U.S. DEPARTMENT OF
ENERGY

Electricity Delivery
& Energy Reliability

American Recovery and
Reinvestment Act of 2009

Integrated Smart Grid Provides Wide Range of Benefits in Ohio and the Carolinas

Smart Grid Investment
Grant Program

September 2014

SMARTGRID.GOV
RECOVERY ACT SMART GRID PROGRAMS

1. Summary

Under the American Recovery and Reinvestment Act of 2009, the U.S. Department of Energy and the electricity industry have jointly invested over $7.9 billion in 99 cost-shared Smart Grid Investment Grant projects to modernize the electric grid, strengthen cybersecurity, improve interoperability, and collect an unprecedented level of data on smart grid and customer operations.

Duke Energy's comprehensive grid modernization program, funded in part by a Smart Grid Investment Grant (SGIG), has reduced outages and improved power quality for Ohio and Carolinas customers. By deploying smart grid technologies and integrating them with upgraded back-end information management systems, Duke has improved operational efficiencies, optimized voltage, automated "self-healing" disruption response, and expanded smart grid technologies to other service territories using lessons learned.

Duke deployed a variety of smart grid technologies, including advanced metering infrastructure (AMI) with an upgraded meter data management system (MDMS), distribution automation, integrated voltage/VAR control (IVVC), a new distribution management system (DMS), electric vehicle charging stations, a customer web portal, and customer pricing pilots. Duke's project is one of the more comprehensive SGIG efforts, and presents insights and lessons from implementing a large variety of technologies across multiple service areas. SGIG funding helped Duke to accelerate and expand its smart grid efforts and upgrade communications and IT system platforms that will enable further smart grid deployments and extend benefits to customers across its system.

A special feature of the Duke project was the formation of a Grid Modernization Project Management Office to facilitate large-scale organizational changes that smart grid deployment and integration often require. Integrating process and change management practices in smart grid deployment was a key to Duke's success and an important lesson learned for smart grid deployments in other utilities.

Table 1 summarizes key results based on data through August 2014.

Table 1. Summary of Key Results		
Customer Benefits and Tools	i.	Customers on 64 Ohio circuits experienced **year-to-year reduced outage frequency and faster restoration** from 30 "self-healing" groups of distribution system field devices that detect and isolate faults and automate restoration for un-faulted circuits.
	ii.	Duke deployed 966,000 smart meters in Ohio and the Carolinas, which have **significantly improved bill accuracy and reduced customer calls**. Meters also help pinpoint outages and dispatch repair crews more quickly.
	iii.	A **new web portal compares customers' relative energy efficiency** with peers, provides hourly energy usage data, and offers specialized tips for energy efficiency.
Operational Efficiencies Impacting Customers	iv.	**Automated meter reading has significantly reduced costs**. Since late 2010, the AMI deployment has reduced truck rolls by more than 920,000, scaled down meter reading staff from 135+ down to 60, and identified 3,325 cases of electricity theft.
	v.	**Improved bill accuracy and call center efficiency from AMI** are

Table 1. Summary of Key Results		
		producing 2–3 times greater cost savings than originally anticipated. Since 2010, remote meter diagnostics resolved 1,393 cases of single-call outages while more accurate readings helped reduce customer calls and labor associated with resolving bill disputes.
	vi.	24/7 integrated Volt/VAR Control (IVVC) is achieving **consistent 2% voltage reduction on more than 200 circuits** in Ohio. This is reducing system losses and fuel costs that ultimately benefit Duke's customers.
	vii.	**Full integration of distribution system assets with remote monitoring and control software**, while a tremendous undertaking, will drive continued benefits—such as IVVC system performance that will increase the amount of power delivered to customers per unit of power generated.
Effective Process and Change Management Prepares for the Future	viii.	Duke's Grid Modernization Project Management Office used **business process management (BPM) and change management (CM) best practices to facilitate large-scale organizational transformation** and prepare Duke for future grid modernization.
	ix.	**Executive vision and management support at all levels** account for much of the project's success; it drove the coordination of people, technology, and business components.
	x.	SGIG funding helped Duke to leverage lessons learned from Ohio to **accelerate implementation in other key states**. SGIG investments in a more robust distribution management system positions Duke to implement additional deployments in all service territories.

2. Introduction

Duke Energy, an investor-owned utility, is one of the largest electric power companies in the United States. Duke owns and operates generation, transmission, and distribution facilities. It supplies and delivers energy to approximately 7.2 million customers in Kentucky, Indiana, Ohio, North Carolina, South Carolina, and Florida. In 2007, Duke began a 10-year smart grid program to primarily deploy advanced metering infrastructure (AMI) and distribution automation across the states it serves. In 2009, Duke Energy received SGIG funding to support deployment activities mainly in Ohio (and partially in the Carolinas). Duke's SGIG project had a total budget of about $555 million, with $200 million of that received through the SGIG Program.

Duke's smart grid goals were to improve the efficiency and reliability of its electricity delivery systems, reduce operations and maintenance costs, and improve customer service. Although Duke's original smart grid plan focused on improving distribution system efficiency and eliminating manual meter reading through AMI, SGIG funding enabled Duke to pursue a more comprehensive grid modernization effort. This included the potential to offer "beyond the meter" products and services designed to give customers a greater role in reducing energy use and carbon emissions. Efforts included 150 plug-in hybrid electric vehicle (PHEV) charging stations installed in the Carolinas, a customer web portal, and pilots for time-based rate programs.

As part of its SGIG project, Duke has deployed 966,000 smart meters in its Ohio and Carolinas service territories, which have reduced meter reading costs and improved outage detection and restoration.

The project's distribution automation deployment included three main initiatives for improved reliability: 1) advanced substation and line components to sectionalize circuits and enable "self-healing" networks that automate fault response, 2) integrated volt-VAR control (IVVC) in Ohio to levelize voltage across the entire circuit and improve efficiency on power lines, and 3) a new distribution management system (DMS) to integrate smart grid automation and control capabilities.

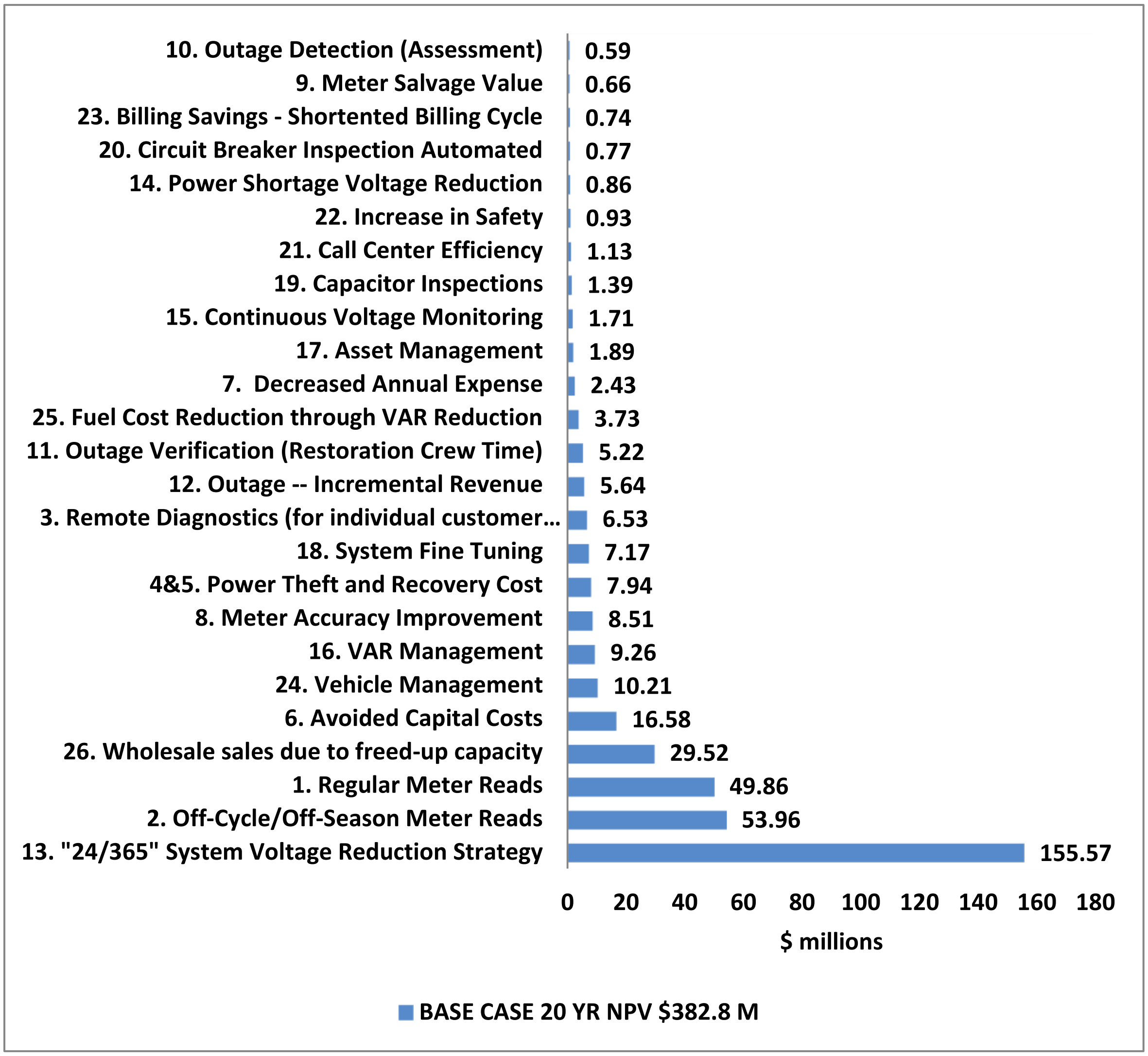

Figure 1. Estimated Net Present Value of Duke Energy's Smart Grid Program

Duke Energy was among the first utilities to rigorously assess and establish the business case for its smart grid deployment. In 2011, Duke supported a third-party evaluation from the Public Utilities Commission of Ohio that validated 26 benefit areas. Quantifying those benefits revealed an estimated 20-year net present value of $382.8 million for planned smart grid investments across the business, from generation to service endpoints—meaning Duke estimated the value of the revenue and benefit streams it can expect over 20 years, and discounted them to today's dollar to account for the changing value of money. Duke's deployment as of 2014 is tracking ahead of the 2011 estimated benefits in aggregate. Figure 1 shows that avoided operating and maintenance costs from continuous voltage monitoring (13) and reduced meter reading labor (1 & 2) account for about two-thirds of the business case. Continuous voltage optimization can also reduce generation to avoid fuel costs and defer distribution capital investments.

Duke has positioned its smart grid plan as a critical component of its entire operations strategy, impacting the way it plans, operates, and maintains generation, transmission, and distribution assets. As a result of this ongoing deployment, Duke is better positioning itself to adapt and respond to utility industry changes and uncertainties and provide better service to customers.

A key success for Duke Energy's smart grid project was the early implementation of business process management (BPM) and change management (CM) best practices. Implementing a DMS and deploying distribution automation were large-scale efforts that required leadership and coordination across multiple business units. Duke facilitated BPM and CM through its newly formed Grid Modernization Organization, which is responsible for industry trend identification, business case development, business and regulatory approval, and upon project approval, project management and business readiness activities.

3. Self-Healing Technologies Improve Reliability and Service

Customers are seeing measurable improvements in outage frequency and faster restoration after disruptions from "self-healing" capabilities built into 64 distribution circuits in Ohio. Self-healing capabilities are made possible by 30 groups of field devices that enable fault detection and automate rapid isolation and restoration of the fault.

Duke's distribution automation efforts installed multiple new devices throughout the system to improve reliability. "Inside the fence" deployments on utility substations included remote terminal units (RTUs), circuit breakers, capacitor bank and voltage regulator controls, and smart relays. "Outside the fence" deployments added new and upgraded components to power lines on particular circuits, including upgraded network capability, capacitor bank and voltage regulator controls, new electronic reclosers, line sensors, and communication retrofits to existing reclosers. Figure 2 shows how these components work together.

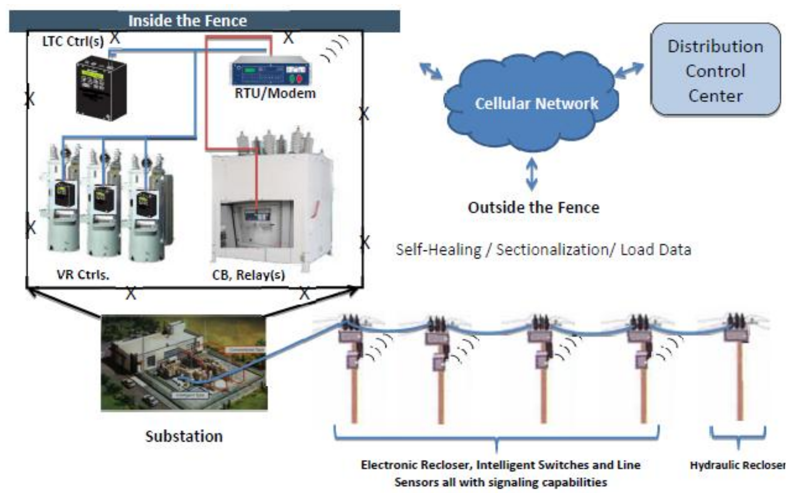

Figure 2. Distribution Automation Components

Duke decided to deploy self-healing capabilities—which include and extend beyond sectionalization capabilities—on key circuits to improve reliability. "Sectionalization" circuits operate hydraulic and electronic reclosers, sectionalizers, and fusing to isolate faults and prevent outages from cascading to other circuits. "Self-healing" circuits operate several electronic reclosers and circuits breakers to isolate a permanent fault and restore power to the un-faulted line segments. Operating Duke's self-healing groups of field devices enables auto-reconfiguration and enhances reliability by rapidly restoring power after a fault is identified. As self-healing technologies were not feasible for all circuits, Duke selected circuits based on the type and number of customers on the circuit, the number of customer miles, and the circuit outage history.

By August of 2014, Duke's 30 self-healing device groups in Ohio had activated 84 times, reducing outage frequency and duration. Three activations alone in 2013 saved 1,223,538 customer minutes of interruptions (CMI), or more than 1.75 Ohio system average interruption duration index (SAIDI) minutes. One event maintained service to a large hospital, while another maintained operation to a key substation. Table 2 shows measurable improvements in system average interruption frequency index (SAIFI)—which measures average interruptions per customer.

Table 2. Self-Healing Teams Show Year-over-Year Reductions in System Average Interruption Frequency Index (SAIFI)

Year	Ohio SAIFI Targets	Actual 12-month Rolling Average through August 2014
2009	1.50	1.30
2010	1.44	1.10
2011	1.38	1.37
2012	1.31	1.08
2013	1.24	0.98
2014	1.17	1.02
2015	1.10	-

4. Smart Meters and In-Home Technologies Improve Customer Service

Smart meter installations are also providing new capabilities and data that Duke is using to offer its customers new services and increased control. As part of the SGIG project, Duke has deployed 966,000 smart meters in its Ohio and Carolinas service territories—630,000 residential meters and 88,000 commercial and industrial (C&I) meters in Ohio (see Figure 3), and 248,000 residential and C&I meters in the Carolinas. The meters can be read remotely and frequently, which has significantly improved bill accuracy and improved call center efficiency for customers. Remote diagnostics often enable the utility to resolve customer issues over the phone with a single call. In Ohio, where about 35% of meters are located indoors, reducing estimated bills has drastically reduced the number of billing-related calls coming into Duke's call center.

Duke created a customer web portal—available through web browsers—that uses smart meter data to provide customers with energy use information. Web portal graphs help customers compare both their current and 13-month electricity use to an "average" home and an "efficient" home in their community. The Tips Integration function provides appropriate feedback and energy recommendations based on a customer's energy usage profile.

Smart meters and distribution management system upgrades also allowed Duke to pilot time-based rates programs, including time-of-use, critical peak pricing, and peak-time rebate programs. Though customer participation was low, the new technology positions Duke to implement similar programs as social, regulatory, and market landscapes change in the future.

Duke also installed 150 residential charging stations for electric vehicles in the Carolinas, supporting customers' efforts to reduce emissions. Duke's "Charge Carolinas" project includes 150 residential stations and the “Plug-In Indiana” project includes 85 residential and 47 commercial stations. Duke will evaluate the new technologies by assessing the performance and customer acceptance of vehicle charging equipment; analyzing load profile data to determine grid impacts; and assessing installation and maintenance costs for the utility and customers. This evaluation will help Duke understand future infrastructure needs from projected increases in demand for electric vehicles over the long term.

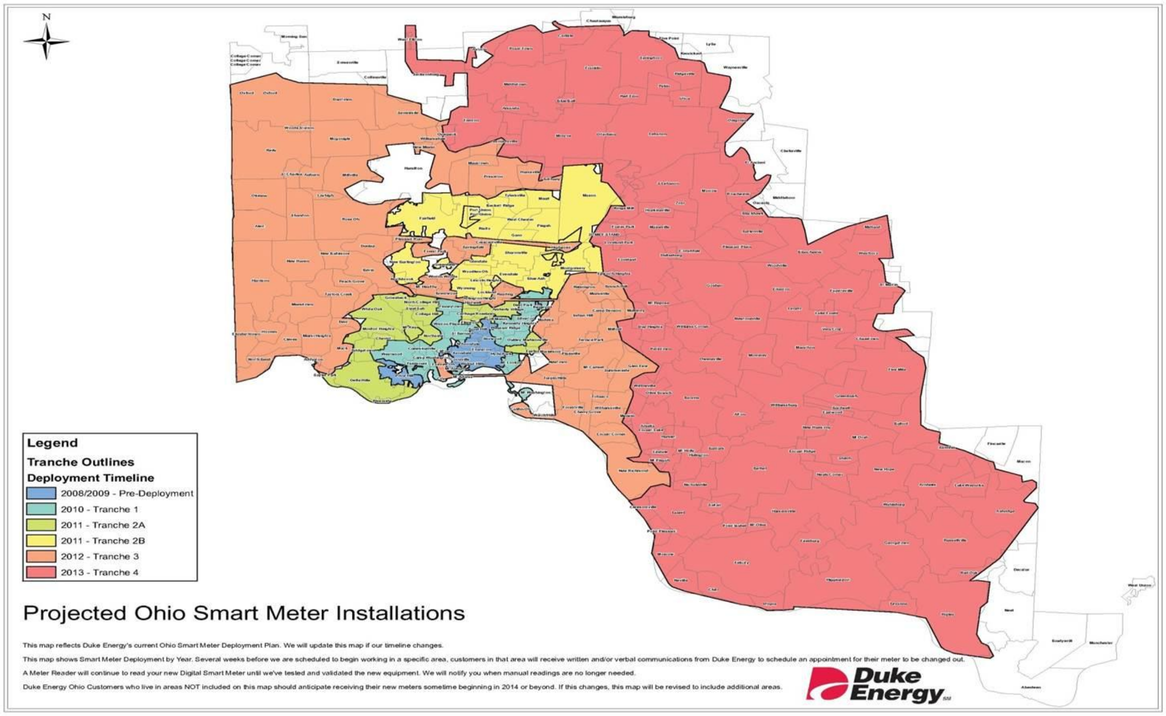

Figure 3. Ohio Smart Meter Installations

5. Operational Improvements

Duke has worked across several business units—beyond simply meter operations or distribution engineering—in order to deliver a broader array of business case benefits, most notably reduced generation fuel costs and other costs. In 2014, Duke is aggregating benefits from its suite of deployments faster than anticipated in the 2011 business case assessment. Key operational improvements are described below.

Duke’s 966,000 smart meters each have remote and off-cycle meter reading capabilities, remote connect/disconnect (residential only), tamper detection, and outage diagnostics features that allow the utility to “ping” meters and determine where power is out.

- Since late 2010, the AMI deployment has **reduced truck rolls by more than 920,000** and scaled down the **staff of meter readers from more than 135 down to 60**.
- The AMI system has also **identified 3,325 cases of electricity theft**, and realized benefits in this area will increase as Duke works to improve the data analytics of tamper alarms.

Call center efficiency and reduction in estimated bills from AMI deployments have exceeded original expectations, bringing close to 2–3 times greater savings than anticipated.

- Since 2010, the AMI system **resolved 1,393 cases of single-call outages with remote diagnostics**.
- In addition, **increased bill accuracy** has not only improved customer experience, but has also **reduced customer calls by 1.4 million** (through 2013) and reduced labor associated with bill disputes.

Duke deployed integrated volt/VAR control (IVVC) components—including load tap changers (LTCs), controls for capacitor banks, and line regulators—that better manage voltage as electricity moves across power lines to improve energy efficiency and reduce demand by lowering line voltage where possible.

- By year end 2014, 77% of Duke's circuits will have IVVC controls.
- More than 200 circuits in Ohio are now **operating IVVC optimization 24/7 and achieving consistent 2% voltage reduction**. This is reducing system losses and fuel costs for Duke's power generation.

The remote capabilities of new capacitor bank controllers **reduced physical inspections by 1,085 units in 2013**. Continuous monitoring instead of a once-a-year physical inspection reduces manual inspection costs and better optimizes voltage.

Duke is achieving many of these benefits through the integration of new components with communications networks and IT platforms. Under SGIG funding, Duke installed a new distribution management system (DMS) to enable new capabilities from device deployments, including fault location, fault isolation/service restoration, IVVC, and automated switching plans. The DMS now provides a data historian, Distribution Operations Training Simulator, and DMS/outage management system (OMS) interface capabilities across Duke's service territory.

Duke's vision involves the integration of distribution system assets with DMS and other back-office systems. While this has been a tremendous undertaking, Duke is starting to achieve the level of IVVC system performance that would lead to increased distribution grid efficiency and more power delivered to customers per unit of power generated.

6. Lessons Learned from Project Implementation

Grid Modernization and Smart Grid Integration

As a result of the Duke-Progress Energy merger in 2012, Duke Energy established a new Grid Modernization Organization. A Support Services function within this organization leads business process management (BPM) and change management (CM) for new projects that require large-scale organizational change. BPM is a process-centric approach for performance improvement that leverages people, process, and technology assets to plan, design, build, monitor, improve, and automate processes. CM prepares people and processes for business changes, particularly those for which project benefits depend on employee adoption, usage, and commitment to project timelines.

Duke embedded BPM and CM resources within project teams, and attributes much of the success of its grid modernization project to the strong executive vision and management support at all levels given through these structures. Effective organizational change was particularly critical for the implementation of a DMS and integration of distribution automation devices, which required staff, technology, and process integration across business units.

For example, DMS changes the roles of the geographic information system (GIS) and information technology (IT) support from traditional back-office staff to operational partners with the business. Adequate communication was a must. DMS required equal IT and business support, so joint business and IT leadership was required for its success. For any large-scale smart grid effort, communications, BPM, and CM structures should be built into the project plan, and relevant business units should be engaged early and often.

Meter Deployment Lessons

Duke Energy compiled several recommendations for deployment methodology based on lessons learned from the SGIG project. Communications equipment should be installed before meter installations to allow for testing. Meters should be deployed on a grid concept, not meter routes. Mapping tools assist with radio frequency (RF) mitigation, vendor performance tracking, and other issues. Before beginning meter installations, the utility needs a plan needs to address an opt-out policy. While Duke encountered opt-out requests during the meter deployment, personal contact with individual customers, local leadership, regulatory staff, and legislative leaders, helped defuse the opt-out issue for the majority of the deployment timeframe.

Forward-looking project planning is key to deployment success. The project deployment schedule should account for the potential release of crews during storm restoration. Creating a separate project planning team from the deployment team also allows one to focus on managing deployment for current conditions, while the other plans for the next phase.

Vendor issues highlighted several lessons learned. For large deployments, using multiple meter installation vendors mitigates the risk of a poor-performing vendor. With multiple vendors, contracts can be developed that allows a contractor to lose or gain work based on their performance rating. A ramp-up styled after a bell curve, rather than a straight line, gives vendors more time to address issues. The vendor should also provide retention incentives to meter installers during the ramp-down phase of the project, to avoid losing resources before the end of the project.

Hard-to-Access Indoor Meters

About 35% of Duke Energy Ohio's electric meters are located indoors, totaling around 238,000. To accommodate this, Duke created a five-step process, called the Hard-to-Access (HTA) process, for contacting customers about replacing indoor meters:

1. Installers used cold canvassing to reach customers at home to replace their meters.
2. If customers were not home during cold canvassing and their meter was inaccessible, a door hanger was left instructing them to call in for an appointment.
3. If after a few days there was no response, Duke attempted to reach the customer by phone: one call during normal business hours, one during weekly evening hours, and one during the weekend.
4. If customers were not contacted during the three phone call attempts, a letter was mailed to their billing address and service address. This notified them of the need to replace their meter and asked for them to contact Duke to make an appointment.

5. If there was no response from the first mailed letter, a second letter was mailed with a deadline for the customer to make an appointment, or risk being disconnected.

Duke received varying success rates for these contact methods. Cold canvassing had a 73% success rate, phone calls had a 22% success rate, the first letter had a 37% success rate, and the second letter had an 89% success rate.

Roughly 235,000 meters went through the HTA process. About 1,700 customers were disconnected, but the majority of customers were reconnected within one to three days. All but 65 customers were reconnected, all of which were likely vacant.

IT Issues

Key business and IT subject matter experts and stakeholders should participate early on in the project, and ensure projects are executed within scope, budget, and schedule. Telecom participation in reviewing and approving vendor designs helps create a smooth transition between post-project operations and support, and also adds to a project's success.

Engaging vendors at the beginning of the project offers many benefits. This ensures they understand the limitations of the product and the project's timeline. Companies should notify vendors soon after issues occur during deployment, and should use out-of-the-box functionality as often as possible. Additionally, quality and timely software deliveries are key to achieving project milestones.

Feeder Segmentation

The feeder segmentation aspect of the project demonstrates successful BPM aspects. Duke used an in-house consulting team with the technical knowledge to address distribution supervisory control and data acquisition (DSCADA) issues. The team also handled change management issues, which expedited acceptance from field personnel, and achieved buy-in from the field System Protection Engineers to develop a business case.

Hiring contract engineers to perform engineering studies also improved the project's efficiency. These engineers could complete basic work until project controls had a structured time schedule. System Protection Engineers reviewed the study results to ensure positive change management.

A dedicated communication resource also added to the success of the project by managing the commissioning process and assembling stakeholder communications kits. The team also supported a tight construction schedule and developed troubleshooting guidelines for field technicians.

Field pilots of new line sensor technologies caught errors or issues before the large-scale deployment. Once devices started functioning and providing data, problems become apparent and could be resolved or addressed before they disrupted full deployment.

PHEV Pilots

Duke's PHEV pilots identified several best practices, including requiring vendors to provide demonstrations of both equipment and back office support prior to bid selection, and conducting smaller field tests before larger-scale deployment. Outsourcing customer enrollment and site scheduling may also ensure customer satisfaction and maintain reputation.

Commercial charging station installations can be expensive and time consuming due to complex site design, construction requirements, multiple-party involvement, power supply variances, Americans with Disabilities Act requirements, and user unfamiliarity with the technology. While public charging stations are important, they were not highly used, and no-cost charging stations do not ensure rapid technology uptake. This makes it difficult to recover the invested capital. However, less expensive hardware and more efficient installation processes in the future could help reduce the installed cost of charging infrastructure installation.

Prepay Pilot Program

Duke conducted pricing pilot programs during 2010, 2011, and 2012 in consultation with its Ohio Smart Grid Collaborative. The goal was to gather statistically significant customer data concerning acquisition preferences, yet the number of actual customer acquisitions was too small to draw any firm conclusions.

Duke offered seven different rate structures to customers at different points in the study, each building on lessons from earlier rate pilots: a Time-Differential Rate with Advance Meters (TD-AM), a Peak Time Rebate (PTR), a combined rate using rates from TD-AM and PTR, a TD-Lite rate, a second iteration of Peak-Time Rebate (PTR 2.0), and Time-of-Use rate structure for 2012 and 2013. By 2013, Duke offered nine different configurations in the pilot and allowed customers to choose a shorter peak period. Duke is now assessing whether this flexibility was more attractive to customers.

7. Future Plans Include Follow-On Activities

The DOE SGIG project is part of a 10-year plan for Duke Energy Business Services to deploy a broad smart grid system across its entire service territory through 2017. SGIG funding helped Duke leverage lessons learned from Ohio to accelerate implementation in other key states outside of the SGIG project, and enabled Duke to implement a more robust system. This included new and upgraded IT systems needed to provide enhanced distribution and metering capabilities, which position Duke for additional deployments and customer pilots across all service territories. In August 2014, Duke filed a seven-year, $1.9 billion plan to modernize its grid serving 800,000 customers in Indiana. The plan includes deployment of self-healing systems, advanced metering infrastructure, and automated controls for voltage optimization, as well as components to address aging infrastructure in general.

This IT backbone is important as Duke pursues opportunities to further integrate installed technologies and achieve new benefits. While smart grid technologies may lead to direct near-term benefits, such as reduced meter reading costs, they could also impact other parts of an operation. For instance, Duke is positioning its voltage reduction efforts through IVVC as an alternative to the addition of generation capacity in its service territory. While this may incrementally add operations and maintenance-related costs for distribution systems, it would better prepare these systems for future uncertainties, such as load growth and distributed energy resource penetration. Though not directly related to its SGIG project, Duke also sees opportunity for greater integration of distributed energy resources (e.g. customer-owned solar PV) through power flow and voltage control capabilities that come with its distribution system investments funded by SGIG.

Duke's long-term vision for its Grid Modernization Program is to create a reliable and scalable networked infrastructure capable of delivering and receiving information from intelligent devices distributed across its power systems, automating components of the distribution system, and leveraging the linked networks for improved operational efficiencies and customer satisfaction.

8. Where to Find More Information

To learn more about national efforts to modernize the electric grid, visit the Office of Electricity Delivery and Energy Reliability's website and www.smartgrid.gov. DOE has published several reports that contain findings on topics similar to those addressed in Duke's SGIG project and this case study. Web links to these reports are listed in Table 3.

Table 3. Web Links to Related DOE Reports

SGIG Program, Progress, and Results	**i.**	Progress Report II, October 2013
	ii.	Progress Report I, October 2012
	iii.	SGIG Case Studies
SGIG Analysis Reports	**iv.**	Demand Reduction from the Application of AMI, Pricing Programs, and Customer Based Systems – Initial Results, December, 2012
	v.	Application of Automated Controls for Voltage and Reactive Power Management – Initial Results, December, 2012
	vi.	Reliability Improvements from Application of Distribution Automation Technologies – Initial Results, December, 2012
Recent Publications	**vii.**	Smart Meter Investments Yield Positive Results in Maine, February 2014
	viii.	Smart Meter Investments Benefit Rural Customers in Three Southern States, March 2014
	ix.	Control Center and Data Management Improvements Modernize Bulk Power Operations in Georgia, August 2014
	x.	Using Smart grid Technologies to Modernize Distribution Infrastructure in New York, August 2014
	xi.	Automated Demand Response Benefits California Utilities and Commercial & Industrial Customers, September 2014
	xii.	New Forecasting Tool Enhances Wind Energy Integration in Idaho and Oregon, September 2014