THE PEW CHARITABLE TRUSTS

Feb 2016

# Distributed Generation: Cleaner, Cheaper, Stronger

# Federal Investment Advances Technology Development

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## About the series

This document series, "Distributed Generation: Cleaner, Cheaper, Stronger," explores the evolving nature of the U.S. electric grid and the role of specific technologies in modernizing the power-generating system.

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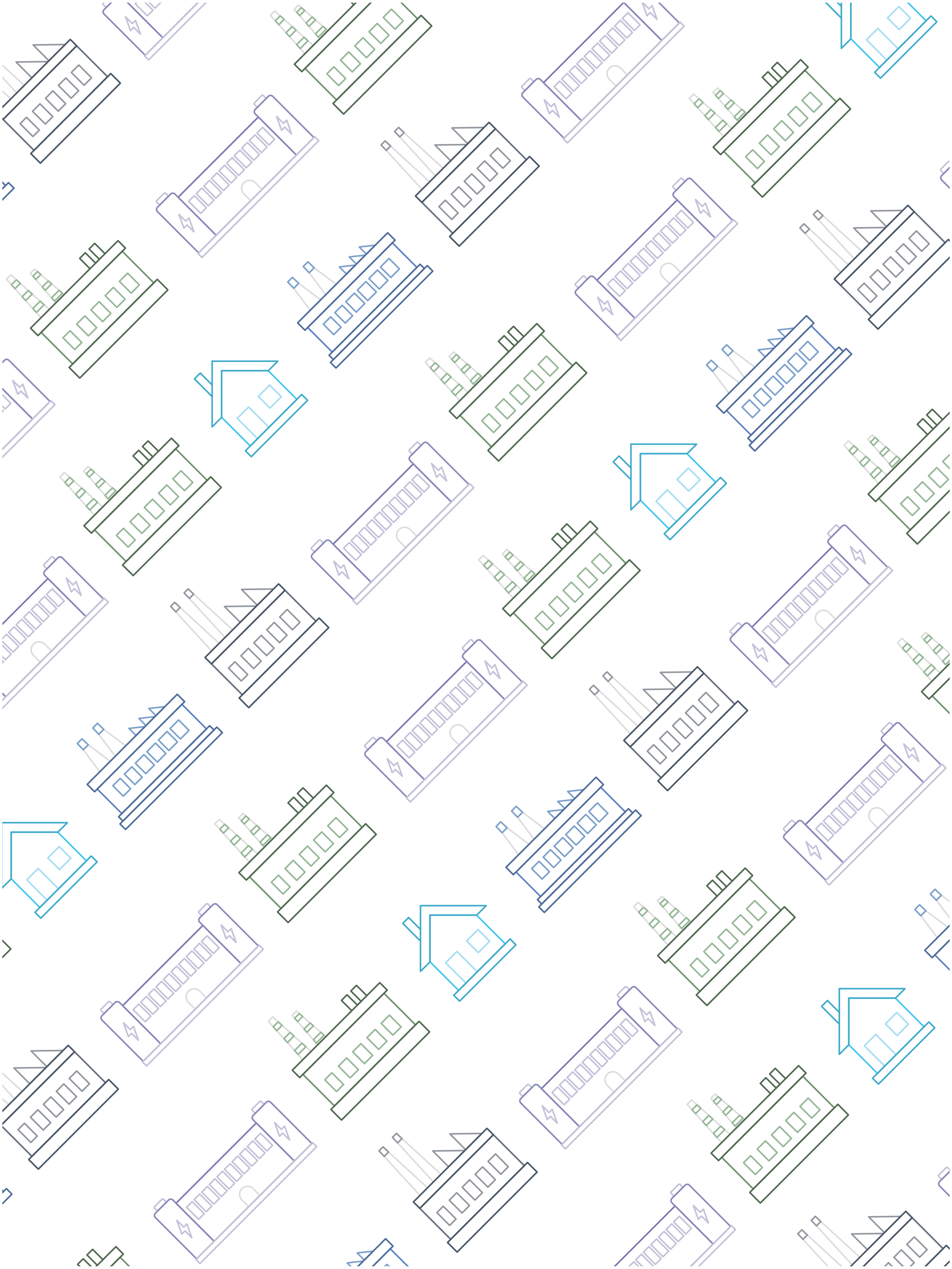


# Distributed Generation: Cleaner, Cheaper, Stronger

# Energy Storage for the Evolving Power System

## Overview

Distributed energy resources allow electricity to be generated closer to where it is used, protecting businesses and institutions from unexpected outages caused by natural disasters and other disruptions. The U.S. national laboratories as well as public-private partnerships provide financial resources and access to research facilities to foster innovations to modernize the power sector from a 100-year-old centralized system to one that incorporates disparate clean technologies such as microgrids, batteries, and energy smart tools. These investments and the resulting new products and capabilities decrease costs, improve grid reliability, reduce emissions, and offer consumers more options.

Energy storage technologies encourage adoption of renewable energy by addressing generation variation resulting from weather conditions. They also aid local utilities by providing an array of grid-balancing services, such as peak shifting—shifting grid usage by consumers from periods of high demand to less intensive times—and backup power supplies. These characteristics support a cleaner and more reliable electric system and present an important market opportunity for the clean energy economy.

## Energy storage makes the system more efficient

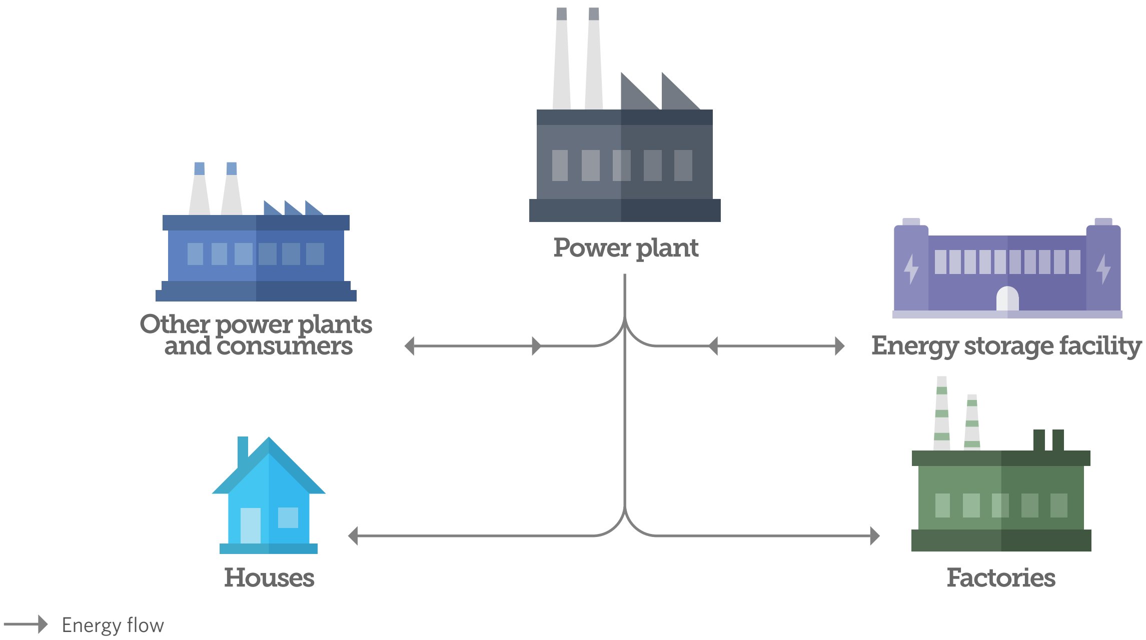
Although demand for electricity often varies by the minute, changing the nation's generating capacity is a slow process. Energy storage technologies enable utilities to better match fixed capacity with variable demand and offer more reliable, secure, and affordable service.

Batteries are an emerging storage option that can improve the central grid's reliability and increase the use of clean and efficient power sources. For example, when the wind is blowing but demand is low, batteries capture energy from spinning wind turbines and save it for later use. Energy storage can similarly enhance the usability of solar and other intermittent renewable resources. Batteries also offer environmental benefits because they have no emissions.[1] Further, energy storage supports local utilities by enabling peak shifting, providing backup power and ancillary grid services,[2] and potentially reducing the need for additional fossil-fueled generation sources.

Figure 1

## Energy Storage Strengthens Distributed Grid Components

Sample system design and interconnection






### Energy Storage Technologies

A variety of innovative technologies are capable of capturing energy as it is produced and storing it until it is needed. Among the leading approaches are:

- Batteries. These devices convert stored chemical energy into electrical energy. A variety of types are available, including lithium-ion, sodium sulfur, and lead acid, and more chemical alternatives are being developed.*
- Flywheels. This mechanical device converts electricity into kinetic energy by constantly spinning a small rotor. When needed, energy is released back to the grid through a turbinelike device.†
- Electrochemical capacitors. These systems store electrical charge in solid materials rather than converting charges to another form through chemical or phase changes, as occurs in batteries.‡
- Superconducting magnetic energy storage. These units employ superconducting coils, power conditioning systems, and cooling mechanisms to inductively store energy.§

*Continued on next page*

* Massachusetts Institute of Technology School of Engineering, "How Does a Battery Work?" http://engineering.mit.edu/ask/how-does-battery-work; U.S. Department of Energy, "Grid Energy Storage," December 2013, http://energy.gov/sites/prod/files/2014/09/f18/Grid%20Energy%20Storage%20December%202013.pdf.

† U.S. Department of Energy, "Grid Energy Storage"; Energy Storage Association, "Flywheels," http://energystorage.org/energy-storage/storage-technology-comparisons/thermal.

‡ U.S. Department of Energy, "Grid Energy Storage"; Cantec Systems, "What Is an Electrochemical Capacitor? How Does It Work? How Does It Differ in Operation and Performance From Today's Standard SLI Battery?" http://www.cantecsystems.com/oldsite/ccrdocs/how-electrochemical-capacitors-work.pdf.

§ U.S. Department of Energy, "Grid Energy Storage."

## Federal support promotes technology development

Despite its ability to strengthen the power system, the storage industry continues to face barriers to widespread deployment, including high costs, limited benefit valuation—that is, quantifying and realizing the monetary worth of contributions to the system, such as improved resiliency and backup power—constrained grid access, and restrictive integration protocols.[3] The U.S. Department of Energy has sought to overcome these and other challenges through initiatives such as research, workshops, funding opportunities, small business innovation grants, collaboration between the agency and the national laboratories, and pilot projects.[4] The department's Office of Electricity Delivery & Energy Reliability supports these efforts through its Energy Storage Program, which works closely with industry partners to research and develop batteries, flywheels, electrochemical capacitors, superconducting magnetic energy storage, power electronics, control systems, and other technologies.[5]

The DOE Office of Science's Basic Energy Sciences Program oversees research on and development of novel materials to better understand the physical and chemical characteristics of advanced energy storage technologies. The office manages these efforts through the Joint Center for Energy Storage Research, a collaboration of four national laboratories, five universities, and four private firms headquartered at Argonne National Laboratory near Chicago. The cooperative center is one of four DOE facilities established in 2010 to address technological barriers in the energy sector through a combination of basic and applied science and engineering expertise.[6]

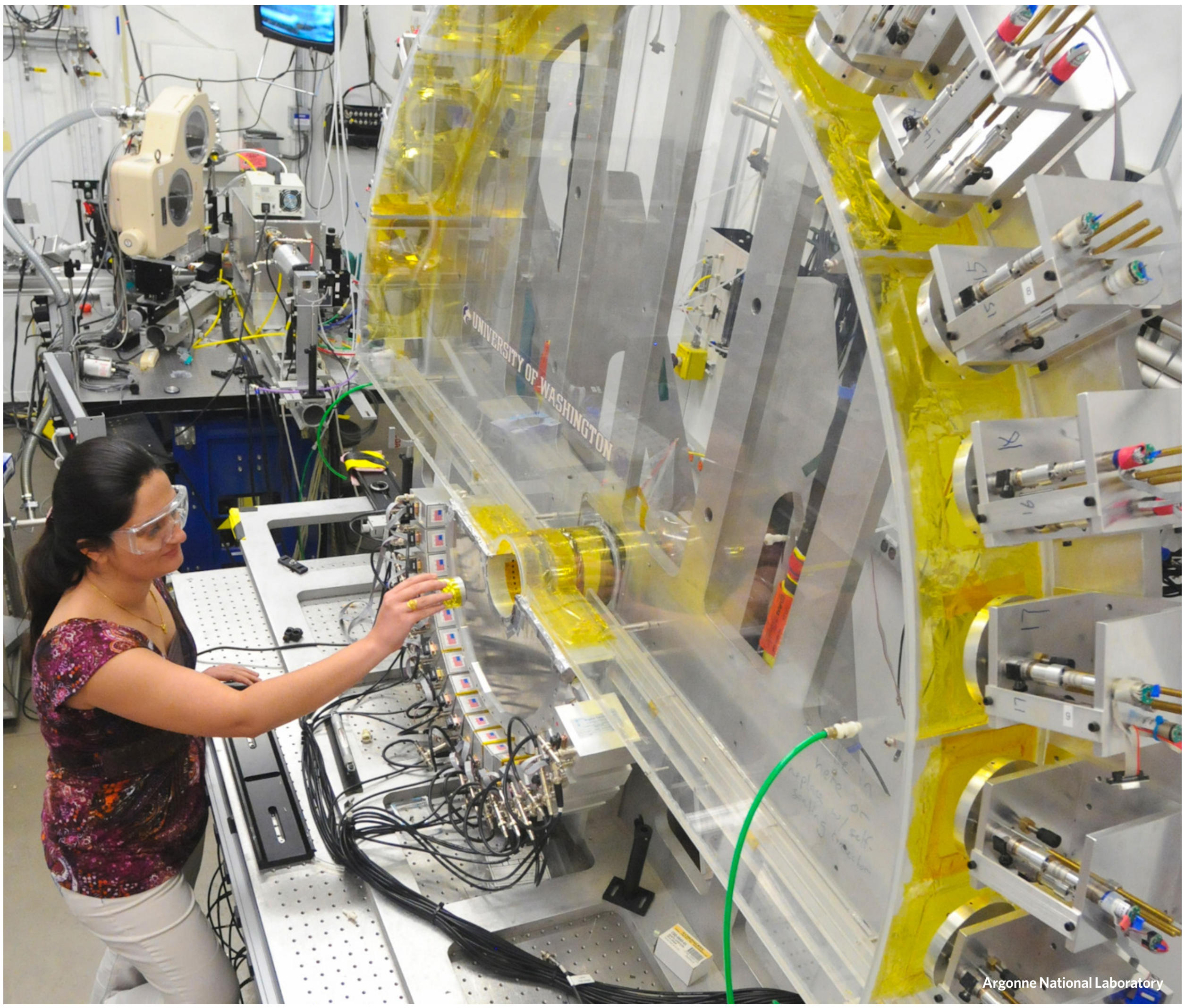
The Advanced Research Projects Agency-Energy (ARPA-E) helps commercialize cutting-edge energy technologies. The agency has several programs focused on research and development to prove and create prototypes of high-risk but promising new energy storage technologies, including transformational electrical energy storage systems.[7] Overall, the agency has provided $75.7 million in funding to 32 completed projects as of December 2015 and is supporting 36 ongoing ventures with over $108 million in grants.[8]

ARPA-E has three energy storage programs. The Advanced Management and Protection of Energy Storage Devices program is working to advance battery performance, safety, and longevity through innovations that reduce technology costs and battery sizes across the energy system.[9] The Cycling Hardware to Analyze and Ready Grid-Scale Electricity Storage program is testing battery technologies to accelerate commercialization under current and projected operating conditions. Finally, the Grid-Scale Rampable Intermittent Dispatchable

Storage program is creating low-cost technologies that can store renewable energy for use at any location on the grid at a cost of less than $100 per kilowatt-hour, compared with market costs for other storage products of $130 to $1,500 per kwh.[10] In November 2015, the agency selected four projects—housed at Oak Ridge National Laboratory, Iowa State University, and two private companies—to receive more than $10 million to develop advanced storage technologies and promote grid integration.[11]

At Sandia National Laboratories, the Energy Storage Systems program is collaborating with industry, academia, and government institutions to increase reliability and performance and market competitiveness of grid storage.[12] The lab also hosts DOE's Global Energy Storage Database, which provides information on grid-connected storage projects and relevant state and federal policies.[13]

In addition to the DOE's efforts, the Department of Defense's Installation Energy Test Bed, established in 2009 to demonstrate new technologies in real-world situations, includes incorporation of commercial-scale energy storage in microgrid systems as one of its five focus areas.[14]




Swati V. Pol, an assistant materials scientist at Argonne National Laboratory, loads an in situ lithium-ion battery into the low-energy resolution inelastic X-ray system at the Advanced Photon Source. This multielement X-ray scattering instrument is helping Argonne researchers understand the fundamental mechanisms that limit the performance of batteries.

### Public-Private Partnership Tackles Energy Storage

The federal government is partnering with private industry and academic institutions to conduct large-scale, complex investigations into emerging technologies. Although battery efficiency and life span have improved over the past decade, further innovation is needed to provide sufficient capacity for use in grid and vehicle sectors. A team at the Joint Center for Energy Storage Research, led by experts from the Argonne National Laboratory, is working to create a next-generation battery that would perform five times faster, at a fifth of the cost of current technologies, to help electric cars drive farther and provide renewable energy storage to improve the electrical grid.*

* U.S. Department of Energy Office of Science, "Research: DOE Energy Innovation Hubs," http://science.energy.gov/bes/research/doe-energy-innovation-hubs; Joint Center for Energy Storage Research, "The National Mission," http://www.jcesr.org/research/the-national-need/.

## Policies to advance energy storage

As of October 2015, 244 energy storage projects were operating or under construction in the U.S., representing 381 megawatts of capacity.[15] Researchers estimate that by 2019, the nation will have energy storage capacity of 861 MW, worth $1.5 billion annually, and by 2022 that capacity could increase more than 10,000 percent from 2014 levels.[16] The rapidly growing market for energy storage presents an important opportunity for investors, businesses, and the overall economy.[17] However, in order for these benefits to be realized, policy changes that address specific components of energy storage systems are needed.

**10,000%** Estimated growth of energy storage market, 2014-22

### Benefit monetization and grid integration

Continued growth of the storage sector will require improved federal policies. Because the traditional utility business model does not monetize the benefits of storage and because regulations are often not designed to cover these resources, the industry faces barriers that inhibit market adoption.[18] Regulatory guidance and best practices are needed to set standards for energy storage performance, safety, packaging, cycle life, operational control, and integration with the grid. For example, the Heat Efficiency through Applied Technology (HEAT) Act introduced in 2015 helps to reduce uncertainty about where and how projects can connect and interact with the grid, improving the environment for development.[19] Valuing the economic, environmental, and security benefits and services of all distributed technologies in the electric system will further clarify the role of these technologies.[20]

One effort that is underway to address these barriers is the work of industry stakeholders and the Federal Energy Regulatory Commission to include storage under the commission's Order 755, which regulates compensation for ancillary grid services, and Order 784, which requires public utilities to take into account the speed and accuracy of regulation resources. These policies help to ensure that storage technologies have a role in nationwide energy markets.[21]

## Investment tax credit

Government grants and tax credits also spur development by helping to reduce the time that investors must wait to see a return on their investments.[22] A few states have adopted storage incentives, but the federal investment tax credit does not recognize most storage technologies. Despite proposals introduced in Congress to expand the ITC, only energy storage projects paired with solar installations are currently eligible for the credit.[23] The ITC is scheduled to expire at the end of 2016, but the clean energy industry is pushing for an extension.

The Internal Revenue Service and U.S. Department of Treasury are also examining possible revisions to the credit. In response to questions from the business community, the agencies issued a notice in the fall of 2015 seeking comment on what types of storage technologies should be considered for ITC eligibility.[24] Businesses and investors need stable, predictable federal tax policy in order to create jobs, invest capital, and deploy pollution-reducing technologies. Allowing tax incentives to lapse jeopardizes long-term investments that have already been made and dampens future growth of clean energy industries.

## Master limited partnerships

A bicameral, bipartisan group in Congress has proposed the Master Limited Partnerships Parity Act (S. 1656 and H.R. 2883), which would allow renewable generation and transmission projects, including electricity storage, to be part of master limited partnerships. [25] Established nearly 30 years ago, these business structures are levied as partnerships whose ownership interests are traded on a market like corporate stock, offering significant tax benefits to investors. They have been effective in attracting private investment in the conventional fuel sector, but clean energy technologies have been barred from accessing this structure to date.

## Financial and planning incentives

A number of other opportunities exist for federal policy to support greater adoption of energy storage technologies:

- Funding mechanisms, such as the Energy Department's loan program, encourage communities to adopt storage technologies by helping to address upfront capital costs that can hinder project development.
- The Department of Defense aims to deploy three gigawatts of renewable energy on Army, Navy, and Air Force installations by 2025 as part of a larger goal to produce or procure at least 25 percent of total facility energy needs from renewable sources.[26]
- Including battery technologies as eligible components of federal government renewable or alternative energy portfolios or energy plans can help drive development.[27]
- Resource planning programs that require evaluation of the potential for these projects when anticipating future capacity ensure that opportunities are not overlooked.[28]

- At the state level, most public utility commissions use the Institute of Electrical and Electronics Engineers' 2003 voluntary standard for interconnection protocols and procedures.[29] This standard is being revised to account for continued sector innovation, including development of energy storage technologies. Updated procedures that are appropriate for emerging technologies will further promote market growth and community adoption by reducing and streamlining interconnection challenges.

The federal government continues to emphasize the important role of storage in the evolving grid through ongoing research and recommendations for future investigation. In April 2015, the Department of Energy released the Quadrennial Energy Review, which examines modernization of the nation's energy infrastructure to promote economic competitiveness, energy security, and environmental responsibility with a focus on energy transmission, storage, and distribution.[30] The QER discusses the importance of industry standards for connection of customer-owned generation to the local distributed system, not only for improving grid safety but also for encouraging overall reliability and promoting incorporation of distributed resources, including storage.[31] The department will use these findings to inform and guide future energy policy development.

## Conclusion

The energy storage market is rapidly evolving in response to advancements that are making these technologies more attractive to consumers and more affordable for investors. In turn, storage systems help to modernize the grid by enhancing power reliability and integrating renewable resources. Federal support in all aspects of the market, from research to deployment, is helping to create new opportunities for the domestic energy industry and resulting in a cleaner, cheaper, and stronger grid. By extending and improving policies such as the investment tax credit and allowing clean and efficient energy properties access to master limited partnerships, federal policymakers can help these technologies advance and expand even more quickly. Congress and the administration should work together to support ongoing initiatives and new proposals to support U.S. leadership in energy storage.

# Endnotes


1 Energy Storage Association, "Applications of Energy Storage Technology," http://energystorage.org/energy-storage/applications-energy-storage-technology.

2 Rocky Mountain Institute, "The Distributed Energy Storage Industry in One Chart," Feb. 4, 2015, http://blog.rmi.org/blog_2015_02_04_the_distributed_energy_storage_industry_in_one_chart.

3 Ibid.

4 U.S. Department of Energy, "Grid Energy Storage," December 2013, http://energy.gov/sites/prod/files/2014/09/f18/Grid%20Energy%20Storage%20December%202013.pdf.

5 U.S. Department of Energy, "Energy Storage," http://energy.gov/oe/services/technology-development/energy-storage.

6 U.S. Department of Energy, "Grid Energy Storage"; U.S. Department of Energy Office of Science, "Research: DOE Energy Innovation Hubs," http://science.energy.gov/bes/research/doe-energy-innovation-hubs/.

7 U.S. Department of Energy, "Grid Energy Storage."

8 Advanced Research Projects Agency-Energy, "Search Projects," http://arpa-e.energy.gov/?q=projects/search-projects.

9 Advanced Research Projects Agency-Energy, "View Programs," http://arpa-e.energy.gov/?q=arpa-e-site-page/view-programs.

10 Ibid; International Energy Agency, "Technology Roadmap: Energy Storage," 2014, https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapEnergystorage.pdf.

11 Advanced Research Projects Agency-Energy, "ARPA-E Open 2015 Project Selections," Nov. 23, 2015, http://arpa-e.energy.gov/sites/default/files/documents/files/OPEN_2015_Project_Descriptions.pdf.

12 U.S. Department of Energy, "Energy Storage Systems Program," http://www.sandia.gov/ess.

13 U.S. Department of Energy Office of Electricity Delivery & Energy Reliability, "DOE Global Energy Storage Database," http://www.energystorageexchange.org.

14 Strategic Environmental Research and Development Program and Environmental Security Technology Certification Program, "Installation Energy Test Bed," https://www.serdp-estcp.org/Featured-Initiatives/Installation-Energy.

15 U.S. Department of Energy, "DOE Global Energy Storage Database."

16 Greentech Media, "U.S. Energy Storage Market to Grow 250% in 2015," March 5, 2015, http://www.greentechmedia.com/articles/read/us-energy-storage-market-grew-400-in-2014; Sam Wilkinson, "The Grid-Connected Energy Storage Market Is Set to Explode, Reaching a Total of Over 40 GW of Installations by 2022," IHS Technology, https://technology.ihs.com/483008/the-grid-connected-energy-storage-market-is-set-to-explode-reaching-a-total-of-over-40-gw-of-installations-by-2022.

17 Energy Storage Association, "Facts & Figures," http://energystorage.org/energy-storage/facts-figures.

18 Robert P. Thornton, "Microgrids: Moving Into the Mainstream," International District Energy Association (June 25, 2014), http://www.districtenergy.org/assets/pdfs/News_items/Thornton-AZ-Corp-Comm-IDEA-Microgrids-Mainstream-June-25-6.22-RPT.pdf.

19 U.S. Department of Energy, "Grid Energy Storage"; U.S. Senate Committee on Energy and Natural Resources, "S. 1202—HEAT Act," May 8, 2015, http://www.energy.senate.gov/public/index.cfm/legislation?ID=85564296-e682-4243-9662-482308e1041e.

20 Thomas Bourgeois et al., "Community Microgrids: Smarter, Cleaner, Greener," Pace Energy and Climate Center, Pace Law School (2013), http://energy.pace.edu/sites/default/files/publications/Community%20Microgrids%20Report%20(2).pdf.

21 Energy Storage Association, "Federal Regulatory Policy Action," http://energystorage.org/policy/regulatory-policy; Preti Flaherty, "FERC Order 784 Boosts Energy Storage," July 24, 2013, http://energypolicyupdate.blogspot.com/2013/07/ferc-order-no-784-boosts-energy-storage.html; Preti Flaherty, "FERC Order 755 Promotes Energy Storage," Dec. 21, 2011, http://energypolicyupdate.blogspot.com/2011/12/ferc-order-755-promotes-energy-storage.html.

22 Thomas Bourgeois et al., "Community Microgrids: Smarter, Cleaner, Greener."

23 Dave Yankee, "Financing Energy Storage With Tax Credits," Deloitte, Sept. 28, 2015, https://www2.deloitte.com/content/dam/Deloitte/us/Documents/energy-resources/us-er-financing-energy-storage-with-tax-credits.pdf; David Meyers and Randy Palombi, "Solar and Storage: Better Together?" Greentech Media, Aug. 17, 2015, http://www.greentechmedia.com/articles/read/Solar-and-Storage-Better-Together.

24 Energy Storage Association, "Legislative Policy Priorities," http://energystorage.org/policy/legislative-policy.

25 U.S. Senator Christopher Coons, "The Master Limited Partnerships Parity Act," http://www.coons.senate.gov/issues/master-limited-partnerships-parity-act; Energy Storage Association, "Legislative Policy Priorities."

26 The White House, "Fact Sheet: Obama Administration Announces Additional Steps to Increase Energy Security," April 11, 2012, https://www.whitehouse.gov/the-press-office/2012/04/11/fact-sheet-obama-administration-announces-additional-steps-increase-ener; Jeff St. John, "The Military Microgrid as Smart Grid Asset," Greentech Media, May 17, 2013, http://www.greentechmedia.com/articles/read/the-military-microgrid-as-smart-grid-asset.

27 KEMA, "Microgrids: Benefits, Models, Barriers and Suggested Policy Initiatives for the Commonwealth of Massachusetts," Feb. 3, 2014, http://nyssmartgrid.com/wp-content/uploads/Microgrids-Benefits-Models-Barriers-and-Suggested-Policy-Initiatives-for-the-Commonwealth-of-Massachusetts.pdf.

28 Thomas Bourgeois et al., "Community Microgrids: Smarter, Cleaner, Greener."

29 Ibid.

30 U.S. Department of Energy, "Quadrennial Energy Review: Energy Transmission, Storage, and Distribution Infrastructure," April 2015, http://energy.gov/sites/prod/files/2015/07/f24/QER%20Full%20Report_TS%26D%20April%202015_0.pdf.

31 Ibid.

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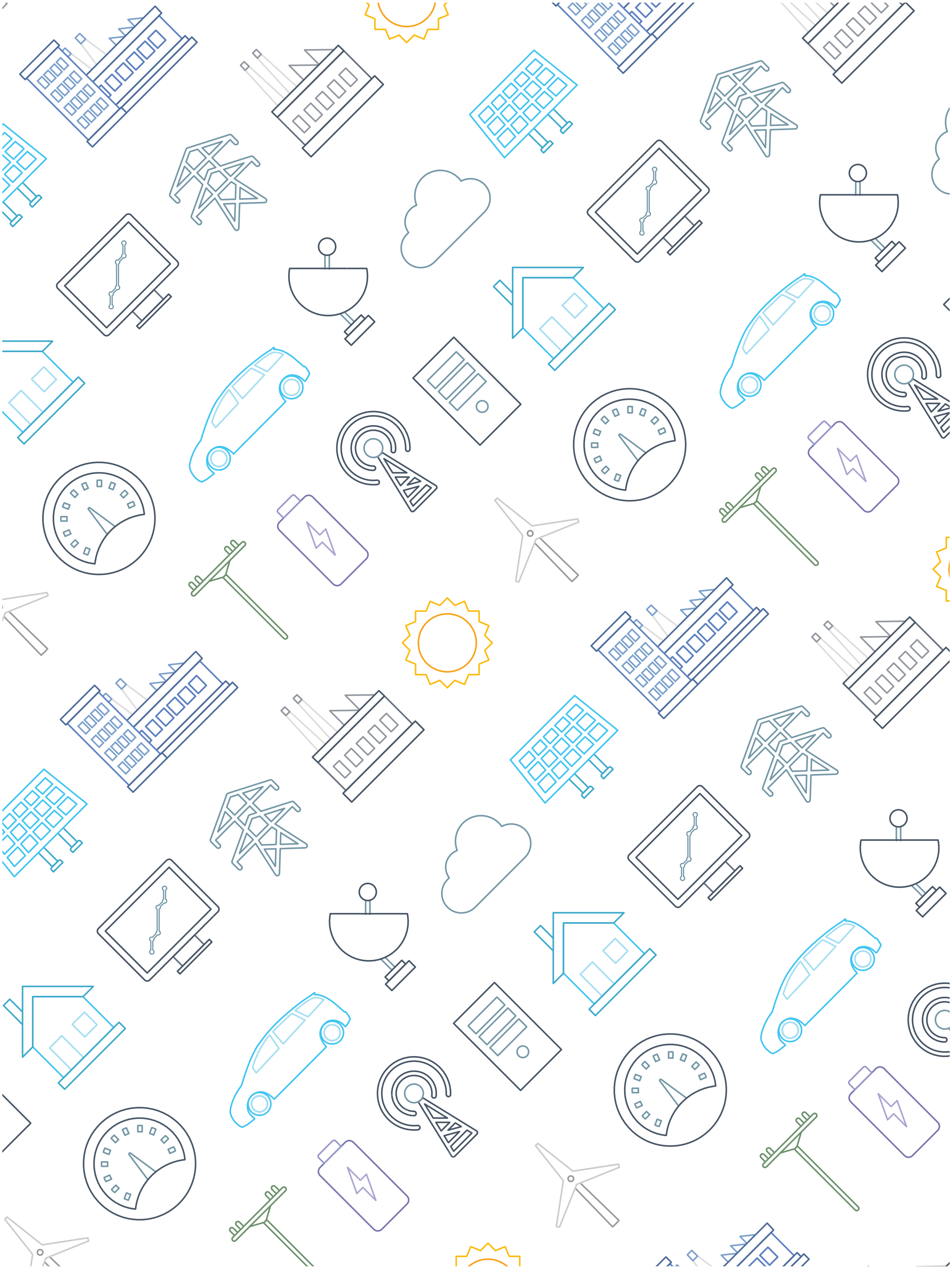

# Distributed Generation: Cleaner, Cheaper, Stronger

# Energy Smart Technologies in the Evolving Power System

## Overview

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Energy smart technologies are products and services that increase the connection and dialogue between electricity producers and end users. They are the heart of a smart grid—a combination of parts plus a process for using information and communication technologies to integrate the components of each electric system—and are contributing to one of the first major foundational changes to the U.S. power system since its inception a century ago.[1] The growth of this market presents a critical opportunity for generators and end users across a vast array of industries to develop new products and improve efficiency and resiliency in the evolving grid.

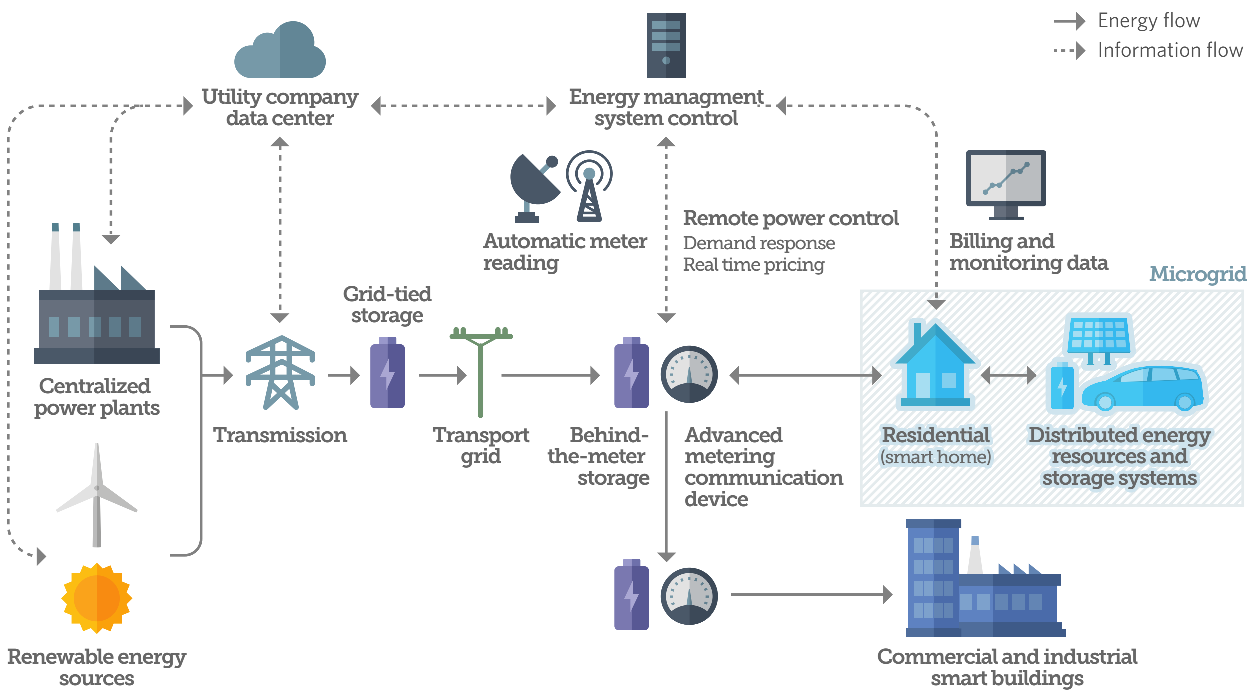
## Smart innovations increase dialogue between producers and users

Energy smart products and devices can be deployed in the residential, commercial, institutional, and industrial sectors. By increasing the analytic data available to grid operators and energy users, smart technologies create an information bridge linking generation, transmission, and distribution with consumers.[2] For example, digital technologies that enable two-way communications are helping to better match the generation of power with demand. These capabilities allow grid managers and end users to make more informed decisions about how and when to use energy based on grid requirements and price signals. And the additional information helps utilities manage their increasingly diverse generation portfolios.

Figure 1

## Digital Products and Processes Integrate Electrical Grid Components

Sample system design and interconnection




Source: LG CNS



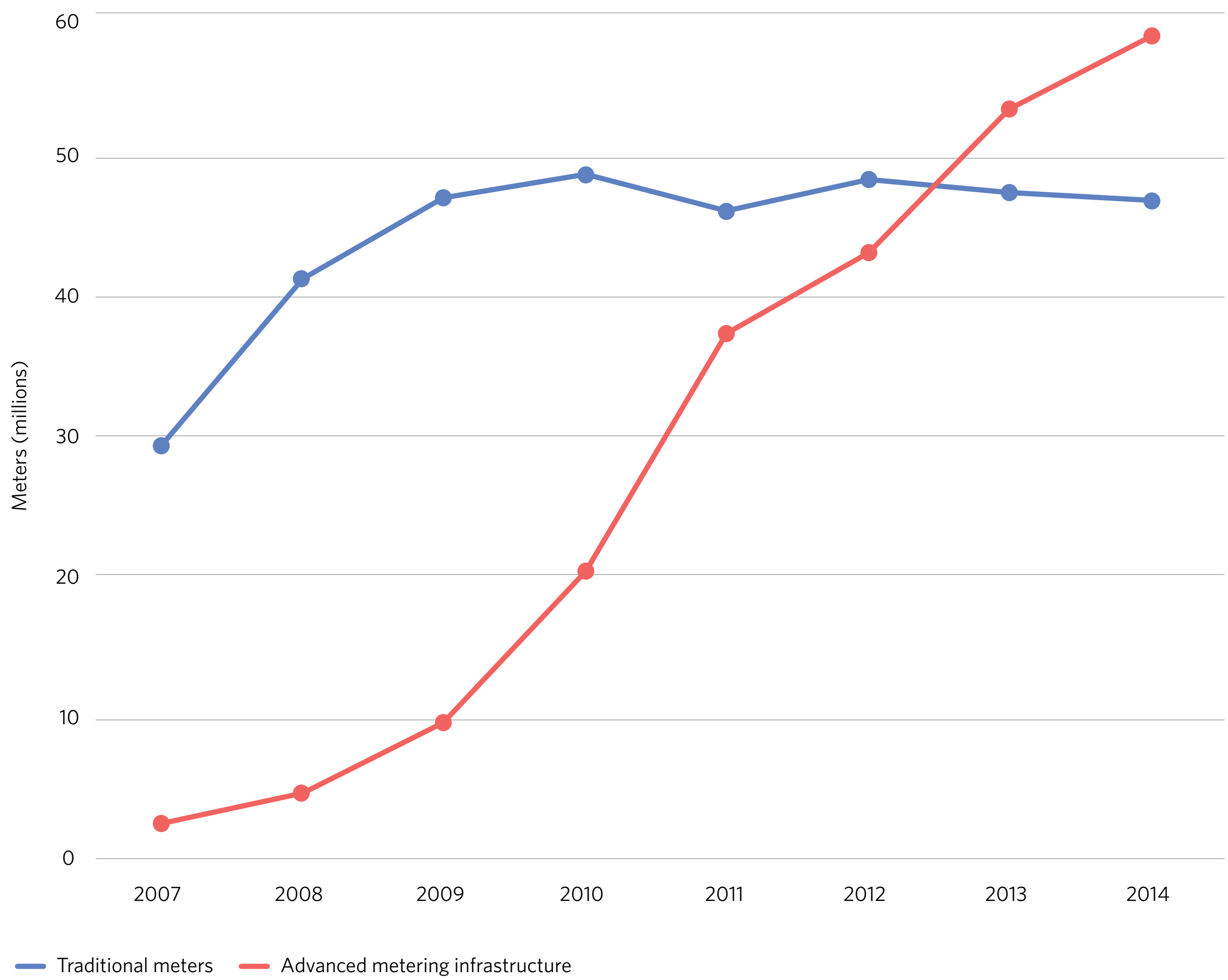
Other new products are making the grid more interconnected and responsive. These include advanced metering infrastructure, automated feeder switches, voltage regulators, and other innovative controls that enable grid stability and resilience. Similarly, smart meters allow utilities and consumers to communicate digitally and make more informed decisions about energy demand, production, and use. Such sharing of data is emblematic of these emerging capabilities. Since 2007, deployment of these meters has grown rapidly, surpassing traditional automated installations for the first time, with over 51.9 million meters in 2013.[3]

**51.9 million** smart meters deployed in 2013

Figure 2

## Smart Meter Installations Have Surpassed Those of Traditional Meters

Changes in deployment of metering infrastructure, 2007-14




Source: U.S. Energy Information Administration



## Energy users reap benefits of smart technologies

New smart devices are providing residential customers with a greater understanding of their energy use and, in turn, driving changes in individual behavior. For example, smart thermostats provide customers with data about what time of day their appliances are cycling on and off and how their energy use compares with that of their neighbors. The thermostats are also a source of tips for saving more power—for example, doing laundry at night when the price of electricity is lower. Some utilities are offering customers digital meters and incentives to temporarily reduce their homes' power use when the grid experiences high demand.

Figure 3

## New Products and Devices Increase End-User Energy Management

Example of residential smart technology opportunities


Source: Austin Good



Many major businesses and sectors are targeting the emerging opportunity of the "connected home," including telecommunications firms such as Verizon and AT&T; information technology firms such as Google and Apple; solar energy firms such as Solar City; home security firms such as ADT; home improvement stores such as Lowe's and Home Depot; and an array of companies that provide individual or bundled services to consumers.

The availability of additional information is also changing the behavior of many industrial, commercial, and institutional energy users. Having access to real-time demand and price data helps end users make more informed decisions on energy use and consumption to optimize their resources. Large-scale power users who make electricity using distributed resources can decide whether to use the energy they generate or sell it back to the grid, taking advantage of real-time pricing. Further, as more improved technologies come online, smart grid devices will allow owners of energy storage equipment to capitalize on the power they are holding.

## Energy Smart Technologies Come in Many Shapes and Sizes

A variety of available energy smart devices can provide consumers with real-time analysis and optimization of energy production and consumption. Among the leading products and processes are:

- **Smart meters and intelligent appliances.** Smart meters allow utilities and consumers to communicate digitally and are usually installed buildingwide. End users also can purchase new versions of commonly used devices—including household appliances, thermostats, irrigation and security systems, and heating and cooling systems—that can communicate with smart meters or central building operations and adapt energy use based on weather conditions and pre-established user preferences. Systems can be controlled remotely through Internet-connected products.
- **Grid automation.** Energy transmission with two-way digital communication allows utility operators to respond to data collected from grid components, such as smart meters and voltage sensors, and efficiently deploy power generation resources.
- **Intelligent demand management.** These technologies are capable of sensing system overloads and rerouting power generation to resolve potential disruptions.
- **Power asset integration.** These interconnected systems include all types of energy generation to take advantage of efficiency and storage technologies as well as renewable resources that may be intermittent, such as solar and wind, but are able to reduce demand peaks and contribute to load management.*

* Litos Strategic Communication, "The Smart Grid: An Introduction," U.S. Department of Energy, http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/DOE_SG_Book_Single_Pages%281%29.pdf; Smartgrid.gov, "What Is the Smart Grid?" https://www.smartgrid.gov/the_smart_grid/renewable_energy.html.

Research shows that energy smart technologies offer a safer, more affordable means of producing and transporting power. It also finds that, compared with traditional fuel sources, these technologies provide a cleaner approach to updating aging infrastructure across the country. An analysis of the economic benefits of smart grid systems by the National Energy Technology Laboratory found that improved operating efficiency could reduce operational maintenance and capital costs for delivery and electricity suppliers and that transmission and congestion losses could each decrease by 10 percent, saving consumers $2.5 billion and $2 billion a year, respectively.[4] A Rocky Mountain Institute report on residential energy smart technologies found that controlling the timing of just two common residential appliances—air conditioners and electric water heaters—could lower U.S. peak demand by 8 percent, lessening required infrastructure investments by 10 to 15 percent through 2030.[5]

Overall, customer applications in residential and commercial building could have economic benefits worth $59 billion by 2019.[6]

## Federal support promotes technology development

The Energy Independence and Security Act of 2007 identified modernization of the nation's electricity transmission and distribution system as vital for ensuring the reliability of its power supply. Since then, the federal government has supported a variety of research, education, and development efforts.[7]

Deployment of advanced metering infrastructure was one priority of the American Reinvestment and Recovery Act of 2009, which provided $3.4 billion in federal government grants for smart grid installation efforts.[8] These investments and associated private-sector initiatives spurred a near-fourfold increase in the number of smart meters installed in the United States from 2009 to 2014.[9] Federal government reports suggest that smart meters and other advanced controls are reducing participating utilities' costs by 13 percent to 77 percent and have the potential to lower peak electric demand by 30 percent or more.[10]

The U.S. Department of Energy's Office of Electricity Delivery & Energy Reliability runs Smartgrid.gov, an online public resource providing information on the technologies that make up a smart grid and their benefits.[11] DOE's Lawrence Berkeley National Laboratory provides technical assistance for research and policy support by developing best practices for design, measurement, verification, and implementation of smart grids and related products.[12]

The Advanced Research Projects Agency-Energy (ARPA-E), which helps commercialize cutting-edge energy technologies, invests in smart grid innovations: The agency has provided more than $37.5 million in funding to 32 completed projects and as of December 2015 is supporting 36 more with almost $29.5 million in grants.[13] In November 2015, it selected five projects focused on grid system performance—two housed at higher education institutions, two at private companies, and one at the Pacific Northwest National Laboratory in Richland, Washington—as 2015 funding recipients and awarded them a total of almost $15 million.[14]

## Policies to advance energy smart technologies

For these benefits to be realized, however, policy changes are needed to address specific components of energy systems.[15] Energy smart technologies are often underutilized and undercompensated, considering the array of services and benefits they provide.[16] Traditional utility business models tend to provide a disincentive to customer efficiency by tying utility profits to the volume of power sales, although in some cases, advanced regulatory policies have been used to decouple utility profits from sales.[17] Load-driven electricity rates and residential demand charges are two regulatory changes that would begin to encourage technology deployment. Policymakers can also support energy smart technology adoption by providing regulatory guidance to states on best practices that clarify how, where, and when systems can be developed and can connect to the grid. This will ensure that all economic, environmental, and security benefits and services of these products are valued.[18]

Government-provided financial incentives that reduce upfront costs for interested parties can spur technology adoption and encourage development. Inclusion of products and processes that reduce power consumption in overall state renewable and efficient energy portfolios can also help drive growth and innovation.[19] Resource planning programs that require consideration of demand reduction as a means to avoid future capacity additions can also help maximize adoption and contribute to market growth in the sector.[20]

In April 2015, the Department of Energy released the Quadrennial Energy Review, examining modernization of the nation's energy infrastructure to promote economic competitiveness, energy security, and environmental responsibility with a focus on energy transmission, storage, and distribution.[21] The report identifies energy smart technologies as key infrastructure improvements that can mitigate environmental impacts and grid vulnerabilities, improve overall grid efficiency and resiliency, and reduce costs.[22] It also discussed the importance of open standard development—similar to the USB standard developed in the mid-1990s for evolving computers, printers, games, and mobile devices—to address the lack of interoperability between different technologies and the larger grid system.[23] The review recommended additional funding of up to $3.5 billion to support energy system modernization through development of smart grid technologies.[24]

## Conclusion

As innovations in energy smart technologies enhance communication between producers and consumers, the role of these products in the power system will continue to evolve. National recognition of the economic and security benefits offered by smart products will be essential to support further deployment and market growth. Establishment of open standards will unify the technologies and drive interconnection. Continued financing of innovation will help to lower costs and increase market adoption, resulting in a cleaner, cheaper, and stronger grid. Although the U.S. Department of Energy has been a longtime sponsor of this type of groundbreaking research, the agency faces ongoing budget limitations. Continued congressional support and federal investment in energy smart technologies will be critical to maintaining the nation's leadership in clean energy.

## Endnotes


1 Roger Levy et al., "An Introduction—Smart Grid 101," Lawrence Berkeley National Laboratory Smart Grid Technical Advisory Project (June 16, 2011), http://smartresponse.lbl.gov/reports/chapter1-3.pdf.

2 Ibid.

3 U.S. Energy Information Administration, "Electric Monthly Update Highlights: February 2015," April 27, 2015, http://www.eia.gov/electricity/monthly/update/archive/april2015/.

4 National Energy Technology Laboratory, "Understand the Benefits of the Smart Grid," June 18, 2010, http://www.netl.doe.gov/File%20Library/research/energy%20efficiency/smart%20grid/whitepapers/06-18-2010_Understanding-Smart-Grid-Benefits.pdf.

5 Rocky Mountain Institute, "Report Release: The Economics of Demand Flexibility," Aug. 26, 2015, http://blog.rmi.org/blog_2015_08_26_report_release_the_economics_of_demand_flexibility.

6 U.S. Department of Energy, "Quadrennial Energy Review: Energy Transmission, Storage, and Distribution Infrastructure," April 2015, http://energy.gov/sites/prod/files/2015/07/f24/QER%20Full%20Report_TS%26D%20April%202015_0.pdf.

7 Smartgrid.gov, "About Smartgrid.gov," https://www.smartgrid.gov/about_smartgridgov.html.

8 U.S. Department of Energy, Office of Electricity Delivery & Energy Reliability, "Recovery Act: Smart Grid Investment Grants," http://energy.gov/oe/technology-development/smart-grid/recovery-act-smart-grid-investment-grants.

9 The Edison Foundation, Institute for Electric Innovation, "Utility-Scale Smart Meter Deployments: Building Block of the Evolving Power Grid" (September 2014), http://www.edisonfoundation.net/iei/Documents/IEI_SmartMeterUpdate_0914.pdf.

10 U.S. Department of Energy, Office of Electricity Delivery & Energy Reliability, "Recovery Act: Smart Grid Investment Grants."

11 Smartgrid.gov, https://www.smartgrid.gov/.

12 Lawrence Berkeley National Laboratory, "Demand Response & Smart Grid," Electricity Markets and Policy Group, https://emp.lbl.gov/research-areas/demand-response-smart-grid.

13 Advanced Research Projects Agency-Energy, "Search Projects," http://arpa-e.energy.gov/?q=projects/search-projects.

14 Advanced Research Projects Agency-Energy, "ARPA-E Open 2015 Project Selections," Nov. 23, 2015, http://arpa-e.energy.gov/sites/default/files/documents/files/OPEN_2015_Project_Descriptions.pdf.

15 Rocky Mountain Institute, "Report Release: The Economics of Demand Flexibility."

16 Robert P. Thornton, "Microgrids: Moving Into the Mainstream," International District Energy Association (June 25, 2014), http://www.districtenergy.org/assets/pdfs/News_items/Thornton-AZ-Corp-Comm-IDEA-Microgrids-Mainstream-June-25-6.22-RPT.pdf.

17 Ibid.

18 Thomas Bourgeois et al., "Community Microgrids: Smarter, Cleaner, Greener," Pace Energy and Climate Center, Pace Law School (2013), http://energy.pace.edu/sites/default/files/publications/Community%20Microgrids%20Report%20(2).pdf.

19 Ibid.

20 Ibid; KEMA, "Microgrids: Benefits, Models, Barriers, and Suggested Policy Initiatives for the Commonwealth of Massachusetts," Feb. 3, 2014, http://nyssmartgrid.com/wp-content/uploads/Microgrids-Benefits-Models-Barriers-and-Suggested-Policy-Initiatives-for-the-Commonwealth-of-Massachusetts.pdf.

21 U.S. Department of Energy, "Quadrennial Energy Review."

22 Roderick Jackson et al., "Opportunities for Energy Efficiency Improvements in the U.S. Electricity Transmission and Distribution System," Oak Ridge National Laboratory (April 2015), http://energy.gov/sites/prod/files/2015/04/f22/QER%20Analysis%20-%20Opportunities%20for%20Energy%20Efficiency%20Improvements%20in%20the%20US%20Electricity%20Transmission%20and%20Distribution%20System_0.pdf; U.S. Department of Energy, "Quadrennial Energy Review."

23 U.S. Department of Energy, "Quadrennial Energy Review."

24 Ibid.

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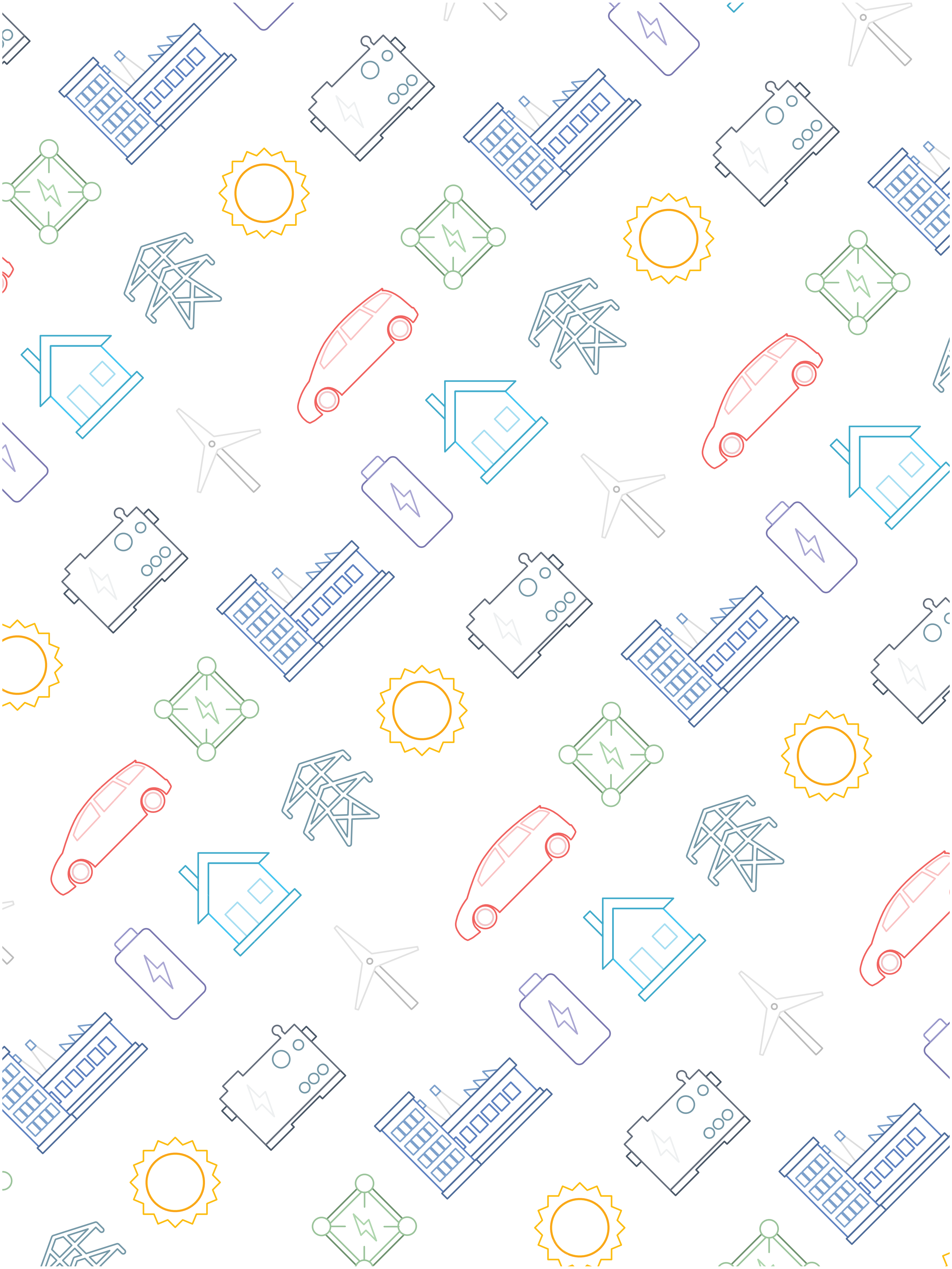


# Distributed Generation: Cleaner, Cheaper, Stronger

# Microgrids in the Evolving Power System

## Overview

Distributed energy resources allow electricity to be generated closer to where it is used, protecting businesses and institutions from unexpected outages caused by natural disasters and other disruptions. The U.S. national laboratories as well as public-private partnerships provide financial resources and access to research facilities to foster innovations to modernize the power sector from a 100-year-old centralized system to one that incorporates disparate clean technologies such as microgrids, batteries, and energy smart tools. These investments and the resulting new products and capabilities decrease costs, improve grid reliability, reduce emissions, and offer consumers more options.

Microgrids are small groupings of interconnected power generation and control technologies that can operate within or independent of a central grid, mitigating disturbances and increasing system reliability. By enabling the integration of distributed resources such as wind and solar, these systems can be more flexible than traditional grids. This market presents a new and important opportunity for end users, generators, and planners to provide increased efficiency and resiliency in the evolving grid.

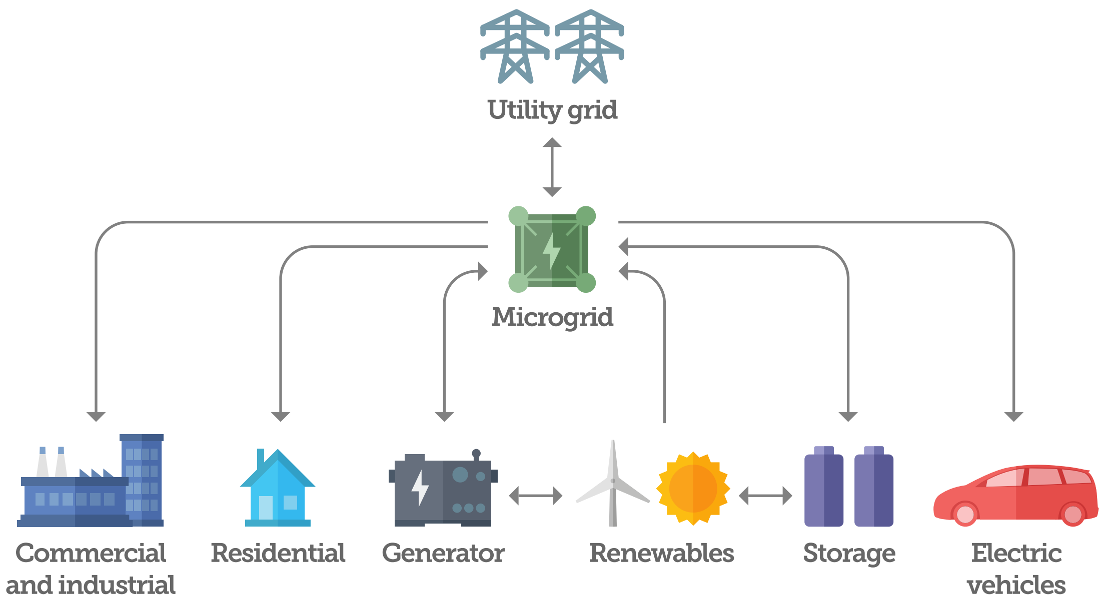
## Localized power generation and management

Microgrids are at the forefront of the nation's evolving electric grid because they balance supply and demand to optimize energy distribution and production within a defined geographic area. Many are able to disconnect from the larger grid and operate autonomously, ensuring uninterrupted power. A microgrid can be as simple as a generator that provides power to a building during a blackout or as complex as generation, distribution, and management technologies that control production and consumption to meet the electricity, heating, and cooling needs of a whole neighborhood.[1]

> "What will make this work is understanding that it's a package deal. It's combined heat and power; it's storage; it's demand reduction."
>
> —Daniel C. Esty, *former commissioner, Connecticut Department of Energy and Environmental Protection*

## Microgrids Can Incorporate a Range of Technologies to Ensure Power for Critical Facilities

Sample system design and interconnection




Source: LG CNS



## Microgrids integrate distributed resources and strengthen the energy system

Microgrids make renewable, storage, and efficiency technologies more attractive by integrating them into a unified energy system. Connecting such a wide variety of resources improves flexibility and efficiency and reduces transmission and distribution losses. Further, increased deployment of clean and efficient power technologies cuts greenhouse gas and other emissions and boosts energy security by enabling the system to mitigate disturbances and, if necessary, operate in isolation from the grid.[2] Microgrids also benefit local utilities by providing on-demand generation and ancillary services (e.g., voltage, frequency, and wave form stability) and by helping to manage the grid load.[3] These attributes offer increased control over fluctuations in demand and can lower costs for all customers by offsetting expensive peak loads with local generation and reducing overall grid congestion by requiring centralized producers to deliver less power.[4]

As of July 2015, 124 microgrids were in operation across the country, with a total capacity of 1,169 megawatts.[5] Industry experts expect that by 2020, nationwide microgrid capacity will exceed 2,850 MW, an increase of almost 145 percent,[6] and estimate that total market value will surpass $3.5 billion, growing nearly 270 percent.[7]

## Federal support promotes technology development

The U.S. Department of Energy leads federal research to advance development and deployment of microgrids through partnerships with organizations such as the national laboratories, academic institutions, and the private sector. The DOE's interest lies in using the technology to improve electricity reliability and resiliency, help communities prepare for future grid outages, and encourage growth of clean and efficient energy industries.[8]

The Energy Department's national labs host a variety of projects to advance microgrid capabilities. At the Lawrence Berkeley National Laboratory, the Microgrids Group studies customer adoption of the systems and researches storage and distribution, project design, and installation.[9] Since 2000, this program has been working on an economic and environmental model to broaden development of resilient microgrids.[10] The Sandia National Laboratories are exploring the role of microgrids in providing energy reliability through a computer-based risk assessment approach that identifies critical needs and enables smart grid functionality (i.e., demand response,[11] interconnection and integration of resources, and net metering).[12] In 2014, the DOE allocated more than $8 million through seven equal awards to support microgrid research, development, and design.[13] Recipients included the University of California, Irvine; the Electric Power Research Institute; Commonwealth Edison Co.; and private-sector businesses.[14]

The Advanced Research Projects Agency-Energy (ARPA-E), which helps commercialize cutting-edge energy technologies, has embraced the microgrid concept. As of December 2015, ARPA-E has invested $86.7 million in funding to 31 completed grid and distributed energy technology projects and is supporting 56 other initiatives with $154.4 million in grants. In early 2015, the agency announced that its Network Optimized Distributed Energy Systems program will invest $30 million in projects that use microgrids to integrate clean and efficient generation with the central grid. The program aims to improve overall power efficiency and reliability and increase the deployment of renewables by 50 percent or more.[15] In November 2015, ARPA-E announced that microgrid research led by the University of Tennessee, Knoxville was among 41 projects selected for a grant of $2.4 million to develop an operating system that responds to changes in power availability with a goal of decreasing the costs.[16]

The Department of Defense's adoption of microgrid technology is helping to spur industry growth and demonstrate feasibility for both military and civilian applications through on-base project deployment. The department is implementing advanced microgrids that incorporate sophisticated controls for managing demand, producing and distributing power, and allowing bases to operate independently of the commercial grid. The Installation Energy Test Bed program, established in 2009 to demonstrate new technologies in real-world situations, includes microgrid commercialization as one of its five focus areas.[17] As a result, bases across the country—including Fort Carson in Colorado and Joint Base Pearl Harbor-Hickam and Camp H.M. Smith in Hawaii—are incorporating renewable and storage technologies with advanced data analysis systems to create self-sufficient and resilient power resources that ensure operational readiness.[18]

## Policies to advance microgrid technologies

For these benefits to be realized, however, improved federal policies that address the specific components of microgrids are needed. These systems tend to be underutilized and undercompensated for the services and social and economic benefits they provide. The traditional utility business model does not adequately incentivize either customer generation of power or efficiency. In addition, most regulatory policies are not designed for customers who are also generators, a factor that limits deployment.[19] An equitable regulatory environment for energy technologies would encourage greater adoption of microgrids and ensure that all economic, environmental, and security benefits and services of these products are recognized and captured.[20]

Lawmakers can create a supportive marketplace by providing regulatory guidance or best practices related to system development and interconnection. Policies that provide certainty about where and how projects can connect and interact with the commercial grid would increase the deployment of microgrids. Valuing economic, environmental, and security benefits and services would further clarify the role of these technologies and allow investors to monetize their attributes for a quicker return on investment, making the projects more attractive.[21]

Government grants and tax credits can also spur adoption by providing capital to prospective users.[22] Many state governments are exploring "green banks"—which provide low-interest, long-term financing for clean energy development—as well as revolving loans and other financial incentives to help communities pay for pre-development assessments.[23] States could also include microgrids as eligible technologies for clean and renewable incentives or alternative energy portfolios to help drive market growth.[24] Further, programs that require consideration of microgrids as part of planning for future capacity needs can ensure that deployment opportunities are not overlooked.[25]

Federal commitments to clean energy can encourage adoption as well. In part because of early funding and a focus on technology demonstration and commercialization efforts, the military is a leading adopter of these systems. According to a report released in April 2015, more than 40 bases have installed microgrids, have plans to develop them, or have conducted preliminary studies.[26] The DOD is expected to produce more than 54.8 MW of capacity by 2018.[27] The Army, Navy, and Air Force will each generate 1 gigawatt of renewable energy by 2025 as part of a larger goal to produce or procure at least 25 percent of total facility energy needs from renewable sources and incorporate microgrids and storage capabilities.[28] Microgrids are also identified for continued investment and research in the DOD Annual Energy Management Report as a means to help achieve these goals.[29]

In April 2015, the Department of Energy released the Quadrennial Energy Review (QER) examining modernization of the nation's energy infrastructure to promote economic competitiveness, energy security, and environmental responsibility, with a focus on energy transmission, storage, and distribution.[30] The report identifies microgrids as a key component of the evolving energy system, contributing to new approaches for flexible and cost-effective grid management.[31]

Among its recommendations, the QER discusses the importance of industry standards for connection of customer-owned generation to the local distributed system, not only for improving grid safety but also for overall system reliability and incorporation of distributed resources.[32] Most state public utility commissions use the Institute of Electrical and Electronics Engineers' 2003 voluntary standard for interconnection protocols and procedures.[33] This standard is under revision to support continued sector innovation, including development of microgrid technologies. Updated procedures that account for emerging technologies could reduce and streamline interconnection challenges, further promoting market growth and community adoption.

## Conclusion

Analysts predict significant growth in the domestic microgrid market in coming years, but that will depend largely on whether federal and state policy values and promotes these technologies. To overcome technical and financial obstacles, federal regulations and guidance must clarify the rules for integrating microgrids. In addition, government support for research and development and public-private partnerships will lead to lower-cost technologies and increased market adoption, resulting in a cleaner, cheaper, and stronger grid. Congressional support and investment in programs that ensure that the technologies of the future are developed and produced domestically are vital to maintaining U.S. leadership in the clean energy arena.

## Endnotes


1 Christopher Villarreal, David Erickson, and Maria Zafar, "Microgrids: A Regulatory Perspective," California Public Utilities Commission Policy & Planning Division (April 14, 2014), http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5118; Thomas Bourgeois et al., "Community Microgrids: Smarter, Cleaner, Greener," Pace Energy and Climate Center, Pace Law School (2013), http://energy.pace.edu/sites/default/files/publications/Community%20Microgrids%20Report%20(2).pdf.

2 U.S. Department of Energy, "The Role of Microgrids in Helping to Advance the Nation's Energy System," http://energy.gov/oe/services/technology-development/smart-grid/role-microgrids-helping-advance-nation-s-energy-system.

3 Christopher Villarreal, David Erickson, and Maria Zafar, "Microgrids: A Regulatory Perspective"; Robert P. Thornton, "Microgrids: Moving Into the Mainstream," International District Energy Association (June 25, 2014), http://www.districtenergy.org/assets/pdfs/News_items/Thornton-AZ-Corp-Comm-IDEA-Microgrids-Mainstream-June-25-6.22-RPT.pdf.

4 Robert P. Thornton, "Microgrids: Moving Into the Mainstream."

5 Dan Boyce, "Military Marches Forward With Microgrids," *Inside Energy* (July 9, 2015), http://insideenergy.org/2015/07/09/military-marches-forward-with-microgrids/.

6 Eric Wesoff, "Microgrid Evolution: Energizing Co. Gets $250M for Grid Project Finance," *Greentech Media* (May 11, 2015), http://www.greentechmedia.com/articles/read/Microgrid-Evolution-Energizing-Co-Gets-250-Million-for-Grid-Project-Finan; Julia Pyper, "U.S. Microgrid Capacity Will More Than Double by 2020—and Include a Lot More Renewables," *Greentech Media* (June 23, 2015), http://www.greentechmedia.com/articles/read/Microgrid-Capacity-Will-More-Than-Double-by-2020.

7 Eric Wesoff, "Microgrid Evolution: Energizing Co. Gets $250M for Grid Project Finance."

8 U.S. Department of Energy, "Microgrid Activities," http://energy.gov/oe/services/technology-development/smart-grid/role-microgridshelping-advance-nation-s-energy-syst-0.

9 Lawrence Berkeley National Laboratory, "Microgrids at Berkeley Lab," https://building-microgrid.lbl.gov/projects.

10 U.S. Department of Energy, "Microgrid Activities."

11 Demand response is an electricity tariff or program established to induce lower electricity use by end-use customers, typically when market prices are high or grid reliability is jeopardized.

12 Sandia National Laboratories, "Energy Surety Microgrid," http://energy.sandia.gov/energy/ssrei/gridmod/integrated-research-and-development/esdm/.

13 U.S. Department of Energy, "Energy Department Announces $8 Million to Improve Resiliency of the Grid," Sept. 8, 2014, http://www.energy.gov/articles/energy-department-announces-8-million-improve-resiliency-grid.

14 Ibid.

15 Sandia National Laboratories, "Energy Surety Microgrid"; Advanced Research Projects Agency-Energy, "ARPA-E Funding Opportunity Announcements," https://arpa-e-foa.energy.gov/Default.aspx?Search=NODES&SearchType.

16 Advanced Research Projects Agency-Energy, "ARPA-E Open 2015 Project Selections," Nov. 23, 2015, http://arpa-e.energy.gov/sites/default/files/documents/files/OPEN_2015_Project_Descriptions.pdf.

17 Strategic Environmental Research and Development Program and Environmental Security Technology Certification Program, "Installation Energy Test Bed," https://www.serdp-estcp.org/Featured-Initiatives/Installation-Energy.

18 Ibid.; Jeff St. John, "The Military Microgrid as Smart Grid Asset," *Greentech Media* (May 17, 2013), http://www.greentechmedia.com/articles/read/the-military-microgrid-as-smart-grid-asset.

19 Robert P. Thornton, “Microgrids: Moving Into the Mainstream.”

20 Thomas Bourgeois et al., “Community Microgrids: Smarter, Cleaner, Greener.”

21 Ibid.

22 Ibid.

23 Ibid.; Coalition for Green Capital, “What Is a Green Bank?” http://www.coalitionforgreencapital.com/whats-a-green-bank.html.

24 KEMA, “Microgrids: Benefits, Models, Barriers, and Suggested Policy Initiatives for the Commonwealth of Massachusetts,” Feb. 3, 2014, http://nyssmartgrid.com/wp-content/uploads/Microgrids-Benefits-Models-Barriers-and-Suggested-Policy-Initiatives-for-the-Commonwealth-of-Massachusetts.pdf.

25 Thomas Bourgeois et al., “Community Microgrids: Smarter, Cleaner, Greener.”

26 Red Mountain Insights, “Military Microgrids Market Potential, Projects and Profiles,” April 2015, http://www.redmountaininsights.com/military-microgrid-l3576.

27 Ibid.

28 The White House, “Fact Sheet: Obama Administration Announces Additional Steps to Increase Energy Security,” April 11, 2012, https://www.whitehouse.gov/the-press-office/2012/04/11/fact-sheet-obama-administration-announces-additional-steps-increase-ener; Jeff St. John, “The Military Microgrid as Smart Grid Asset.”

29 Office of the Assistant Secretary of Defense for Energy, Installations, and Environment, “Energy Management Reports,” http://www.acq.osd.mil/eie/OE/OE_library.html.

30 U.S. Department of Energy, “Quadrennial Energy Review: Energy Transmission, Storage, and Distribution Infrastructure,” April 2015, http://energy.gov/sites/prod/files/2015/07/f24/QER%20Full%20Report_TS%26D%20April%202015_0.pdf.

31 Ibid.

32 Ibid.

33 Ibid.

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