U.S. DEPARTMENT OF ENERGY | Electricity Delivery & Energy Reliability

American Recovery and Reinvestment Act of 2009

Smart Grid Investment Grant Program

Progress Report II

October 2013

SMARTGRID.GOV
RECOVERY ACT SMART GRID PROGRAMS

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Executive Summary

Since 2009, the U.S. Department of Energy (DOE) and the electricity industry have jointly invested over $7.9 billion in 99 cost-shared Smart Grid Investment Grant (SGIG) projects involving more than 200 participating electric utilities and other organizations to modernize the electric grid, strengthen cybersecurity, improve interoperability, and collect an unprecedented level of data on smart grid operations. This second SGIG Progress Report describes program accomplishments since 2009, highlighting key updates from the first SGIG Progress Report published in July 2012.

> *You don't achieve benefits just by putting a smart meter on a house. The next wave of smart grid investment is going to be connecting the dots. Integrating and developing these technologies is one of the keys to developing a comprehensive and effective smart grid.*
>
> – Gary Rackliffe, ABB's Vice President for Smart Grid in North America

The Smart Grid Investment Grant Program

The SGIG program is a cost-shared initiative that seeks to accelerate the transformation of the nation's electric power grid through the deployment and use of smart grid technologies and systems. The American Recovery and Reinvestment Act of 2009 (Recovery Act) provided $3.4 billion in federal funding, and project recipients have invested an additional $4.5 billion in private funding, for a total budget of $7.9 billion.

These funds are helping to build a smarter and more modern electric grid that will be needed to accomplish our nation's most important economic, energy, and environmental priorities. More intelligent electricity delivery systems use two-way communications and automated controls to provide essential capabilities to meet the needs of a growing digital economy, enable greater levels of clean energy development, and strengthen the electric grid to be more resilient to natural disasters and cyber-attacks. The SGIG program is demonstrating progress in each of these areas and is expected to encourage future investments by providing greater know-how for accomplishing grid modernization.

While the $7.9 billion SGIG program represents a significant public and private investment, it is a relatively small down payment on the hundreds of billions of dollars the electric power industry will need to fully modernize the electric grid over the next several decades. To leverage the impact of SGIG investments, and assist industry with identifying appropriate grid modernization approaches, DOE is focused on three primary SGIG objectives: (1) accelerate deployment of smart grid technologies and systems, (2) assess impacts and benefits, and

(3) strengthen cybersecurity protections and practices. In achieving these objectives, effective collaboration between DOE and the electric power industry is paramount. As a result, DOE emphasizes the use of partnerships, information sharing, and outreach activities with key stakeholders including electric utilities; federal, regional, state, and local agencies and consumer groups; equipment manufacturers and vendors; trade associations; and universities and national laboratories.

Implementation Progress

Accelerating the deployment of smart grid technologies and systems is a key objective of the SGIG program. Figure ES-1 shows that project spending on equipment installations has made significant progress since 2009. The majority of projects are expected to complete equipment installations in 2013 and continue data analysis and reporting through 2015. However, because of extenuating circumstances (e.g., weather-related delays), DOE has granted a one-year, no-cost extension to certain projects; these projects are expected to complete installations by 2014, with continued reporting through 2016.

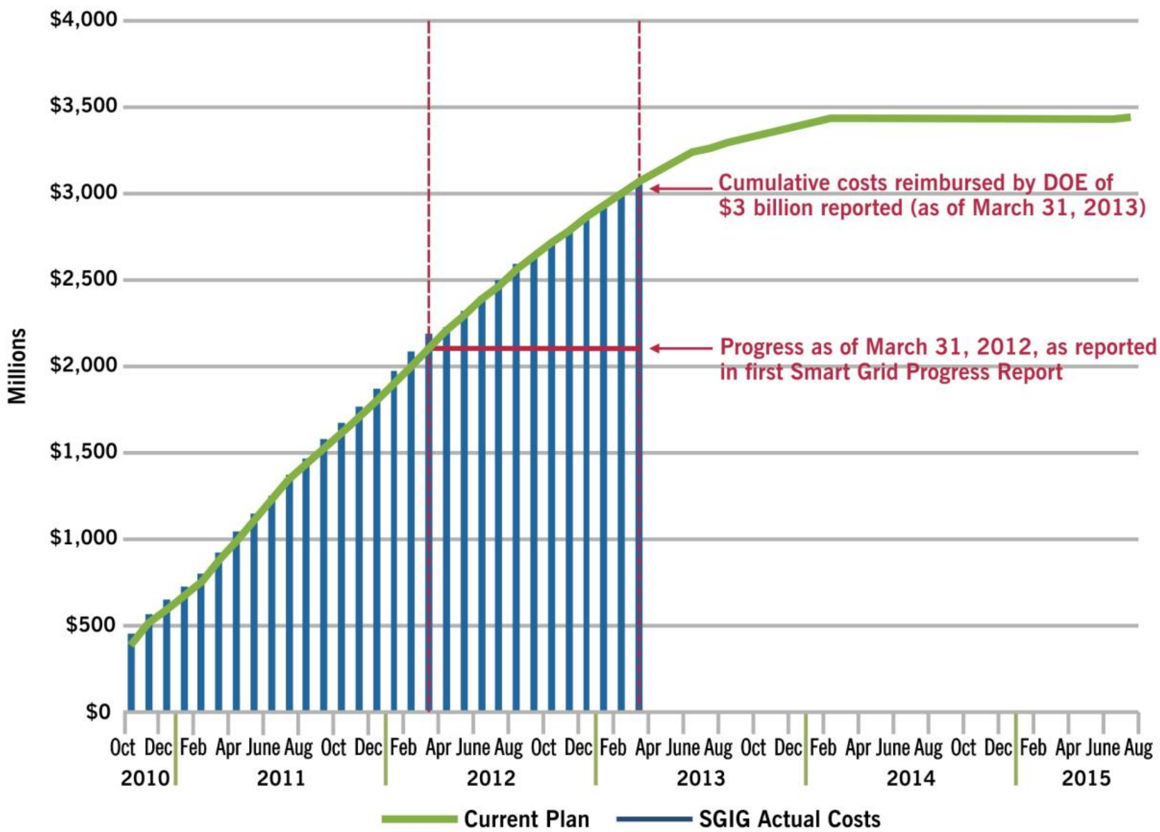

Figure ES-1. Current Plan versus Actual SGIG Costs Reimbursed by DOE (as of March 31, 2013)

As of March 31, 2013, DOE has reimbursed recipients more than $3 billion, which represents more than 90 percent of DOE's total SGIG funds. With the recipient's cost share of at least 50 percent, total SGIG spending is over $6 billion. In addition, more than three-quarters of the 99 SGIG projects report having completed more than 70 percent of their project's tasks. The vast majority of projects are on track for successful budget and schedule performance.

Figure ES-2 shows combined DOE and project spending by types of technologies and systems, including changes from last year. Advanced metering infrastructure (AMI) installations are nearing completion, while customer systems, which depend on AMI installations and sometimes regulatory approvals, are lagging somewhat. Many projects have also had to tackle communications and systems integration issues to get smart meters and customer systems to work together effectively. Expenditures for electric transmission and distribution systems also increased compared with last year.

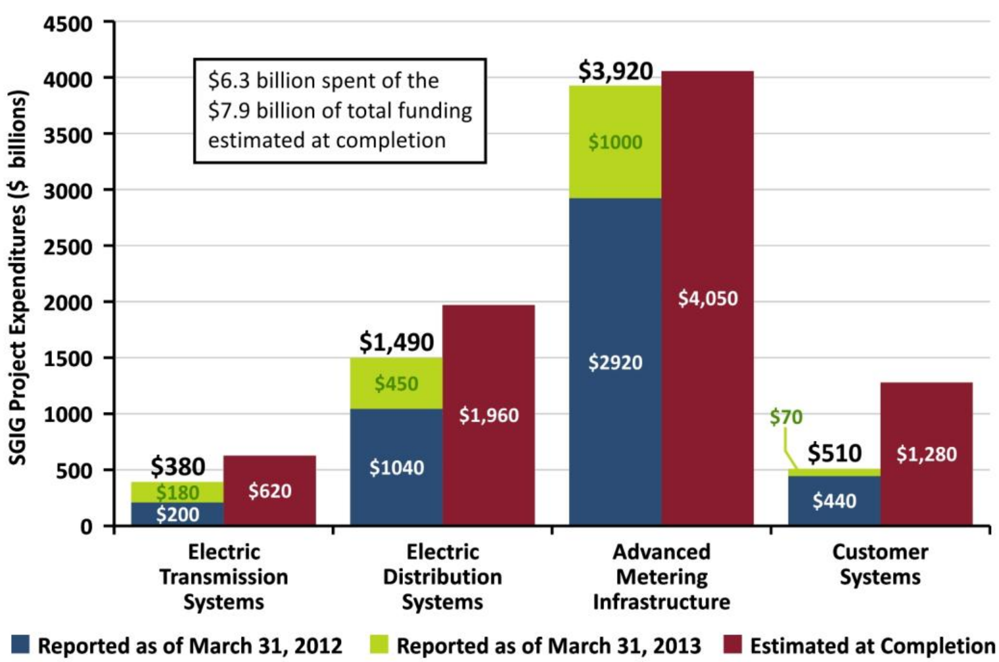

Figure ES-2. SGIG Expenditures by Categories of Technologies and Systems (as of March 2013)

For certain technologies, the projects are making considerable strides in national coverage and expansion of industry capabilities. For example, the 11 SGIG synchrophasor projects have collectively installed 826 networked phasor measurement units (PMUs)—exceeding the 800 expected at completion and more than quadrupling the number of networked PMUs installed in the United States before the SGIG program. In addition, the 65 SGIG smart meter projects have installed a total of 14.2 million smart meters, 92 percent of the 15.5 million the program is expected to install at completion.

Strengthening cybersecurity is another SGIG program objective and a critical element of all SGIG projects. DOE continues to work with project recipients to ensure that adequate protections are in place. Through monitoring of each project's cybersecurity plans, DOE has identified areas of improvement for the projects to address. In addition, information sharing activities have enabled project teams to learn from one another and take further steps to strengthen their cybersecurity practices.

Selected Highlights

Assessing impacts and benefits is a key DOE objective for the SGIG program. Since the release of the first SGIG Progress Report (July 2012), DOE has published six reports that analyze the data provided by the SGIG projects over the last two years. This analysis is based on initial reporting from the projects and shows opportunities for improving grid operations, saving money, and encouraging consumer involvement from deployment of smart grid technologies and systems.

Recent DOE Analysis Reports

- **Synchrophasor Technologies and Their Deployment in the Recovery Act Smart Grid Programs** (August 2013)
- **Reliability Improvements from the Application of Distribution Automation Technologies – Initial Results** (December 2012)
- **Application of Automated Controls for Voltage and Reactive Power Management – Initial Results** (Published December 2012)
- **Operations and Maintenance Savings from Advanced Metering Infrastructure – Initial Results** (Published December 2012)
- **Demand Reductions from the Application of Advanced Metering Infrastructure (AMI), Pricing Programs, and Customer-Based Systems – Initial Results** (Published December 2012)
- **Analysis of Customer Enrollment Patterns in Time-Based Rate Programs – Initial Results from the SGIG Consumer Behavior Studies** (Published July 2013)

Major findings from DOE's initial analysis of project results include:

- The new information provided by SGIG-installed synchrophasor technologies on electric transmission systems (e.g., networked phasor measurement units, PMUs) is beginning to permit grid operators to see and correct for disturbances, such as frequency oscillations, before they become more serious grid stability issues. Analysis is showing that average installed costs of networked PMUs vary considerably across the projects, as these devices can have different functional specifications and capabilities, and thus different costs. In addition, some projects are upgrading existing equipment such as digital fault recorders with phasor measurement capabilities, and such upgrades cost considerably less than installing new equipment.

- Deployment of automated feeder switches and supporting sensors, communications equipment, and control systems is showing reliability improvements that include shorter (up to 56%) and less frequent (11%–49%) outages, and fewer affected customers. Reports from one of the projects after a recent wind storm show that within seconds the number of customer outages was reduced from 80,000 to less than 40,000, and that restoration time was reduced by over one day, saving the utility over a million dollars and helping to avoid outage costs.

- Deployment of voltage regulators, automated capacitor banks, and other advanced voltage and volt-ampere reactive (VAR) technologies is showing conservation voltage reductions that range from 1 to 2.5 percent during peak periods, which is consistent with findings from other industry studies. In addition, in comparison with other energy savings methods from voltage controls, such as capacitor bank switching for line loss reductions, conservation voltage reductions have much greater capabilities for saving energy.

- Deployment of smart meters is improving operational efficiencies and saving utilities money from reductions in meter reading costs, fewer truck rolls for service connections and disconnections, and more efficient metering services. Initial cost saving estimates range from 13 to 77 percent, depending on several factors including the status of legacy systems, integration issues, and customer densities per line mile.

- Deployment of smart meters in conjunction with time-based rate programs and customer systems such as programmable communicating thermostats is reducing electricity demand during peak periods to improve asset utilization and defer needs for new capacity. Studies from the projects show peak demand reductions that can exceed 30% depending on the rate design and type of customer system being used. One project reported that based on their SGIG results, they decided to roll-out their demand response programs to 20 percent of their customers and thereby defer construction of a 170 MW peaking power plant.

- Customer recruitment rates are critical factors in the successful implementation of time-based rate programs. Recruitment rate analysis for the nine SGIG projects that are conducting consumer behavior studies shows that they range from 5 to 28 percent for opt-in offers (i.e., the customers were informed of the study and asked to join), and 78 to 87 percent for opt-out offers (i.e., those solicited did not reject the offer and were placed into a program). In addition, the analysis finds that focus groups, surveys, and other research on customer preferences were vital components for test marketing terms and concepts and successfully recruiting customers to participate.
- Progress toward a smarter grid as defined in DOE's Smart Grid Systems Report is exemplified in many of the SGIG projects. Examples show customers becoming more engaged in electricity market decisions; more renewable and distributed energy resources being integrated with grid operations; greater availability of new product and service offerings; and opportunities for power quality improvements, better operating efficiencies, improved responses to system disturbances, and more resilient operations and improved outage management.

Next Steps

Over the next year, the SGIG program will move toward project completion and continue to deploy smart grid technologies and systems. Quarterly reports on installations and costs will be posted on www.smartgrid.gov. In addition, project reporting on impacts and benefits will proceed and provide new opportunities for analysis and reporting on grid impacts, costs, benefits, lessons learned, and other useful information for investment decision making. DOE will continue sharing all reports, analysis, and case studies with interested stakeholders on the website, through conferences, and by other information sharing mechanisms. Those interested can sign up for email updates when new information is posted on the website at http://www.smartgrid.gov/email_alerts.

Through the SGIG projects and beyond, DOE will continue working in partnership with the electricity sector to accelerate adoption of new technologies and systems, remove barriers to new and efficient energy markets, and build an advanced and secure modern grid.

1. Introduction

This report provides an update on the progress of the Smart Grid Investment Grant (SGIG) program to catalyze investment in the nation's electric power grid and to advance knowledge sharing among market participants and decision makers. This report is an update to the first SGIG Progress Report, which was published in July 2012.

1.1 The American Recovery and Reinvestment Act of 2009

Congress enacted the American Recovery and Reinvestment Act of 2009 (Recovery Act)[1] to create jobs, stimulate business, and invest in long-term economic growth. The Recovery Act included $4.5 billion to jump-start grid modernization through implementation of several programs managed by the U.S. Department of Energy (DOE). Collectively, the Recovery Act grid modernization programs represent one of the largest federal investments in new technologies for electric power delivery since the Rural Electrification Act of 1935.[2]

> *….I support the investments made in the DOE Smart Grid program. This included $4.5B in Recovery Act funds for the Smart Grid Investment Grant program, demonstrations, as well as other efforts. The implementation of smart grid technologies is revolutionizing electric delivery in the United States to meet the needs of the 21st century economy. The transformation to a smarter grid will increase the reliability, efficiency, and security of the country's electrical system; encourage consumers to manage their electricity use; reduce greenhouse gas emissions; and allow the integration of all clean energy sources and electric vehicles into the grid of tomorrow.*
>
> – Ernest J. Moniz, Secretary of Energy

The SGIG program is a cornerstone of the Recovery Act grid modernization effort. The SGIG program received the largest share of the Recovery Act grid modernization funding ($3.4 billion), and these funds were matched with an additional $4.4 billion in private sector funds for a total budget of $7.8 billion. However, in the course of carrying out activities, several projects decided to increase their funding share, thus raising the total SGIG budget to $7.9 billion. The SGIG program awarded these funds to 99 projects that are investing in advanced transmission and distribution systems, advanced metering infrastructure (AMI), and customer systems. As

[1] Public Law 111-5.

[2] Public Law 74-605.

shown in Figure 1, these projects involve 228 utilities and other organizations, include every region of the country, and touch almost every state.

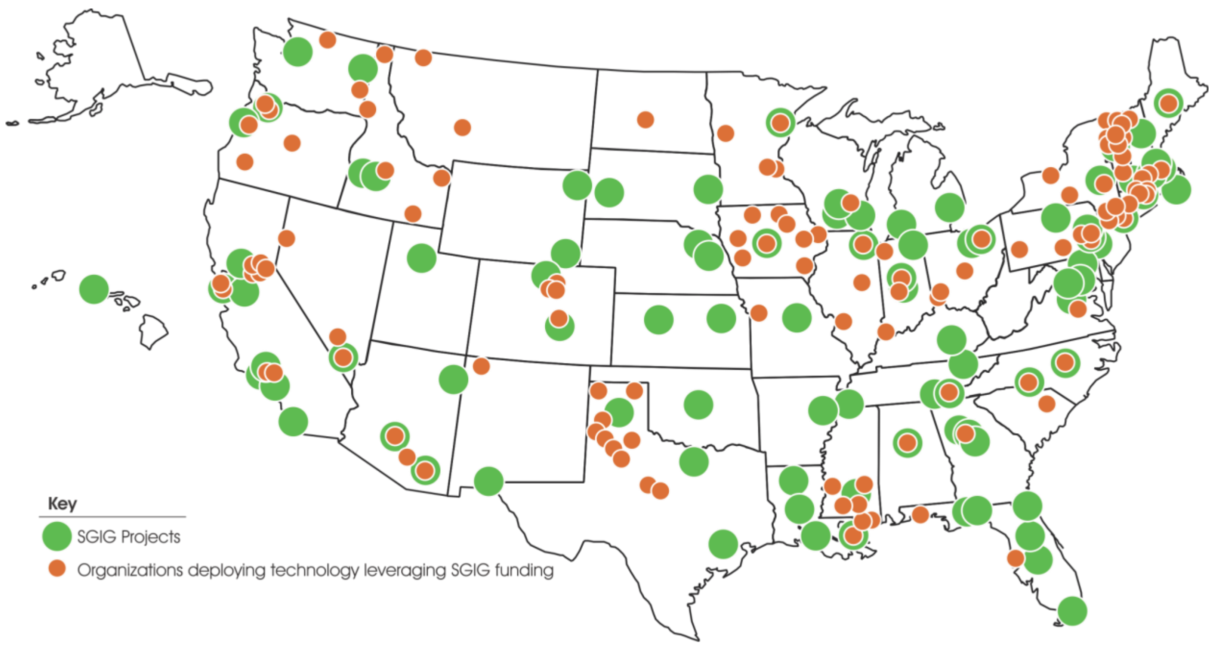

Figure 1. The SGIG Program: 99 Projects Involving 228 Electric Utilities and Other Organizations

1.2 SGIG Program Objectives

DOE's role in managing the SGIG program has three components: (1) selecting and monitoring the 99 SGIG projects; (2) analyzing project impacts, benefits, and lessons learned and determining how these accomplishments are realized; and (3) identifying innovative ways to catalyze follow-on smart grid investments, including communicating results to key stakeholders and target audiences. These activities support the SGIG program's three main objectives:

- Accelerate deployment of smart grid technologies across the transmission and distribution system, and empower customers with information so they can better manage their electricity consumption and costs.
- Measure the impacts and benefits of smart grid technologies to reduce uncertainty for decision makers and attract additional capital and further advance grid modernization.
- Accelerate the development and deployment of effective cybersecurity protections for smart grid technologies and systems.

In accomplishing these objectives, DOE is also evaluating SGIG program contributions toward achieving the seven characteristics of a smarter grid. The following seven characteristics identify what a smart grid will accomplish:[3]

- Enable informed participation by consumers in retail and wholesale electricity markets.
- Accommodate all types of central and distributed electric generation and storage options.
- Enable new products, services, and markets.
- Provide for power quality for a range of needs by all types of consumers.
- Optimize asset utilization and operating efficiency of the electric power system.
- Anticipate and respond to system disturbances.
- Operate resiliently to attacks and natural disasters.

SGIG activities are thus aimed at helping to build a smarter and more modern electric grid that will be needed to accomplish our nation's most important economic, energy, and environmental priorities. More intelligent electricity delivery systems use two-way communications and automated controls to provide essential capabilities to meet the needs of a growing digital economy, enable greater levels of clean energy development, and strengthen the electric grid to be more resilient to natural disasters and cyber-attacks. The SGIG program is demonstrating progress in each of these areas and is expected to encourage future investments by providing greater know-how for accomplishing grid modernization properly.

1.3 Organization of this Report

Section 2 of this report provides a summary of the advances that the SGIG program has undertaken during the last year, including advances in cybersecurity, and interoperability. Section 3 provides a summary of the implementation progress of the SGIG projects in four areas: electric transmission systems, electric distribution systems, AMI, and customer systems. Section 3 also includes eight project examples, two per area, that present highlights from those that have completed their deployment and installation activities. Section 4 presents information on impacts, benefits, and lessons learned drawn from the SGIG reports that were published in the last year. Section 5 highlights fourteen projects that illustrate progress that the SGIG program has made toward achieving a smarter grid. Section 6 provides information on DOE's SGIG program priorities through 2015. Appendix A provides a list of DOE information resources for grid modernization. Appendix B provides a list of the 99 SGIG projects.

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[3] Making progress toward these characteristics was stated as an SGIG program goal in the funding opportunity announcement (DE-FOA-0000058), which was issued on June 25, 2009.

2. SGIG Program Developments

Since last year's SGIG Progress Report, DOE has continued to provide oversight, analysis, and communications for the SGIG program. This section provides new information on SGIG program developments.

2.1 Program Management

DOE continues to work with the projects to monitor progress toward achieving schedule and spending milestones and project-specific goals and objectives. As many of the projects are nearing completion of installations, DOE has developed a systematic project closeout process that requires each project to undertake a series of steps to effectively complete the requirements of the Recovery Act and DOE guidance.

DOE is in its second year of conducting site visits with the projects and from July 2012 through March 31, 2013, DOE conducted 55 site visits to SGIG projects. The purpose of these face-to-face meetings, which are ongoing, is to provide an opportunity for the projects and DOE to review equipment installations, expenditures, cybersecurity planning, and metrics and benefits reporting and make suggestions for improvements, as appropriate.

2.2 Metrics and Benefits Analysis

As the projects complete installations, DOE's effort to assess SGIG grid impacts, costs, benefits, and lessons learned becomes a more significant program priority. Efforts now focus on providing decision makers with better information for understanding, evaluating, and moving forward with follow-on smart grid investments.

Specifically, DOE and the projects are conducting analysis and producing reports and case studies that address key issues with the costs and performance of technologies, and consumer responses, that decision makers have identified as being important for understanding business cases and reducing uncertainties about the cost-effectiveness of various smart grid technologies and systems. Because the SGIG project recipients continue to report information on metrics and benefits for two years after deployments of technologies and systems are complete, reports and case studies that inform decision makers will be produced through the end of the SGIG program.

Section 4 provides summaries of seven recent DOE reports that present quantitative results, qualitative lessons learned, and observations about the reasons the technologies and systems are causing certain impacts and benefits to occur. Lawrence Berkeley National Laboratory (LBNL) has also published two reports on the SGIG consumer behavior studies.[4]

Going forward, as more data from the SGIG projects become available, DOE plans to conduct further analysis and more actively report results to electricity sector decision makers across the country.

2.3 Cybersecurity

Deploying smart grid technologies and systems with “built-in” cybersecurity protections is a key objective that affects all of the SGIG projects. DOE is working closely with the projects to implement sound cybersecurity plans and practices.

The SGIG projects have been implementing cybersecurity plans (CSPs) for over two years. Each CSP must ensure reasonable protections against broad-based, systemic failures in the electric grid resulting from cybersecurity breaches. For many projects, cybersecurity planning is a new responsibility, and building company capabilities is this area has only recently become a top priority. Projects are beginning to learn what works well and what doesn’t and these lessons learned are essential to the successful implementation of the CSPs in their smart grid projects.

Review of CSPs is an important element of DOE’s annual SGIG project site visits. Progress by the program in cybersecurity is a result of a joint commitment by DOE and the projects to continuous improvement. The site visits have shown that the projects are at various levels of cybersecurity maturity and DOE suggestions have helped recipients revise and improve their CSPs. During the most recent site visits, DOE began introducing the Electricity Subsector Cybersecurity Capability Maturity Model (ES-C2M2) to provide a tool to enable the projects to continue improvements in their cybersecurity plans and practices after their SGIG project is complete. ES-C2M2 is a tool for electric utilities and grid operators to assess their cybersecurity capabilities and prioritize actions and investments to improve cybersecurity; it combines elements from existing cybersecurity efforts into a common tool that can be used consistently across the industry.

To capture lessons learned and identify potential gaps from CSP implementation, DOE hosted its second Smart Grid Cybersecurity Information Exchange with the projects to provide a venue for sharing first-hand experiences and learning from each other. This information exchange was held in Washington, DC, on December 5 and 6, 2012, and involved peer-to-peer discussions of

[4] A. Todd, P. Cappers, C. Goldman, Residential Customer Enrollment in Time-based Rate and Enabling Technology Programs, LBNL (2013); P. Cappers, A. Todd, C. Goldman, Summary of Utility Studies, LBNL (2013).

lessons learned in developing and implementing smart grid CSPs. The discussions enabled SGIG and Smart Grid Demonstration Program (SGDP) recipients to (1) share information and lessons learned in developing and implementing their CSPs; (2) learn about available tools, techniques, and resources for strengthening the security of cyber systems; and (3) gain a common understanding of how to sustain cybersecurity processes once the Recovery Act projects are completed. A summary of the discussions at the 2012 DOE Smart Grid Cybersecurity Information Exchange was published in July 2013.

DOE also continues its work on cybersecurity with the SGIG projects in other ways. A DOE website is maintained to continue to help SGIG projects develop, implement, and manage their CSPs and promote sound cybersecurity policies and practices. The site provides information, tools, and resources from government and industry sources.

SGIG Progress in Cybersecurity

Snohomish County Public Utility District (SnoPUD) is the second largest publicly owned utility in Washington State and serves 325,000 electric customers. Benjamin Beberness, Chief Information Officer, recently said, “SnoPUD utilizes NIST SP800-53 for its risk framework and catalog of controls…In conjunction with NIST SP800-53, we use the Department of Energy (DOE) Electricity Subsector Cybersecurity Capability Maturity Model (ES-C2M2) to guide the program…SnoPUD’s DOE smart grid grant really was the catalyst of our cybersecurity preparation… We are leveraging the DOE ES-C2M2 to continue to mature our program. We are also very active in local, regional and national cyber security forums and events. This collaboration helps SnoPUD understand the risks utilities are or will be facing and how others are dealing with them…and leverage the ES-C2M2 maturity model to grow your security program over time focusing on your greatest risks and leverage a control framework like NIST SP800-53 to understand your risks and the controls to mitigate.”

2.4 Interoperability

Interoperability is the capability of two or more networks, systems, devices, applications, or components to share and readily use information securely and effectively with little or no inconvenience to the user.[5] Achieving greater levels of interoperability is critical for the successful implementation of smart grid technologies, tools, and techniques and is an important aspect of the SGIG program.

[5] GridWise Architecture Council, “Introduction to Interoperability and Decision Maker’s Interoperability Checklist, v1.0.”

With funding under the Recovery Act, the National Institute of Standards and Technology (NIST) formed the Smart Grid Interoperability Panel (SGIP) in 2009. In May of that year, NIST released the initial set of 16 interoperability standards, which addressed a wide range of subjects, including smart meters, distributed generation components, and cybersecurity. This was followed in 2010 with "Release 1.0" of a report that included about 75 initial interoperability standards and 15 "priority action plans" to address gaps in the standards. Release 2.0 of the NIST Framework and Roadmap for Smart Grid Interoperability Standards was published in 2012 and included updates to the initial list of standards and expansions to address gaps identified in Release 1.0.

In 2011, and in accordance with Section 1305(d) of the Energy Independence and Security Act of 2007, NIST provided the Federal Energy Regulatory Commission (FERC) with five initial "families" of smart grid standards to be used for rulemakings. FERC decided not to proceed with rulemakings, indicated further work was needed, and identified the SGIP as the appropriate entity for advancing industry standards for smart grid technologies and systems.

In December 2012, SGIP evolved from a government project to an independent, privately funded organization with a growing number of paying members, including many SGIG utilities and organizations. This change underscores the commitment of the electric power industry to advance interoperability standards.

The Green Button Initiative

An important step forward in the last year for improving interoperability and customer access to personal energy data is the Green Button Initiative, championed at the federal level by the White House, NIST, and DOE. The Green Button Initiative is an industry-led effort that responded to a White House call to action and is based on a common technical standard developed in collaboration with NIST and SGIP for providing customers with easy access to their electricity usage information. The Initiative is voluntary and aimed, in part, toward enabling software developers and other entrepreneurs to leverage a sufficiently large market to support the creation of innovative applications that can help consumers make the most of their electricity usage information. There are almost 40 electric utility participants in the Green Button Initiative, of which 12 participate in SGIG projects. In addition, there are more than 50 vendor and other members, most of whom have supplied Green Button-compatible equipment or services to SGIG projects. In the last year, the number of customers served by utilities participating in the Green Button Initiative doubled from about 12 million to more than 25 million, and these numbers are growing.

SGIG projects are at the forefront of innovations and developments in this area. For example, Central Maine Power, which implements an SGIG project and is a participant in the Green Button Initiative, is also a partner with the Gulf of Maine Research Institute to demonstrate a student-focused energy education program to affect household attitudes and behaviors toward energy consumption. This project involves about 1,000 students, special software ("PowerHouse"), and access to metered consumption data from the utility so that the seventh and eighth graders can monitor and change household electricity consumption and costs. If the program is successful, scale-up efforts could eventually cover the entire state.

2.5 Outreach and Communications

Effective communications of impacts, benefits, and lessons learned is a top SGIG program priority. In the last year, DOE has produced or updated twenty-two case studies, each of which highlights a specific project, and published seven reports on the initial results and economic impacts of the SGIG program (these reports are summarized in Section 4). Appendix A lists the key federal websites on smart grid; these have been updated with new content over the last year.

In addition to publishing reports and other website-posted materials on the SGIG program DOE also communicates information on SGIG impacts, benefits, costs, and lessons learned with key stakeholders through major industry meetings, including:

- Institute of Electrical and Electronic Engineers (IEEE) Professional Engineering Society workshops
- National Association of Regulatory Utility Commissioners (NARUC) regional and annual meetings
- Demand Response Town Hall meeting
- Electric Power Research Institute (EPRI) Power Delivery and Utilization Workshops
- National Electricity Forum
- North American SynchroPhasor Initiative (NASPI)
- DistribuTech
- Trustworthy Cyber Infrastructure for the Power Grid (TCIP-G)
- DOE Electricity Advisory Committee meetings
- Trade Associations (Edison Electric Institute [EEI], National Rural Electric Cooperative Association [NRECA], American Public Power Association [APPA])
- Gridwise Alliance
- Gridwise Architecture Council
- Federal Smart Grid Task Force meetings
- Other federal agency meetings including the White House Office of Science and Technology Policy, Office of Management and Budget, Department of Homeland Security, the Federal Energy Regulatory Commission, the Department of Commerce, and the National Institute of Standards and Technology (NIST)

In 2012, DOE and IEEE met and identified a set of collaborative activities for communicating the results of the SGIG projects to the electric power industry. Existing IEEE publications and conferences provide established mechanisms for reaching utility decision makers, and joint DOE–IEEE activities can be beneficial for leveraging SGIG information and reports on impacts, costs, benefits, and lessons learned. One of the first joint activities involves organizing six panel discussions at the IEEE's upcoming *Innovative Smart Grid Technologies Conference*, to be held in Washington, DC, in February 2014. At this conference, more than 15 SGIG project recipients will be invited to share their experiences implementing smart grid technologies and systems and engage in discussions with audience members from other utilities to identify common problems and potential solutions.

3. SGIG Implementation Progress

DOE continues to monitor implementation progress for each SGIG project to ensure on-schedule and on-budget performance. Progress includes (1) the overall schedule of activities and level of expenditures, (2) the deployment of technologies and systems, and (3) initial results and lessons learned.

3.1 Schedule of Activities and Expenditures

The key SGIG program activities continue to be on schedule. Figure 2 shows the overall schedule of key SGIG activities as of March 31, 2013. Installation of equipment is nearing completion in most projects. Several of the projects, in order to meet obligations, decided on their own to increase their cost share. Hence, the overall budget has increased from last year's SGIG Progress Report. And, as Figure 3 indicates, 76 projects have completed 70 percent or more of their SGIG project tasks.

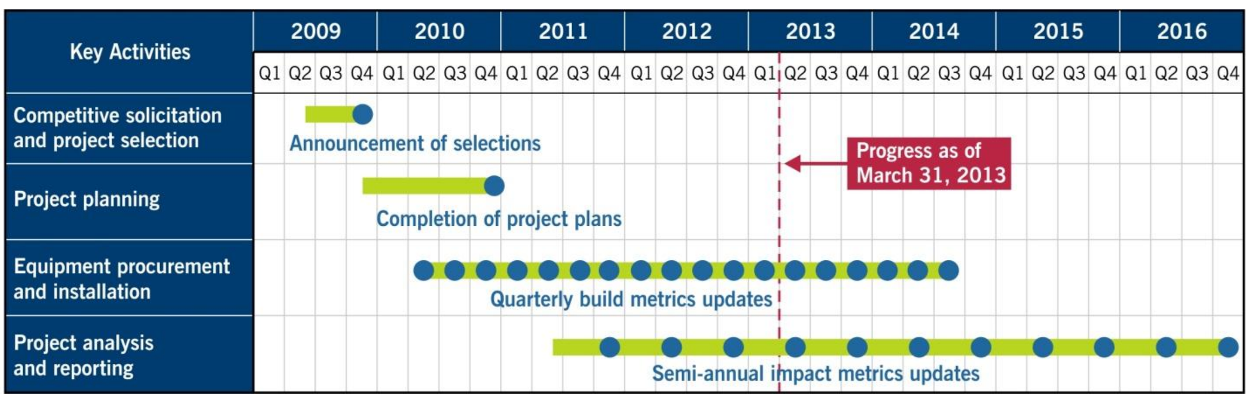

Figure 2. Schedule of SGIG Program (as of March 31, 2013)

DOE also continues to monitor expenditures of the DOE portion of the SGIG funds. Based on information reported by the projects as of March 31, 2013, Figure 4 shows that cumulative reimbursements by DOE are $3.1 billion, which is slightly above the plan and more than 90 percent of DOE's total SGIG budget of $3.4 billion.

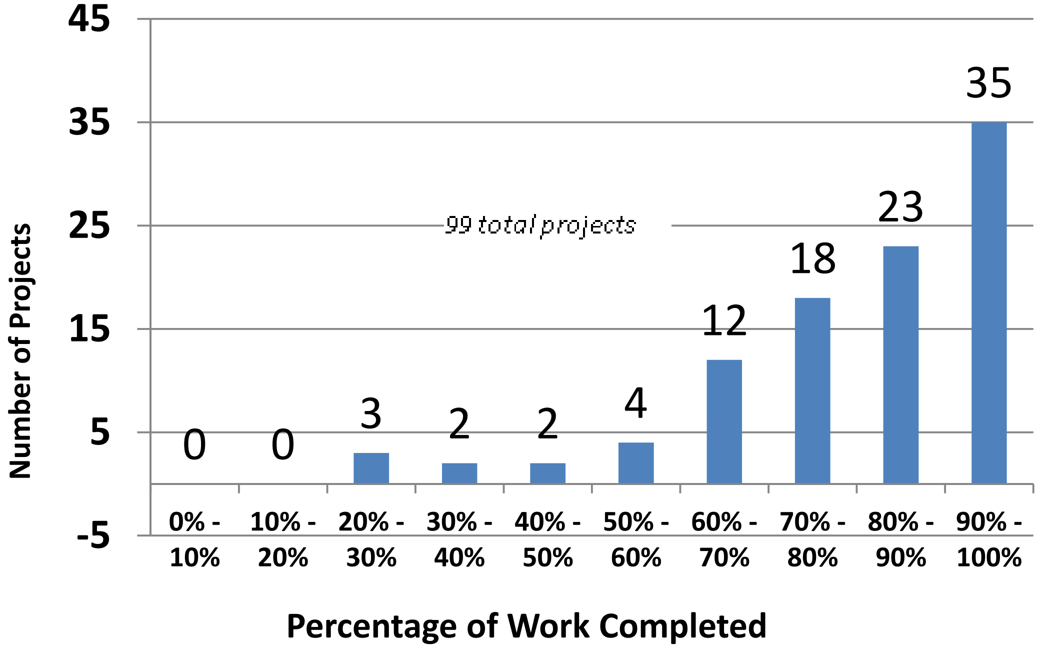

Figure 3. Number of SGIG Projects by Percentage of Work Completed (as of March 31, 2013)

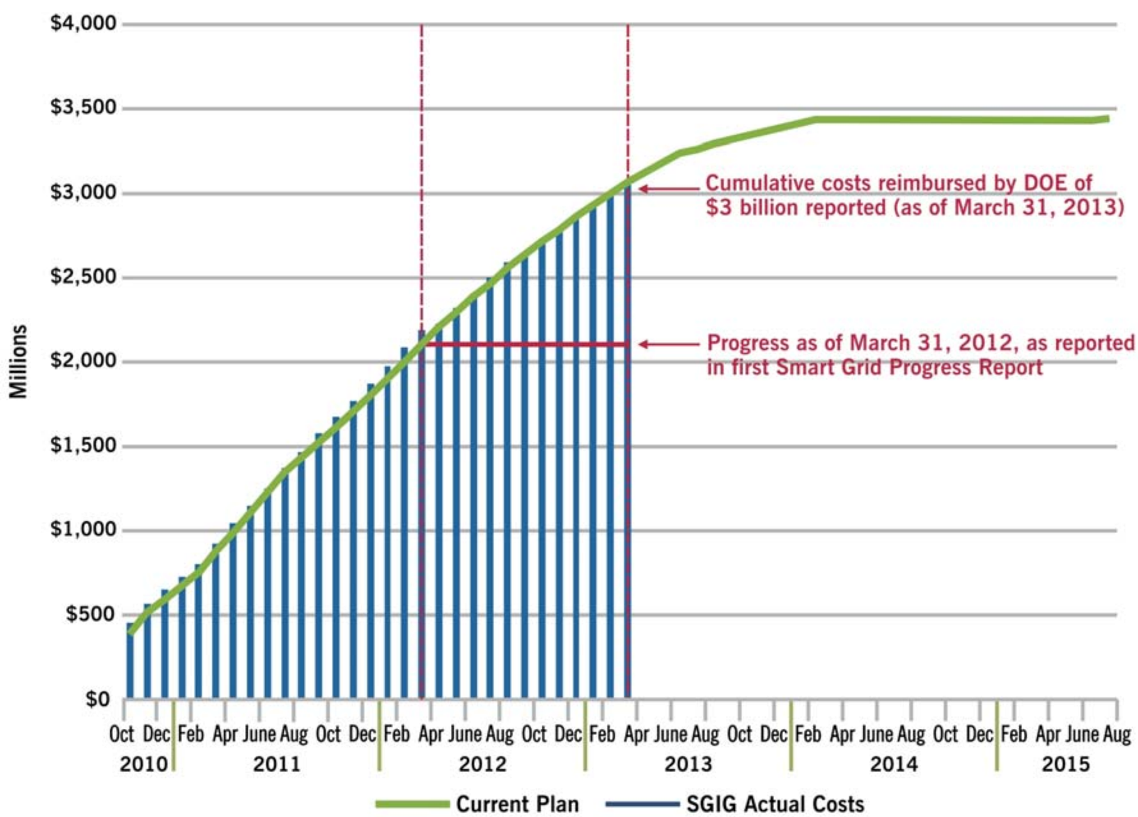

Figure 4. Current Plan versus Actual SGIG Costs Reimbursed by DOE (as of March 31, 2013)

3.2 Implementation Progress Overview

The SGIG projects are grouped in four areas based on the project's primary objective. However, many of the projects have multiple objectives and activities in several of these areas. Appendix B contains a list of the 99 projects and the areas in which they have activities.

Figure 5 below compares total SGIG project expenditures from March 31, 2012, to March 31, 2013, including both DOE and project funds. Advanced metering infrastructure (AMI) installations are nearing completion, while customer systems, which depend on AMI installations and sometimes regulatory approvals, are lagging somewhat. Many projects have also had to tackle communications and systems integration issues to get smart meters and customer systems to work together effectively. Expenditures for electric transmission and distribution systems also increased compared with last year.

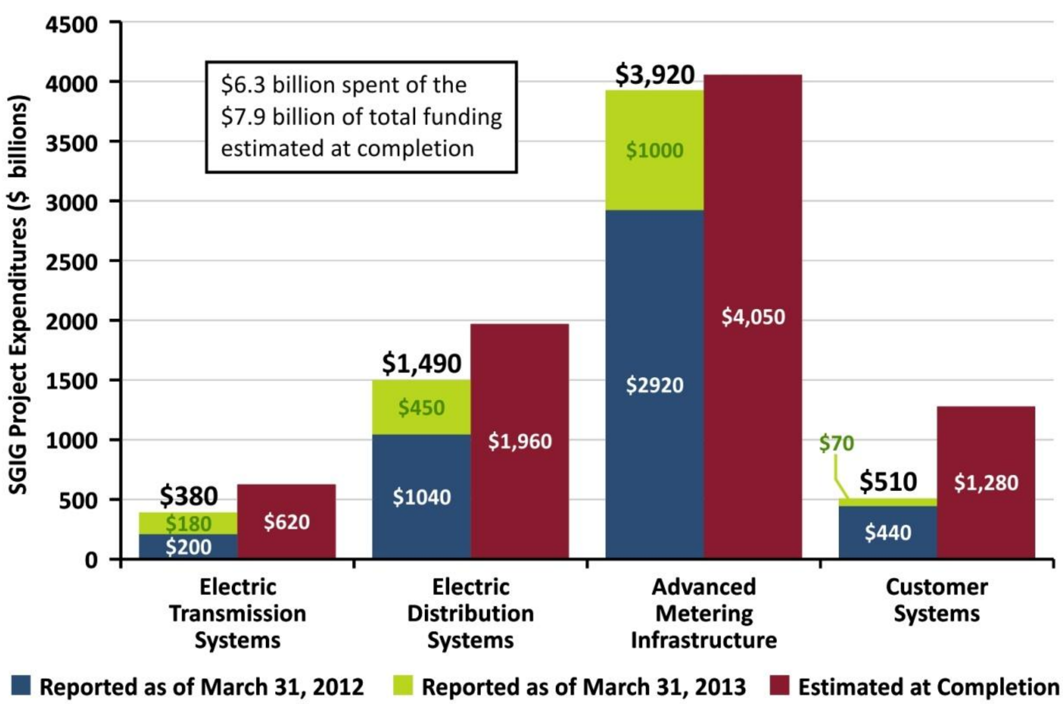

Figure 5. SGIG Expenditures by Categories of Technologies and Systems (as of March 2013)

3.3 Electric Transmission System Projects

Electric transmission system projects for SGIG involve deployment of synchrophasor technologies (which include phasor measurement units [PMUs]), communications infrastructures, field measurement devices (such as line monitors), and equipment upgrades to enable better wide-area monitoring and improved reliability of the bulk transmission system. Electric transmission system technologies and systems are often accompanied by information management and visualization tools so that data collected by field measurement devices can be sent over communications networks to transmission system operators and processed there for use in models and other analytical tools. Data from field measurement devices to back-office systems are typically transmitted via communications systems that can involve both public and private wireless and fiber optic networks.

Electric Transmission System Deployment Progress

There are 19 SGIG electric transmission system projects, which have total funding of approximately $620 million (including DOE and project funds). As of March 31, 2013, electric transmission system expenditures totaled approximately $380 million, which is approximately 60 percent of the budgeted funds.

The 19 electric transmission system projects involve five of the nation’s regional transmission organizations and independent system operators, and more than 60 transmission system owners participating as either leads or sub-projects. Eleven projects are installing synchrophasor technologies, and eight are installing line monitors and other equipment to provide smart grid capabilities that upgrade their transmission and/or communications systems.

Before the SGIG program, there were about 166 networked PMUs installed in locations across the United States. The SGIG objective for electric transmission system projects is to install an additional 800 networked PMUs and achieve near-nationwide coverage. As a result, after completion of installation of SGIG-funded PMUs, there will be a total of at least 921 networked PMUs installed and operational across the country. Though substantial progress has been made, synchrophasor software applications remain in their early phases of development and will not be fully operational until the systems that transmit, store, process, and manage synchrophasor data are fully integrated and tested.

Table 1 provides a summary of the PMU deployments and expenditures for the 11 SGIG synchrophasor projects. A total of 826 PMUs are installed and operational, which exceeds the target of 800 PMUs at completion. Several of the projects have installed more PMUs than originally expected to achieve specific project objectives.

Phasor Measurement Units (PMUs)	
Number of Projects	11
Number of PMUs Expected at Completion	at least 800
Number of PMUs Installed (as of March 2013)	826
Investment to Date	$65.45 million

Table 1. Deployment PMUs (as of March 2013)

Figure 6 shows the progress with PMU installations for each of the eleven SGIG synchrophasor projects. The projects are installing PMUs according to their project timelines and are generally on schedule.

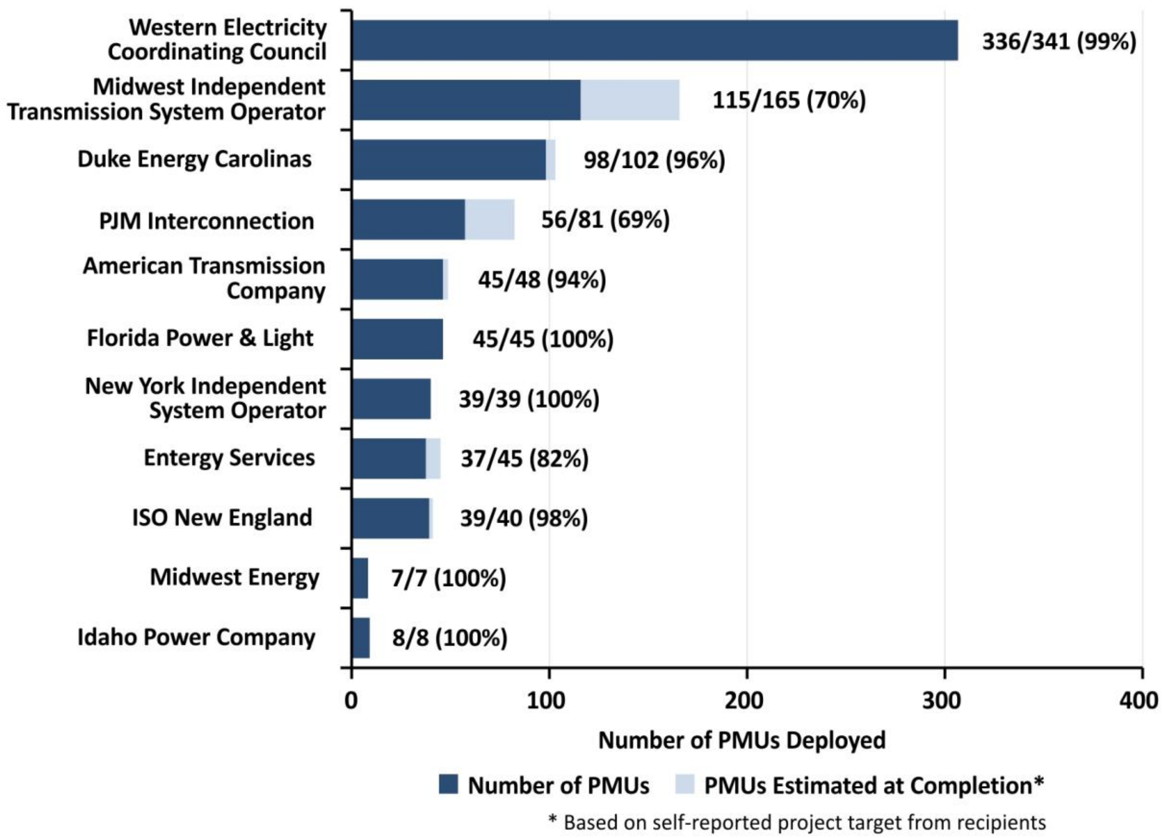

Figure 6. Percentage of SGIG PMU Deployments by the Synchrophasor Projects (as of March 31, 2013)

Electric Transmission System Project Examples

The examples shown below highlight two electric transmission system projects that have completed their equipment installation activities. The projects are representative of all of the SGIG electric transmission system projects and illustrate progress in advancing communications and control systems for transmission system operations and synchrophasor technologies and systems for wide-area visibility, model validation, and post-event forensic analysis.

Georgia System Operations Corporation

The Georgia System Operations Corporation (GSOC) Energy Management Infrastructure Initiative (GEMINI) Project involves upgrades to the company's transmission operations, communications and control systems, along with new analysis tools for grid operators. The objective of the GEMINI project is to increase the reliability, security, interoperability, and efficiency of the GSOC electric grid, which supports 39 rural electric distribution cooperatives that then sell electricity from the GSOC system to consumers.

GSOC has completed its upgrade of the software and hardware platforms for the energy control system, which is used to manage the operation of the transmission system and the dispatch of generation resources. The GEMINI project has also implemented advanced analysis software for improved monitoring, planning, and electricity cost analysis. The improvements to the communications infrastructure—wide-area monitoring, visualization, and control systems—enable GSOC to rapidly analyze operations across its entire transmission system and automatically communicate information about disruptions or changes in power flow on the grid to its member electric cooperatives. The project has enhanced GSOC's capability to detect, prevent, communicate, respond to and recover from system disruptions. The GEMINI project has resulted in increased efficiency of the overall power delivery system, in part by furnishing GSOC with the ability to use digital controls to manage and modify electricity demand.

Entergy Services, Inc.

Entergy Services' Deployment and Integration of SynchroPhasor Technology project is deploying phasor measurement units (PMUs), phasor data concentrators (PDCs), and state-of-the-art decision support tools across most of its service territory, which includes service to 2.8 million customers in Arkansas, Louisiana, Mississippi, and Texas. The goal of the SGIG-funded project is to expand the existing prototype Entergy PMU system into a wide-area monitoring system that enables a more expansive view of the bulk transmission system while revealing dynamic operating details.

As of March 31, 2013, the project had installed a total of 37 PMUs, and the original goal of 41 units increased to 45 units. These technologies, and other communications and monitoring applications, are enhancing grid visibility of the bulk power system in near-real time, enabling detection of disturbances that may produce instabilities or outages, and facilitating sharing of information with neighboring regional control areas. Furthermore, as a central component of the project, phasor training has been provided to 600 Entergy grid operators and engineers, giving them access to new PMU-based decision support tools, advanced software applications, and a wide-area visualization system.

3.4 Electric Distribution System Projects

SGIG electric distribution system projects involve the deployment of technologies and systems for improving distribution system operations, including outage management with field devices such as automated feeder switches and reclosers, and voltage/volt–ampere reactive (VAR) control with field devices such as automated capacitors, voltage regulators, and voltage sensors. These field devices can work autonomously or be monitored and controlled via communications networks linked to back-office systems for distribution and/or outage management. Grid operators use these systems for applications such as fault detection, power flow control, islanding, voltage/VAR control, and preventative maintenance for transformers, capacitors, switches, and other equipment.

Electric Distribution System Deployment Progress

There are 57 SGIG electric distribution system projects. Several of the projects are involved in deployments that cover major portions of their service territories, but the majority of the projects are involved in smaller-scale deployments on a limited number of feeders and substations.

Electric distribution system expenditures are generally on schedule and budget. The total funding for the electric distribution system projects is approximately $1.96 billion (including both DOE and project funds). As of March 31, 2013, electric distribution system expenditures totaled approximately $1.49 billion (76 percent). These expenditures include the costs of field devices, communications infrastructure, and information management systems.

There are an estimated 160,000 distribution circuits in the United States,[6] and the SGIG objective for the electric distribution system projects is to install electric distribution technologies and systems on 6,500 of them (about 4 percent). Tables 2 and 3 provide the status of equipment installations as of March 31, 2013, for two of the key electric distribution technologies and systems. The number of installed automated switches now exceeds the total number that was originally expected at completion. The number of installed capacitors is about 60 percent of the total expected at completion.

Figure 7 compares expenditures from March 31, 2012, to March 31, 2013 (including both DOE and project funds) for several electric distribution system technologies and systems. As shown, compared to expenditures on communications and data management systems, expenditures on field devices comprise approximately 66 percent of the total. The field devices include automated capacitors, automated switches, relays, regulators, and equipment monitors.

[6] Navigant Consulting Inc., "Assessment of the Total Number of Distribution Circuits in the United States," Analysis Memorandum to the U.S. Department of Energy, June 2012.

Automated Switches	
Number of Projects	46
Number of Automated Switches Expected at Completion*	at least 7,500
Number of Automated Switches Installed (as of March 2013)	7,661
Investment to Date	$384.8 million

*Based on self-reported project targets from recipients

Table 2. Deployment Progress of Automated Distribution Circuit Switches (as of March 2013)

Automated Capacitors	
Number of Projects	43
Number of Automated Capacitors Expected at Completion*	at least 18,500
Number of Automated Capacitors Installed (as of March 2013)	11,102
Investment to Date	$103.6 million

*Based on self-reported project targets from recipients

Table 3. Deployment Progress of Automated Capacitors (as of March 2013)

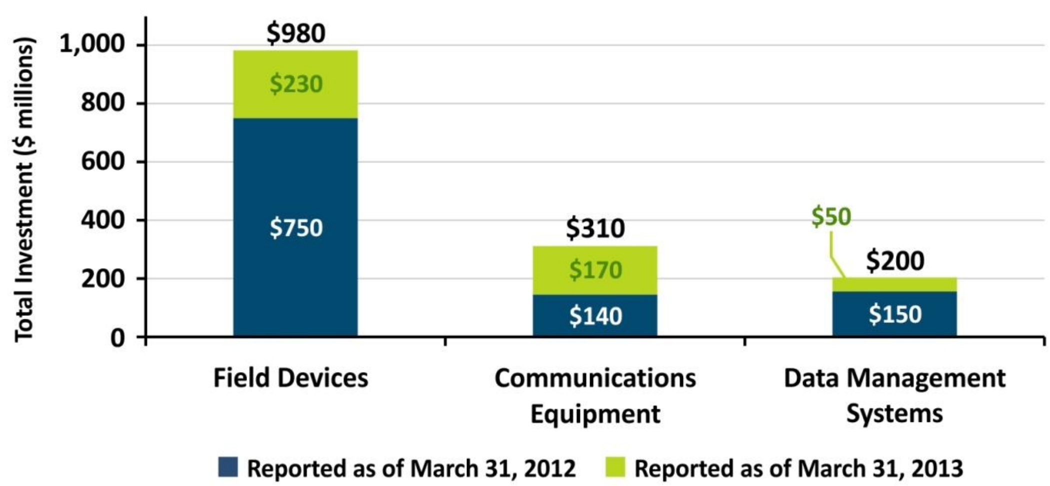

Figure 7. Breakdown of DOE Investment on Electric Distribution System Projects by Investment Type (as of March 2013; total = $1,490 million)

Electric Distribution System Project Examples

The examples shown below highlight two electric distribution system projects that have completed their equipment installation activities. The projects are representative of the SGIG electric distribution system projects and illustrate progress in advancing distribution management systems, applications of communications and controls for capacitor banks, and automation of substation operations.

Wisconsin Power and Light

Wisconsin Power and Light's (WPL) SGIG project has completed its deployment of a new centralized energy management system. The dual goals of the WPL smart grid distribution automation project have been 1) to improve distribution system efficiency through the deployment of automated capacitor banks and voltage/VAR control system (VVCS), and 2) to ensure system reliability by adding intelligent communications and control modules to many of the capacitor banks. The project will benefit many of WPL's approximately 460,000 customers.

The WPL SGIG project has completed its capacitor bank controller installations, deploying 575 capacitor bank controls, surpassing the minimum target of 480. Based on distribution load data, the VVCS adjusts capacitor bank settings in response to changing grid conditions. The capacitors improve power quality and voltage/VAR control, thereby reducing distribution energy losses. Based on these completed technology deployments, the company estimates a reduction of 150,000 megavolt ampere (MVA)-hours per year, which translates to fuel savings of $300,000 annually. Capacitor bank maintenance cost savings are estimated at $6,000 per year.

Hawaiian Electric Company

Hawaiian Electric Company, Inc. (HECO) serves 95 percent of Hawaii's 1.2 million residents. HECO's East Oahu Switching project involves the installation of automation equipment for a key part of the utility's distribution grid, coupled with upgrades to the control and communications platform for grid operators. The goal of the project is to integrate smart grid concepts for automating and modernizing the sub-transmission and distribution networks to improve reliability and operational efficiency of HECO's distribution circuits in the eastern part of the island of Oahu.

The distribution automation involves upgrades in eastern Oahu near Honolulu, with 8 of the company's 146 overall substations receiving new supervisory control and data acquisition (SCADA) equipment and software. A new automated switch for a 46-kilovolt (kV) sub-transmission line, along with a communications and monitoring system, integrates the new automated distribution equipment with the existing grid. Benefits of the project include quicker troubleshooting during outages and reduced restoration times—in some situations, from hours to minutes—enhanced distribution system reliability, and decreased operations and maintenance costs. The upgrades benefit approximately 12,400 customers. Project implementation costs around $15 million, 45 percent less than the standard "overbuild" alternative of approximately $28 million—and without the disruption that digging up the streets causes to traffic and businesses.

3.5 Advanced Metering Infrastructure Projects

The SGIG AMI projects involve deployment of smart meters; communications networks to transmit data from the meters at 15-, 30-, or 60-minute intervals; and back-office systems (such as meter data management systems) to receive, store, and process the data from the meters. All of these project recipients use smart meters for collecting interval load data, while a few of the projects also use smart meters for collecting data on voltage levels and power quality. This information can be used in electric distribution systems for voltage management. In addition, the smart meters can be used by electric distribution systems for outage management because they automatically send signals to grid operators when the power is off. Power-off signals can be used with geographic information systems (GISs) to pinpoint outage locations.

Many of the AMI project recipients are using the outage detection capabilities of the smart meters to pinpoint outage locations and dispatch repair crews to exactly where they are needed. In some cases, AMI is integrated with the company's outage management system and GIS to accelerate response and restoration efforts and reduce the number of truck rolls.

Advanced Metering Infrastructure Deployment Progress

There are 65 SGIG AMI projects that plan to install a total of at least 15.5 million smart meters, which will more than double the number of smart meters that were installed nationwide before the establishment of the SGIG program. Table 4 provides a summary of smart meter installations and expenditures, showing that about 14.2 million smart meters have been installed as of March 31, 2013, which is about 92 percent of the 15.5 million that are expected at completion. Figure 8 compares costs for AMI from March 31, 2012, to March 31, 2013, and shows that for the SGIG projects, smart meters account for 65 percent of total AMI expenditures.

The 14.2 million smart meters that have been installed by the SGIG AMI projects as of March 31, 2013, represent almost 24 percent of the 65 million smart meters that industry is estimating will be installed nationwide by 2015,[7] which will be a major fraction of the 144 million meters currently serving electric customers in the United States today.[8]

[7] Edison Foundation, Institute for Electricity Efficiency, "Utility-Scale Smart Meter Deployments, Plans & Proposals" (May 2012).

[8] Energy Information Administration, "Electric Power Annual 2010" (November 2011).

Smart Meters	
Number of Projects	65
Number of Smart Meters Expected at Completion	at least 15.5 million
Number of Smart Meters Installed (as of March 2013)	14.2 million
Investment to Date	$2,550 million

Table 4. Deployment Progress of AMI Smart Meters (as of March 2013)

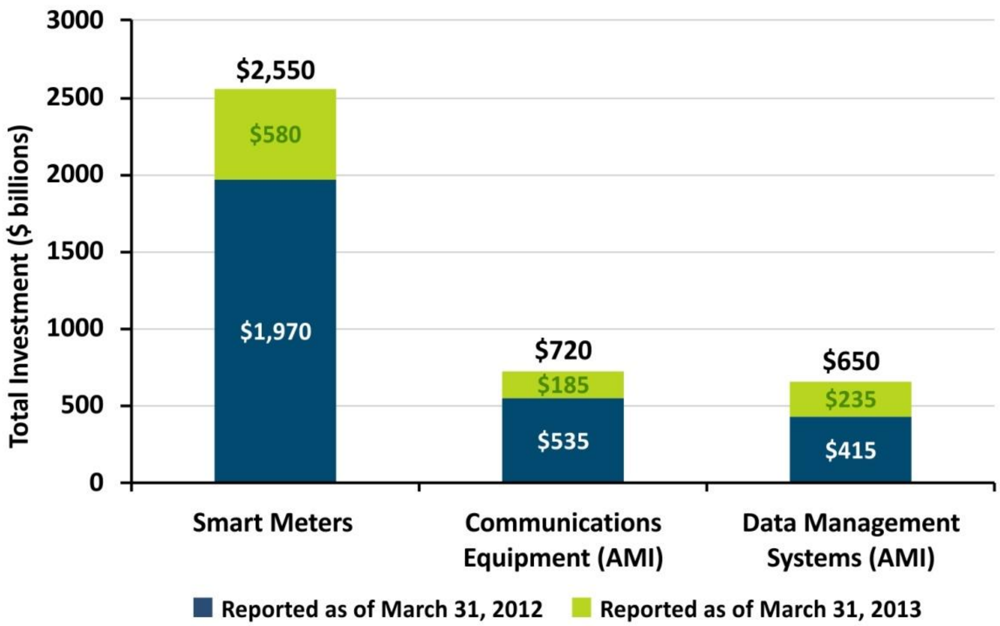

Figure 8. Breakdown of DOE Investment on Advanced Metering Infrastructure Projects by Investment Type (as of March 2013; total = $3.92 billion)

Advanced Metering Infrastructure Project Examples

The examples shown below highlight two AMI projects that have completed their equipment installation activities. The projects are representative of the SGIG AMI projects and illustrate progress in advancing AMI-enabled capabilities including automated meter reading, remote service connections and disconnections, outage management, and time-based rate programs.

Central Maine Power

The Central Maine Power Company (CMP) AMI project has completed installation of more than 5,000 network devices and nearly 620,000 smart meters to all of its 625,000 residential, commercial, and industrial customers, which are in an 11,000-square-mile service area in central and southern Maine. The SGIG-funded AMI project includes the completed installation of a wireless mesh system that provides two-way communications between smart meters and CMP's communications systems and the infrastructure to support home area networking. The project is designed to create a technology platform to provide customers with access to a web portal to view their electricity usage information, which they can then use to help manage electricity bills. The project is reducing operations and maintenance costs and service restoration times for customers through quicker and more accurate location of faults and power outages.

The project has already realized notable benefits. There has been a 92 percent reduction in physical meter reads, which has resulted in an estimated reduction of 750,000 miles (34,000 truck rolls), equivalent to $0.5 million in cost reduction. Also, with the installation of its new AMI, CMP has the capability to ping meters allowing them to assess outage boundaries and verify when power has been restored to specific customers. On average, the company estimates 15-minute savings in responding to outages with the new meter outage messaging and pinging capabilities.

Vermont Transco, LLC

Vermont Transco, LLC (eEnergy Vermont) installed over 304,000 smart meters covering nearly 85 percent of all Vermont customers, as well as distribution equipment to automate over 40 circuits. The project is a collaboration of all 20 of the State's utilities, Efficiency Vermont (the statewide energy efficiency utility), and Vermont Transco, which provides services to the 20 electric distribution utilities in Vermont. The goals of the complex eEnergy Vermont project are to enhance existing outage management systems, provide customers with tools to lower electricity consumption and, subsequently, lower the State's peak load.

The SGIG-funded project has completed deployment of its AMI, which provides two-way communication between customers and the utilities. The smart meters offer additional features, including remote connect and disconnect and improved remote troubleshooting capability. The project also has completed installation of automated voltage regulators and SCADA equipment at selected substations, enabling better management of the distribution system and reducing operations and maintenance costs. SCADA remote terminal units expand the SCADA network and include an outage management system to reduce outage restoration time by making it easier to locate faults.

The project includes two consumer behavior studies, which are assessing time-based rate programs, including time-of-use and peak-time rebate programs. Customers involved in the consumer behavior studies are provided with web portals and in-home displays. With these new tools, eEnergy Vermont's customers are able to make informed decisions and leverage the new technologies to shift consumption from more expensive peak load periods. Utility members of the project have already realized benefits. For example, Burlington Electric Department reduced truck rolls for meter reading to less than 10 percent of meters, and the Village of Johnson Electric Department reported expedited outage restoration times as a result of pager notifications from SCADA systems.

3.6 Customer Systems Projects

The SGIG customer systems projects involve deployment of technologies and systems for customers to better understand and manage their electricity consumption and costs. Specifically, the customer systems projects involve deployment of direct load control devices, web portals (through which customers can access AMI information via the Internet), in-home displays (IHDs), and programmable communicating thermostats (PCTs). The SGIG customer system projects also involve communications systems for transmitting information from in-home devices to and from AMI systems and back-office systems of the power companies.

In addition, many customer system project recipients are deploying time-based rate programs, either in addition to, or as replacements for, traditional rates. Time-based rate programs include time-of-use (TOU) rates, critical peak pricing (CPP), critical peak rebates (CPR), and variable peak pricing (VPP).

SGIG Consumer Behavior Studies

A subset of 9 SGIG project recipients is conducting a total of 11 consumer behavior studies. These studies involve application of experimental design techniques such as randomized controlled trials to improve understanding of the magnitude of demand response, customer acceptance, and customer retention in time-based rate programs. Customers participating in the studies have smart meters and various types of customer systems such as PCTs, IHDs, and web portals; several include assessments of information and education programs and materials.

All of the studies cover two years and include publication of interim evaluations, which cover the first year of the study, and final evaluations, which cover the entire two years of the study. Publication schedules vary based on the timing of the implementation of the studies. Two of the studies are complete and have published both of their reports. Seven of the other studies have completed the first year and are in the process of publishing their interim evaluations. The final evaluation reports for these seven studies will be published after the summer of 2014. The final two studies are recruiting customers for their studies now. Their interim evaluations will be published after the summer of 2014, and their final evaluations will be published after the summer of 2015. The published reports are posted on the consumer behavior study page of smartgrid.gov.

Customer Systems Deployment Progress

There are 66 SGIG project recipients deploying various types of customer systems. Figure 9 compares the number of customer system devices installed from March 31, 2012, to March 31, 2013. The number of customer system devices installed (623,000) is relatively small compared to the number of smart meters installed (14.2 million), which shows that there are very few customer system projects involved in large-scale roll-outs, as the vast majority are involved in small-scale deployments and testing.

Figure 10 provides information on customer system project expenditures as of March 31, 2013, and shows that compared to expenditures on web portals and data management systems, expenditures on devices account for 54 percent of the total.

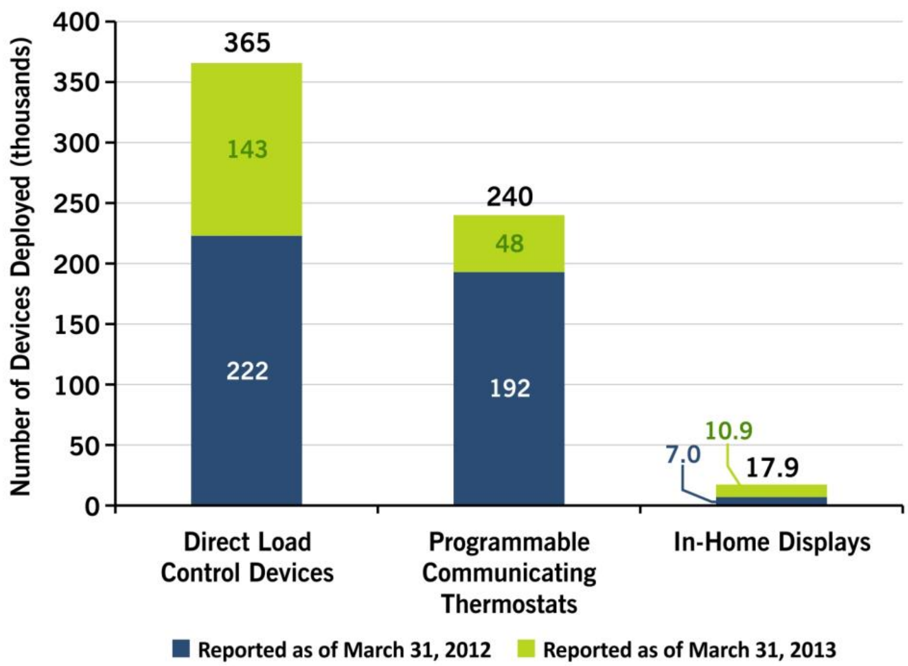

Figure 9. Number of Customer System Devices Deployed (as of March 2013)

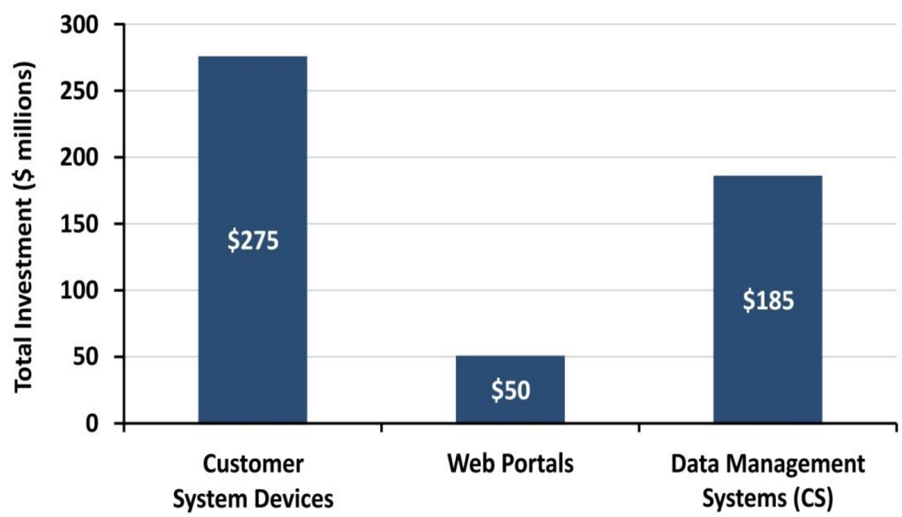

Figure 10. Breakdown of DOE Investment of Customer System Projects by Investment Type (as of March 2013; total = $510 million)

In addition, a small but growing number of customers across the nation are signing up to participate in time-based rate programs. As of March 31, 2013, approximately 265,000 customers were enrolled in time-based rate programs out of a total customer population of approximately 38 million. This illustrates that the vast majority of the customer system projects involve implementation of time-based rate programs on a pilot basis and that relatively small numbers of participants are involved.

Customer Systems Project Examples

The examples shown below highlight two customer system project recipients that have completed their equipment installation activities. The projects are representative of all of the SGIG customer system projects and illustrate progress in advancing customer capabilities, including information and education for understanding and managing electricity consumption and costs, time-based rates for reducing or shifting electricity demands during peak periods, and direct load control for peak load management.

Entergy New Orleans

The Entergy New Orleans Inc. (ENO) AMI pilot project has completed its installation of approximately 5,000 smart meters. As part of its AMI deployment, ENO has successfully deployed 3,500 customer web portal accounts, 3,000 IHDs, and 400 PCTs. The air conditioning load management program enrolled 400 customers.

Pilot participants, who include 4,600 low-income participants in Orleans Parish, are able to utilize IHDs and a web portal to review energy consumption, participate in either a peak-time rebate or an air conditioning load management program, and make decisions about energy consumption based on price signals and potential monetary savings. The SGIG-funded project web portals and home area network (HAN) devices provide customers with month-to-date and projected month ending usage and dollar amounts, and graphs of electricity usage for the previous 24-hour and 30-day periods.

ENO is conducting two studies based on the pilot project to assess customer acceptance of real-time pricing programs and the impact of consumer end-use tools and technologies on low-income customers. Statistical analysis of the consumer behavior studies will be available soon as part of the SGIG program. Lesson learned from the pilot will be shared with other utilities and investment decision makers.

Oklahoma Gas & Electric (OG&E)

OG&E's Smart Grid program is an initiative involving system-wide deployment of a fully integrated AMI, distribution automation system, and consumer behavior study. OG&E undertook its consumer behavior study for the summers of 2010 and 2011, which included 6,000 customers out of its 765,000 customer base in Oklahoma. Study participants were randomly assigned various combinations of customer systems, including IHDs, PCTs, and a web-based customer portal. OG&E tested real-time pricing in the study, which included TOU, CPP and VPP rate structures. The study found that there were measurable demand reductions for all of the combinations of rates and customer systems, and the customers with PCTs utilizing VPP rate structures offered the greatest peak-hour demand reductions.

The greatest outcome of the study, however, is the decision by OG&E to scale up the program to 120,000 customers by the summer of 2016. In 2011, OG&E implemented the SmartHours demand response program, in which OG&E provides customers with a free PCT—which allows customers to automatically manage energy consumption—and receive advance notice of the next day's peak price. With well over 40,000 customers enrolled in the program by the end of 2012, the program reduced peak power demand by at least 70 megawatts (MW) (an average of 2.02 kilowatts [kW] per home with PCT installed). OG&E's overall program goal is to reduce annual peak load by 170 MW and delay the need to build a new fossil fuel power plant, which has been scheduled for 2020. In June 2013, the company received the prestigious Edison Award for its successful implementation of smart grid technologies and innovative customer programs and is considered to be a leader among utilities for its achievements under the SGIG program.

4. Grid and Economic Impacts and Lessons Learned

This section presents highlights from seven reports on SGIG impacts and lessons learned that DOE has published since July 2012 when the first SGIG Progress Report was published. In many cases, the results presented in these reports are termed "initial" because at the time the reports were published, the available information covered relatively small numbers of projects and data collection periods. The reports contain both quantitative and qualitative information in the following areas:

- Deployment of synchrophasor technologies in electric transmission systems
- Reliability improvements from application of distribution automation technologies and systems
- Application of automated controls for voltage and reactive power management
- Operations and maintenance cost savings from application of AMI
- Peak demand impacts from application of smart meters, time-based rates, and customer systems
- Enrollment patterns in time-based rate programs under the SGIG consumer behavior studies
- Economic impacts of Recovery Act investments in smart grid projects

4.1 Synchrophasor Technologies and their Application in the Recovery Act Smart Grid Programs

DOE published a report that discusses the 12 SGIG and SGDP projects (11 of the projects are SGIG projects) that are deploying synchrophasor technologies and systems to improve the reliability, operational efficiency, and resiliency of the electric transmission system.[9] Table 5 summarizes an analysis of the cost data provided thus far from the SGIG and SGDP synchrophasor projects. The reported costs are the total installed cost of the technologies and systems, which includes the cost of the device or system itself; design and engineering costs; labor and materials costs for installation, as well as any needed construction; and overhead expenses. The cost data are preliminary in that in some of the projects, not all of the project participants had fully reported all of the cost-share amounts they had contributed.

[9] North American Electric Reliability Corporation, *Real-Time Application of Synchrophasors for Improving Reliability* (Princeton, NJ, October 18, 2010). This report provides in-depth descriptions and discussions of synchrophasor technologies and their application in electric transmission systems.

Technology	Median Value of the Reported Costs[10]
Phasor Measurement Units (PMUs)	$43,400/PMU
Phasor Data Concentrators (PDCs)	$107,000/PDC

Table 5. Costs of Deploying Synchrophasor Technologies

Source: Calculated from data reported by the projects.

As mentioned, the reported costs include installation and any other costs which the project allocated to the PMU or PDC cost categories. Based on discussions with vendors, the cost of the equipment itself could be as low as 25 percent of the total reported installed cost – but this fraction varies depending on the vendor, equipment, and the complexity of the project.

In addition, the value of the installed costs for PMUs and PDCs varies considerably across projects. In some projects, the installed costs for PMUs and PDCs are more than double the median value; in other projects the installed costs are less than half the median value. There are several reasons for this variation. For one, the devices can have different functional specifications and capabilities, and thus have different costs. In addition, some projects upgraded existing equipment such as digital fault recorders to give them PMU capabilities; such upgrades cost considerably less than installing new PMUs. And, the projects also faced different construction requirements in installing the devices, which can have a big effect on installed costs.

4.2 Reliability Improvements from the Application of Distribution Automation – Initial Results

DOE published a report that discusses the 48 of the 57 SGIG electric distribution projects that are seeking to improve electric distribution system reliability. Initial results came from four of the projects that reported quantitative information based on their operational experiences. Table 6 provides a summary of the initial results from the four projects and covers a total of 1,250 distribution feeders.[11] The table shows the changes in the major reliability indices due

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[10] Each project reported costs for every PMU or PDC that was installed. An average was calculated for each project of the costs of those PMU and PDC installations. The average cost values for each project for PMUs and PDCs were then placed in order from highest to lowest and the median value from that list is reported in Table 3.

[11] The reliability indices shown in Table 4 are the ones commonly used by the electric power industry to estimate changes in reliability. The changes were calculated from baselines that the projects estimated using at least three years of historical data.

primarily to automated feeder switching and is based on measured results from the summer and winter periods from April 1, 2011, to March 31, 2012.

Reliability Indices	Description	Range of Percent Changes
SAIFI	System Average Interruption Frequency Index (outages)	-11% to -49%
MAIFI	Momentary Average Interruption Frequency Index (interruptions)	-13% to -35%
SAIDI	System Average Interruption Duration Index (minutes)	+4% to -56%
CAIDI	Customer Average Interruption Duration Index (minutes)	+29% to -15%

Table 6. Changes in Reliability Indices from Automated Feeder Switching

Negative changes in Table 6 indicate the reliability indices are improving while positive changes indicate the reliability indices are getting worse. Major findings include:

- Projects with automated feeder switching were able to reduce the frequency of outages, the number of customers affected by both sustained outages and momentary interruptions, and the total amount of time that customers were without power (as measured by customer minutes interrupted). In general, these changes were in line with the expectations of the projects.

- Projects are generally applying automated feeder switching to their worst performing feeders. The results show that the greatest percentage improvements in reliability from automated feeder switching occur when applied on the worst performing feeders.

- In most cases, the projects were not yet using the full set of automated capabilities. For example, many projects also plan to use distribution management systems for accomplishing automated feeder switching, and none of the four reporting projects had this feature fully operational yet. This underscores the need for further data and analysis as many of the projects plan to use this feature in the future.

- Several of the projects had more prior experience with automated feeder switching than others. The projects report a substantial learning curve for grid operators, equipment installers, and field crews in figuring out the full set of capabilities and how to use them to their best advantage. The projects with more experience reported having more confidence in the grid impacts and reliability improvements they observed.

- Projects pursued both centralized and distributed forms of control systems for automated feeder switching, depending on their circumstances and objectives. The relative merits of these two approaches, and the circumstances when they best apply, are important considerations.

- The initial results raise questions about the usefulness of CAIDI as an index for measuring the effects of automated feeder switching on the duration of customer interruptions. Caution is raised because automated feeder switching generally reduces the number of customers experiencing sustained outages (reducing the denominator of the index), relative to the duration of the sustained outages (expressed in the numerator.)

4.3 Automated Controls for Voltage and Reactive Power Management – Initial Results

DOE published a report discussing the 26 SGIG projects that are implementing advanced voltage and VAR optimization technologies to improve electric distribution system operations. Initial results are based on 8 SGIG projects involving 31 feeders that reported hourly load data, and two projects that provided data on their experiences with conservation voltage reductions for peak periods. Major findings include:

- For the 31 feeders for which projects have reported hourly load data, one-half are witnessing line loss reductions in the range of 0 percent to 5 percent, and 5 feeders experienced loss reductions greater than 5 percent. These results are in the range of other industry estimates which indicate that line loss reductions of 5 percent to 10 percent are possible.

- In general, feeders with the worst baseline power factors (i.e., those with the highest amount of inductive loads) showed the greatest reductions in line losses. Many of the utilities are targeting their worst performing feeders. However, overcompensation for reactive power was observed in the remaining feeders, which resulted in line loss increases. In these cases, capacitor banks were often operated for voltage support rather than reactive power compensation.

- The initial results for conservation voltage reductions indicate a potential for peak demand reductions of approximately 1 percent to 2.5 percent. These initial results are consistent with the expectations of the projects and results from other studies in the literature. In comparison to energy savings attributable to line loss reductions, conservation voltage reductions have greater impacts on reducing energy requirements.

4.4 Operations and Maintenance Cost Savings from Application of AMI – Initial Results

DOE published a report discussing the 63 SGIG projects that are installing AMI to improve operational efficiencies and support billing and customer services. Many of the SGIG AMI projects are still in the process of integrating smart meters with billing and other enterprise systems. Fifteen of the projects representing 3.5 million meters reported initial results to DOE based on operational experiences for a one year period from April 1, 2011, to March 31, 2012. Table 7 provides a summary of the initial results for four metrics: meter operations costs, vehicle miles driven, vehicle fuel consumption, and vehicle emissions.

Meter O&M Savings Metrics	Range of Percentage Improvements
Change in meter operations cost	-13% to -77%
Change in vehicle miles driven, fuel consumption, and CO_2 emissions	-12% to -59%

Table 7. Initial Results from AMI Operations for 15 SGIG Projects

Improvements were observed for all four metrics but there was variation in the results across the 15 projects. The variations were the result of several factors, including differences in legacy metering systems, meter operations practices, and the sizes and geographies of the service territories. Further analysis of more projects and time periods is needed before the root causes of the variations can be more completely understood. Major findings include:

- Cost reductions and productivity improvements observed to date are primarily related to reductions in labor and vehicle costs from remote meter reading, and automation of other billing-related services.
- Of the projects that have completed deployment, the utilities with lower customer densities per distribution line-mile observed larger savings per customer served than those with higher customer densities.
- Several of the projects had prior experience with the deployment of AMI and its integration with legacy systems. Having previous experience has been beneficial for these projects in getting AMI to operate properly and with a minimum amount of delay, including having fewer customer and systems integration issues.

4.5 Demand Reductions from the Application of Advanced Metering Infrastructure, Pricing Programs, and Customer-Based Systems – Initial Results

DOE published a report on the 62 SGIG projects that are implementing advanced metering, customer systems, and time-based rates to achieve certain demand-side objectives such as peak-load reductions. Initial results focus on the three projects that produced quantitative evaluation reports of peak demand impacts from demand-side operations in the summer of 2011. Table 8 provides a summary of the initial results from the three projects: Oklahoma Gas & Electric (OG&E), Marblehead Municipal Lighting Department (MMLKD), and Sioux Valley Energy (SVE). Collectively, these projects offered time-based rates at that time to about 7,000 customers, and each had the primary objective of reducing electricity consumption during peak periods.

	OG&E	MMLD	SVE
Number of study participants	6,000 residential customers	500 residential customers	600 mostly residential customers
Type of time-based rate(s)	Time-of-use and variable peak pricing with critical peak pricing components	Critical peak pricing	Critical peak pricing
Type of customer systems	In-home displays, programmable communicating thermostats, web portals	Web portals	Web portals
Peak demand reduction during critical peak events	Up to 30%	37%	Up to 25%
Customer acceptance	Positive experience, many reduced electricity bills	Positive experience, but did not use the web portals often	Interested in continued participation, many reduced electricity bills

Table 8. Summary of the Initial Results (Summer 2011)

With two years of data, the OG&E study provides more information on its results than the other two projects. The analysis shows peak demand reductions of as much as 30 percent from a sample of about 6,000 primarily residential customers (including control groups) that used programmable communicating thermostats, in-home displays, and web portals to respond to time-based rates that included combinations of time-of-use, critical peak, and variable peak pricing. Customers reported positive experiences, had few complaints, and many reduced their monthly electricity bills based on the use of these new programs. Based on their two years of experience, OG&E decided to roll-out its time-based rate programs to approximately 20 percent of its customers (120,000) by 2016, with the aim of deferring investment in about 170 MW of power plant capacity.

4.6 Analysis of Customer Enrollment Patterns in Time-Based Rate Programs – Initial Results from the SGIG Consumer Behavior Studies

DOE published a report on enrollment patterns in the 11 SGIG consumer behavior studies.[12] The primary metric for the analysis of enrollments is recruitment rate, which is defined as the number of recruited customers divided by the number of solicited customers. Differences in recruitment rates reflect the solicitation strategy (e.g., opt-in versus opt-out) but also the amount of time and effort that was devoted to market research and customer education, and the effectiveness of marketing materials and education campaigns. Major findings include:

- For the 19 solicitation efforts[13] that have occurred for the SGIG consumer behavior studies to date, recruitment rates range from 5 percent to 28 percent for opt-in offers (i.e., the customers were informed of the study and asked to join), and 78 percent to 87 percent for opt-out offers (i.e., those solicited did not reject the offer and were placed into a program).
- For opt-out solicitations, the type of time-based rate offer does not substantially affect the customer recruitment rate: time-of-use (TOU) rate offers had a recruitment rate of 81 percent, flat rates with critical peak pricing offers had an 81 percent recruitment rate, and time-of-use and critical peak pricing offers had a 78 percent recruitment rate. This finding holds for opt-in solicitations, as flat rates with critical peak pricing components had 17 percent recruitment rates, and those offering time-of-use rates had 16 percent recruitment rates. The addition of technology offerings also did not significantly alter this finding as programs involving IHDs had 16 percent recruitment rates, and those without IHDs had 17 percent recruitment rates.
- For both opt-in and opt-out solicitations, many of the projects found that focus groups, surveys, and other research on customer preferences were vital components for test

[12] The report is based on analysis by Lawrence Berkeley National Laboratory. See P. Cappers et al. (2013) Residential Customer Enrollment in Time-based Rate and Enabling Technology Programs: P. Cappers et al. (2013) Summary of Utility Studies.

[13] A *program offer* represents the different types of time-based rate, technology, and opt-in versus opt-out proposals made to customers when they are solicited to enroll in a study. A *solicitation effort* is defined to be a one complete set of program offers made to one group of customers to participate in a particular study (e.g., one solicitation effort may have an opt-out offer, a TOU rate offer, and no technology offer).

marketing terms and concepts for recruiting customers to participate in solicitation efforts. This was because the opinions of the utilities about what would be effective marketing terms frequently differed from what customers thought would be effective.

4.7 Economic Impact of Recovery Act Investment in the Smart Grid

DOE published a report that provides analysis of the impacts of the SGIG and SGDP investments on jobs and the economy. The analysis finds that Recovery Act investments in SGIG and SGDP projects before March 2012 (almost $3.0 billion) ultimately generated an estimated $6.8 billion in total economic output. Economic benefits from these investments extend beyond the energy sector, as for every $1.0 million directly spent, the gross domestic product grew by $2.5 million—a higher multiplier than other federal infrastructure investments. In addition, SGIG and SGDP projects supported about 47,000 full-time-equivalent jobs in multiple sectors, including about 12,000 direct jobs among smart grid vendors.

The results of the analysis are summarized in Table 9, and the major findings include:

- Smart grid deployments positively impact employment and labor income. Among smart grid vendors—an ecosystem of manufacturers, information technology companies, and technical services providers—about 12,000 direct jobs were supported, with the remaining jobs being in those companies' respective supply chains and induced by the money spent throughout the broader economy.

- Investments in smart grid industries support high-paying jobs. Industrial sectors that benefit directly include computer systems design, technical and scientific services and consulting, and electrical and wireless equipment and component manufacturing. Industrial sectors that experience indirect and induced benefits include real estate, wholesale trade, financial services, restaurants, and health care.

	Total Impact	
	All Vendors	Smart Grid Vendors Only
Employment (jobs)	47,000	33,000
Labor Income (2010$)	$2.86 Billion	$2.07 Billion
GDP (2010$)	$4.18 Billion	$2.91 Billion
Economic Output (2010$)	$6.83 Billion	$4.79 Billion
State and Local Taxes (2010$)	$0.36 Billion	$0.26 Billion
Federal Taxes (2010$)	$0.66 Billion	$0.49 Billion

Table 9. Summary of SGIG Economic Impacts

5. Progress Toward a Smarter Grid

In 2005, DOE convened seven regional workshops across the country involving regulators, utilities, vendors, legislators, research institutions, universities, and other stakeholders to forge a common definition of a smarter grid. This collaborative effort resulted in the widely accepted "seven characteristics of a smarter grid," which have served as guiding principles for the SGIG program. The purpose of categorizing smart grid technologies and systems through characteristics is to highlight the many ways in which the nation's electric power grid is being modernized to provide continued reliability and resiliency.

DOE collects data to evaluate progress in grid modernization through the Smart Grid System Report. The Smart Grid System Report to Congress is a biennial assessment mandated in Section 1302 of the Energy Independence and Security Act of 2007 and explores the current status of smart grid development, its future prospects, and the technical and financial obstacles to progress. It also outlines the scope of a smart grid, assesses the stakeholder landscape, and provides several recommendations for future reports. The second edition of this report was published in 2012 and briefly addresses how near-term progress in smart grid deployments has increased as a result of investments by the Recovery Act smart grid projects, including SGIG.

The SGIG program is designed to accelerate the modernization of the nation's electric power grid. The expanded capabilities that the SGIG projects are deploying represent a real jump start in the investments needed. Examples of how SGIG projects contribute to the smart grid characteristics are provided below.

5.1 Enabling Informed Participation by Consumers in Retail and Wholesale Electricity Markets

A smarter grid with advanced consumer-focused capabilities provides choices that involve new technologies and new information about electricity consumption and costs, and demand-side programs involving time-based rates, load management, and energy-efficiency strategies. The two projects highlighted below provide examples of how SGIG is furthering progress to enable informed participation by consumers in retail and wholesale electricity markets.

Sacramento Municipal Utility District (SMUD)

The Sacramento Municipal Utility District (SMUD) SGIG project, *SmartSacramento®*, is implementing a number of services that enable SMUD customers to fully participate in the electricity marketplace through time-based rate and demand response (DR) programs. SMUD's smart grid team is partnering with six public agencies to develop services and solutions that educate, inform, and enable residential and commercial customers to access and use newly available information to better manage and control their energy use. The utility has issued over 4,000 in-home displays, prepared in advance so that customers need only hit the "on" button. SMUD also offers a unique in-home display check-out program so customers can try the technology for two months to learn about their whole-house consumption with real-time data, and then return the devices to SMUD or a nearby public library. Also new to SMUD customers are tips to educate and inform customers via dynamic websites, text messages, automated calls, emails, and social media, as well as access to energy usage data via a web portal. SMUD has also developed customer-centric educational videos using simple visuals to explain time-based electricity pricing. The communications inform consumers about energy usage, associated costs, and options for reducing both; and the tools empower and encourage those customers to control their own usage levels.

In parallel with deployment of customer-facing applications, SMUD is conducting three direct load control pilot studies, an advanced lighting controls program, a smart thermostat pilot, and a consumer behavior study. The 2012 direct load control pilot began testing strategies for pre-cooling a residence before a demand response event, and the 2013 pilot involves installation of 1,000 PCT thermostat devices in residential and small commercial buildings. SMUD is also conducting a 2013 smart charging pilot using 60 utility-managed EVSEs (electric vehicle supply equipment) to control Level 2 charging of electric vehicles. For the lighting program, commercial customers were offered financial incentives of up to $300,000 per customer, not to exceed 80 percent of project cost, to install advanced lighting systems at their businesses, with the potential to achieve electricity savings of 50 to 90 percent. For example, a light-emitting diode (LED) lighting system with advanced controls was installed at Blue Diamond Growers, followed by close monitoring of energy consumption. Based on results to date, annual energy savings at Blue Diamond are estimated at 236,477 kilowatt hours, or 79 percent of annual usage. The smart thermostat pilot provides over 800 EcoFactor, Allure, or Nest self-optimizing thermostats to customers that want to increase energy efficiency with "set it and forget it" technologies controlled over the Internet. The consumer behavior study is evaluating the timing and magnitude of changes in residential customers' peak demand patterns due to varying combinations of customer systems, different recruitment methods (i.e., opt-in vs. opt-out), and several time-based rates. Study results will enable SMUD to develop rate designs that engage consumers and result in effective load control and reduced energy consumption.

NV Energy

The NV Energy *NV Energize Project* is deploying smart grid technologies and systems that support advanced customer service options, allowing the utility to provide tools for consumers to review and adjust energy usage as well as manage costs and bills.

Customers with smart meters can sign up for MyAccount, a secure web portal that provides customers with energy use at 15-minute intervals, costs to date, projected bills, and emailed threshold alerts for both dollar amounts and kilowatt usage. Through the portal, customers have access to additional usage data as well. Customers can also subscribe to an emailed weekly summary alert that provides costs and projected bills. Thanks to increased access to electricity consumption information, customers have better capabilities for monitoring, understanding, and capturing the value from altering their consumption behavior.

The utility is also implementing an advanced demand response management system that integrates the utility's portfolio of demand response programs and provides a link to customer service, control operations, system operations, and other functions. Demand response activities include roll-out of an advanced heating, ventilation and air conditioning (HVAC) optimization solution that operates on an Internet-connected HAN system, which reduces annual cooling energy consumption by 10 percent to 20 percent.

5.2 Accommodating all Types of Central and Distributed Electric Generation and Storage Options

A smart grid envisions accommodating not only large centralized power plants but also the growing array of distributed energy resources (DER). DER includes renewable energy, combined heat and power, distributed fossil-fired generation, energy storage, and demand response options. The two projects highlighted below provide examples of how SGIG is furthering progress to enable all types of central and distributed electric generation and storage options.

Idaho Power Company

Idaho Power Company (IPC) has developed a wind power forecasting tool to increase the accuracy of wind forecasting to better schedule other generation resources and accommodate fluctuations in wind generation. Without this wind forecasting tool, IPC was often required to carry additional operating reserves to ensure there is always sufficient generation to cover an unplanned loss of large amounts of wind generation. Carrying such additional operating reserves can be very costly and result in inefficient operating of the generation system. IPC saw an opportunity to address these issues by building a wind forecasting tool that provides grid operators with more timely and accurate information on the availability of wind capacity on an hourly basis. IPC employees worked with universities and consulting firms to produce the forecasting tool. For example, IPC's wind forecasting tool recently predicted that approximately 500 MW of wind capacity would be available to serve load. IPC grid operators were able to use 15 percent of natural gas-fired reserves instead of 100 percent, with a resulting savings of approximately $50,000 for this one event.

City of Glendale Water and Power

Glendale Water and Power (GWP) is installing systems to accommodate thermal energy storage devices for reductions in peak demand. The municipal utility has connected 166 thermal energy storage units at 13 Glendale city buildings and 43 local small, medium, and large commercial businesses to its wireless communications network. These units achieve peak load reductions by providing 1.3 MW of thermal energy storage and making ice at night, when overall demand is relatively low and local power is available from GWP's landfill gas plant, and using the ice for space cooling during the day, decreasing the need to purchase power when prices are highest.

5.3 Enabling New Products, Services, and Markets

A smarter grid is built up from complex technologies, often serving engineering and control functions that do not always make the benefits easy to recognize. SGIG projects have enabled equipment manufacturers, vendors, and software developers to refine product offerings and improve their performance and cost effectiveness. The two projects highlighted below provide examples of how SGIG is furthering progress to foster development of new products, services, and markets.

Whirlpool Corporation

Through the Whirlpool Corporation *Smart Appliance Project*, the company entered a new market with the launch of its first suite of smart appliances: a large-capacity washer/dryer set, a side-by-side refrigerator, and a console dishwasher. The appliances are meant to enhance the effectiveness of time-based rate and load management programs to reduce peak demand. For example, a big gap between on-peak and off-peak electricity prices motivates customers to do laundry in off-peak hours, helping to mitigate peak power demand on the grid. Whirlpool developed an application so that the appliances can “talk” to smart phones and tablets and is finalizing a web version that communicates with Android devices and laptop/desktop computers. Both allow consumers access to information and controls to manage and defer energy consumption. Appliance companies in the United States, Europe, and Asia have been testing smart appliances in utility pilots since the 1990s, but Whirlpool is among the first to complete testing and enter the commercial marketplace.

Reliant Energy Retail Services, LLC

Reliant Energy Retail Services, LLC’s (Reliant’s) *Smart Grid Enabled Consumer Participation Project* is deploying new services and market offerings, collectively dubbed Reliant e-Sense™, for retail customers in Texas. Prior to receiving SGIG funding, Reliant had spent more than three years investing in development and testing of consumer-focused smart grid products and could offer these products to a limited number of consumers. The grant has allowed Reliant to address challenges and offer these tools and technologies to a larger number of consumers at an accelerated pace. Technologies include in-home devices such as home energy monitors that provide real-time usage information, and smart programmable demand response-enabled thermostats that can be managed through a web portal or mobile device. Tools support consumer engagement with the smart grid: a mobile app that provides energy usage and cost data on demand, a weekly email with details about usage and projected bill amounts, customized alerts about electricity consumption and costs, and the e-Sense web portal for online account management.

Reliant has also initiated a time-based rate program and a demand response program (thermostat control). The SGIG project has successfully enrolled over 600,000 customers in its service programs—100,000 more than initially targeted. On the leading edge, Reliant was the first electricity retailer in Texas to participate in the Green Button Initiative. Separate from but in parallel with the SGIG project, Reliant has initiated Smart Energy Home, an exhibit featuring several of the SGIG-funded products working in a model home. The interactive experience takes visitors "inside" a smart energy home and shows them how advanced technologies can change the way Americans use electricity.

5.4 Providing for Power Quality for a Range of Needs by all Types of Consumers

Many SGIG projects are installing technologies and systems that address the power quality needs of all types of consumers. For example, automated controls for voltage and reactive power management can be used to optimize voltage levels for consumers along feeder lines and result in energy savings and lower costs. Distribution automation can be used to proactively solve problems before they affect customers or limit their effects if service interruptions do result. The two projects highlighted below provide examples of how SGIG is furthering progress to provide for the power quality needs of all types of consumers.

Orange & Rockland (subsidiary of Consolidated Edison)

Orange & Rockland, a subsidiary of Consolidated Edison, is participating in Consolidated Edison's *Smart Grid Deployment Project* by implementing automated distribution technologies and systems and enhancing electricity delivery and services for its customers. The utility is deploying an integrated system model (ISM) for operating its electric distribution system by communicating with switches, reclosers, SCADA, and voltage and VAR controls, and processing this data through ISM for a more reliable system with improved power quality. The ISM is updated daily to validate data and ensure accurate controls for operating reclosers to reduce frequency and duration of outages and for voltage and reactive power management to reduce line losses, optimize voltage levels for conservation voltage reductions, enable phase rebalancing for improved power quality, and improve power factors to reduce reactive power requirements. Analysis shows that during the pilot, phase imbalances on tested circuits were improved from about 59 percent to about 15 percent. Power factors on tested transformers were increased from about 93 percent to about 99 percent.

Southern Company Services Inc.

Southern Company Services Inc.'s *Smart Grid Project* involves deployment of new distribution technologies that can reduce peak load through conservation voltage reduction. The energy company is automating capacitor banks and voltage regulators on several thousand distribution feeders in its Georgia Power and Alabama Power service territories. The automated capacitors improve the power factor, reduce line losses, and flatten the voltage profile for the system. In addition, Southern Company has developed and deployed electronic devices to continuously monitor capacitor health, enabling quick identification and response to problems. Selected feeder regulator controls have been replaced with SCADA-enabled automated regulator controls, allowing quick adjustment of voltage parameters. Next steps include incorporating voltage/VAR optimization control algorithms, currently in development, into the distribution management system. Collectively, these automated and integrated devices support optimized voltage levels along feeder lines, resulting in the ability to reduce the feeder voltage and peak load, and thereby reduce the need for additional generation peaking units.

5.5 Optimizing Asset Utilization and Operating Efficiency of the Electric Power System

SGIG projects are installing technologies and systems to improve asset utilization and operating efficiencies. For example, sensors that measure conditions on power lines can enable operators to increase throughput by applying dynamic line ratings to more accurately assess loading. System-control devices can be adjusted to reduce losses and eliminate congestion. Operating efficiency increases when selecting the least-cost energy-delivery system available through these adjustments of system-control devices. The two projects highlighted below provide examples of how SGIG is furthering progress to optimize asset utilization and operating efficiency of electric power systems.

M2M Communications (acquired by EnerNoc)

The M2M Communications (now EnerNoc) *Agricultural Load Control Program in Central California Valley Grid Project* has developed a two-way, web-to-wireless controller for irrigation pumps and installed this equipment as part of the Peak Energy Agriculture Rewards (PEAR) program, an agricultural demand response program in California. The program is marketed to agricultural customers within Pacific Gas and Electric (PG&E) and Southern California Edison (SCE) service territories. The controllers collect real-time information on water use and soil conditions, enabling farmers to make informed decisions as to whether they can participate in peak demand events and earn cash incentives. The controllers turn the irrigation pumps off and on in response to announcements of critical peak events. M2M estimates that PEAR program participation reduced summer peak demand by an average of 18 MW per event, and avoided peak demand charges for farmers can be as much as $10,000 per pump per year.

The information provided by the controllers also helps farmers save electricity and water year-round, increasing the overall efficiency of day-to-day operations in California's cost-competitive agriculture industry. M2M has installed its irrigation load control system on 300 pumps in the PG&E service territory, representing about 60 MW of interruptible load. Reducing load during peak periods is a key tool for optimizing system assets and can contribute to more efficient use of generation resources.

PECO, an Exelon Company

PECO's *Smart Future Greater Philadelphia Project* includes deployment of advanced metering infrastructure (AMI) to improve overall operational efficiency and service for customers and enable two-way communications. To date the company has installed more than 600,000 new AMI electric meters. As part of this effort, PECO will be conducting a pilot program to offer Time-of-Use Rates to 120,000 customers. PECO has already realized many benefits of new metering technology with the company's current automated meter reading (AMR) system, however the transition from AMR to AMI still provides additional customer and economic benefits—specifically savings associated with remote connect/disconnect capabilities, increased efficiencies, and enhanced tampering detection. This deployment also involves distribution automation systems including 100 new reclosers and communications upgrades for 300 existing reclosers. These devices will help reduce sustained outages and restoration times and improve operational efficiency. Since project inception, PECO has experienced a 43 percent improvement in the project level SAIFI on the recloser circuits. The selection of these circuits, as well as the location of each recloser, reflects PECO's reliability strategy to reduce the number of customers affected when an incident occurs.

5.6 Anticipating and Responding to System Disturbances

Fewer and shorter outages are among the objectives of many of the SGIG projects. Outage notification from smart meters, for example, helps pinpoint locations for dispatching repair crews and shortening restoration times. Monitoring substation equipment can identify problems with transformers and other devices before they fail so repairs or replacements can be made before customers lose power. Automated feeder switching can re-route power flows around faults or downed power lines so that fewer customers are affected. The two projects highlighted below provide examples of how SGIG is furthering progress to anticipate and respond to system disturbances.

CenterPoint Energy Houston Electric, LLC

CenterPoint Energy Houston Electric, LLC's (CenterPoint's) *Smart Grid Project* is anticipating and responding to system disturbances by installing equipment that will reduce the frequency of outages and restore service more quickly when outages do occur. A distribution management system (DMS) and multi-layer communications system consisting of fiber, Ethernet, microwave, cellular, and wireless mesh networks are being integrated with AMI. The DMS will monitor and analyze distribution system health using sensor data, and provide operators and repair crews with information to respond to abnormal operating conditions. AMI is also used to transmit premise-level outage and restoration notifications to the utility's outage management system and DMS. CenterPoint is automating feeders by replacing electromechanical substation relays with microprocessor-based relays, installing automated feeder switches, and retrofitting existing switches. These devices are integrated with the DMS, which compiles information from SCADA, smart meters, and other distribution equipment to support fault location, isolation, and service restoration (FLSIR). Based on this information, the DMS will be able to remotely assess operating conditions on the distribution system, locate faults, and reroute power for service restoration.

Florida Power & Light Company

Thanks to Florida Power & Light Company's (FPL's) *Energy Smart Florida* program, company personnel now have access to unprecedented information in near-real time related to system performance, allowing for equally quick responses to system disturbances. Newly installed diagnostic systems collect and interpret data from intelligent devices installed at substations, such as battery banks and transformers. For example, new monitors have been installed on transformers to evaluate their health, and battery banks are monitored for voltage levels and impedance. This information is transmitted to enhanced performance and diagnostic centers. FPL leverages its existing diagnostic centers by increasing the number of and interface with field devices, as well as improving the center's ability to analyze and respond to the data collected.

These enhanced centers are the "nerve center" of the FPL smart grid, gathering and analyzing information on operating conditions to enable predictive maintenance and faster recovery from disruptions. The SGIG project completed implementation in the spring of 2013 and already has success stories. For example, a newly installed monitor detected a faulty transformer, allowing FPL to switch customers served by this transformer to another one while the faulty transformer was replaced. The quick action prevented an outage that would have affected several thousand customers—and demonstrated FPL's optimized usage of monitoring devices to support reliable power delivery.

5.7 Operating Resiliently to Attacks and Natural Disasters

Resilience refers to the ability of a system to react to events and recover to full operations in a reasonable time period. A more resilient grid addresses cybersecurity from the outset, as a requirement for all elements, and ensures an integrated and balanced approach across the system. The two projects highlighted below provide examples of how SGIG is furthering progress toward more resilient operations in addressing natural disasters and cybersecurity events.

Electric Power Board of Chattanooga

The Electric Power Board of Chattanooga (EPB) is better prepared for natural disasters and has improved the resilience of its electric distribution system for faster restoration of services following outages. EPB expects that the number of customer-minutes lost to power outages will be reduced by 40 percent or more, with increased reliability worth at least $35 million a year to Chattanooga area businesses and homeowners. Outage notification and response from FLSIR made valuable contributions to speeding up restoration times in Chattanooga during a tornado outbreak in April 2011. When nine tornados ripped through neighborhoods and business districts—affecting the entire EPB system—automated feeder switching and FLISR actions were pivotal for EPB, which had 123 "smart" switches in service. The smart switches remotely detect faults on distribution lines caused by lightning strikes, high winds, or fallen tree limbs, and then are able to automatically isolate damaged sections of power lines and reroute power flows to reduce the number of affected customers. Only one of the 123 switches installed went offline during the storm; this proved to be very valuable, as thousands of hours of outage time were avoided. EPB was able to avoid sending repair crews out in the field 250 times. The utility has deployed approximately 1,200 smart switches system-wide. Information derived from the smart switches will help the company analyze the impact of storms and will be useful for future planning purposes.

Consolidated Edison Company of New York, Inc.

The Consolidated Edison Company of New York, Inc. (Con Edison's) *Smart Grid Deployment Project* is deploying various types of distribution automation to operate resiliently against attack and natural disaster. Their distribution automation benefits are primarily focused on reducing outages and providing for the rapid restoration of electrical service as expeditiously as possible. During Hurricane Sandy, Con Edison avoided over 100 truck rolls through automated operation of overhead circuits to minimize customer impact. They are further storm-hardening their existing infrastructure with transformer monitoring and overhead and underground sectionalizing switches. This storm-hardening effort will expand the system monitoring, mitigate the customer impact of major storms, and isolate critical facilities and minimize equipment damage.

The company has expanded automated overhead switches by 35 percent and realized a 25 percent improvement in SAIFI and resulted in over 17,000 avoided customer outages. The company has tripled the underground distribution feeder sectionalizing capability and reduced the risk of major outages in targeted underground distribution networks by over 30 percent. Con Edison has implemented new cyber-secure SCADA systems to address the threat of a cyber attack and to enable automated switching for increased operational flexibility and a self-healing grid.

Additionally, the transformer monitoring systems installed through the project have already detected irregularities in transformer performance, allowing Con Edison to remove transformers from service prior to fault. Avoiding transformer failures is a significant project success, since catastrophic failures of high-energy equipment in an urban environment can be a significant safety concern. Con Edison has more than doubled the underground distribution system monitoring capability through installation of 8000 sensors, resulting in $1 million annual savings through condition-based monitoring.

6. Next Steps

SGIG's substantial $7.9 billion combined federal and private investment is showing progress toward improved reliability, reduced operations costs, shorter and less frequent outages, economic returns, and job creation for industry participants. Yet these outcomes are only the first step. The program now must put these results to work: reducing utilities' and regulators' uncertainty around smart grid benefits and impacts; streamlining technology integration by sharing best practices and lessons learned; and building strong business cases for utility and public investment.

Over the next year, the SGIG program will move toward project completion and continue to deploy smart grid technologies and systems. Quarterly reports on installations and costs will be posted on www.smartgrid.gov. In addition, project reporting on impacts and benefits will proceed and provide new opportunities for analysis and reporting on grid impacts, costs, benefits, lessons learned, and other useful information for investment decision making. DOE will continue sharing all reports, analysis, and case studies with interested stakeholders on the website, through conferences, and by other information sharing mechanisms. Those interested can sign up for email updates when new information is posted on the website at http://www.smartgrid.gov/email_alerts.

Through the SGIG projects and beyond, DOE will continue working in partnership with the electricity sector to accelerate adoption of new technologies and systems, remove barriers to new and efficient energy markets, and build an advanced and secure modern grid.

Appendix A. Smart Grid Resources

The smart grid resources listed below represent websites and publications developed and/or hosted by DOE or other federal agencies.

Website Address	Website Content
SMARTGRID.GOV http://www.smartgrid.gov (The SmartGrid.gov website was established by DOE for the purpose of providing public information on all aspects of federally funded smart grid activities, including SGIG and SGDP.)	• General information on smart grid technologies, tools, and techniques • Background information on Recovery Act smart grid programs, including SGIG, Smart Grid Demonstration Program (SGDP), and the Workforce Training for the Electric Power Sector Program (WFT) • Equipment installations and spending by SGIG and SGDP projects • Two-page project descriptions of the SGIG, SGDP, and WFT projects • Background information and Reports for the SGIG consumer behavior studies • Analysis Reports and case studies for the SGIG projects • Technology performance Reports for the SGDP projects
U.S. Department of Energy **Office of Electricity Delivery and Energy Reliability Website** http://www.energy.gov/oe (The OE webpage on the DOE website outlines OE's organization, activities, and programs, including its smart grid efforts.)	• Information about OE's smart grid efforts, including smart grid R&D, the Advanced Grid Integration Division's SGIG program, and other smart grid information • Blog entries highlighting important Recovery Act smart grid project developments

Website Address	Website Content
Recovery Act website **http://www.recovery.gov** (RecoveryAct.gov was established by the Recovery Act Board to promote accountability by coordinating and conducting oversight of Recovery funds to prevent fraud, waste, and abuse and to foster transparency on Recovery Act spending by providing the public with accurate, user-friendly information).	• Information about all federal government Recovery Act projects, including SGIG
Smart grid cybersecurity website **https://www.arrasmartgridcyber.net** (Established by DOE, this website provides information on smart grid cybersecurity)	• Information on the cybersecurity aspects of the Recovery Act smart grid projects, including webinars and other resources outlining requirements and accomplishments
U.S. Department of Commerce **National Institute of Standards and Technology smart grid website** **http://www.nist.gov/smartgrid** (This webpage on NIST website outlines NIST smart grid activities, focused on standards.)	• Information on smart grid interoperability standards, interoperability framework, and the Smart Grid Interoperability Panel
U.S. Department of Commerce **National Institute of Standards and Technology Smart Grid Interoperability Panel 2.0** **http://www.nist.gov/smartgrid/sgipbuffer.cfm** **http://sgip.org** **http://sgip2.org/SitePages/Home.aspx** **(**SGIP was established by NIST as a public/private partnership that defines requirements for essential communication protocols and other common specifications and coordinates development of these standards by collaborating organizations. In April 2013, the SGIP fully transitioned to a non-profit private-public partnership organization, SGIP 2.0, Inc., supported by industry stakeholder funding and funding provided through a cooperative agreement with NIST.)	• Information on efforts to harmonize smart grid standards and advance the interoperability of smart grid devices and systems.

Website Address	Website Content
International Energy Agency (IEA) Implementing Agreement for a Co-operative Programme on Smart Grids (ISGAN) website http://www.iea-isgan.org (ISGAN provides members with opportunities for information sharing and analysis of smart grid topics to foster international development of grid modernization investments. DOE is the lead agency for U.S. participation in ISGAN.)	• Information on ISGAN member activities, publications, and projects to advance smart grid around the world.
Gridwise Architecture Council website http://www.gridwiseac.org (The GridWise Architecture Council (GWAC) was formed by DOE to promote and enable interoperability among the many entities that interact with the nation's electric power system. GWAC members represent many constituencies of the electricity supply chain and users. The GWAC maintains a broad perspective and provides industry guidance and tools on the interoperability of implementations of smart grid technology.)	• Information on the path to and value of interoperability and integration of automation, informational, and control systems involved in utility system operations.

Appendix B. List of SGIG Projects

Legend:
ETS – Electric Transmission Systems
EDS – Electric Distribution Systems
AMI – Advanced Metering Infrastructure
CS – Customer Systems

SGIG Project Recipients	Project Types			
	ETS	EDS	AMI	CS
American Transmission Company LLC (I)	X			
American Transmission Company LLC (II)	X			
Atlantic City Electric Company		X		X
Avista Utilities		X		
Baltimore Gas and Electric Company			X	X
Black Hills Corporation/Colorado Electric			X	X
Black Hills Power			X	
Burbank Water and Power		X	X	X
CenterPoint Energy Houston Electric, LLC		X	X	X
Central Lincoln People's Utility District		X	X	X
Central Maine Power Company			X	X
Cheyenne Light, Fuel and Power Company			X	
City of Anaheim Public Utilities Department		X	X	
City of Auburn, Indiana		X	X	X
City of Fort Collins Utilities		X	X	X
City of Fulton, Missouri			X	X
City of Glendale Water & Power		X	X	X
City of Leesburg, Florida		X	X	X
City of Naperville, Illinois		X	X	X
City of Quincy, Florida			X	X
City of Ruston, Louisiana		X	X	X
City of Tallahassee, Florida		X		X
City of Wadsworth, Ohio		X	X	X
Cleco Power LLC			X	
Cobb Electric Membership Corporation			X	X
Connecticut Municipal Electric Energy Cooperative		X	X	X
Consolidated Edison Company of New York, Inc.		X		

SGIG Project Recipients	Project Types			
	ETS	EDS	AMI	CS
Cuming County Public Power District		X		X
Denton County Electric Cooperative		X	X	X
Detroit Edison Company*		X	X	X
Duke Energy Business Services LLC		X	X	X
Duke Energy Carolinas, LLC	X			
El Paso Electric		X		
Entergy New Orleans, Inc.			X	X
Entergy Services, Inc.	X			
EPB		X	X	X
FirstEnergy Services Corporation*		X	X	X
Florida Power & Light Company	X	X	X	X
Georgia System Operations Corporation Inc.	X			
Golden Spread Electric Cooperative, Inc.		X	X	X
Guam Power Authority		X	X	X
Hawaiian Electric Company Inc.		X		
Honeywell International, Inc.				X
Idaho Power Company	X	X	X	X
Indianapolis Power and Light Company		X	X	X
Iowa Association of Municipal Utilities			X	X
ISO New England, Inc.	X			
JEA			X	X
Knoxville Utilities Board		X	X	X
Lafayette Consolidated Government	X	X	X	X
Lakeland Electric*			X	X
M2M Communications				X
Madison Gas and Electric Company		X	X	
Marblehead Municipal Light Department*			X	X
Memphis Light, Gas and Water Division		X		
Midwest Energy Inc.	X			
Midwest Independent Transmission System Operator	X			
Minnesota Power*		X	X	X
Modesto Irrigation District		X	X	X
Municipal Electric Authority of Georgia	X	X		
Navajo Tribal Utility Authority			X	

SGIG Project Recipients	Project Types			
	ETS	EDS	AMI	CS
New Hampshire Electric Cooperative			X	X
New York Independent System Operator, Inc.	X			
Northern Virginia Electric Cooperative		X		
NSTAR Electric Company		X		
NV Energy*			X	X
Oklahoma Gas and Electric Company*		X	X	X
Pacific Northwest Generating Cooperative			X	X
PECO Energy Company		X	X	X
PJM Interconnection, LLC	X			
Potomac Electric Power Company (DC)		X	X	X
Potomac Electric Power Company (MD)		X	X	X
Powder River Energy Corporation		X		
PPL Electric Utilities		X		
Progress Energy Service Company	X	X	X	X
Qualcomm Atheros, Inc.				X
Rappahannock Electric Cooperative		X	X	X
Reliant Energy Retail Services, LLC				X
Sacramento Municipal Utility District*		X	X	X
Salt River Project			X	X
San Diego Gas and Electric Company	X	X		
Sioux Valley Energy			X	X
Snohomish County PUD		X		
South Kentucky Rural Electric Cooperative Corp.			X	X
South Mississippi Electric Power Association		X	X	X
Southern Company Services, Inc.	X	X		
Southwest Transmission Cooperative, Inc.	X	X	X	X
Stanton County Public Power District			X	
Talquin Electric Cooperative, Inc.		X	X	X
Town of Danvers, Massachusetts		X	X	X
Tri State Electric Membership Corporation			X	X
Vermont Transco, LLC*		X	X	X
Vineyard Energy Project				X
Wellsboro Electric Company			X	X
Westar Energy, Inc.		X	X	X

SGIG Project Recipients	Project Types			
	ETS	EDS	AMI	CS
Western Electricity Coordinating Council	X			
Whirlpool Corporation				X
Wisconsin Power and Light Company		X		
Woodruff Electric			X	