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DOE's Office of Electricity Delivery and Energy Reliability (OE): A Primer, with Appropriations for FY2016

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Summary

The nation's energy infrastructure is undergoing a major transformation. 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) is tasked with the lead role to address those infrastructure issues. OE is also responsible for the physical security and cybersecurity of energy infrastructure. As an illustration, 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.

Since 2005, the Energy and Water Development (E&W) appropriations bill has funded all DOE programs, including those operated by OE. That office 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.

President Obama has declared grid modernization to be a high priority, stressing its importance to jobs, economic growth, and U.S. manufacturing competitiveness. Further, OE has a key role in supporting the grid integration of renewable energy, which is a focus of the President's Climate Action Plan and is a strategic resource for state responses to the Environmental Protection Agency's proposed Clean Power Plan.

DOE's FY2016 request for OE sought $270 million, nearly double the FY2015 appropriation of $147 million. As part of that requested increase, DOE proposed to create a new Transformer Resilience R&D program and a new State Energy Reliability and Assurance grant program. About half of the requested OE increase would have gone to the new grant program. The next largest increases were sought for the Smart Grid and Cybersecurity programs. The FY2016 request also noted that OE plays the central role in two of DOE's broad cross-cutting initiatives: grid modernization and cybersecurity.

For the OE portion of the FY2016 E&W bill (H.R. 2028), the House approved $187 million (includes $0.9 million rescission) and the Senate Appropriations Committee approved $151 million (includes $0.9 million rescission); but the Administration issued a veto threat. Ultimately, E&W appropriations appeared as Division D of the Consolidated Appropriations Bill (H.R. 2029). The bill was enacted as P.L. 114-113. The law provided $206 million for OE. The proposed new grant program was not funded, but funding was provided for the new Transformer Resilience program. Both the Smart Grid and Cybersecurity programs received larger amounts than were requested.

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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). In the early days, the program was focused mainly on energy storage—especially to even out the variable power production from wind and solar technologies—but also to support large coal and nuclear power plants. The development of computer capacity and miniaturization 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, the computerization and networking have become vulnerable to unwanted computer-driven intrusions and disruptions, revealing a new cybersecurity challenge for electric power system technology.

The nation's energy infrastructure is diverse and complex. It includes distributed networks, varied system structures (electricity, oil, and natural gas), an array of operating models (public and private), and different systems in both the physical space and cyberspace. The energy sector consists of thousands of electricity, oil, and natural gas assets[1] that are geographically dispersed and provide for all nationally important systems and networks. Thus, interdependency within the sector and across the nation's critical infrastructure sectors is significant. Coordinating the security and resilience of energy assets is complicated by the borderless nature of energy and 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); updating communication networks (e.g., analog to digital); accommodating new end-use technologies such as distributed resources; planning for increased interdependencies of natural gas, water, and electricity systems; and devising business models that manage these challenges in providing reliable and affordable electricity service. These activities must be balanced against the need for cost control, physical security, cybersecurity, improved reliability and resiliency, and flexibility to deal with market uncertainties and a changing climate. Additional opportunities arise due to increasing natural gas production from shale and decreasing costs for information technologies that allow grid operators to better monitor and control the grid and that enable customers to better manage power use.

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.[2] 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. It is the federal government's lead entity for energy sector-specific responses to energy security emergencies—whether caused by physical infrastructure problems or by cybersecurity issues.

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

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

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 private industry and federal, state, local, and tribal governments on a variety of initiatives to modernize the electric grid. Grid modernization is critical to addressing aging infrastructure, achieving public policy objectives, sustaining economic growth, supporting environmental stewardship, and mitigating risks to secure the nation. The 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.[3]

Organizational Structure

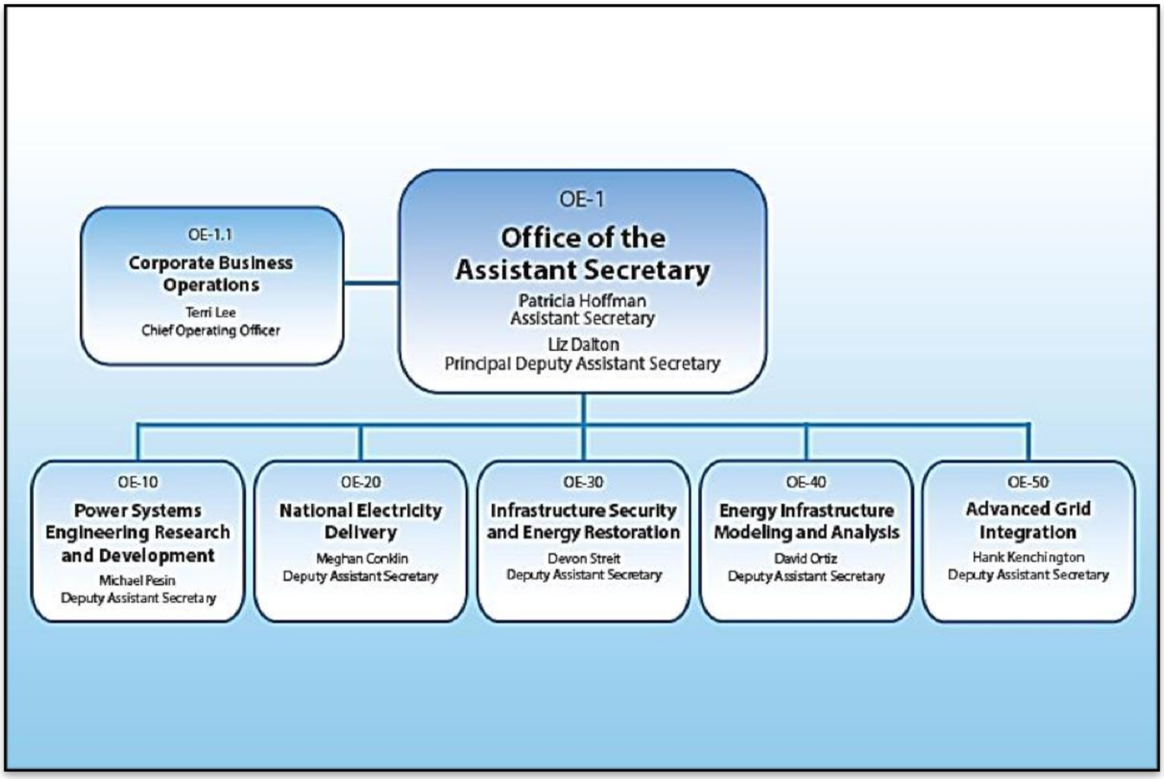
In 2007, DOE established an independent Assistant Secretary for OE and, thereby, elevated the office to an administrative status equal to that for the major energy technologies (nuclear, fossil, renewables).[4] OE currently has five deputy assistant secretaries, each of whom reports to the Assistant Secretary. This structure is displayed in **Figure 1**, below.

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

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

Figure 1. OE Organizational Structure

(As of January 2016)



Source: DOE, Office of Electricity Delivery and Energy Reliability, *Our Organization*, http://energy.gov/oe/about-us/our-organization.

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. On the supply side, there is a diversification of resources as aging, low-efficiency capacity is replaced by a mix of central stations and distributed generation, powered by a mix of fossil and renewable resources. On the demand side, diversification includes a rapidly growing use of distributed generation and interactive control systems in buildings, industrial equipment, and consumer goods. Accompanying these changes is a convergence of digital communications and control systems ("smart grid" technologies) to improve performance and engage consumers. Additionally, grid operations are moving from directing systems with a handful of control points at central stations to ones with potentially millions of highly interactive distributed

> control points. 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."[5]

Further, from the 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. Growth in the deployment of variable generation, electronic converters, and digital communications and control technologies is impacting core characteristics of the electricity system. 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. The RDD&D opportunities identified for this rapidly evolving sector include planning models, operational tools, transmission components, distribution hardware, control systems, electricity storage and cybersecurity. These opportunities need to be developed in anticipation of an agile, flexible, and resilient electric power system to enable effective integration of variable supplies and participatory demand.[6]

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."[7] To help achieve this vision, DOE targets three key national targets:

- 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.[8]

The initiative will assess its progress not only by looking at RD&D efforts in individual technical areas but also by looking at three integrated demonstrations, referred to in the MYPP as DOE major technical achievements. They are:

1. **A transmission and distribution system operating reliably on a lean reserve margin.** Full power system visibility will be provided by real-time sensor networks enabling new approaches to system design, control, operations, protection, and optimization. There will be an integrated effort to demonstrate the

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

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

[7] 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.

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

delivery of reliable and affordable grid services with a substantially reduced amount of system reserve capacity.

2. **Resilient distribution feeders with high percentages of low-carbon distributed energy resources (50%)**. This will be achieved through advances in real-time system monitoring, for high penetration of clean, distributed generation, and the proliferation of smart consumer end-use devices. There will also be new approaches to distributed control, engagement with bulk system reliability management, and coordination across local intelligent assets, including multiple microgrids, over a range of feeder innovations that meet both changing consumer expectations and traditional demand for reliability, resilience, and affordability.
3. **An advanced modern grid planning and analytics platform.** This will be a platform of integrated high performance tools that couple transmission, distribution and communications tools. These tools will have the capacity to reflect uncertainty, and substantially increase the speed and productivity of tools that enable stakeholders to achieve timely evaluation of future grid alternatives. This platform will be integrated with vendor products and leveraged into ongoing technical assistance with states and regions to substantially improve planning and regulatory assessments of the modern grid.[9]

The MYPP states that multiple demonstrations will be conducted across various regions of the country to underpin these "major technical achievements." Those major grid modernization achievements will be supported by six specific technical areas: (1) Devices and Integrated Systems Testing, (2) Sensing and Measurements, (3) System Operations, Power Flow, and Control, (4) Design and Planning Tools, (5) Security and Resilience, and (6) Institutional Support.[10]

Administration Perspective and Goals

OE also plays a critical role in implementation of the President's Climate Action Plan to mitigate the risks and enhance resilience against threats posed by climate change. The FY2016 OE request aimed to support the 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.

Program 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.[11]

[9] DOE, *MYPP, Executive Summary*, p. xiv-xv.

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

[11] 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 (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).[12] 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[13] and other related technologies in their electric power transmission systems.[14] That deployment of synchrophasors, however, covered only a small portion of the total national grid.

Funding Comparison with Energy Technologies

Figure 2 provides a condensed visual summary of the relative portion of funding for electric systems in three different historical time periods.

(...continued)

R&D programs to include renewable (wind, solar, biomass, geothermal, hydro) energy and energy efficiency 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)

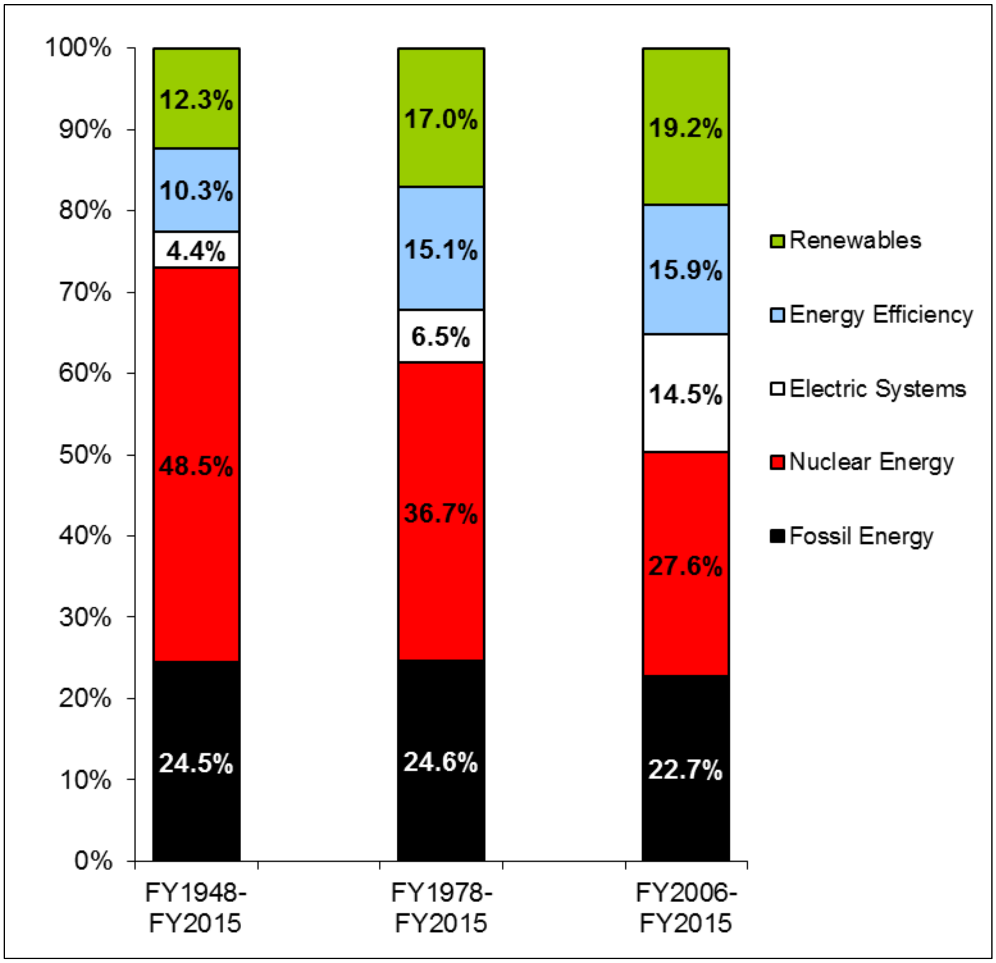
[12] The Recovery Act funding supported smart grid activities that were authorized primarily by Title 13 of the Energy Independence and Security Act of 2007 (EISA, P.L. 110-14).

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

[14] 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 2. DOE Energy Technology Share of Funding, Comparison over Three 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[15] has funded all DOE programs, including those operated by OE.[16] The office mainly conducts R&D, which is often performed in partnership with industry. OE administers a wide range of R&D programs, each with its own set of goals and objectives.

[15] For an overview of the FY2016 E&W appropriations process, see CRS Report R43966, *Energy and Water Development: FY2016 Appropriations*, by (name redacted)

[16] 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 spending each year, but Congress did not significantly boost spending until FY2016. **Table 1**, below, shows the recent pattern of OE requests and final appropriation levels.

Table 1. OE Requests and Final Appropriations, FY2011–FY2016

($ 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

Source: DOE Budget Requests, FY2011 through FY2016; and personal communication with Yulia Korzh, OE, February 8, 2016.

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

FY2016 Highlights

Summary

DOE presented its FY2016 budget request on February 2, 2015.[17] The request for OE was $270 million, which would have nearly doubled the FY2015 level.[18] As part of that requested increase, DOE proposed to create a new Transformer Resilience and Advanced Components R&D program and a new State Energy Reliability and Assurance grant program. About half of the requested OE increase would have gone to the new grant program. The next largest increases were sought for the Smart Grid and Cybersecurity programs.

The House Committee on Appropriations reported the Energy and Water Development (E&W) Appropriations Bill, 2016 (H.R. 2028) with a recommendation of $186.65 million (includes $0.9 million rescission) for OE.[19] The $186.6 million figure for OE was adopted in House floor action.[20] Subsequently, the Senate Committee on Appropriations recommended $151.4 million (includes $0.9 million rescission).[21] The congressionally recommended overall amount for DOE drew a veto threat from the Administration mainly for reasons unrelated to OE funding. Subsequently, the E&W bill was incorporated as Division D of the Consolidated Appropriations

[17] A video replay of Secretary Moniz's verbal 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 verbal presentation is available at http://energy.gov/articles/secretary-monizs-remarks-presenting-department-s-fy-2016-budget-request-delivered.

[18] 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.

[19] See H.Rept. 114-91, *Energy and Water Development Appropriations Bill, 2016,* p. 89, April 24, 2015.

[20] H.R. 2028 as engrossed in House (passed House), p. 21.

[21] S.Rept. 114-54, *Energy and Water Development Appropriations Bill, 2016*, p. 75, May 21, 2015.

Act, FY2016 (H.R. 2029). The final enacted version of H.R. 2029 (P.L. 114-113, Division D) provided $206 million for OE.[22]

Congressional Action

After the Administration issued its FY2016 budget request, Congress held a number of DOE oversight and appropriations hearings. As noted above, further actions were taken in the House and Senate on DOE funding recommendations in the E&W bill, H.R. 2028. Late in the first session, after lengthy negotiations, the E&W bill was incorporated into H.R. 2029. The various steps of the congressional process for the FY2016 E&W appropriations are outlined in **Table 2**.

Table 2. OE FY2016 Appropriations Chronology

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

Date	Action
February 2, 2015	DOE issues FY2016 budget request.
February 11, 2015	House Energy and Commerce Committee's Subcommittee on Energy and Power held a hearing on the DOE request.
February 12, 2015	Senate Committee on Energy and Natural Resources (SENR) held a hearing on the DOE request.
February 26, 2015	House Appropriations Committee's Subcommittee on Energy and Water Appropriations held a hearing on the DOE request.
March 25, 2015	Senate Appropriations Committee's Subcommittee on Energy and Water Appropriations held a hearing on the DOE request.
April 13, 2015	House Appropriations Committee's Subcommittee on Energy and Water Appropriations released a draft report with recommended funding for FY2016 E&W appropriations bill.
April 15, 2015	House Appropriations Committee's Subcommittee on Energy and Water Appropriations held a subcommittee markup.
April 21, 2015	House Appropriations Committee issued draft report on FY2016 E&W appropriations bill with recommended funding for FY2016 E&W appropriations bill.
April 21, 2015	Office of Management and Budget (OMB) issued a letter to the House Appropriations Committee that expressed the Administration's concerns with the draft E&W appropriations bill.
April 22, 2015	House Appropriations Committee held a full committee markup. Several amendments were adopted, none of which affected the provisions for OE.
April 24, 2015	House Appropriations Committee issued the E&W appropriations bill (H.R. 2028) and final report (H.Rept. 114-91) with recommended funding for FY2016 E&W appropriations.
April 28, 2015	OMB issued a Statement of Administration Policy that strongly opposed House passage of H.R. 2028.
May 1, 2015	House approved H.R. 2028, without amendments to the committee recommendations for OE.
May 21, 2015	Senate Appropriations Committee reported (S.Rept. 114-54) its recommendations for H.R. 2028.

[22] The text of the enacted bill is available at https://www.congress.gov/114/bills/hr2029/BILLS-114hr2029enr.pdf.

Date	Action
December 17, 2015	House approved H.R. 2029, Consolidated Appropriations Act, 2016. A modified version of the E&W appropriations bill (H.R. 2028) was included as Division D. The explanatory statement on H.R. 2029 was printed in Congressional Record.
December 17, 2015	Senate approved H.R. 2029.
December 18, 2015	President signed H.R. 2029 into law as P.L. 114-113. The E&W bill was incorporated as Division D.

Source: Multiple sources were used.

Funding Increases

This section presents the key OE program funding increases enacted and describes some highlights for each of those programs.

Increases Ranked by Program

Several programs received a significant funding increase for FY2016. **Table 3** shows all program increases in dollar amounts and percentages, relative to FY2015.

Table 3. OE FY2016 Program Increases, in Rank Order

($ millions, FY2016-FY2015 difference)

Program	Increase	Percent Increase
Smart Grid R&D	$19.6	127%
Cybersecurity (CEDS)	$16.0	35%
Energy Storage	$8.5	71%
Transformer Resilience (TRAC)	$5.0	—
Clean Energy Transmission and Reliability (CETR)	$4.7	14%
Infrastructure Security and Energy Restoration (ISER)	$3.0	50%
National Electricity Delivery (NED)	$1.5	25%

Source: Congressional Record, *Explanatory Statement on Consolidated Appropriations Act, 2016*, December 17, 2015, pp. H10108-H10109, https://www.congress.gov/crec/2015/12/17/CREC-2015-12-17-bk2.pdf.

Notes: Transformer Resilience is a new program for FY2016.

Highlights of Key Program Increases

Table 3 shows that the largest OE increases are for smart grid and cybersecurity.[23] A discussion of the planned FY2016 activities in these two areas follows.

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

Smart Grid

Congress provided $5 million more than the nearly $15 million increase sought in the DOE request. The *Explanatory Statement for H.R. 2029* (P.L. 114-113) was silent on the focus of the approved $5 million increase over the DOE request.

The DOE request stated that the "endpoint target" of the smart grid program is "achievement of a self-healing and resilient distribution grid, with integration of networked microgrids and market-based control signals operating under the ADMS [advanced distribution management system] that allows for widespread deployment of distributed renewable and clean energy resources and demand response by 2030."[24] Specifically, the DOE-requested portion of the increase aims to launch two new efforts: ADMS technologies and market-based signal controls (MBCS).

- ADMS software will support distribution management and the integration of large amounts of renewable energy.[25]
- MBCS will employ simulation and test cases to improve operational flexibility for increased use of customer and third-party assets (including end-use devices, batteries, distributed generation, solar power, and electric vehicle chargers).[26]

Cybersecurity

Congress provided $10 million more than the DOE requested increase of $6 million. The *Explanatory Statement for H.R. 2029* (P.L. 114-113) was silent on the focus of the approved increase over the DOE requested amount.

The DOE request stressed "the critical need to accelerate and expand efforts to strengthen the energy infrastructure against cyber threats."[27] Specifically, the DOE-requested portion of the increase aimed to establish a "virtual energy sector advanced digital forensics analysis platform." In simpler terms, this project will apply virtual reality visualization technologies to help utilities distinguish between a normal system failure and malicious activity and to help them mitigate any malicious activity.[28]

Cross-Cutting Initiatives

The FY2016 request also sought to continue crosscutting programs that coordinate across the department and seek to tap DOE's full capability to effectively and efficiently address national energy, environmental, and national security challenges. OE serves as the central part of the Grid Modernization and Cybersecurity crosscut programs.

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[24] DOE, *FY2016 Budget Request (vol. 3)*, p. 359, http://energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume3_7.pdf.

[25] For more about ADMS, see the section on Smart Grid R&D, p. 14.

[26] DOE, *FY2016 Budget Request (vol. 3)*, pp. 352-353. For more about MBCS, see "Smart Grid R&D," below.

[27] DOE, *FY2016 Budget Request (vol. 3)*, p. 362.

[28] DOE, *FY2016 Budget Request (vol. 3)*, pp. 363-365.

FY2016 Funding Table

OE operates seven program offices[29] and one administrative office. Each program office has its own set of goals and funding needs. **Table 4** shows the funding breakdown by program office.

Table 4. Electricity Delivery and Energy Reliability (OE) Appropriations

($ millions)

Program	FY2013 Approp.	FY2014 Approp.	FY2015 Approp.	FY2016 Approp.	FY2016-FY2015	Percent Change
Clean Energy Transmission and Reliability (CETR)	24.1	32.4	34.3	39.0	4.7	13.7%
Smart Grid R&D	20.6	14.6	15.4	35.0	19.6	127.0%
Cybersecurity for Energy Delivery Systems (CEDS)	30.1	43.5	46.0	62.0	16.0	34.8%
Energy Storage	18.9	15.2	12.0	20.5	8.5	70.8%
Transformer Resilience and Advanced Components (TRAC)	—	—	—	5.0	5.0	—
National Electricity Delivery (NED)	6.6	6.0	6.0	7.5	1.5	25.0%
Infrastructure Security and Energy Restoration (ISER)	6.1	8.0	6.0	9.0	3.0	50.0%
Program Direction	25.6	27.6	27.6	28.0	0.4	1.4%
Total OE Appropriation	132.0	147.2	147.3	206.0	58.7	39.9%

Sources: DOE Budget Requests for FY2015 and FY2016, vol. 3; and P.L. 114-113, Division D. Personal communication with Yulia Korzh, OE, February 8, 2016.

Program Goals and Activities

For FY2016, the OE request proposed to create one new R&D program (Transformer Resilience and Advanced Components), which was funded,[30] and a new grant program (State Energy Reliability and Assurance), which was not funded. For each of the existing and proposed programs, this section describes goals, objectives, and funding.

Clean Energy Transmission and Reliability (CETR)[31]

The electricity system depends upon the inherent stability of a network of traditional power plants to balance electric power supply and demand. When disruptions occur, power grid operators are usually able to take actions to maintain system stability. However, the basic structure of the system is changing. In particular, the rising levels of wind and solar power generation create resource uncertainty and electric current instability. Both conditions pose a challenge to system

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

[30] TRAC was funded at $5 million, which was one-half of the requested amount.

[31] The CETR program is covered in DOE, *FY2016 Budget Request*, pp. 333-345. Note: This page reference is for DOE's PDF file available on the web—the printed version has slightly different pagination.

stability. Also, a widening range of loads (e.g., backup for rooftop solar) are becoming active participants in the electricity system, which adds more complexity to system models and operations.[32]

The electricity system must provide key services even during disruptions. A growing number of extreme weather-related events highlight the urgent need for reliable and robust monitoring, modeling, and analytical tools to support both industry operations and governmental emergency response efforts.

The CETR program aims to improve energy system decisionmaking by fostering the development of system measurement, modeling, and risk analysis. The program is designed to lay the foundation for a modern grid and ensure that elements of risk and uncertainty are properly addressed in decisions about investments to improve energy infrastructure. CETR activities are organized into three R&D subprograms: Transmission Reliability, Advanced Modeling Grid Research, and Energy Systems Risk and Predictive Capability.

Transmission Reliability Program

Existing electric transmission lines were designed to carry electric power from major power plants to urban and industrial load centers. The grid was originally designed mostly for this purpose—not for the market-driven flows of power that it currently serves. Usually mounted on tall metal towers, these lines operate at high voltage and carry high levels of electric current. Competition and market forces are causing the volume of power transactions to grow rapidly. Also, the structure of power generation is changing—due to coal plant retirements, increased use of natural gas-fired generators, and integration of large wind farms. This decentralization of the power generation mix can affect power quality and causes the grid to be used in ways for which it was not originally designed.

Special electric power sensors, known as synchrophasors,[33] were designed to monitor (measure) electric power flow with high precision and, thus, can reveal much about the health of power systems. The Transmission Reliability program supports the development of cyber-secure grid management applications that employ synchrophasors to enhance the flexibility, reliability, and resilience of the national power system. Spurred by the Northeast blackout of 2003, DOE joined with electric utilities and the North American Electric Reliability Council (NERC) to install synchrophasors throughout the grid. The Recovery Act of 2009 (P.L. 111-5) provided $4.5 billion for the smart grid and grid modernization provisions in EISA (Title 13).[34] A large portion of those funds were used to accelerate the rate of synchrophasor deployment. As the network of these devices expands, the richer[35] data pattern and yield enables the advancement of grid operator

[32] Improved capacity for transmission of renewable energy power generation could be important to implementing the renewable energy aspects of the Environmental Protection Agency's (EPA's) Clean Power Plan.

[33] These monitoring devices, also called phasor measurement units (PMUs), measure the instantaneous voltage, current, and frequency at specific locations in an electricity transmission system—usually at transmission substations. These data measurements represent the "heart-beat" and health of the power system. Voltage and current are parameters that characterize the delivery of electric power from generation plants to end-user loads, while frequency is the key indicator of the balance between electric load and generation. Thus, keeping frequency very close to 60 Hertz (cycles per second) is key to ensuring the proper operation of the power system and its reliability. For more details, see DOE, OE, *Synchrophasor Technologies and their Deployment in the Recovery Act Smart Grid Program*, 2013, p. 2, https://www.smartgrid.gov/sites/default/files/doc/files/Synchrophasor%20Report%2008%2009%202013%20DOE%20%282%29%20version_0.pdf.

[34] See conference report, H.Rept. 111-16, p. 25.

[35] In this use, the term "richer" means increased frequency and amount of data made available for real-time monitoring.

tools to detect, track, and analyze grid dynamics and to provide real-time visual monitoring of system conditions.[36] OE expects these advances to lead to automated system controls and to reduce the spread and duration of system outages by 2020.

In FY2016, OE expects to complete "production-grade" grid operator software applications that will be purchased by utilities.[37] The expanded software applications would be applied to the use of microgrids, energy storage, distributed generation, and electric vehicle charging.

Advanced Modeling Grid Research Program

This program conducts research on computer models that underpin energy management systems used by grid operators to plan, monitor, and control the electric system. The goal is to enhance reliability and enable advanced problem mitigation and recovery strategies. Objectives include improved grid resilience to events that otherwise rapidly drive network failures and blackouts; developing predictive capabilities for system anomalies and uncertainties; and integrating models to improve operational planning and enable dynamic reconfiguration of electric system elements to achieve technical and economic objectives. R&D activities focus on data management and the development of computer models and simulations.

Energy Systems Risk and Predictive Capability (ESRPC) Program

The need for national capabilities to assess near- and long-term risks to energy infrastructures was illustrated by the massive impacts of Superstorm Sandy (2012), the major hurricanes in 2008 (Gustav and Ike) and in 2005 (Katrina and Rita), and the 2013-2015 western drought and accompanying wildfires. ESRPC's goal is to advance national capability for risk-informed decisionmaking for energy systems. Potential near-term actions include developing strategies to reduce the risk of system interruptions due to extreme weather. Longer-term actions include identifying a portfolio of energy system improvements that could reduce the system-wide risks from weather events.

For FY2016, ESRPC will focus on developing analytical tools that estimate seasonal and regional extreme weather risks to energy systems that cover large geographic areas. ESPRC's research covers three types of analytic products and predictive models for system planning: (1) real-time information on extent of disruption and likely near- and long-term effects, (2) long-range (five- to eight-year timeframe) risk guidance for investment in national energy infrastructure (e.g., effect of sea level rise on infrastructure in cities), and (3) guidance for nontraditional sources of man-made risk, such as supply chain disruptions.

[36] While the richer data stream improves the capability of industrial control (IC) systems, the higher speed of the automated data flow may also increase cybersecurity concerns. For more on this aspect, see CRS Report R43989, *Cybersecurity Issues for the Bulk Power System*, by (name redacted) .

[37] NERC provides a more detailed description of "production-grade" software. See NERC, *Real-Time Application of Synchrophasors for Improving Reliability*, October 2010, p. 21, http://www.nerc.com/docs/oc/rapirtf/RAPIR%20final%20101710.pdf.

Smart Grid R&D[38]

This program develops technologies, tools, and techniques to modernize the distribution portion of the electric delivery system—power lines, transformers, and other infrastructure—that takes power from the high-voltage transmission system and delivers it to individual businesses and homes.[39] Program goals aim to accommodate rising amounts of customer-owned generation equipment (e.g., solar photovoltaics, PV), support the shift to electric vehicles (EVs), improve resilience to extreme weather events, reduce outages, and enable greater customer control over power use and quality while maintaining electric power affordability.

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.

Microgrids

There is a major focus on microgrids, which are localized power grids that can disconnect from the traditional grid to operate independently.[40] Because most power outages occur at the distribution level, microgrid developments can help mitigate grid disturbances and strengthen grid resilience. OE's microgrid program goals are to develop commercial scale microgrid systems (with a capacity less than 10 megawatts)[41] that are capable of reducing outage time of required loads by more than 98%. This would be accomplished at a cost comparable to non-integrated baseline solutions, while reducing emissions by 20% and improving system energy efficiencies by 20% by 2020.[42]

Advanced Distribution Management Systems (ADMS)

This program promotes higher performing grids by integrating new assets and information streams with ADMS. An OE report describes these systems:

> ADMS is a software platform that integrates numerous utility systems and provides automated outage restoration and optimization of distribution grid performance. ADMS functions can include automated fault location, isolation, and service restoration (FLISR); conservation voltage reduction; peak demand management; and volt/volt-ampere reactive (volt/VAR) optimization.[43] In effect, an ADMS transitions utilities from paperwork,

[38] The Smart Grid program is covered in DOE, FY2016 Budget Request, pp. 346-353. For more about smart grid issues, see CRS Report R41886, *The Smart Grid and Cybersecurity—Regulatory Policy and Issues*, by (name redac ted) .

[39] The smaller medium- and low-voltage lines of the electric distribution system cover more distance than high voltage transmission lines.

[40] The Smart Grid R&D Program adopts the definition of the microgrid by the Microgrid Exchange Group (MEG); namely, "A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode." DOE, OE, *Summary Report: 2012 DOE Microgrid Workshop*, p. 1, http://energy.gov/sites/prod/files/2012%20Microgrid%20Workshop%20Report%2009102012.pdf.

[41] One megawatt (MW) represents 1 million watts, or 1,000 kilowatts.

[42] DOE, OE, *Summary Report: 2012 DOE Microgrid Workshop*, p. 1. Also, see DOE, *Microgrid Activities*, http://energy.gov/oe/services/technology-development/smart-grid/role-microgrids-helping-advance-nation-s-energy-syst-0.

[43] Volt/VAR optimization reduces electric line losses and increases grid efficiency. These technologies have advanced (continued...)

> manual processes, and siloed [separated] software systems to systems with real-time and near-real-time data, automated processes, and integrated systems.[44]

The report on ADMS notes further that existing mechanisms for the diagnosis of end-of-the-line power problems have yet to employ modern computer capabilities:

> Considering that this is an era in which smart phones and Google Maps are ubiquitous, it may come as a surprise that utilities have very little visibility into their distribution systems. Most systems still rely on breakers to disconnect the lines in the event of a fault, customers to call in to report an outage, and line crews to find the affected circuit and restore power.[45]

DOE observes that ADMS is a fledgling industry that lacks mature, field-proven vendor products. However, DOE's technology program is working with vendors to help fill that gap. ADMS integration into existing utility operating systems is difficult. Those systems were traditionally custom-built, and evolved with technologies over the course of several decades. Integrating new systems with old—or getting them to "talk" to each other—is complicated and requires an information technology foundation that can support each component of an ADMS.[46]

In FY2016, the program aims to enhance operational visibility and system asset control. It will start the development of an open source ADMS platform that supports the full range of distribution management applications (such as fault location, service restoration, and operational optimization). Also, the program will begin to develop data analytics for large volumes of grid data needed to validate distribution grid operations.

Market-Based Control Strategies (MBCS)

Smart Grid investments will also explore market-based controls in FY2016. The process of coupling market-based control signals with electric distribution operations is generally known as transactive energy. Transactive energy refers to the use of a combination of economic (resource bidding) and physical control techniques to improve grid reliability and efficiency. Regarding the economic aspect, a transactive energy system may lead to collection of data from more nodes (access points on the grid) and, thus, yield finer-grained levels of real-time pricing for each data point.[47] Also, by coordinating the activity of the growing number of distributed energy resources, transactive energy systems can help maintain power system reliability and security while increasing efficiency.[48] Development of the MBCS process is intended to create value to both utilities and customers. This new control paradigm is to enable utilities to balance supply and demand at all levels of the grid, by actively seeking participation of customer-owned and third-

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(...continued)

to include Volt/Volt-Ampere Reactive Optimization (VVO) sensors, equipment and software capable of reducing overall distribution line losses by 2%–5% through tight control of voltage and current fluctuations. See National Electrical Manufacturers Association (NEMA), *Volt/VAR Optimization Improves Grid Efficiency*, https://www.nema.org/Policy/Energy/Smartgrid/Documents/VoltVAR-Optimazation-Improves%20Grid-Efficiency.pdf.

[44] DOE, OE, *Voices of Experience: Insights into Advanced Distribution Management Systems*, (DOE/GO-OT-6A42-63689) February 2015, p. 3, https://www.smartgrid.gov/document/insights_advanced_distribution_management_systems.

[45] OE, *Voices of Experience*, p. 3.

[46] OE, *Voices of Experience*, p. 6.

[47] This may result in a need for regulations keyed to a more dynamic energy market.

[48] For more about transactive energy, see DOE, Gridwise Architecture Council, *Gridwise Transactive Energy Framework (version 1.0)*, January 2015, http://www.gridwiseac.org/pdfs/te_framework_report_pnnl-22946.pdf.

party assets in grid services through transparent, competitive forces of demand and supply.[49] The prices or incentives offered by market forces will engage the self-interest of customers and other third parties, and will also serve as a control signal to coordinate operation of their assets with the power grid. Hence, transactive energy will result in greatly increased flexibility needed for maintaining reliability in a low-carbon future, while allowing customers to fully participate in grid operations.

For FY2016, the program aims to develop simulation tools and to apply validating tools to initial test cases that were funded by the Recovery Act. Transactive approaches will be evaluated to refine controllability, stability limits, and efficacy of operating distributed assets (end-use devices, distributed generation, batteries, PV solar systems, inverters, EV chargers, etc.) and networked communication systems.

Cybersecurity for Energy Delivery Systems (CEDS)[50]

Reliable and resilient energy infrastructure is essential to our economy, health and safety, and national security. OE's mission to modernize the electric grid cannot be achieved without the research, development, and integration of secure energy delivery control systems. The energy sector—including electricity, oil, and natural gas—has experienced a dramatic increase in cyber probes,[51] data exfiltration,[52] and malware[53] development for potential attacks. The growing seriousness of these intrusions marks an era of state actor level threats to the nation. The dynamic cyber threat landscape, continuous advances in energy delivery system technologies, and the use of legacy devices in ways not previously envisioned underscore the importance of this continuous transition.

The Cybersecurity (CEDS) program aims to strengthen the energy infrastructure against current and future cyber threats. The strategic framework for DOE's role is shaped mainly by Presidential Policy Directive 21, *Critical Infrastructure Security and Resilience.*[54] The directive calls on the sector-specific agencies (SSAs) to serve as a day-to-day federal interface for the dynamic prioritization and coordination of various sector-specific activities. As the energy SSA, DOE has the mission, history, and expertise to work with industry to mitigate the risk of cyberattacks on the energy system. To fulfill this responsibility, DOE collaborates with vendors, utility owners, and operators of the electricity and oil and natural gas sectors to strengthen the cybersecurity of critical energy infrastructure.

OE has the lead role in addressing this DOE responsibility. To meet this requirement the CEDS program conducts cyber risk and incident management activities with four key objectives: (1)

[49] One might think of this process as a sort of "supply-response" mechanism, as a parallel concept to the growing practice of demand-response programs.

[50] The Cybersecurity program is covered in DOE, FY2016 Budget Request, pp. 354-360. For more about cybersecurity issues, see CRS Report R41886, *The Smart Grid and Cybersecurity—Regulatory Policy and Issues*, by (name redac ted) .

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

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

[53] 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.

[54] The CEDS program structure also aligns with guidance provided in the *2011 Roadmap to Achieve Energy Delivery Systems Cybersecurity*, prepared by the Energy Sector Control Systems Working Group of the Critical Infrastructure Partnership Advisory Council, September 2011, http://energy.gov/sites/prod/files/Energy%20Delivery%20Systems%20Cybersecurity%20Roadmap_finalweb.pdf.

accelerate information sharing to enhance situational awareness; (2) expand implementation of the Cybersecurity Capability Maturity Models and Risk Management Process, (3) conduct technology R&D to improve energy reliability and resilience, and (4) exercise and refine the energy sector's cyber incident response capabilities.

Energy Storage[55]

The Storage program is designed to develop and demonstrate new and advanced energy storage technologies (e.g., batteries, pumped hydro, flywheels) that will enable the stability, resiliency, and reliability of the future electric utility grid. The program also aims to support increased use of variable renewable energy resources such as wind and solar power generation. The Storage program addresses four challenges identified in the 2013 DOE strategic plan for *Grid Energy Storage*:[56] cost-competitive energy storage technology, validated reliability and safety, equitable regulatory environment, and industry acceptance.

The implementation of grid-scale energy storage projects throughout the country is accelerating. Microgrids involving storage are being installed by the military for energy security and by states, including New Jersey and Massachusetts, for emergency preparedness. However, storage technology still needs to make substantial improvements in safety, cycle life, energy density, and cost before becoming fully competitive. R&D activities focus on lowering cost while improving the value, performance, safety, and reliability of stationary energy storage technologies for utility-scale applications.

Transformer Resilience and Advanced Components (TRAC)[57]

DOE requested a new funding line to establish this new program in FY2016. The focus is on shielding electric system transformers[58] from a variety of sources that could inflict damage by creating unwanted electric currents. Larger-scale electric utility transformers are vulnerable to certain conditions that can cause a spike in current or voltage.[59] If not protected from such threats, damage to a transformer creates vulnerabilities for other electric system equipment. The proposed program's activities would expand upon initial work funded previously under OE's Infrastructure Security and Emergency Response (ISER) program.

Transformers and utility substation equipment are often exposed to the elements and are vulnerable to natural and man-made threats. To ensure a reliable and resilient power system, grid components need to be designed and built to withstand the impact of lightning strikes, extreme

[55] The Energy Storage program is covered in DOE, *FY2016 Budget Request*, pp. 361-366.

[56] DOE, *Grid Energy Storage*, December 2013, http://energy.gov/oe/downloads/grid-energy-storage-december-2013.

[57] The Transformer Resilience and Advanced Components program is covered in DOE, *FY2016 Budget Request*, pp. 367-369.

[58] Most people have seen the round, barrel-shaped objects mounted on neighborhood electric utility poles. Those objects are transformers that reduce (step down) the current and voltage on those lines to a lower level that is appropriate for the equipment used in homes, institutions, and commercial buildings. Another familiar example of a transformer is the power adapter that often comes packaged with various consumer electronic devices such as laptop computers and computer monitors. These devices reduce, or otherwise adapt, household current and voltage to levels that won't damage sensitive electronic devices. The TRAC program focuses on much larger, grid-scale transformers.

[59] For more about transformer security issues, see CRS Report R43604, *Physical Security of the U.S. Power Grid: High-Voltage Transformer Substations*, by (name redacted) . For more about legislation on this issue, see CRS Insight IN10425, *Electric Grid Physical Security: Recent Legislation*, by (name redacted) .

weather, sun-driven "space weather,"[60] electrical disturbances, accidents, equipment failures, and attacks (physical or cyber). Currently, 70% of large power transformers (LPTs) are aged 25 years or more, 60% of circuit breakers are aged 30 years or more, and 70% of transmission lines are aged 25 years or more. The advanced age of these components degrades their ability to withstand physical stresses and may result in higher failure rates. Failure of key components can lead to widespread outages and long recovery times.[61]

The TRAC program supports grid modernization and resilience by addressing the unique challenges facing transformers and other key components that transport power from generation sites to demand sites. As the hardware of the electric power system evolves to improve resilience and accommodate clean energy sources, R&D and testing is needed to understand the physical impact this evolution has on transformers and other vital grid components and to adapt these components with new technologies.

The program will analyze the impact of geomagnetically-induced[62] ground currents (GIC) on the power grid and support power electronics development. The TRAC program aims to advance the understanding of the risks and impacts of geomagnetic disturbances (GMD) and electromagnetic pulses (EMP) on large power transformers (LPTs) and other grid components.[63]

LPTs are the most critical pieces of equipment in the grid. Induced currents from GMD/EMP can overload LPTs, damaging internal components and increasing failure rates. The nature of the vulnerability of different types of transformers to GMD/EMP as well as the predictability of GMD phenomena is not well understood.

Additionally, increased use of distributed generation will introduce new challenges with reversed power flows, increased harmonics,[64] and larger fault currents that can impact transformers and other grid components. The program will be conducted in close cooperation with equipment manufacturers and electricity asset owners and operators.[65]

[60] Coronal mass ejections (CMEs) appear to pose the most serious threats to the power grid. A CME occurs when the sun ejects charged particles that interact with Earth's magnetic field, creating a "magnetic storm" that can cause long-lasting blackouts of the power grid. Scientists note that "[t]he sudden increase in power can damage sensitive electronic equipment. Power transformers can overload, causing long-lasting blackouts. Long metal structures like oil and gas pipelines can carry currents, which can enhance their corrosion over time.... " See space.com, "Space Weather: Sunspots, Solar Flares and Coronal Mass Ejections," http://www.space.com/11506-space-weather-sunspots-solar-flares-coronal-mass-ejections.html.

[61] For instance, a single LPT that is damaged can temporarily disrupt power to 500,000 homes and, as a typically custom-designed piece of equipment weighing over 100 tons, it could take up to two years to manufacture and deliver a replacement. DOE, *FY2016 Budget Request*, p. 367. For more about LPTs, see DOE, Large Power Transformers and the U.S. Electric Grid, 2012, http://energy.gov/sites/prod/files/Large%20Power%20Transformer%20Study%20-%20June%202012_0.pdf.

[62] These currents are caused by coronal mass ejections from the sun. This is a more intense experience of the same phenomenon that causes the aurora borealis, or "northern lights."

[63] For more on this aspect, see CRS Congressional Distribution Memo, *Space Weather and EMP Threats to the Electric Grid*, by (name redacted) .

[64] Harmonics are a distortion of the normal electrical current waveform, generally transmitted by nonlinear loads. Switch-mode power supplies (SMPS), variable speed motors and drives, photocopiers, personal computers, laser printers, fax machines, battery chargers and uninterruptible power supplies (UPSs) are examples of nonlinear loads.

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

National Electricity Delivery (NED)[66]

Upon request, this program provides technical and policy expertise to states, regions, and tribes to help develop and implement reliable and affordable electricity infrastructure. NED also authorizes the import and export of electricity, issues permits for cross-border transmission lines, and coordinates federal transmission permitting on federal lands.

The NED program helps state, regional, local, and tribal entities to develop, refine, and improve their electric power programs, policies, and laws. Also, the program helps these entities develop and implement reliable and affordable electricity infrastructure—including generation, transmission, storage, distribution, and demand-side electricity resources. Through this work, OE aims to strengthen these individual systems, which in turn will strengthen the entire electricity infrastructure.

At the federal and international level, NED leads governmental actions in authorizing electricity exports and permitting transmission infrastructure construction across international borders. Also, in accordance with the Federal Power Act, NED conducts a triennial national transmission congestion study,[67] and helps coordinate transmission permitting on federal lands.

Infrastructure Security and Energy Restoration (ISER)[68]

The ISER program leads national efforts to enhance the reliability, survivability, and resiliency of all national energy infrastructure, including that for electricity, petroleum, and natural gas. The program aims to mitigate consumer energy disruptions and—when energy emergencies occur—to drive an efficient restoration process. ISER conducts activities in cooperation with public and private sector stakeholders, including asset owners and operators. Its key partners include industry and state governments.

ISER activities are grouped under three main areas: (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.

The program provides long-term strategic actions to help secure the national energy supply against a variety of challenges. Those challenges include more frequent, stronger, and more destructive weather events; increasing incidents of physical attacks; potential accidents as a result of aging infrastructure or human error; high-impact, low frequency (HILF) threats such as a catastrophic earthquake or an extended drought; and the continuing cyber threat. These challenges are amplified by the increasing complexity of the energy infrastructure and systems and the interdependencies affecting other critical industries.

To further strengthen OE's ability to secure the U.S. energy infrastructure, ISER promotes the development of advanced mitigation solutions for "hardening" infrastructure against all hazards, natural and man-made. The program focuses mainly on the hazards that pose the greatest risk to

[66] The National Electricity Delivery program is covered in DOE, *FY2016 Budget Request*, pp. 370-376.

[67] The most recent triennial national transmission congestion study was published in 2015. See, DOE, National Electric Transmission Congestion Study, September 2015, http://www.energy.gov/sites/prod/files/2015/09/f26/2015%20National%20Electric%20Transmission%20Congestion%20Study_0.pdf.

[68] The Infrastructure Security and Energy Restoration program is covered in DOE, *FY2016 Budget Request*, pp. 377-386.

the nation's energy infrastructure, including HILF events and more frequent physical threats such as devastating weather events.

Upon request, ISER also provides technical assistance to international partners, in collaboration with the U.S. Department of State, to analyze and secure energy assets.

State Energy Reliability and Assurance Grants[69]

DOE proposed this grant program as a new activity for FY2016. The $63 million proposal to establish the program was the single largest funding increase that OE requested. The program would have provided grants to states, localities, regions, and tribal entities (or groups of states and tribes). Two distinct grant programs would have been created: Grants for Electricity Transmission, Storage, and Distribution Reliability (ETSDR) and Grants for Energy Assurance. Of the $63 million requested, $27.5 million would have gone to the ETSDR subprogram and $35.5 million would have gone to the Energy Assurance subprogram.

As a rationale for the program, OE's request noted that states have considerable jurisdiction over the electricity system. DOE observes that states are "excellent test beds for the evolution of the electric power system" and, with federal support, could provide innovative ways to address new trends by allowing the electric sector to provide services that meet goals for reliability, resiliency, efficiency, environmental, and energy assurance. Such activities are in place now, but need to be adequately funded and better integrated within states and across states. DOE says that its long history of technical assistance to states has positioned it to help coordinate those planning processes within states and across state lines.

Grants for Electricity Transmission, Storage, and Distribution Reliability

DOE proposed this new program for state energy market and policy design systems to address system interdependencies and scale-up of renewable energy integration. The program was designed to support the grid modernization crosscut initiative. The requested $27.5 million would have funded grants to states and others to develop energy system reliability plans to advance electric reliability planning and integrate the plans with environmental protection (including climate adaptation), climate resiliency, and efficiency infrastructure planning and action.[70]

Energy Assurance Grants

The energy assurance planning grants would have provided formula grants to improve the short-term and long-term capacity of state, local, and tribal governments to identify the potential for energy disruptions, quantify the impacts of those disruptions, and develop responsive plans to mitigate the threat of future disruptions. The requested $35.5 million would have been used to

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[69] The State Energy Reliability and Assurance Grants program is covered in DOE, *FY2016 Budget Request*, pp. 387-391.

[70] More specifically, the ETSDR program would have provided planning grants to promote long-term electricity system reliability planning, including (1) integrating plans and actions for transmission, storage, and distribution (TSD) reliability, climate resiliency, and environmental compliance, (2) plans for the evolving interdependencies of electricity, natural gas and water systems; (3) regulatory reforms to enable investments in TSD that address the challenges of the evolving system, including reforms for distributed generation and energy efficiency; (4) plans for upgrades of infrastructure to make it more resilient to climate change and extreme weather; (5) design incentives and cost recovery mechanisms for reliability and climate resiliency investments; and (6) foster within-state and multi-state cooperation.

update energy assurance plans; require testing, training, and exercises; and ensure that plans and assessments were shared.

A key DOE rationale for the proposed program was the fact that state and local governments are ultimately responsible for responding to disasters and disruptions. This program was designed for OE to help those governments build and maintain preparedness and assurance capabilities.[71] The program would have financed state, local, and tribal government efforts to enhance resiliency through energy assurance planning and the testing of, training for, and exercising of those plans.[72] This grant program would have been undertaken in cooperation with OE's ISER program, which would have served as a convener of forums for information sharing and coordination of state energy assurance plans with other state and local disaster and emergency response plans, private sector response plans, and the plans of neighboring states.

Program Direction[73]

This administrative activity funds the costs associated with the OE workforce, including salaries, benefits, travel, training, building occupancy, information technology services, and other related expenses. The program funding also provides for the costs associated with contractor services that support OE's mission.

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 R43567, *Energy and Water Development: FY2015 Appropriations*, coordinated 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 R43966, *Energy and Water Development: FY2016 Appropriations*, 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)

[71] The goal of state and local energy assurance planning is 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.

[72] Such plans would have been designed to include (1) energy emergency procedures that address multiple lifeline (e.g., food, housing, and shelter) sectors, (2) integration with state energy plans, state hazard mitigation plans, and other policies, and (3) mechanisms to track the duration, response, restoration and recovery time of energy supply disruption events.

[73] The Program Direction activity is covered in DOE, *FY2016 Budget Request*, pp. 392-395.

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