.	10.5
New Programs, Proposed							
Grid Institute	—	—	—	—	14.0	0.0	0.0
State Distribution-Level Reform	—	—	—	—	15.0	0.0	0.0
State Energy Assurance	—	—	—	—	15.0	0.0	0.0
Program Direction	25.6	27.6	27.6	28.0	29.0	n.s.	28.5
Total OE Appropriation	132.0	147.2	147.3	206.0	262.3	225.0	206.0

Source: DOE Budget Requests for FY2017, FY2016, and FY2015, vol. 3; P.L. 114-113, Division D; personal communication with Yulia Korzh, OE, February 8, 2016; H.Rept. 114-532; and S.Rept. 114-236.

a. The term "n.s." is an abbreviation for "not specified."

[52] For FY2016, Congress approved funding to support DOE's request to establish a new program, Transformer Resilience and Advanced Components (TRAC).

FY2017 Congressional Action

After the Administration issued its FY2017 budget request, Congress held a number of DOE oversight and appropriations hearings. As noted previously, further actions were taken in the House and Senate on DOE funding recommendations in the E&W bills, S. 2804 and H.R. 5055. In the Senate, S. 2804 was incorporated into H.R. 2028 as an amendment in the nature of a substitute, and it was approved on the Senate floor. The Senate-passed FY2017 E&W bill included $206 million for OE—the same amount as the FY2016 appropriation. In the House, H.R. 5055 was defeated in House floor action. That bill had included $225 million for OE, which was the amount recommended by the House Appropriations Committee. In late September 2016, a continuing resolution (P.L. 114-223, Division C) set FY2017 funding for OE at the FY2016 level through December 9, 2016. On December 10, 2016, a second continuing resolution provided funding at the FY2016 level through April 28, 2017.The various steps of the congressional process for the FY2017 E&W appropriations are outlined in **Table 4**.

Table 4. OE FY2017 Appropriations Action Chronology

(Highlights of Committee and Floor Action, with Administration responses)

Date	Action
February 9, 2016	DOE issued FY2017 budget request.
March 1, 2016	House Committee on Appropriations, Subcommittee on Energy and Water Appropriations held hearing on the DOE FY2017 budget request for applied energy programs.
March 2, 2016	House Committee on Energy and Commerce, Subcommittee on Energy and Power held a hearing on the DOE request.
March 3, 2016	Senate Committee on Energy and Natural Resources held a hearing on the DOE request.
March 9, 2016	Senate Appropriations Committee's Subcommittee on Energy and Water Appropriations held a hearing on the DOE request.
April 12, 2016	House Appropriations Committee's Subcommittee on Energy and Water Appropriations released a draft report with recommended funding for FY2017 E&W appropriations bill.
April 13, 2016	House Appropriations Committee's Subcommittee on Energy and Water Appropriations held a subcommittee markup.
April 13, 2016	Senate Appropriations Committee's Subcommittee on Energy and Water Appropriations held a subcommittee markup.
April 14, 2016	Senate Appropriations Committee reported S. 2804 (S.Rept. 114-236), which contained its recommendations for FY2017 E&W appropriation.
April 19, 2016	House Appropriations Committee held a full committee markup. A few amendments were adopted, none of which affected the provisions for OE.
April 19, 2016	House Appropriations Committee issued a draft E&W appropriations bill and draft report, with recommended funding for FY2017 E&W appropriations.
April 20, 2016	OMB issued a Statement of Administration Policy (SAP) that opposed the Senate version of H.R. 2028, mainly due to funding levels below the request for the Advanced Research Projects Agency-Energy (ARPA-E) and the Office of Energy Efficiency and Renewable Energy (EERE). The SAP for the Senate bill also objected to the $206 million recommended for OE.
April 26, 2016	House Appropriations Committee issued the E&W appropriations bill (H.R. 5055) and final report (H.Rept. 114-532), with recommended funding for FY2017 E&W appropriations.
May 12, 2016	Senate approved its version of H.R. 2028 (an FY2016 E&W appropriations bill that was not passed by the House), which adopted the text of S. 2804 as an amendment in the nature of a substitute.

Date	Action
May 23, 2016	OMB issued a Statement of Administration Policy that opposed the House bill (H.R. 5055), mainly due to funding levels set below the request for ARPA-E and EERE. The SAP for the House bill also objected to the $225 million recommended for OE.
May 26, 2016	In a House floor vote, the House version of the E&W bill (H.R. 5055) was defeated.
September 29, 2016	The President signed H.R. 5325 into law (P.L. 114-223). Division C of the law was termed a "continuing resolution (CR)," which is in effect through December 9, 2016. Division C includes a continuation of E&W appropriations for OE at the FY2016 level.
December 10, 2016	The President signed H.R. 2028 into law (P.L. 114-254). It continues FY2017 appropriations at the FY2016 funding level, through April 28, 2017,.

Source: Multiple sources were used.

Additional Reports Related to OE Programs, Funding, and Policy

For additional background on selected OE programs, funding, and policy aspects, see the following CRS reports.

CRS Report R44465, *Energy and Water Development: FY2017 Appropriations*, by (name redacted)

CRS Report R43966, *Energy and Water Development: FY2016 Appropriations*, by (name redacted)

CRS Report RS22858, *Renewable Energy R&D Funding History: A Comparison with Funding for Nuclear Energy, Fossil Energy, and Energy Efficiency R&D*, by (name redacted)

CRS Report R41886, *The Smart Grid and Cybersecurity—Regulatory Policy and Issues*, by (name redacted)

CRS Report R43604, *Physical Security of the U.S. Power Grid: High-Voltage Transformer Substations*, by (name redacted)

CRS Insight IN10425, *Electric Grid Physical Security: Recent Legislation*, by (name redacted)

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