Guidebook for ARRA Smart Grid Program Metrics and Benefits

June 2010

DOE wants to work in partnership with the recipients of Smart Grid Demonstration Program and Renewable and Distributed System Integration awards* to determine what information is required and how best to gather it for developing and reporting metrics and benefits. This Guidebook serves as a way to begin a dialogue. In the coming months, DOE will work with each grant recipient to finalize the best approach for accomplishing this task.

*This Guidebook has been modified from the Guidebook for SGIG projects issued December 7, 2009 to tailor to both Smart Grid Demonstration Program and Renewable and Distributed System Integration projects.

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1.0 Context

The United States Department of Energy (DOE) has been charged with leading national efforts for the modernization of the electric grid. The Office of Electricity Delivery and Energy Reliability (OE) is responsible for heading this effort. In recent years, DOE's research and energy policy programs have been responsible for coordinating standards development, guiding R&D, and convening industry stakeholders involved in the implementation of the smart grid. The American Recovery and Reinvestment Act (ARRA) has placed an unprecedented funding resource in the hands of DOE, resulting in both the Smart Grid Investment Grant Program (SGIG) and the Smart Grid Demonstration Program (SGDP), which includes regional and energy storage demonstrations (i.e., Smart Grid Programs). The DOE's National Energy Technology Laboratory (NETL) will manage both the SGDP and Renewable and Distributed Systems Integration (RDSI) program demonstration projects.

As part of the Smart Grid Programs, DOE will award approximately $4 billion to utilities, equipment suppliers, regional transmission organizations, states, and research organizations to jump-start smart grid deployment and demonstration on a massive scale. The projects to be undertaken by these Recipients will support critical national objectives including:

- Number and percentage of customers using smart-grid enabled energy management systems;
- Number and percentage of distribution system feeders with distribution automation; and
- Number and percentage of transmission lines instrumented with networked sensors used to assess and respond to real-time grid disturbances (i.e., time-synchronized situational awareness capability).

As the steward of this tremendous public trust, DOE is duty bound to make sure that the money awarded to Recipients is invested in a way that maximizes the public benefit in both the near and long terms. The American taxpayers, their representatives, and DOE expect this, and will ask tough questions about the development of the smart grid. To answer these questions, Technical Project Officers (TPOs) from NETL's Energy Delivery Technologies Division will manage the SGDP and RDSI projects, and the Data Analysis Team[1] will analyze the information from each of the Recipients to determine the progress of smart grid implementation and the resulting impacts. DOE is particularly interested in six areas, including:

1. Job Creation and Marketplace Innovation;
2. Peak Demand and Electricity Consumption;
3. Operational Efficiency;
4. Grid Reliability and Resilience;
5. Distributed Energy Resources and Renewable Energy; and

[1] The Data Analysis Team includes NETL's Integrated Electric Power Systems Division, its support contractors, and Sandia National Laboratory (for the energy storage demonstrations).

6. Carbon Dioxide Emissions.

The Guidebook for ARRA SGDP/RDSI Metrics and Benefits ("Guidebook") describes the type of information to be collected from each of the Recipients and how it will be used by DOE to communicate overall conclusions to the public.

2.0 Approach

The scale, complexity, and variety of the smart grid projects being undertaken across the country require an approach to data collection, analysis, and communication that is structured, but flexible. It should be sufficiently prescriptive without stifling creativity and learning. It should provide the information that leads to insight, not just data to be warehoused. Therefore, the Data Analysis Team will analyze information submitted to the TPO that will help answer some key questions, including:

- What infrastructure, equipment and devices were deployed?
- What functionality or capability was envisioned or sought?
- What programs, policies and business concepts were tried?
- What happened, and why?
- What were the benefits derived?

As shown in Figure 1, DOE's approach involves three basic steps: gather information from Recipients; analyze the information; and communicate the results to the public.

Figure 1. Approach

The Data Analysis Team will analyze the data provided by Recipients to determine the impacts of the SGDP and RDSI programs. As mentioned previously, these impacts will be communicated within six topic areas. Communicating results will be done at the project and Program level, and proprietary information from Recipients will not be disclosed.

2.1 Process for Gathering and Reporting Project Information

Recipients are expected to gather information and report it to their TPOs using "Build Metrics" and "Impact Metrics." Build Metrics track what the Recipients spent their money on, and measure progress toward a smart grid. These metrics will comprise hardware and software, and the programs that will leverage these investments. It will include what utilities bought (e.g., smart meters) and what customers bought (e.g., smart appliances). DOE is also interested in the number of customers that are participating in demand management programs, or installed capacity of renewable distributed generation leveraging smart grid technology.

Impact Metrics measure how, and to what extent, a smarter grid is affecting grid operations and performance, or how it is enabling customer programs once the project is operational. When projects become operational, the impacts should become measureable. For example, a Recipient that has implemented distribution automation may see a significant reduction in customer outage minutes. Another Recipient may show a drop in peak demand from a Critical Peak Pricing program.

Recipients must also provide baseline Build and Impact Metrics. Baseline values should reflect the parameter values of the Recipient's smart grid or energy storage initiatives without the SGDP or RDSI project, analogous to "business as usual" in a business case analysis. Baseline data can include historical performance data on the circuit(s) or data collected on the circuit(s) during the project prior to the operation of the smart grid or storage systems.

Actual data to be captured, the rate of capture[2], on-site data archive capability[3], and duration of baseline data collection will be determined in collaboration with the Data Analysis Team. For the energy storage demonstrations, Recipients must provide baseline data at the storage system's grid connection point or other mutually agreed upon point of connection. At a minimum, data should include power output characteristics (e.g., current, voltage, and power factor) sufficient to demonstrate performance.

For projects that include demonstration of storage technologies, Recipients must provide the following information on the Data Acquisition System (DAS) prior to purchase and installation:

1. 1-line schematic of DAS, which will include meter location(s) on grid and all relevant hardware needed to download data to TPO; and
2. Specifications for DAS components.

For energy storage demonstrations targeting technology performance, Recipients should address the following at a minimum[4]:

- Deliver a prototype system that can be grid connected and electrically charged and discharged with a plan for scaling the system to utility power levels

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[2] Rate of capture refers to whether data is collected in real-time, as an average over a specified period of time, or periodically. For energy storage demonstrations, rate of capture is dictated by the application.
[3] On site data archive capability is required to ensure that data is not lost in the event of any problems with the clearinghouse data depository. In general, it can be assumed that data will need to be saved in the on-site DAS for one year minimum.
[4]As listed in the sub-area 2.5 Demonstration of Promising Technologies for energy storage in the original Funding Opportunity Announcement DE-FOA-0000036

- Identify and describe elements of electric storage systems that the project will significantly improve (i.e. cost, storage capacity or density, lifetime, environmental impact, safety, etc.) through the demonstration
- Describe targeted market applications for the proposed new energy storage solution and provide an analysis of the value proposition for various stakeholders
- Describe anticipated performance and installed cost targets over time
- Address potential environmental impacts of the proposed system
- Contain a demonstration plan with multiple milestones, at appropriate points, in the development cycle
- Propose a project capable of being ready for operation within 4 years of project award

For energy storage demonstrations, Recipients should submit a list of applications (i.e., uses) and technical performance data required to evaluate each application (see Table C-2 and Sandia National Laboratory's *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide*[5]). At a minimum, technical performance data shall capture round-trip efficiency and waveforms upstream and downstream of storage to measure its effect on the grid, and will be based on the application(s) of the storage system.

Finally, Recipients need to both determine and report "Project" and "System" level Build and Impact Metrics. "Project" data pertains to the specific scope of the project funded by ARRA and Recipient cost share. "System" data pertains to all the utility's assets within its service territory for transmission, distribution, AMI, Distributed Energy Resources, etc. For the Build Metrics, "System" data is intended to include any non-SGDP funded (neither ARRA nor Recipient cost share) equipment or systems (IT, communication, etc.) installed by Recipients which may facilitate the functionality of Smart Grid assets under the SGDP project. For example:

1. Recipient installs automated feeder switches on feeders in addition to those that are part of the SGDP project. Recipient should capture the automated feeder switches installed by the SGDP under the Build Metric "Project" level and all other automated feeder switches installed in the distribution system under the Build Metric "System" level.
2. Recipient demonstrates voltage optimization by installing automated capacitor banks funded by the SGDP and using automated regulators that either already exist or are being installed in a non-SGDP funded project. Recipient should capture automated capacitors under the Build Metric "Project" level and automated regulators under the Build Metric "System" level.
3. Recipient installs smart meters in an unrelated project. AMI may not affect the functionality of the SGDP-funded project but it may affect reliability or customer electricity use optimization. Since DOE does not want to overstate the impact of SGDP-related assets, it is important to identify system assets that will affect Impact Metrics

[5] SAND2010-0815, February 2010 http://www.smartgrid.gov/sites/default/files/resources/energy_storage.pdf

measured at the system level. To the extent possible, DOE would like to capture all the material Smart Grid activities within the system even if they are not funded by SGDP.

Structured templates for Build and Impact Metrics, including baseline values, will be completed as part of a Draft Metrics and Benefits Reporting Plan (which describes the methods and resources used to gather Build Metrics, collect field data, and calculate Impact Metrics and overall project benefits), to be submitted to TPOs within 90 days after Recipients receive awards.

Recipients will report Build Metrics to TPOs within 30 days of the end of each calendar quarter. Recipients will report Impact Metrics to TPOs in interim and final Technology Performance Reports (TPR) with frequency agreed upon on a project-by-project basis and outlined in the Metrics and Benefits Reporting Plan. The TPRs should also include the status of cost-benefit data and analyses with respect to the baseline system configuration and the demonstrated system configuration, as applicable. If the project contains more than one distinct technology or groups of technologies, Recipients will prepare a TPR for each. All applicable data should be reported to the Recipients' TPOs, and a select subset will be further analyzed and consolidated with data from other SGDP and RDSI projects through Smartgrid.gov, the data information hub for all federal activities related to Smart Grid.

Table 1 summarizes the two kinds of information that Recipients will be required to provide with baseline at the "Project" and/or "System" level and the reporting interval for each.

Table 1. Type of Information to be Collected

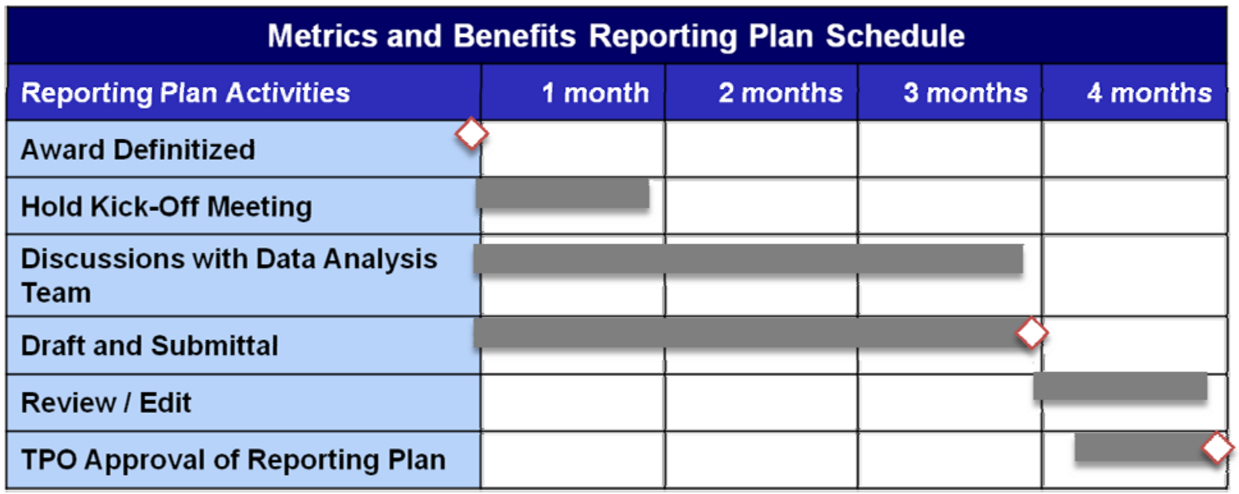
Information Type	Description	Reporting Interval
Build Metrics	Build metrics refer to the monetary investments, electricity infrastructure assets, policies and programs, marketplace innovation and jobs data that are part of smart grid projects.	Quarterly
Impact Metrics	Impact metrics refer to smart grid capabilities enabled by projects and the measurable impacts of smart grid projects that deliver value.	Varies by project

2.2 Process for Developing the Metrics and Benefits Reporting Plan

Table 2 outlines the process for finalizing this plan:

1. After receiving an award, each Recipient will have 90 days to submit a Draft Metrics and Benefits Reporting Plan.
2. The Data Analysis Team will work with each Recipient to customize the data collection and reporting requirements for each project, using the structured templates included in Appendix A.
3. The TPO will review the Draft Metrics and Benefits Reporting Plan and provide comments to the Recipient.
4. Recipients will provide a Final Metrics and Benefits Reporting Plan upon TPO's review and approval of the Draft Plan.

Table 2. Type of Information to be Collected



The Data Analysis Team expects to work collaboratively with Recipients to develop consistency and quality in the methods used to calculate metrics and develop appropriate baselines. However, it is the Recipients' responsibility to collect and assemble data required to produce the metrics and benefits. In addition, Recipients shall be available to answer questions that the TPO or Data Analysis Team may have regarding how the metrics were developed. The TPO and Data Analysis Team will provide guidance and assistance regarding these issues on an as-needed basis.

3.0 Gathering Information

3.1 Measurement of Smart Grid Progress – How Much Have We Built?

Section 1302 of Title XIII of the Energy Independence and Security Act of 2007 requires that a *Smart Grid System Report*[6] be prepared and submitted to Congress biennially to describe "the status of smart grid deployments nationwide." In order to measure the progress of smart grid deployment, the *Smart Grid System Report* identifies fifteen Build Metrics. These metrics were distilled down from the list developed during the DOE Smart Grid Implementation Workshop.[7] The framework described here uses Build Metrics to measure progress toward a smart grid organized into five categories, as presented in Table 3. The Data Analysis Team will work with the Recipients to identify data requirements that pertain to each category, which are discussed in the following sections.

Table 3: Build Metric Definitions

Metric Type	Description
Monetary Investments	Total project costs (ARRA plus Recipient cost share) by category and smart grid classification
Electricity Infrastructure Assets	Transmission and distribution equipment and energy resources that, when assembled together, comprise smart grid project equipment
Policies and Programs	Policies and programs that determine the commercial and operational rules for utilities and their customers (e.g., pricing programs)
Job Creation	New jobs created and retained as a result of projects by category and smart grid classification
Marketplace Innovation	New products, services and programs associated with projects by category and smart grid classification

Monetary Investments

This reporting is required by both the Office of Management and Budget (OMB) and DOE. The guidance below is specific to DOE reporting requirements. DOE requests that Recipients:

- Report or if needed estimate Monetary Investments for the installed cost of equipment in accordance with Table 4
- Provide installed costs which only include direct labor costs (i.e. construction, installation, integration, testing, and commissioning), recognizing that estimates may be required to calculate direct labor costs based on the Recipients' accounting practices
- Segment ARRA and Recipient cost share amounts for installed costs
- Recognize monetary investments related to assets when they are deployed and become property records or company assets (not when they are received from a supplier)

[6] U.S. Department of Energy, July 2009 http://www.smartgrid.gov/sites/default/files/resources/systems_report.pdf

[7] "Metrics for Measuring Progress toward Implementation of the Smart Grid," DOE Smart Grid Implementation Workshop, June 20-21, 2008

Table 4. Installed Cost ($000) Smart Grid Program Equipment

AMI				Customer Systems						
Monetary Investment	AMI Back Office Systems	Communication Equipment	AMI Smart Meters	Customer Back Office Systems	Customer Web Portals	In Home Display	Smart Appliances	Programmable Controllable Thermostats	Participating Load Control Device
ARRA	-				-		-		
Cost Share	-				-		-		
Total	-				-		-		
Other Assets and Costs that do not align with the categories listed above:									
Electric Distribution									
Monetary Investment	Back Office Systems	Distribution Management System	Communications Equipment / SCADA	Feeder Monitor / Indicator	Substation Monitor	Automated Feeder Switches	Capacitor Automation Equipment	Regulator Automation Equipment	Fault Current Limiter
ARRA	-				-		-		-
Cost Share	-				-		-		-
Total	-				-		-		-
Other Assets and Costs that do not align with the categories listed above:									
Electric Distribution Distributed Energy Resources (DER)									
Monetary Investment	DER Interface / Control Systems	Communication Equipment	DER / DG Interconnection Equipment	Distributed Generation (DG)	Renewable DER	Stationary Electricity Storage	Plug-in-Electric Vehicles		
ARRA	-				-		-		
Cost Share	-				-		-		
Total	-				-		-		
Other Assets and Costs that do not align with the categories listed above:									
Electric Transmission									
Monetary Investment	Back Office Systems	Advanced Applications (Software)	Dynamic Rating Systems	Communication Equipment	PDC	PMU	Line Monitoring Equipment		
ARRA	-				-		-		
Cost Share	-				-		-		
Total	-				-		-		
Other Assets and Costs that do not align with the categories listed above:									

- - - -
- - - -
- - - -

Electricity Infrastructure Assets

Assets refer to transmission and distribution equipment that when assembled together provide smart grid functionality. Smart grid assets improve the ability to automate and remotely control grid operations, and also provide customers with real-time data so that they can make informed decisions about their energy consumption. For instance, AMI gives the utility the ability to conduct real-time load measurement and management, and it gives the customer the real-time data required to optimize their electricity use in order to reduce cost.

Furthermore, assets can include energy resources that either deliver electricity or contribute to load reduction. Energy resources that will interact with the grid include: distributed generation, stationary electricity storage, plug-in electric vehicles, and smart appliances. These resources can communicate and make operating decisions based on signals from the grid or customers. TPOs will collect information regarding the deployment of these types of devices. Potential data requirements are described in Table 5.

Table 5. Build Metrics – Electricity Infrastructure Assets

Asset Type	Description of Information	Illustrative Examples
Transmission & Distribution Equipment		
AMI Systems	Number of customer end points included in a network involving smart meters, communications and data management systems designed to collect electricity usage and related information from customers and deliver information to customers. This information is reported by customer class, and would include the general features or capability of the devices. It should also be reported as a percentage of service territory covered.	• 50,000 residential smart meters that record electricity consumption in 15-minute intervals. Meters include remote connection/disconnection capability. (10% of service territory covered) • A wireless mesh communications network covering 100 square miles • Meter data management system
Customer Display Device or Portal	Number of customer end points that have devices or portals through which energy and related information can be communicated to and from utilities or third party energy service providers. This information would be reported by customer class and include the general features or capability of the devices. Connection to other appliances included.	• 10,000 residential energy displays including real-time and historical consumption and pricing information • Web-based energy information portal available to 100,000 residential and small commercial customers
Distribution Automation	Number of automated distribution feeders or DA devices that can be used to perform automatic switching, reactive device coordination, or other feeder operations/control.	• 20 automated distribution feeders • 40 advanced fault detectors • Integration with Distribution Management System for feeder optimization • Equipment health sensors
Advanced Interrupting Switches	Number of switches or technology that can detect and clear faults more quickly or without reclosing.	• 10 advanced feeder switches
Power Quality Monitors	Number of devices monitoring power quality within the distribution system. This capability could also be included as a smart meter feature.	• 100 PQ monitors deployed along 10 distribution feeders
Substation Automation	Number of substations or substation devices employing advanced sensors, communications, information processing or actuators. This could include equipment loading and health monitors.	• Five automated substations, including LAN and gateway hardware, breaker controls and online transformer monitoring - Common Information Model (CIM) compliant
Phasor Measurement Units (PMUs)	Number of PMUs deployed, and or the scope of the power system being monitored. This information could also include data concentrators, information management systems, or analytical tools for utilizing phasor data. Integration with NASPInet.	• 10 PMUs • 3 phasor data concentrators • Software to analyze phasor data and identify abnormal conditions
Transmission Line Monitors	Number of monitoring devices that can measure transmission line loading, operating temperature, ground clearance, or other parameters that would affect capability.	• 25 monitors installed on 345 kV transmission lines providing dynamic line ratings to grid operators
Substation Transformer Monitors	Number of substation transformers with monitoring devices that measure station transformer loading, operating temperature, oil condition, or parameters that affect capability.	• 10 monitors installed on 345/115 kV substation transformers monitoring operating temperature and oil condition
Controllable/ Regulating Inverters	Number of inverters that can be coordinated or managed collectively, or provide grid support.	• 500 regulating PV inverters to manage feeder voltage

Table 5. Build Metrics – Electricity Infrastructure Assets (cont.)

Asset Type	Description of Information	Illustrative Examples
Fault Current Limiter	Number of fault current limiting devices. This information would include the nature of the application.	• Three fault current limiters applied in transmission substations to avoid breaker overloading
Advanced Analysis/Visualization Software	Systems installed to analyze grid information or help human operators.	• Phasor data management systems • Wide area monitoring and control systems
High Temperature Superconductor (HTS) Cable	Number of HTS cable systems. These could be used for capacity or applications such as Very Low Impedance (VLI) to control impedance and power flow.	• Two HTS cable systems, including length and capacity
Energy Resources		
Distributed Generation	The amount of DG installed as part of the project, including resource type, capacity (total MW), number of units, ownership, expected capacity factor, regulating capability, and point of interconnection	• 50 MW of PV installed on commercial rooftops, interconnected behind the meter but can export to the grid; 250 kW to 500 kW typical system size; no regulating capability from inverters; expected capacity factor of 15%.
Large Scale Renewable Energy	The amount of large scale renewable energy (e.g., wind farms, solar)	• 250 MW of concentrating solar power interconnected on transmission; expected capacity factor of 27% • 350 MW wind farm interconnected on transmission; expected capacity factor of 25%
Stationary Electricity Storage	The amount of stationary electricity storage installed as part of the project, including resource type, capacity (MVA), energy stored (MWh), number of units, and point of interconnection	• 10 MW of neighborhood energy storage (100 units at 100 kW each) connected to primary distribution • 15 MW energy storage system located at a 34 kV substation
Plug-in Electric Vehicles	The number of PEVs in operation, along with a description of the charging points	• 100 customer-owned PEVs charged at residences at customer discretion • 50 commercially owned PEVs charged at fleet charging stations at night
Smart Appliances/Devices	Number of appliances/devices by type (type refers to the class of appliance that can be controlled or receive pricing data. For example, thermostats, pool pumps, clothes washers/dryers, water heaters, etc.)	• 1,000 smart refrigerators that can be cycled by the utility or a third party energy service provider • 10,000 residential thermostats that can respond to pricing and load control signals from the utility
Load Served by Microgrids	The number of customers and aggregate load (by class) served by microgrids. Microgrids are defined as electrical systems that include multiple loads and distributed energy resources that can be operated in parallel with the grid or as an electrical island.	• 200 residential and small commercial customers with a total peak load of 10 MW, served by a neighborhood microgrid including distributed PV and energy storage • An institutional campus with a peak load of 5 MW, served by a combined heat and power generator and energy storage

Policies and Programs

There are also policies and programs that may be implemented along with smart grid assets in order to obtain the maximum benefits possible. For example, customers with access to dynamic pricing programs have an incentive to use the information provided by AMI/smart meters. TPOs will collect information regarding the deployment and adoption of these types of policies and programs. Examples of these policies and programs include, but are not limited to:

- Demand Response;
- Dynamic Pricing;
- Critical Peak Pricing;
- Distributed Resource Interconnection Policy; and
- Policy/Regulatory Progress for Rate Recovery.

Potential data requirements are described in Table 6.

Table 6. Build Metrics – Policies and Programs

Policy/Program	Description of Information	Illustrative Examples
Pricing and Load Management	Program information by customer class. Also include information about participation rates.	• Real-time pricing • Direct load control • Critical Peak Pricing
Distributed Energy Resources (DER) Interconnection Standard	Standard process for interconnection requests and approval. This could vary by size and DER type.	• DER interconnection standard for inverter based resources less than 1 MW • DER interconnection standard for resources greater than 1 MW
Net Metering for DER	Policy that allows for bidirectional metering and credit for DER export.	• Net metering policy with credits for residential DERs with capacity less than 20 kW
DER Export Pricing Tariff	Retail tariff that pays DER owners for electricity produced and exported.	• DER production tariff for residential and commercial systems less than 20 kW
Feed-in Tariff	Information about feed-in tariffs for renewable energy that may apply, including resource characteristics and pricing.	• Feed-in tariff for clean energy resources at a rate of 35 cents per kWh with a per customer cap of 1 MW.
Renewable Portfolio Standard	Information about renewable portfolio standards that may apply.	• RPS target of 20% by 2020, with information about qualifying resources.
Energy Efficiency Resource Standard	Information about energy efficiency resource standards that may apply.	• EERS target of 10% of demand growth by 2015, with program details.
Rate Decoupling	Information describing rate decoupling or similar structures designed to eliminate utility disincentives associated with reduced electricity sales.	• Retail rate decoupling program details. • True-up mechanism for fixed costs.
Financial Investments	Total annual private equity and venture-capital funding of smart-grid startups located in the U.S.	• $5B of public equity issued by companies • $2B of private equity investment in smart grid startup companies
Smart Grid R&D	R&D programs related to smart grid, including annual program budgets.	• $200M in smart grid R&D between federal and state research organizations
Rights to Customer Data	State law requires that customer usage information is available to third parties.	• Hourly data for 7,000 customers is shared with two third party energy providers

Job Creation and Marketplace Innovation

The *Smart Grid System Report*[8] suggests that new jobs, products, services, and markets will develop in response to the growth of the smart grid. Smart grid investments can enable new products and services by providing the basis for a system where all customers are dynamically connected, much like the Internet. Predicting all the possible innovation will be difficult, but like the Internet, the smart grid will be a foundation which can spur potentially endless innovation once the key infrastructure is in place. The measurement of marketplace innovation will be qualitative, and the measurement of job creation and retention will be quantitative.

Recipients will report new programs and joint ventures with suppliers, as well as novel methods of taking advantage of the functionality that the smart grid provides. Potential data requirements are listed in Table 7.

Table 7. Build Metrics – Marketplace Innovation

Market Category	Measure	Regional Demonstration	Energy Storage Demonstration	RDSI
Products	*Number of Products*	-	-	-
	Customers with Access	-	-	-
	Customers Adopting	-	-	-
Services	*Number of Services*	-	-	-
	Customers with Access	-	-	-
	Customers Adopting	-	-	-
Pricing Programs	*Number of Programs*	-	-	-
	Customers with Access	-	-	-
	Customers Participating	-	-	-

DOE issued jobs reporting guidance in February 2010, which is addressed in the rest of this section.[9] The OMB requires Recipients to report a subset of jobs created by ARRA funds on FederalReporting.gov within 10 business days of the end of each calendar quarter. In order to capture comprehensive job figures, DOE requires SGDP/RDSI Recipients to report additional jobs created and retained (below) to their TPOs within 30 business days of the end of each calendar quarter.

- OMB requires Recipients of Federal contracts to report jobs created by prime entities only. DOE requires Recipients to report jobs created at both the prime recipient/contractor and sub-recipient/subcontractor level.
- DOE requires Recipients to report jobs created from both ARRA and non-ARRA funds.
- Appendix B provides the Department of Labor defined job categories that have been combined to create the eight higher level categories in Table 8.

[8] U.S. Department of Energy, July 2009 http://www.smartgrid.gov/sites/default/files/resources/systems_report.pdf

[9] http://www.oe.energy.gov/SGIG_Corporate_Reporting_Guidance-FNL.pdf

Table 8. Build Metrics – Jobs Created and Retained

Job Category	Regional Demonstration	Energy Storage Demonstration	RDSI
Managers	-	-	-
Prime Recipient	-	-	-
Sub-Recipient	-	-	-
Vendor	-	-	-
Engineers	-	-	-
Prime Recipient	-	-	-
Sub-Recipient	-	-	-
Vendor	-	-	-
Computer-related Occupations	-	-	-
Prime Recipient	-	-	-
Sub-Recipient	-	-	-
Vendor	-	-	-
Environmental and Social Scientists	-	-	-
Prime Recipient	-	-	-
Sub-Recipient	-	-	-
Vendor	-	-	-
Construction, Electrical, and Other Trades	-	-	-
Prime Recipient	-	-	-
Sub-Recipient	-	-	-
Vendor	-	-	-
Analysts	-	-	-
Prime Recipient	-	-	-
Sub-Recipient	-	-	-
Vendor	-	-	-
Business Occupations	-	-	-
Prime Recipient	-	-	-
Sub-Recipient	-	-	-
Vendor	-	-	-
Recording, Scheduling, Computer Operator Occupations	-	-	-
Prime Recipient	-	-	-
Sub-Recipient	-	-	-
Vendor	-	-	-

Jobs reported to DOE will encompass all direct jobs created during the reporting timeframe as a result of ARRA funding. Jobs created and retained before receiving ARRA funds should not be included. In addition, DOE will allow Recipients to report indirect jobs[10] created or retained on a voluntary basis. DOE will verify job data reported against other reported data from Recipients, including invoices and financials. If Recipient's reported data cannot be verified, then DOE will work with the Recipients to resolve job data issues. Jobs created and retained

[10] Indirect jobs are the "employment impact on materials suppliers and central service providers." OMB Memo M-09-21, June 22, 2009 http://www.whitehouse.gov/omb/assets/memoranda_fy2009/m09-21.pdf

should be reported in full-time equivalents (FTEs). Jobs reported to TPOs should be expressed in OMB's measurement of quarterly FTEs.

DOE has identified formulas (below) for calculating FTEs and for calculating the cost share percentage for the project.

- **FTEs from ARRA Funds:**
  ARRA-funded FTE = Total Hours Worked in Jobs Created from ARRA Funds / Number of Hours in Sector Specific Full-time Schedule
- **Total FTEs** (from ARRA + non-ARRA funds) **from ARRA-Supported Project:**
  Total FTE = Total Hours Worked on ARRA-Supported Project / Number of Hours in Sector Specific Full-time Schedule
- **Cost Share:**
  Cost Share = (Total Cost of ARRA-Supported Project – ARRA Funds) / Total Cost of ARRA-Supported Project
  Or in other terms,
  Cost Share = Non-ARRA funds invested in ARRA-Supported Project

For example, Table 9 assumes the Recipient is preparing its second report and defines a full time schedule as 2080 hours per year or 520 hours worked per quarter.

Table 9. Example of Job Calculations for internal DOE Reporting

ARRA Funded Employees	Period 2 (10/1 – 12/31)
Employee 1	520
Employee 2	520
Employee 3	260
Total:	1,300
Full Time Schedule per Employee	520
Total ARRA Funded FTEs: 1300/520 = 2.5 JOBS	
Non-ARRA Funded Employees	**Period 2 (10/1 – 12/31)**
Employee 1	520
Employee 2	520
Employee 3	260
Employee 4	52
Total:	1,352
Full Time Schedule per Employee	520
Total Non-ARRA FTEs: 1352/520 = 2.6 JOBS	
Total FTEs: 2.5 ARRA Funded FTEs + 2.6 non-ARRA Funded FTEs = **5.1**	
Total Cumulative Headcount = 7 3 ARRA Funded Headcount + 4 Non-ARRA Funded Headcount	

DOE jobs reporting requires Recipients to provide a 'Total Cumulative Head Count' on a monthly basis. Total Cumulative Head Count allows DOE to accurately reflect the direct impact of ARRA funds on the American workforce. This metric reflects the number of unique individuals that have been compensated for work under ARRA *since the inception of an ARRA project* (i.e. full-time, part-time, or temporary). This number will be the number of unique workers that worked the" total hours worked in jobs created from ARRA funds," which is used in the FTE calculations. Total unique head count for any performance period will be greater than or equal to the FTE figure reported to DOE.

Recipients are to report the number of cumulative head-count based on the number of unique identifiers in payroll systems indicating the number of people paid using ARRA funding. Examples of unique identifiers may include social security numbers or work permit numbers. While these unique identifiers will not be collected by the DOE, Recipients should maintain payroll records with unique identifiers that track the number of distinct individuals that received compensation. In the case of an audit, Recipients will be expected to demonstrate that the number of distinct identifiers exists in their payroll records.

- **Total Cumulative Head Count** = Cumulative number of employees hired on a full-time, part-time or temporary basis to work on an ARRA supported project

3.2 Measurement of Smart Grid Impact – What was the Outcome?

The Impact Metrics described in Table 10 are measurements of how the smart grid works. Electricity infrastructure assets in conjunction with the policies and programs will activate smart grid functionality that will modernize the grid and provide enhanced sensing, communication, information processing, and control to the utility. The new functionality will provide benefits which can be quantified and monetized to determine the value of the project or the overall program. The Data Analysis Team will use the Impact Metrics to conduct a quantitative cost-benefits analysis.

In order to ensure consistent reporting, quantification, and monetization of benefits, the Data Analysis Team will apply a benefit analysis framework (see Appendix C). This framework serves as the starting point for a dialogue between the Data Analysis Team and each Recipient to determine the best approach for calculating benefits based on each project's advanced grid functionality. DOE's algorithms for determining these benefits are in the report *Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects*.[11]

These algorithms will be customized so that the Impact Metrics finalized between the Data Analysis Team and each Recipient can be used to most appropriately calculate project benefits. The Data Analysis Team expects to iterate with each of the Recipients to establish consistency among the projects with respect to calculating benefits.

The framework (summarized in Appendix C) identifies the assets implemented as part of the project, the functionality that is activated due to those assets, and the benefits that can be realized as a result of new functionality.

[11] Co-funded by DOE and Electric Power Research Institute (EPRI), January 2010 http://www.smartgrid.gov/teams

Table 10. Impact Metrics

Metric	Description of Information	Illustrative Examples
Customer Electricity Usage	Load data and electricity cost by customer class, including tariff and/or SIC code	• Hourly load data by customer • Monthly customer electricity costs
Utility O&M Costs	Activity based cost for relevant utility costs	• Meter reading • Distribution operations and maintenance • Transmission operations & maintenance • Substation operations and maintenance • Customer care/call center operations
Equipment Failures	Incidents of equipment failure within the project scope	• Line transformer failures due to winding deterioration • Circuit breaker bushing failure • Underground cable failure
Power Quality Incidents	The number of incidents that power quality exceeded set tolerances (e.g., voltage surges sags, voltage impulses, or harmonic distortion). Incidents could be measured by the project or reported by customers.	• Incidents of low voltage on distribution reported by smart meters • Customer complaints of equipment tripping
Reliability Indices	IEEE Std 1366™-2003 IEEE reliability indices including SAIDI, SAIFI, CAIDI, MAIFI	• SAIDI, SAIFI, CAIDI, MAIFI for the project infrastructure
Substation Load	Substation loads for those substations involved in the project (Projects demonstrating Smart Grid benefits at the feeder and/or substation level need to monitor the effects at the level at which they could be measured.)	• Hourly readings for real and reactive power
Substation Overloads	Incidents when substation equipment load exceeded normal ratings	• Hours that the total transformer loading exceeded normal nameplate rating • Percentage of time that the substation load exceeded planning criteria
Transmission Line Load	Transmission line loads for those lines involved in the project	• Hourly readings for real and reactive power for lines involved in the project
Transmission Line Overloads	Incidents when transmission line load exceeded normal rating	• Hours that the total line loading exceeded normal rating • Percentage of time that the line load exceeded criteria
Deferred Transmission Capacity Investment	The new transmission capacity deferred as a result of smart grid information or operations	• A $10 million transmission line upgrade was deferred two years due to dynamic line rating • A $500 thousand substation transformer upgrade was deferred for a year by implementing demand response
Distribution Feeder Load	Hourly feeder loads (real and reactive) for those feeders involved in the project	• Hourly readings for real and reactive power for those feeders involved in the project
Distribution Feeder Overloads	Incidents when distribution feeder load exceeded normal rating	• Hours that the total line loading exceeded normal rating • Percentage of time that the line load exceeded planning/operations criteria

Table 10. Impact Metrics (cont.)

Metric	Description of Information	Illustrative Examples
Deferred Distribution Capacity Investment	The new distribution capacity deferred as a result of smart grid information or operations	• A $1 million distribution feeder upgrade was deferred for two years due to better managing voltage along the feeder • A distribution substation upgrade was avoided due to real-time load transfer to a neighboring substation during peak times
T&D Losses	Electricity losses of infrastructure within the project scope	• Transmission line losses were reduced by 5% by implementing conservation voltage reduction • Feeder peak losses reduced by dispatching energy storage during peak times
Power Factor	Power factor of the system within the project scope	• Distribution feeder power factor improved to 0.99 following voltage regulation by DERs
Generation Capacity Factor	Capacity factor of electricity generation relevant to the project and its area	• Generation capacity factor of 33%
Deferred Generation Capacity Investment	MW of generation capacity deferred, along with estimated cost, and total generation investment deferred	• 350 MW natural gas peaker plant deferred; capital carrying charge of $60 million per year
Energy Supplied from Renewable Resources	MWh of electricity produced by renewable sources	• 1.5 GWh of electricity from wind generation • 300 MWh of electricity from rooftop PV
Energy Supplied from Distributed Resources	MWh of electricity produced by distributed sources	• 200 MWh of electricity from combined heat and power generation
Electricity Theft	Identification of meter tampering and/or electricity theft	• Meters with potential tampering • Meters with suspect readings
Vehicle Emissions	Reduction in polluting emissions from utility service fleet vehicles, and reduction in vehicle miles travelled associated with operational efficiency gains and automation	• Reduction in vehicle miles travelled associated with automation and operational efficiency

4.0 Analyzing & Communicating Results

The Smart Grid Programs are expected to transform how customers interact with their utility and how utilities operate the grid, delivering several important results (Figure 2).

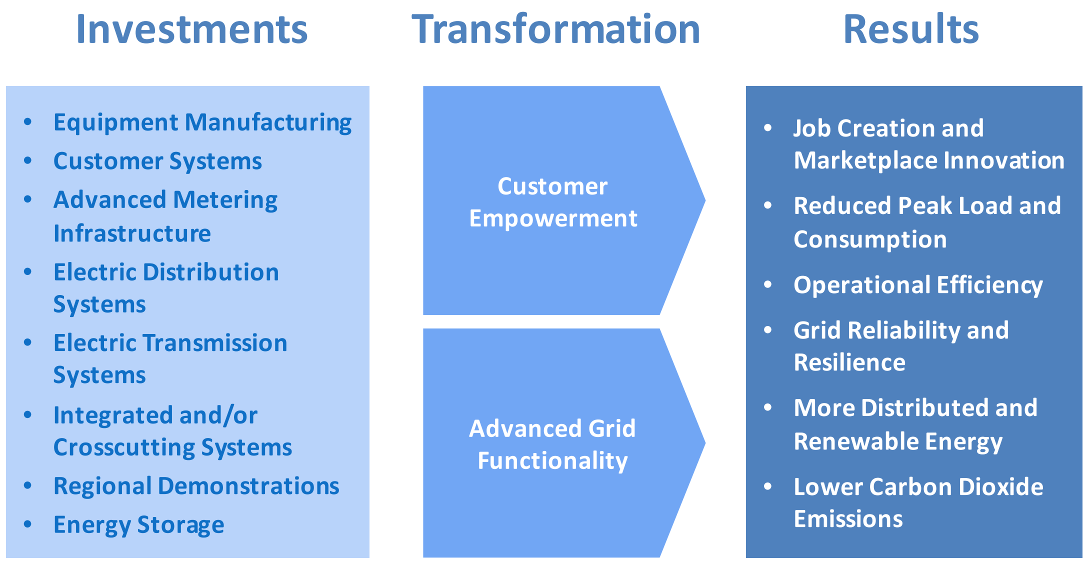


Figure 2. Smart Grid Program Investments, Transformation, and Results

The Data Analysis Team will use the data collected from Recipients to track investments, monitor and measure transformation, and report the results of the smart grid demonstrations. The Data Analysis Team will analyze the individual project data and a combination of data from all the projects to build a foundation of reliable facts and insights for the public. The information will be grouped by project type allowing the results to be examined on a programmatic basis.

DOE will communicate the impact of the smart grid investments in separate topics, namely:

1. Job Creation and Marketplace Innovation;
2. Peak Demand and Electricity Consumption;
3. Operational Efficiency;
4. Grid Reliability and Resilience;
5. Distributed Energy Resources and Renewable Energy; and
6. Carbon Dioxide Emissions.

For example, if the public is interested in how much carbon dioxide (CO_2) was reduced, DOE will be able to share the results for that particular topic. Those interested in investing in the smart grid can use these topic results to understand where other investments or demonstrations should focus. These topics will also help substantiate the impact of the nascent smart grid technologies and help DOE understand how and why the projects accomplished the results that they achieved from the smart grid technologies that were deployed.

4.1 Investments

The Data Analysis Team will track the total investment (ARRA and Recipient cost share) for SGDP/RDSI projects over the next five years (Table 11).

Table 11. Investments by Smart Grid Project Categories

SGDP/RDSI	Investment in millions					
	2010	2011	2012	2013	2014	Total
Regional Demonstration	$ -	$ -	$ -	$ -	$ -	$ -
Energy Storage Demonstration	$ -	$ -	$ -	$ -	$ -	$ -
RDSI	$ -	$ -	$ -	$ -	$ -	$ -

The investments will fund the deployment of technologies and tools that contribute to the development of a modernized transmission and distribution system, and enable the active participation of customers. The SGDP/RDSI projects will accelerate the spread of these customer-related and grid-related assets throughout the U.S. (Figure 3). The Data Analysis Team will measure the penetration rates of smart grid technologies, tools and techniques resulting from SGDP/RDSI projects.

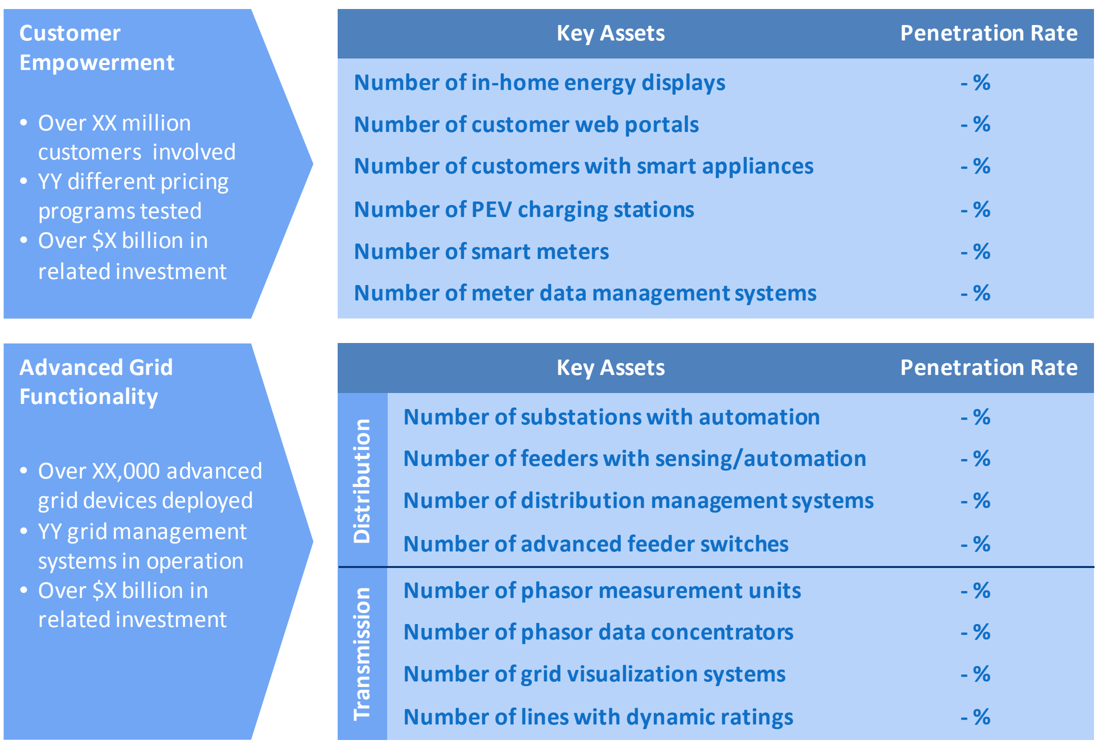


Figure 3: Assets Deployed for Customer Empowerment and Advanced Grid Functionality

4.2 Transformation of the Electric Power Sector

Assets deployed as part of the Smart Grid Programs will help empower electricity customers and enable advanced grid functionality for utilities (Figure 3 above). Both sides of the supply-demand relationship will gain a significant degree of information and control with which to increase the value of electricity.

Electricity Customer Empowerment

Many projects will be aimed at enabling smart grid functions on the customer-side-of-the-meter. Energy displays, information portals, smart appliances and distributed energy resources will provide customers with the information and energy management capability they need to become empowered energy partners rather than passive electrical load. Customers will be able to make informed decisions about when and how to satisfy their energy needs. They will also be positioned to participate actively in new energy programs and markets. The Data Analysis Team will work with SGDP/RDSI Recipients to identify data requirements that will allow for an aggregate assessment of how consumers, as a whole, altered their consumption, as well as a more categorical reporting of response at a disaggregated level of detail.

Advanced Grid Functionality

In addition to customer empowerment, the Data Analysis Team will monitor the transformation of the grid in terms of the advanced functionality realized and the related benefits. The Data Analysis Team will apply a standard methodology to identify functions and benefits for each of the projects. For instance, two projects might share a common idea of deploying smart metering and communications along with a dynamic electricity pricing program. Team A might call this a "real time load management program", and that term will have a rich meaning to Team A. Team B might say "this is part of our automated demand response program." On the surface, the two teams might appear to be talking about two different things. However, upon closer inspection, both projects involve the same kinds of assets (e.g., smart meters, communications, and portals) and a program where they are sending pricing signals or commands to customers. Using the framework described in Appendix C, both projects would involve "Real Time Load Measurement & Management" as a function. Both of the projects would also involve a policy/program that the Data Analysis Team would categorize as "Demand Response."

4.3 Results

The customer empowerment and advanced grid functionality supported by the Smart Grid Programs will deliver results that DOE will communicate within six topics. These are illustrated in the following sections.

Job Creation and Marketplace Innovation

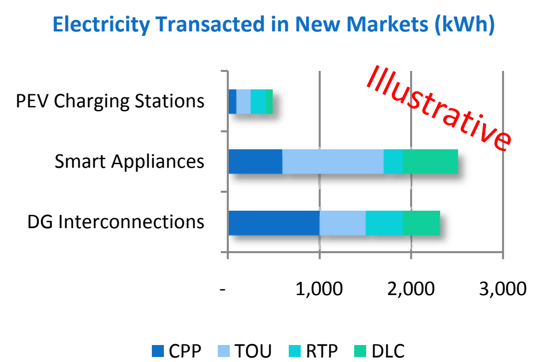
Key metrics track the economic impact of the Smart Grid Programs

Total Jobs Created and Retained *(number)*	X,XXX,XXX
New Programs and Policies *(number)*	XX
Customers with Access to New Pricing Products *(number)*	X,XXX,XXX
Retail Infrastructure:	
• number of DG Interconnections	XXX,XXX
• number of Customer Portals	XXX,XXX
• number of Smart Appliances	XXX,XXX
• number of PEV Charging Stations	XXX,XXX

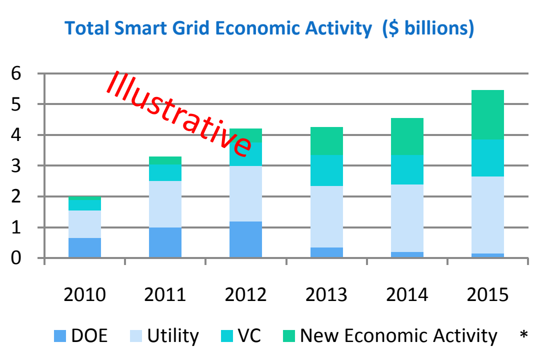
The Smart Grid Programs will create jobs and support the deployment of new products and services. The implementation of technology and infrastructure, and the associated transformation of electricity as a service will stimulate innovation in the marketplace. New offerings will emerge to help customers manage electricity use. New resources such as distributed renewable generation and plug-in electric vehicles will require new sales channels, installation, maintenance and management services.

The Smart Grid Programs have the potential to contribute to long term growth in economic activity associated with smart grid. Key aspects of this growth will be reflected in continued investment by utilities in smart grid equipment and services, venture capital investments in related start-ups and economic activity associated with new products and services. Utilities, contractors, equipment manufacturers, and energy services providers will have new jobs to be filled by a skilled and highly technical workforce.

Electricity transactions in new markets is growing for all types of pricing programs

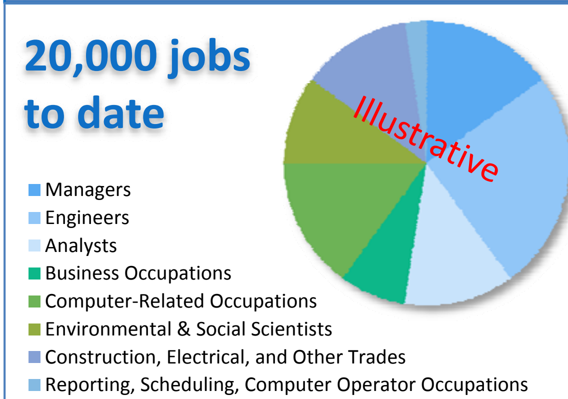


DOE investment has stimulated significant new economic activity



*Transaction revenue from PEVs, DG, and other new products.

Smart Grid Programs have helped create over 20,000 jobs to date

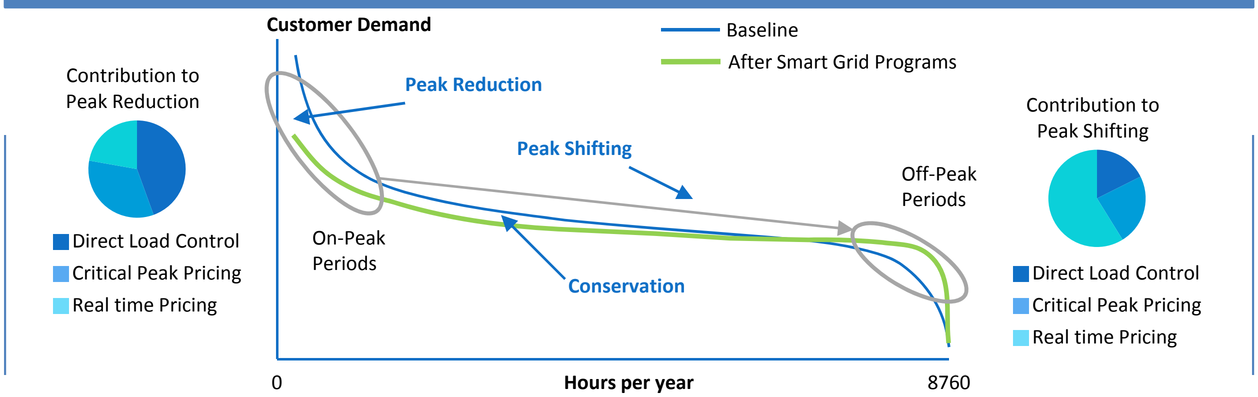


Peak Demand and Electricity Consumption

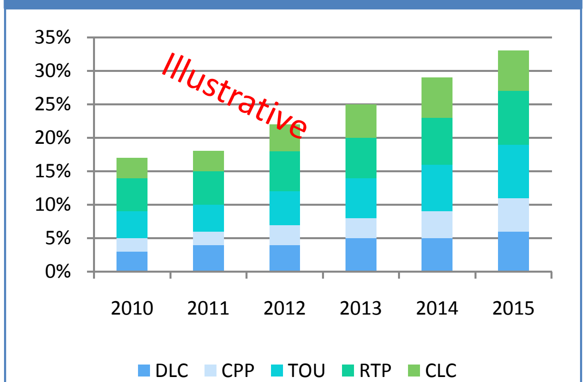
Key Assets and Customer Devices that will contribute to Demand Management	
Smart meters *(units)*	X,XXX,XXX
Customer energy displays or customers with portal access (number)	X,XXX,XXX
Distribution Automation Systems (number)	X,XXX
Grid-responsive, non-generating demand-side devices purchased *(units)*	X,XXX,XXX

Smart meters, energy displays and portals, and smart appliances will help customers make informed decisions about the electricity they use. These technologies, combined with new pricing programs and load control techniques will help utilities manage peak power demand and improve the utilization of generation, transmission and distribution assets. Customers will benefit from being able to manage their electricity consumption in ways consistent with their personal and business priorities, considering factors such as total cost, convenience, and resource composition.

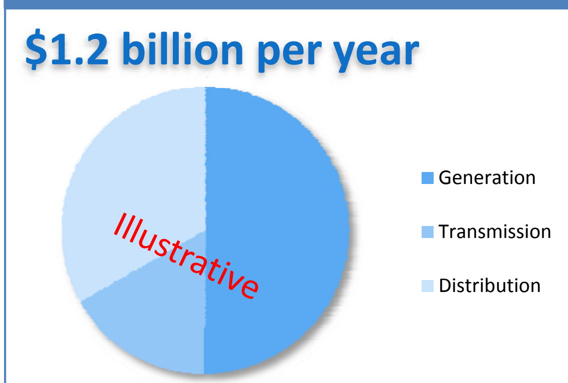
Technologies and pricing programs designed to reduce peak demand and electricity consumption have modified the load curve



Pricing programs have reduced peak demand 20% over the past five years



Demand management has enabled deferral of $1.2 billion in capital upgrades each year



Operational Efficiency

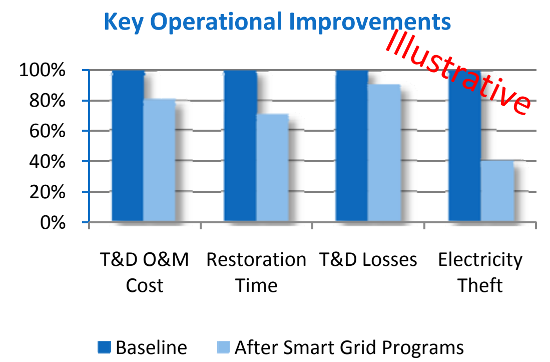
Large portions of today's electricity infrastructure require a high degree of manual operation. The advanced sensing, communications, information processing and control created by the Smart Grid Programs will help utilities gain efficiencies that can be leveraged to help reduce operating costs and improve responsiveness to customers. New technologies such as advanced metering infrastructure, distribution automation and phasor measurement units will help utilities and grid operators build, operate and maintain an electricity infrastructure that is more resource efficient, reliable and environmentally friendly, creating significant value for stakeholders over the long term. The data and metrics for this area will show how the ARRA-funded projects have supported this.

Key assets enable improvements in Operational Efficiency

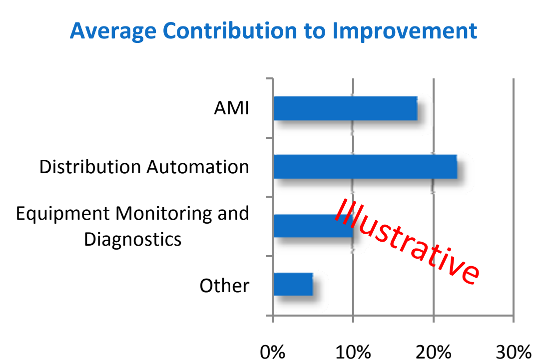
Meters being read automatically *(number of smart meters)*	2,500,000
Feeders with remote or automated switching *(number of feeders)*	247
Devices with condition monitoring (number)	200,000,000
Average Service Restoration Time *(minutes)*	74
T&D Losses *(MWh)*	7.3
Electricity theft savings *(MWh)*	10,000,000

Illustrative

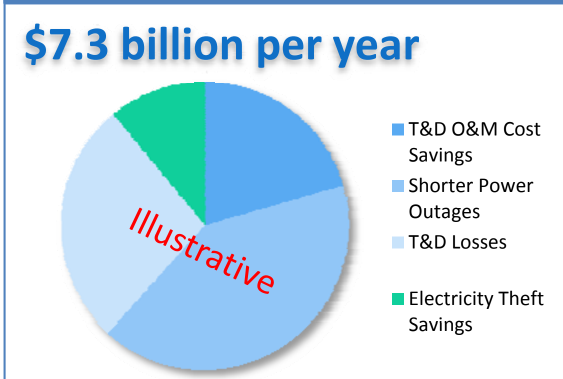
Smart Grid Programs are supporting significant reductions in operating costs and response time



AMI and distribution automation are the major contributors to operational efficiency



Operational efficiency gains have produced $7.3 billion worth of value each year

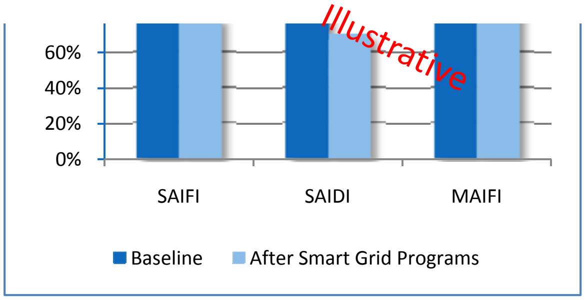


Grid Reliability and Resilience

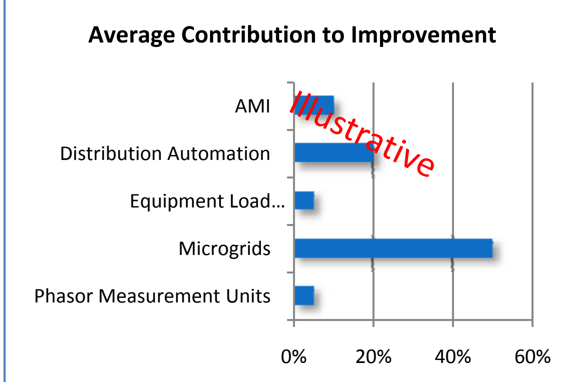
Key assets support Grid Reliability and Resilience	
Customer end-points monitored *(number of smart meters)*	2,500,000
Feeders with remote or automated switching *(number of feeders)*	123
Load served within microgrids *(MW)*	245
Phasor monitoring points on transmission *(number of PMUs)*	82
System elements with dynamic capability ratings *(number)*	5,000

Power interruptions have a significant economic impact on electricity customers, resulting in billions of dollars in lost productivity each year. Improving the reliability and resilience of electric transmission and distribution systems will reduce the frequency and duration of power interruptions experienced by customers. This reliability improvement will translate to economic value as customers from the residential, commercial and industrial classes face fewer and shorter disruptions to their lives and businesses. The economic value preserved is determined based on the studies that have estimated the value of lost production due to the impact and duration of power interruptions on specific customer classes.

Smart Grid Programs have shown reliability improvements of about 20%

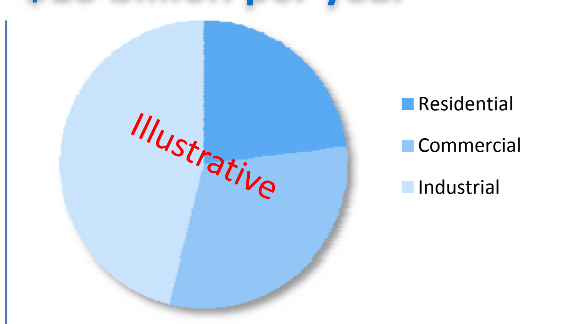


Distribution Automation and microgrids make the greatest contribution to improved reliability



Reliability improvements have prevented $13 billion in lost economic value each year

$13 billion per year



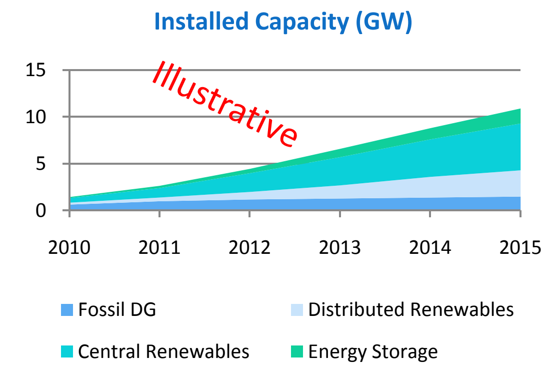
Distributed Energy Resources and Renewable Energy

The number of distributed and renewable energy resources is growing	
DG Systems Installed (number)	XXX,XXX
Renewable Energy Systems Installed (number)	XXX,XXX
DER Interconnections (number)	X,XXX,XXX
Plug in Electric Vehicle Interconnections (number)	XX,XXX

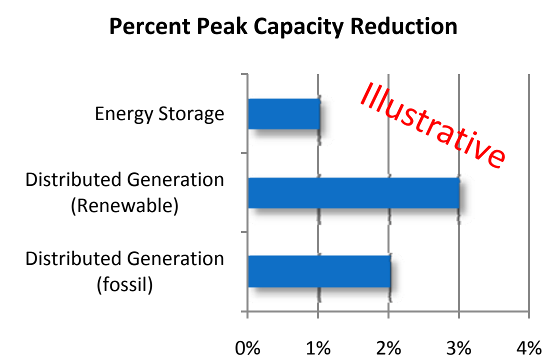
The monitoring, coordination and control capabilities supported by smart grid technologies will enable power grids to accommodate an increased number and variety of generation (including distributed renewable energy and combined heat and power, and central and remote renewable energy systems) and storage options. Integrating these resources efficiently and reliably provides various benefits such as lower peak power demand, flatter load curves, and lower electricity losses – all of which contributes to lower costs for utilities and their customers.

The contribution of renewable energy to meeting our overall electricity needs is expected to grow rapidly over the coming years. Distributed fossil generation and energy storage will contribute proportionally more to reducing peak capacity from central sources than will renewable energy. Smart grid systems will allow the full benefits of this wide variety of generation options to be captured.

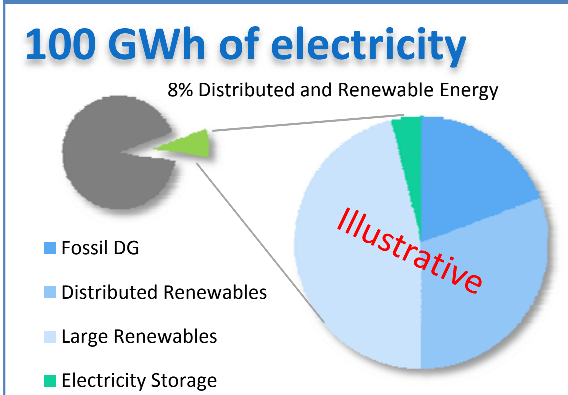
The installed capacity of distributed generation and renewable energy has increased by 270%



Distributed and renewable energy is offsetting peak capacity by about 6%



Distributed and renewable energy has produced 100 GWh of electricity this year



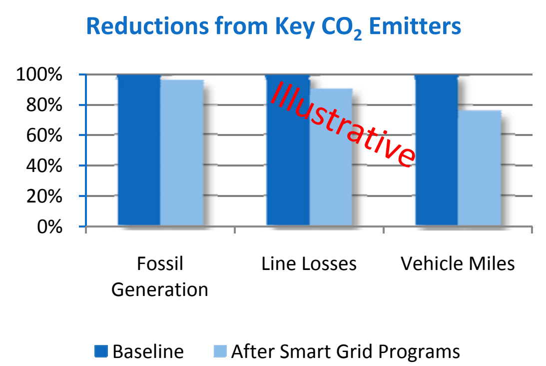
Carbon Dioxide Emissions

Key Metrics that contributed to lower CO_2 Emissions	
Reduced Fossil Generation *(MWh)*	X,XXX,XXX
Reduced Line Losses *(MWh)*	X,XXX,XXX
Reduced Vehicle Miles Traveled (miles)	X,XXX,XXX
Plug in Electric Vehicle (PEV) Interconnections (number)	XX,XXX

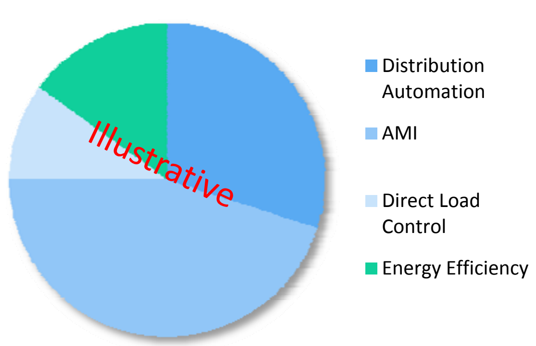
The smart grid will play a key role in facilitating the reduction of carbon dioxide (CO_2) emissions. This will be accomplished by enabling higher penetrations of renewable energy, reducing utility vehicle emissions through automation, improving the ability of utilities to manage demand thereby reducing power plant operations, and by increasing the energy efficiency of the transmission and distribution system. By supporting the adoption of plug-in electric vehicles, the smart grid will also contribute to reductions in fossil-based transportation fuels.

Grid-related technologies such as advanced metering infrastructure and distribution automation, combined with customer-related technologies such as energy information systems and smart appliances, will help deliver significant reductions in CO_2.

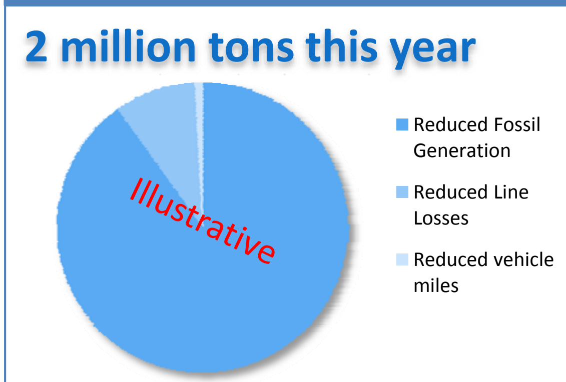
Smart Grid Programs are demonstrating progress toward reducing CO_2 emissions



Distribution automation and AMI are key resources for enabling CO_2 reductions



Over 2 million tons of CO_2 were saved as a result of Smart Grid Programs this year



Appendix A: Data Collection and Reporting Templates

Build Metrics and Impact Metrics will be reported for all projects. However, Recipients will be expected to report only those metrics that are relevant for their project.

Tables A-1. Build Metrics

Generally Not Applicable to SGDP Energy Storage Projects

A 1.1. BUILD METRICS: AMI and Customer System Assets			
Metric	**Project Value**	**System Value**	**Remarks**
End-Points (meters)	#	#	Total meters in planned implementation
Portion of Customers with AMI			
Residential	%	%	Customers with AMI by class
Commercial	%	%	
Industrial	%	%	
Metering Features			
Interval Reads of 1 hour or Less	Interval	Interval	Indicate the read interval of meters
Remote Connection/Disconnection	Yes/No	Yes/No	Indicate if meters will be used for this purpose
Outage Detection/Reporting	Yes/No	Yes/No	
Power Quality Monitoring	Yes/No	Yes/No	
Tamper Detection	Yes/No	Yes/No	
Backhaul Communications Network	Description	Description	Network characteristics from collectors to head-end
Meter Communications Network	Description	Description	Network characteristics from collectors to meters
Headend system	Description	Description	Characteristics of system
Meter Data Management System	Description	Description	Characteristics of system
Meter Data Analysis Systems	Description	Description	Software for analyzing and manipulating meter data
Enterprise Systems Integration			
Billing	Yes/No	Yes/No	Indicate if AMI will be integrated with system
Customer Information System	Yes/No	Yes/No	
Outage Management System	Yes/No	Yes/No	
Distribution Management System	Yes/No	Yes/No	
Others	Yes/No	Yes/No	
Home Area Network	Description	Description	Network characteristics within customer premise
In-Home Displays	#	#	Number of customers with a dedicated energy display
Web Portal	#	#	Number of customers with access to a web portal
Energy Management Devices/Systems	#	#	Number of customers with an energy management device or system

A 1.1. BUILD METRICS: AMI and Customer System Assets			
Metric	**Project Value**	**System Value**	**Remarks**
Direct Load Control Devices	#	#	Number of devices that can be cycled or controlled by a utility or third party
Programmable Controllable Thermostat	#	#	Number of customers with a device
Smart Appliances	#	#	Number of appliances that can be programmed or can respond to pricing signals or schedules
Other Customer Devices	#/ Description	#/ Description	Numbers of other customer devices or systems

A 1.2. BUILD METRICS: Pricing Programs			
Policy/Program	**Project Value**	**System Value**	**Remarks**
Retail Rate Design and Rate Level			Include program characteristics, customers with access, and participation rates
Flat	Yes/No	Yes/No	
Flat with Critical Peak Pricing	Yes/No	Yes/No	
Flat with Peak-Time Rebate	Yes/No	Yes/No	
Tier	Yes/No	Yes/No	
Tier with Critical Peak Pricing	Yes/No	Yes/No	
Tier with Peak-Time Rebate	Yes/No	Yes/No	
Time-of-Use	Yes/No	Yes/No	
Variable Peak Pricing	Yes/No	Yes/No	
Time-of-Use with Critical Peak Pricing	Yes/No	Yes/No	
Time-of-Use with Peak-Time Rebate	Yes/No	Yes/No	
Real-Time Pricing	Yes/No	Yes/No	
Real-Time Pricing with Critical Peak Pricing	Yes/No	Yes/No	
Real-Time Pricing with Peak Time Rebate	Yes/No	Yes/No	
Pre-Pay Pricing	Yes/No	Yes/No	
Net Metering	Yes/No	Yes/No	
Rate Decoupling	Yes/No	Yes/No	
Other Programs	Yes/No	Yes/No	

A 1.3. BUILD METRICS: Distributed Energy Resources			
Metric	**Project Value**	**System Value**	**Remarks**
Distributed Generation	#; MW; MWh	#; MW; MWh	Number of units, total installed capacity and total energy delivered
Energy Storage	#; MW; MWh	#; MW; MWh	Number of units, total installed capacity and total energy delivered
DG Interface	Description	Description	Characteristics of DG interface or interconnection, including information and control capability for utility
PEV Charging Points	#	#	# charging points, capacity, total energy transacted

A 1.4. BUILD METRICS: Electric Distribution System Assets			
Metric	**Project Value**	**System Value**	**Remarks**
Portion of System with SCADA	%	%	Including distribution substation and feeder monitoring/control
Portion of System with Distribution Automation (DA)	%	%	Including feeders, substations, and key equipment
DA Devices			
Automated Feeder Switches	#	#	Locally or centrally coordinated/operated
Automated Capacitors	#	#	
Automated Regulators	#	#	
Feeder Monitors	#	#	Including voltage and current sensors
Remote Fault Indicators	#	#	Detection and reporting of fault location
Transformer Monitors (line)	#	#	Loading and/or equipment health
Smart Relays	#	#	Settings can be coordinated with other devices
DA Communications Network	Description	Description	Characteristics of system, including integration or dependencies with other networks (e.g., AMI)
Other DA devices	#	#	Characteristics of DA devices
DA System Features/Applications			
Fault Location, Isolation and Service Restoration (FLISR)	Yes/No	Yes/No	Indicate if DA will be used for these purposes
Voltage Optimization	Yes/No	Yes/No	
Feeder Peak Load Management	Yes/No	Yes/No	
Microgrids	Yes/No	Yes/No	
Other Applications	Yes/No	Yes/No	
Distribution Management System			
Integration with AMI	Yes/No	Yes/No	Including loading, voltage and power quality sensing and reporting from meters
Integration with Outage Management System	Yes/No	Yes/No	Includes outage detection and reporting from OMS
Integration with Transmission Management System	Yes/No	Yes/No	Interface with high voltage energy management system
Integration with Distributed Energy Resources	Yes/No	Yes/No	Interface with customer energy management systems and DERs
Fault Current Limiter	#	#	
Other Distribution Devices	#	#	Characteristics of Distribution devices

Generally Not Applicable to SGDP Energy Storage Projects

A 1.5. BUILD METRICS: Electric Transmission System Assets			
Metric	**Project Value**	**System Value**	**Remarks**
Portion of Transmission System Covered by Phasor Measurement Systems	%	%	Including lines, transmission substations, and key equipment
Phasor Measurement Systems			
PMUs	#/ Description	#/ Description	Make and model, security measures, consistency with NASPI and synchrophasor standards, substation name, location, nominal voltage level, settings, CEII designation, PT/VT and CT transducer make and model
Phasor Data Concentrators	#/ Description	#/ Description	Make and model, security measures, consistency NASPI and synchrophasor standards, number of PMUs networked
Communications Network	Description	Description	Type and characteristics
Advanced Transmission Applications			Applications utilizing phasor data or other Smart Grid information for transmission operations and planning
Angle/Frequency Monitoring	Yes/No	Yes/No	Indicate if Phasor Measurement Systems will be used for these purposes
Post-mortem Analysis (including compliance monitoring)	Yes/No	Yes/No	
Voltage Stability Monitoring	Yes/No	Yes/No	
Thermal Overload Monitoring	Yes/No	Yes/No	
Improved State Estimation	Yes/No	Yes/No	
Steady-State Model Benchmarking	Yes/No	Yes/No	
DG/IPP Applications	Yes/No	Yes/No	
Power System Restoration	Yes/No	Yes/No	
Dynamic Capability Rating Systems			Systems designed to determine real-time ratings
Transmission lines	#	#	Based on line loading, temperature, sag or other operating parameters
Station Transformers	#	#	Based on equipment loading, temperature, oil condition, or other operating parameters
Other Transmission Equipment	#	#	Other equipment that could benefit from a real-time rating
Other Transmission Devices	#	#	Characteristics of transmission devices

Tables A-2. Impact Metrics

Generally Not Applicable to SGDP Energy Storage Projects

A 2.1. IMPACT METRICS: AMI and Customer Systems			
Metric	**Project Value**	**System Value**	**Remarks**
Metrics Related Primarily to Economic Benefits			
Hourly Customer Electricity Usage	kWh $/kWh	Not Applicable	Hourly electricity consumption information (kWh) and applicable retail tariff rate. The nature of this data will be negotiated with DOE.
Monthly Customer Electricity Usage	kWh $/kWh	Not Applicable	Monthly electricity consumption information (kWh) and applicable retail tariff rate. The nature of this data will be negotiated with DOE.
Peak Generation and Mix	MW Mix	MW Mix	Specify intermittent generation by type and amount
Peak Load and Mix	MW Mix	MW Mix	Specify controllable load by type
Annual Generation Cost	$	$	Total cost of generation to serve load
Hourly Generation Cost	$/MWh	$/MWh	Aggregate or market price of energy in each hour
Annual Electricity Production	MWh	MWh	Total electricity produced by central generation
Ancillary Services Cost	$	$	Total cost of ancillary services
Meter Operations Cost	$	Not Applicable	Includes operations, maintenance, reading and data management
Truck Rolls Avoided	#	Not Applicable	Could include trips for meter reading, connection/ disconnection, inspection and maintenance
Metrics Related Primarily to Environmental Benefits			
Meter Operations Vehicle Miles	Miles	Not Applicable	Total miles accumulated related to meter operations
CO_2 Emissions	Tons	Tons	Could be modeled or estimated
Pollutant Emissions (SOx, NOx, PM-10)	Tons	Tons	Could be modeled or estimated
Metrics Related Primarily to AMI System Performance			
Meter Data Completeness	%	Not Applicable	Portion of meters that are online and successfully reporting in
Meters Reporting Daily by 2AM	%	Not Applicable	Portion of daily meter reads received by 2AM the following day

A 2.2. IMPACT METRICS: Electric Distribution Systems			
Metric	**Project Value**	**System Value**	**Remarks**
Metrics Related Primarily to Economic Benefits			
Hourly Customer Electricity Usage*	kWh $/kWh	Not Applicable	Hourly electricity consumption information (kWh) and applicable retail tariff rate
Annual Storage Dispatch*	kWh	Not Applicable	Total number of hours that storage is dispatched for retail load shifting
Average Energy Storage Efficiency*	%	Not Applicable	Efficiency of energy storage devices installed
Monthly Demand Charges*	$/kW-month	Not Applicable	Average commercial or industrial demand charges
Distribution Feeder or Equipment Overload Incidents	#	Not Applicable	The total time during the reporting period that feeder or equipment loads exceeded design ratings
Distribution Feeder Load	MW MVAR	Not Applicable	Real and reactive power readings for those feeders involved in the project. Information should be based on hourly loads
Deferred Distribution Capacity Investments	$	Not Applicable	The value of the capital project(s) deferred, and the time of the deferral
Equipment Failure Incidents	#	Not Applicable	Incidents of equipment failure within the project scope, including reason for failure
Distribution Equipment Maintenance Cost	$	Not Applicable	Activity based cost for distribution equipment maintenance during the reporting period
Distribution Operations Cost	$	Not Applicable	Activity based cost for distribution operations during the reporting period
Distribution Feeder Switching Operations	#	Not Applicable	Activity based cost for feeder switching operations during the reporting period
Distribution Capacitor Switching Operations	#	Not Applicable	Activity based cost for capacitor switching operation during the reporting period
Distribution Restoration Cost	$	Not Applicable	Total cost for distribution restoration during the reporting period
Distribution Losses	%	Not Applicable	Losses for the portion of the distribution system involved in the project. Modeled or calculated.
Distribution Power Factor	pf	Not Applicable	Power factor for the portion of the distribution system involved in the project. Modeled or calculated.
Truck Rolls Avoided	#	Not Applicable	Estimate of the number of times a crew would have been dispatched to perform a distribution operations or maintenance function
Metrics Related Primarily to Reliability Benefits			
SAIFI	Index	Not Applicable	As defined in IEEE Std 1366-2003, and do not include major event days. Only events involving infrastructure that is part of the project should be included.
SAIDI/CAIDI	Index	Not Applicable	
MAIFI	Index	Not Applicable	
Outage Response Time	Minutes	Not Applicable	Time between outage occurrence and action initiated

A 2.2. IMPACT METRICS: Electric Distribution Systems			
Metric	**Project Value**	**System Value**	**Remarks**
Major Event Information	Event Statistics	Not Applicable	Information should including, but not limited to project infrastructure involved (transmission lines, substations and feeders), cause of the event, number of customers affected, total time for restoration, and restoration costs.
Number of High Impedance Faults Cleared	#	Not Applicable	Faults cleared that could be designated as high impedance or slow clearing
Metrics Related Primarily to Environmental Benefits			
Distribution Operations Vehicle Miles	Miles	Not Applicable	Total mileage for distribution operations and maintenance during the reporting period
CO2 Emissions	Tons	Tons	Could be modeled or estimated
Pollutant Emissions (SOx, NOx, PM-10)	Tons	Tons	Could be modeled or estimated

*These metrics are only applicable to energy storage demonstrations.

A 2.3. IMPACT METRICS: Electric Transmission Systems			
Metric	**Project Value**	**System Value**	**Remarks**
Metrics Related Primarily to Economic Benefits			
Annual Storage Dispatch*	MWh	MWh	Total number of hours that storage is dispatched for wholesale energy markets or ancillary services
Capacity Market Value*	$/MW	$/MW	Capacity value
Ancillary Services Price*	$/MWh	$/MWh	Ancillary service price during hours when Storage was dispatched
Annual Generation Cost	Not Applicable	$	Total cost of generation to serve load
Hourly Generation Cost	Not Applicable	$/MWh	Aggregate or market price of energy in each hour
Peak Generation and Mix	Not Applicable	MW Mix	Specify intermittent generation by type and amount
Peak Load and Mix	Not Applicable	MW Mix	Specify controllable load by type
Annual Generation Dispatch	Not Applicable	MWh	Total electricity produced by central generation
Ancillary Services Cost	Not Applicable	$	Total cost of ancillary services
Congestion (MW)	MW	Not Applicable	Total transmission congestion during the reporting period
Congestion Cost	$	Not Applicable	Total transmission congestion cost during the reporting period
Transmission Line or Equipment Overload Incidents	#	Not Applicable	The total time during the reporting period that line loads exceeded design ratings
Transmission Line Load	MW MVAR	Not Applicable	Real and reactive power readings for those lines involved in the project. Information should be based on hourly loads

A 2.3. IMPACT METRICS: Electric Transmission Systems			
Metric	**Project Value**	**System Value**	**Remarks**
Deferred Transmission Capacity Investments	$	Not Applicable	The value of the capital project(s) deferred, and the time of the deferral
Equipment Failure Incidents	#	Not Applicable	Incidents of equipment failure within the project scope, including reason for failure
Transmission Equipment Maintenance Cost	$	Not Applicable	Activity based cost for transmission equipment maintenance during the reporting period
Transmission Operations Cost	$	Not Applicable	Activity based cost for transmission operations during the reporting period
Transmission Restoration Cost	$	Not Applicable	Total cost for transmission restoration during the reporting period
Transmission Losses	%	Not Applicable	Losses for the portion of the transmission system involved in the project. Could be modeled or calculated
Transmission Power Factor	pf	Not Applicable	Power factor for the portion of the transmission system involved in the project. Could be modeled or calculated
Metrics Related Primarily to Transmission Reliability			
BPS Transmission Related Events Resulting in Loss of Load (NERC ALR 1-4)	#	Not Applicable	BPS Transmission Related Events Resulting in Loss of Load (NERC ALR 1-4)
Energy Emergency Alert 3 (NERC ALR 6-2)	#	Not Applicable	Energy Emergency Alert 3 (NERC ALR 6-2)
Metrics Related Primarily to Environmental Benefits			
Transmission Operations Vehicle Miles	Miles	Not Applicable	Total mileage for transmission operations and maintenance during the reporting period
CO_2 Emissions	tons	tons	Could be modeled or estimated
Pollutant Emissions (SOx, NOx, PM-10)	tons	tons	Could be modeled or estimated
Metrics Related Primarily to Energy Security Benefits			
Event Capture and Tracking			
Number, Type ,and Size	Events Cause Load Lost	Not Applicable	Causes could include line trips, generator trips, or other large disturbances
Duration	Minutes/ Hours	Not Applicable	
PMU Dynamic Data	PMU Data	Not Applicable	From related PMUs
Detection	Application	Not Applicable	Application that detected the event
Events Prevented	#	Not Applicable	Include reason for prevention
Metrics Related Primarily to PMU/PDC System Performance			
PMU Data Completeness	%	Not Applicable	Portion of PMUs that are operational and successfully providing data
Network Completeness	%	Not Applicable	Portion of PMUs networked into regional PDCs
PMU/PDC Performance	Reliability Quality	Not Applicable	

A 2.3. IMPACT METRICS: Electric Transmission Systems			
Metric	**Project Value**	**System Value**	**Remarks**
Communications Performance	Availability	Not Applicable	
Application Performance	Description	Not Applicable	Usefulness of applications, including reliability improvements, markets and congestion management, operational efficiency

*These metrics are only applicable to energy storage demonstrations.

Appendix B: Group Names for Department of Labor Job Categories

SGP Group	Department of Labor Occupation Category	
Managers		
	11-1011	Chief executives
	11-1021	General and operations managers
	11-2020	Marketing and sales managers
	11-3011	Administrative services managers
	11-3021	Computer and information systems managers
	11-3031	Financial managers
	11-3051	Industrial production managers
	11-3061	Purchasing managers
	11-3071	Transportation, storage, and distribution managers
	11-9021	Construction managers
	11-9041	Engineering managers
Analysts		
	13-1081	Logisticians
	13-1111	Management analysts
	13-1199	Business operation specialists, all other
	13-2011	Accountants and auditors
Computer-Related Occupations		
	15-1011	Computer and information scientists, research
	15-1021	Computer programmers
	15-1030	Computer software engineers
	15-1031	Computer software engineers, applications
	15-1032	Computer software engineers, systems software
	15-1041	Computer support specialists
	15-1051	Computer systems analysts
	15-1061	Database administrators
	15-1071	Network and computer systems administrators
	15-1081	Network systems and data communications analysts
	15-1099	Computer specialists, all other
	15-2031	Operations research analysts
	15-2041	Statisticians
	15-2090	Miscellaneous mathematical science occupations
Engineers		
	17-2051	Civil engineers
	17-2061	Computer hardware engineers
	17-2070	Electrical and electronics engineers
	17-2071	Electrical engineers
	17-2072	Electronics engineers, except computer
	17-2081	Environmental engineers
	17-2112	Industrial engineers
	17-2141	Mechanical engineers
	17-2199	Engineers, all other
	17-3022	Civil engineering technicians
	17-3023	Electrical and electronic engineering technicians
	17-3024	Electro-mechanical technicians
	17-3025	Environmental engineering technicians
	17-3026	Industrial engineering technicians
	17-3027	Mechanical engineering technicians
	17-3029	Engineering technicians, except drafters, all other
	17-3031	Surveying and mapping technicians
SGP Group	**Department of Labor Occupation Category**	

Environmental and Social Scientists		
	19-2040	Environmental scientists and geoscientists
	19-3011	Economists
	19-3020	Market and survey researchers
	19-4061	Social science research assistants
	19-4090	Other life, physical, and social science technicians
Business Occupations		
	23-1011	Lawyers
	27-1024	Graphic designers
	27-3031	Public relations specialists
	27-3040	Writers and editors
	33-1000	First-line supervisors/managers, protective service workers
	41-4011	Sales representatives, wholesale and manufacturing, technical and scientific products
	41-4012	Sales representatives, wholesale & manufacturing, except technical & scientific products
	43-1000	Supervisors, office and administrative support workers
	43-2000	Communications equipment operators
	43-3000	Financial clerks
	43-4000	Information and record clerks
Recording, Scheduling, Computer Operator Occupations		
	43-5000	Material recording, scheduling, dispatching, and distributing occupations
	43-5041	Meter readers, utilities
	43-5061	Production, planning, and expediting clerks
	43-5071	Shipping, receiving, and traffic clerks
	43-5081	Stock clerks and order fillers
	43-6011	Executive secretaries and administrative assistants
	43-9011	Computer operators
	43-9020	Data entry and information processing workers
	43-9061	Office clerks, general
	43-9071	Office machine operators, except computer
	43-9081	Proofreaders and copy markers
	43-9111	Statistical assistants
	43-9199	Office and administrative support workers, all other
Construction, Electrical, and Other Trades		
	47-1011	First-line supervisors/managers of construction trades and extraction workers
	47-2061	Construction laborers
	47-2070	Construction equipment operators
	47-2111	Electricians
	47-2150	Pipelayers, plumbers, pipefitters, and steamfitters
	47-3010	Helpers, construction trades
	47-4011	Construction and building inspectors
	49-2092	Electric motor, power tool, and related repairers
	49-2094	Electrical and electronics repairers, commercial and industrial equipment
	49-2095	Electrical and electronics repairers, powerhouse, substation, and relay
	49-9040	Industrial machinery installation, repair, and maintenance workers
	49-9051	Electrical power-line installers and repairers
	49-9052	Telecommunications line installers and repairers
	49-9069	Precision instrument and equipment repairers, all other
	49-9099	Installation, maintenance, and repair workers, all other
	51-2020	Electrical, electronics, and electromechanical assemblers
	51-2022	Electrical and electronic equipment assemblers
	51-2023	Electromechanical equipment assemblers

Appendix C: Methodology for Analyzing Smart Grid Functions, Energy Storage Applications, and Benefits

As described in Section 3, electricity infrastructure assets can be implemented to modernize the delivery and use of electricity through thirteen functions defined in Table C-1. For energy storage demonstrations, Recipients will submit a list of applications (i.e., uses) and technical performance data required to evaluate each application (see Table C-2 and Sandia National Laboratory's *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide*[12]).

To determine the impact of the smart grid, DOE identified benefits associated with each of the functions. The energy resources that are enabled by smart grid functions can also provide benefits. DOE identified a list of potential benefits that are categorized as Economic, Reliability, Environmental or Security (see Table C-3). To determine the value of these benefits, they are first quantified in terms of their physical units (e.g., MWh) and then monetized. Table C-4 presents the linkage between assets and functions. Table C-5 shows the relationship between the functions and the benefits realized. All benefits will require an approach for calculating the baseline to be used for comparison and Recipients will be required to report this baseline data.

Quantifying the benefits refers to measuring the effects or outcomes that the project will show. For example, a project may try to minimize peak demand on a feeder. The Recipients could report the demand measured on the feeder before the project was implemented and the demand measured on the feeder after the project was in operation. In most cases, the Recipients will be required to collect and assimilate raw data and then report the outcome as project benefits to the TPO and Data Analysis Team. However, in a few predetermined cases, the Recipient will be required to report raw data, and the Data Analysis Team will process it to determine the outcome. The Data Analysis Team will use a standardized approach to monetize the value, for those benefits that are not in the economic category. In this example, the value of peak load reduction is based on the amount of money saved by eliminating the need to build a new peaker plant.

[12] SAND2010-0815, February 2010 http://www.smartgrid.gov/sites/default/files/resources/energy_storage.pdf

Table C-1. Definitions of Functions

Function	Definition
Fault Current Limiting	Fault current limiting can be achieved through sensors, communications, information processing, and actuators that allow the utility to use a higher degree of network coordination to reconfigure the system to prevent fault currents from exceeding damaging levels.
Wide Area Monitoring, Visualization, & Control	Wide area monitoring and visualization requires time synchronized sensors, communications, and information processing that make it possible for the condition of the bulk power system to be observed and understood in real-time so that action can be taken.
Dynamic Capability Rating	Dynamic capability rating can be achieved through real-time determination of an element's (e.g., line, transformer etc.) ability to carry load based on electrical and environmental conditions.
Power Flow Control	Flow control requires techniques that are applied at transmission and distribution levels to influence the path that power (real & reactive) travels. This uses such tools as flexible AC transmission systems (FACTS), phase angle regulating transformers (PARs), series capacitors, and very low impedance superconductors.
Adaptive Protection	Adaptive protection uses adjustable protective relay settings (e.g., current, voltage, feeders, and equipment) in real time based on signals from local sensors or a central control system. This is particularly useful for feeder transfers and two-way power flow issues associated with high DER penetration.
Automated Feeder Switching	Automated feeder switching is realized through automatic isolation and reconfiguration of faulted segments of distribution feeders via sensors, controls, switches, and communications systems. These devices can operate autonomously in response to local events or in response to signals from a central control system.
Automated Islanding and Reconnection	Automated islanding and reconnection is achieved by automated separation and subsequent reconnection (autonomous synchronization) of an independently operated portion of the T&D system (i.e., microgrid) from the interconnected electric grid. A microgrid is an integrated energy system consisting of interconnected loads and distributed energy resources which, as an integrated system, can operate in parallel with the grid or as an island.
Automated Voltage & VAR Control	Automated voltage and VAR control requires coordinated operation of reactive power resources such as capacitor banks, voltage regulators, transformer load-tap changers, and DG with sensors, controls, and communications systems. These devices could operate autonomously in response to local events or in response to signals from a central control system.
Diagnosis & Notification of Equipment Condition	Diagnosis and notification of equipment condition is defined as on-line monitoring and analysis of equipment, its performance and operating environment to detect abnormal conditions (e.g., high number of equipment operations, temperature, or vibration). Automatically notifies asset managers and operations to respond to conditions that increase the probability of equipment failure.
Enhanced Fault Protection	Enhanced fault protection requires higher precision and greater discrimination of fault location and type with coordinated measurement among multiple devices. For distribution applications, these systems will detect and isolate faults without full-power re-closing, reducing the frequency of through-fault currents. Using high resolution sensors and fault signatures, these systems can better detect high impedance faults. For transmission applications, these systems will employ high speed communications between multiple elements (e.g., stations) to protect entire regions, rather than just single elements. They will also use the latest digital techniques to advance beyond conventional impedance relaying of transmission lines.
Real-time Load Measurement & Management	Provides real-time measurement of customer consumption and management of load via AMI systems (smart meters, two-way communications) and embedded appliance controllers that help customers make informed energy use decisions via real-time price signals, TOU rates, and service options.
Real-time Load Transfer	Real-time load transfer is achieved through real-time feeder reconfiguration and optimization to relieve load on equipment, improve asset utilization, improve distribution system efficiency, and enhance system performance.

Function	Definition
Customer Electricity Use Optimization	Customer electricity use optimization is possible if customers are provided with information to make educated decisions about their electricity use. Customers should be able to optimize toward multiple goals such as cost, reliability, convenience, and environmental impact.

Table C-2. Overview of Energy Storage Applications

Application	Overview
Electric Energy Time Shift	Involves purchasing inexpensive electric energy, available during periods when price is low, to charge the storage plant so that the stored energy can be used or sold at a later time when the price is high (i.e., arbitrage).
Electric Supply Capacity	Depending on the circumstances in a given electric supply system, energy storage could be used to defer and/or to reduce the need to buy new central station generation capacity and/or to 'rent' generation capacity in the wholesale electricity marketplace.
Load Following	Storage is well-suited to load following for several reasons. First, most types of storage can operate at partial output levels with relatively modest performance penalties. Second, most types of storage can respond very quickly (compared to most types of generation) when more or less output is needed for load following. Consider also that storage can be used effectively for both load following up (as load increases) and for load following down (as load decreases), either by discharging or by charging.
Area Regulation	Most thermal/baseload generation used for regulation service is not especially well-suited to provide regulation, because generation is not designed for operation at part load or to provide variable output. Storage may be an attractive alternative to most generation-based load following for at least three reasons: 1) in general, storage has superior part-load efficiency, 2) efficient storage can be used to provide up to two times its rated capacity (for regulation), and 3) storage output can be varied rapidly (e.g., output can change from none/full to full/none within seconds rather than minutes).
Electric Supply Reserve Capacity	Generation resources used as reserve capacity must be online and operational (i.e., at part load). Unlike generation, in almost all circumstances, storage used for reserve capacity does not discharge at all – it just has to be ready and available to discharge if needed.
Voltage Support	Distributed storage may be especially attractive because reactive power cannot be transmitted efficaciously over long distances. Many major power outages are at least partially attributable to problems related to transmitting reactive power to load centers. So, distributed storage – located within load centers where most reactance occurs – provides voltage support.
Transmission Support	Energy storage used for transmission support improves T&D system performance by compensating for electrical anomalies and disturbances such as voltage sag, unstable voltage, and sub-synchronous resonance. The result is a more stable system with improved performance (throughput).
Transmission Congestion Relief	Storage could be used to avoid congestion-related costs and charges, especially if the charges become onerous due to significant transmission system congestion. Storage systems would be installed at locations that are electrically downstream from the congested portion of the transmission system. Energy would be stored when there is no transmission congestion, and it would be discharged (during peak demand periods) to reduce transmission capacity requirements.
T&D Upgrade Deferral	Consider a T&D system whose peak electric loading is approaching the system's load carrying capacity (design rating). In some cases, installing a small amount of energy storage downstream from the nearly overloaded T&D node will defer the need for a T&D upgrade.

Application	Overview
Substation Onsite Power	There are at least 100,000 battery storage systems at utility substations in the U.S. They provide power to switching components and to substation communication and control equipment when the grid is not energized. The vast majority of these systems use lead-acid batteries, mostly vented and to a lesser extent valve-regulated, with 5% of systems being powered by NiCad batteries. Apparently, users are generally satisfied, though reduced need for routine maintenance, improved reliability, and longer battery life would make alternatives attractive, especially if the cost is comparable to that of the incumbent technologies.
Time-of-Use Energy Cost Management	Involves storage used by energy end users (utility customers) to reduce their overall costs for electricity. Customers charge the storage during off-peak time periods when the electric energy price is low, and discharge the energy during times when on-peak TOU energy prices apply. Although similar to electric energy time-shift application, this application's electric energy prices are based on the customer's retail tariff vs. the prevailing wholesale price.
Demand Charge Management	Energy storage could be used by electricity end users (i.e., utility customers) to reduce the overall costs for electric service by reducing demand charges, by reducing power draw during specified periods, normally the utility's peak demand periods.
Electric Service Reliability	In the event of a complete power outage lasting more than a few seconds, the storage system provides enough energy to ride through outages of extended duration; to complete an orderly shutdown of processes; and/or to transfer to on-site generation resources.
Electric Service Power Quality	Involves using energy storage to protect on-site loads downstream (from storage) against short-duration events that affect the quality of power delivered to the load.
Renewables Energy Time Shift	Many renewable energy generation resources produce a significant portion of electric energy when that energy has a low financial value (e.g., at night, on weekends, during holidays - off-peak times). Energy storage used in conjunction with renewable energy generation could be charged using low-value energy from the renewable energy generation so that energy may be used to offset other purchases or sold when it is more valuable.
Renewables Capacity Firming	Applies to circumstances involving intermittent output from renewable energy-fueled generation. The objective is to use storage to 'fill in' so that the combined output from renewable energy generation plus storage is somewhat-to-very constant.
Wind Generation, Grid Integration, Short Duration	As wind generation penetration increases, the electricity grid effects unique to wind generation will also increase. Storage could assist with orderly integration of wind generation (wind integration) by managing or mitigating the more challenging and less desirable effects from high wind generation penetration. Short duration applications include: reduce output volatility and improve power quality.
Wind Generation, Grid Integration, Long Duration	Long duration applications include: reduce output variability, transmission congestion relief, backup for unexpected wind generation shortfall, and reduce minimum load violations.

Table C-3. Benefits Potentially Realized by Smart Grid Demonstrations

Benefit Category	Benefit Sub category	Benefit
Economic	Market Revenue*	Arbitrage Revenue (consumer) Capacity Revenue (consumer) Ancillary Service Revenue (consumer)
	Improved Asset Utilization	Optimized Generator Operation (utility/ratepayer) Deferred Generation Capacity Investments (utility/ratepayer) Reduced Ancillary Service Cost (utility/ratepayer) Reduced Congestion Cost (utility/ratepayer)
	T&D Capital Savings	Deferred Transmission Capacity Investments (utility/ratepayer) Deferred Distribution Capacity Investments (utility/ratepayer) Reduced Equipment Failures (utility/ratepayer)
	T&D O&M Savings	Reduced Distribution Equipment Maintenance Cost (utility/ratepayer) Reduced Distribution Operations Cost (utility/ratepayer) Reduced Meter Reading Cost (utility/ratepayer)
	Theft Reduction	Reduced Electricity Theft (utility/ratepayer)
	Energy Efficiency	Reduced Electricity Losses (utility/ratepayer)
	Electricity Cost Savings	Reduced Electricity Cost (consumer) Reduced Electricity Cost (utility/ratepayer)*
Reliability	Power Interruptions	Reduced Sustained Outages (consumer) Reduced Major Outages (consumer) Reduced Restoration Cost (utility/ratepayer)
	Power Quality	Reduced Momentary Outages (consumer) Reduced Sags and Swells (consumer)
Environmental	Air Emissions	Reduced Carbon Dioxide Emissions (society) Reduced SO_X, NO_X, and PM-10 Emissions (society)
Security	Energy Security	Reduced Oil Usage (society) Reduced Wide-scale Blackouts (society)

*These benefits are only applicable to energy storage demonstrations.

Table C-4. Smart Grid Assets that Provide Functions

Smart Grid Assets	Functions												
	Fault Current Limiting	Wide Area Monitoring, Visualization, and Control	Dynamic Capability Rating	Power Flow Control	Adaptive Protection	Automated Feeder Switching	Automated Islanding and Reconnection	Automated Voltage and VAR Control	Diagnosis & Notification of Equipment Condition	Enhanced Fault Protection	Real-Time Load Measurement & Management	Real-time Load Transfer	Customer Electricity Use Optimization
Advanced Interrupting Switch										•			
AMI/Smart Meters								•			•		•
Controllable/regulating Inverter							•	•					
Customer EMS/Display/Portal													•
Distribution Automation					•	•	•	•				•	
Distribution Management System			•		•	•	•	•			•	•	
Enhanced Fault Detection Technology										•			
Equipment Health Sensor			•						•				
FACTS Device				•									
Fault Current Limiter	•												
Loading Monitor			•						•			•	
Microgrid Controller							•						
Phase Angle Regulating Transformer				•									
Phasor Measurement Technology		•	•	•	•		•	•		•			
Smart Appliances and Equipment (Customer)													•
Software - Advanced Analysis/Visualization		•	•										
Two-way Communications (high bandwidth)		•			•	•	•	•			•	•	
Vehicle to Grid Charging Station													•
VLI (HTS) cables				•									

Table C-5. Smart Grid Benefits Realized by Functions and Enabled Energy Resources

Benefits			Functions													Energy Resources		
			Fault Current Limiting	Wide Area Monitoring, Visualization, and Control	Dynamic Capability Rating	Power Flow Control	Adaptive Protection	Automated Feeder Switching	Automated Islanding and Reconnection	Automated Voltage and VAR Control	Diagnosis & Notification of Equipment Condition	Enhanced Fault Protection	Real-Time Load Measurement & Management	Real-time Load Transfer	Customer Electricity Use Optimization	Distributed Generation	Stationary Electricity Storage	Plug-in Electric Vehicles
Economic	Market Revenue	Arbitrage Revenue															•	
		Capacity Revenue															•	
		Ancillary Services Revenue															•	
	Improved Asset Utilization	Optimized Generator Operation		•													•	•
		Deferred Generation Capacity Investments													•	•	•	•
		Reduced Ancillary Service Cost		•						•			•		•	•	•	•
		Reduced Congestion Cost		•	•	•									•	•	•	•
	T&D Capital Savings	Deferred Transmission Capacity Investments	•	•	•	•									•	•	•	•
		Deferred Distribution Capacity Investments			•								•	•	•	•	•	•
		Reduced Equipment Failures	•		•						•	•						
	T&D O&M Savings	Reduced Distribution Equipment Maintenance Cost									•							
		Reduced Distribution Operations Cost						•		•								
		Reduced Meter Reading Cost											•					
	Theft Reduction	Reduced Electricity Theft											•					
	Energy	Reduced Electricity Losses								•			•	•	•	•	•	
	Electricty Cost Savings	Reduced Electricity Cost													•	•	•	•
Reliability	Power Interruptions	Reduced Sustained Outages					•	•	•		•	•	•			•	•	•
		Reduced Major Outages		•					•				•	•				
		Reduced Restoration Cost					•	•			•	•						
	Power Quality	Reduced Momentary Outages										•					•	
		Reduced Sags and Swells										•					•	
Environmental	Air Emissions	Reduced CO_2 Emissions				•		•		•			•		•	•	•	•
		Reduced SO_x, NO_x, and PM-10 Emissions				•		•		•			•		•	•	•	•
Security	Energy Security	Reduced Oil Usage (not monetized)						•			•		•					•
		Reduced Widescale Blackouts		•	•													