Guidebook for ARRA Smart Grid Program Metrics and Benefits

December 7, 2009

DOE wants to work in partnership with the recipients of Smart Grid Investment Grant 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.

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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 research and development, 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 the Smart Grid Investment Grant (SGIG) program and the Smart Grid Demonstration (SGD) program ("Smart Grid Programs").

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).
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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 longer 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 DOE will collect information from each of the award recipients ("Project Teams"), and analyze the information 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
6. Carbon Dioxide Emissions.

The Guidebook for ARRA Smart Grid Program Metrics and Benefits ("Guidebook") describes the type of information to be collected from each of the Project Teams 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, DOE will gather information 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 Project Teams; analyze the information; and communicate the results to the public.

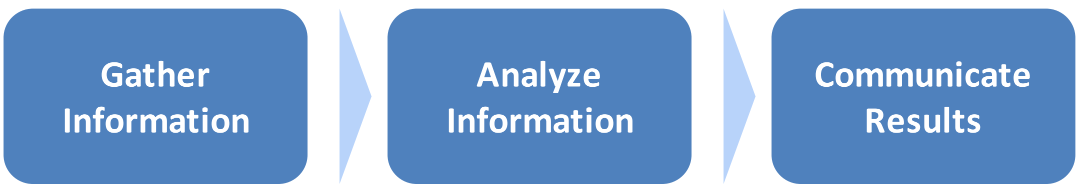


Figure 1. Approach

DOE will analyze the data provided by Project Teams to determine the impacts of the Smart Grid Programs. As mentioned previously, these impacts will be communicated within six topic areas. Communicating results will be done at the Program level, and proprietary information from individual Project Teams will not be disclosed.

2.1 Process for Gathering and Reporting Project Information

Project Teams are expected to gather information and report it using "Build Metrics" and "Impact Metrics".

Build Metrics track what the Project Teams 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 the installed capacity of renewable distributed generation leveraging smart grid technology. This will include the build metrics resulting from ARRA funding as well as from private funds supplied by the Project Team cost-share. Project Teams will report Build Metrics quarterly using structured templates. These templates will be completed as part of a Draft Metrics and Benefits Reporting Plan to be submitted within 60 days after the Project Team receives its award.

Impact Metrics measure how, and to what extent, a smarter grid is affecting grid operations and performance, or how it is enabling customer programs and behavior changes. When projects become operational, the impacts should become measureable. For example, a Project Team that has implemented distribution automation may see a significant reduction in customer outage minutes. Another Project Team may show a drop in peak demand from a Critical Peak Pricing program. Project Teams will report Impact Metrics semi-annually using structured templates. As with the Build Metric templates, these will be completed as part of the Draft Metrics and Benefits Reporting Plan. At the beginning of the project, Project Teams must also provide "Baseline" Impact Metrics. This will support "before and after" comparisons of grid performance and customer behavior as the project progresses.

Table 1 summarizes the two kinds of information that Project Teams will be required to provide 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 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.	Semi-Annually

2.2 Process for Developing the Metrics and Benefits Reporting Plan

Project Teams must submit a Draft Metrics and Benefits Reporting Plan to DOE within 60 days after award. The following outlines the process for finalizing this plan:

1. DOE provides the Guidebook to Project Teams;
2. A Benefits and Metrics Team from DOE will work with each Project Team to customize the data collection and reporting requirements for each project. This will be done using the structured templates included in Appendix A. The Benefits and Metrics Team will be working in conjunction with the DOE Project Management Team.
3. After receiving an award, each Project Team will have 60 days to work with DOE to submit a Draft Metrics and Benefits Reporting Plan.
4. DOE will review the Draft Metrics and Benefits Reporting Plan.
5. Project Teams will provide a Final Metrics and Benefits Reporting Plan upon DOE review and approval of the Draft Plan.

DOE expects to work collaboratively with Project Teams to develop consistency and quality in the methods used to calculate metrics and develop appropriate baselines. However, it is the Project Team's responsibility to collect and assemble data required to produce the metrics and benefits. In addition, Project Teams shall be available to answer questions DOE may have regarding how the metrics were developed. DOE 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[1] 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.[2] The framework described here uses Build Metrics to measure progress toward a smart grid organized into five categories, as presented in Table 2. Each category is discussed in the following sections. It should be noted that the Build Metrics obtained from the Smart Grid Programs represent only a portion of the smart grid Build Metrics to be represented in the Smart Grid Systems Report since private industry may be investing in smart grid technologies without ARRA funds. DOE requests Project Teams to report on Build Metrics that are outside the Smart Grid Programs as part of their baseline data. This information is required for subsequent updates of the Smart Grid System report and for other DOE programmatic reports.

Table 2: Build Metric Definitions

Metric Type	Description
Monetary Investments	Total project costs (DOE plus private 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

Project Teams will be required to report the total funds (DOE plus recipient cost share) that have been expended to date. DOE will work with the Project Teams to determine the appropriate amount and detail of data required for analysis. A list of data that will be required is shown in Table 3. Crosscutting projects should report monetary investments in the category with primary responsibility.

[1] "Smart Grid System Report", *U.S. Department of Energy*, July 2009, pg. 1-84, Office of Electricity website.

[2] "Metrics for Measuring Progress Toward Implementation of the *Smart Grid*", DOE Smart Grid Implementation Workshop held on June 20-21, 2008.

Table 3. Build Metrics – Monetary Investments

Project Cost Reporting by Category and Smart Grid Project Classification ($1000's)							
Cost Category	Customer Systems*	AMI	Electric Distribution	Electric Transmission	Equipment Manufacturing	Regional Demonstration	Energy Storage
Personnel	-	-	-	-	-	-	-
Contractual	-	-	-	-	-	-	-
Construction	-	-	-	-	-	-	-
Equipment	-	-	-	-	-	-	-

*Customer systems are all the smart grid devices on the customer side of the meter

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. DOE will collect information regarding the deployment of these types of devices. Attributes such as compliance with prevailing standards will also be collected.

DOE will work with the Project Teams to identify data requirements that pertain to each project. Potential data requirements for measuring progress and tracking assets are described in Table 4. Baseline data or a starting point for each Build Metric will be required as part of the reported data and information.

Table 4. 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

Table 4. Build Metrics – Electricity Infrastructure Assets (Continued)

Asset Type	Description of Information	Illustrative Examples
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
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 that have access to dynamic pricing programs, have an incentive to use the information provided by advanced metering infrastructure (AMI)/smart meters. DOE will be collecting 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.

DOE will work with the Project Teams to identify data requirements for each project such as those listed in Table 5.

Table 5. 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 Systems Report[3] 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 because it provides the basis for a system where all customers are dynamically connected, much like the Internet. For example, the smart grid may enable consumer oriented "smart" equipment, as well as other devices that can be used to enable existing equipment to respond to smart grid conditions. 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 the creation and retention of jobs will be quantitative, and the measurement of marketplace innovation will be qualitative. DOE will work with the Project Teams to identify data requirements that pertain to each project.

Project Teams 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 for measuring progress on market innovation are listed in Table 6.

Table 6. Build Metrics – Marketplace Innovation

Market Reporting by Category and Smart Grid Project Classification								
Market Category	Measure	Customer Systems	AMI	Electric Distribution	Electric Transmission	Equipment Manufacturing	Regional Demonstration	Energy Storage
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	-	-	-	-	-	-	-

Potential data requirements for measuring progress and tracking job creation and retention are listed in Table 7. Jobs will be reported by category and smart grid project classification. Jobs that involve cross-cutting smart grid projects should be allocated to the category with primary responsibility or activity. Appendix B provides the Department of Labor defined job categories that have been combined to create the eight higher level categories shown in Table 7 that will be used for reporting. Jobs created and retained should be reported in full-time equivalents (FTEs). For the purposes of reporting Build Metrics, jobs created and retained will include those resulting from ARRA funding as well as recipient funding. Jobs created and retained will be reported quarterly based on a calendar year. The requirement for reporting jobs is based on a simple calculation used to avoid overstating the number of other than full-time, permanent jobs.

[3] "Smart Grid System Report", *U.S. Department of Energy*, July 2009, pg. 1-84, Office of Electricity website.

This calculation converts part-time or temporary jobs into "full-time equivalent" (FTE) jobs. In order to perform the calculation, a recipient will need the total number of hours worked (including hours funded by the Recovery Act and hours funded by the Recipient cost share) by category and the total number of hours worked for the entire project by labor category. The number of hours in a full-time schedule for a quarter will equal 520 (one-quarter of 2,080) and for a month will equal 173.33. The formulas for reporting quarterly and monthly can be represented as follows:

Cumulative Hours Worked (qtr 1…n) / Cumulative hours in a full-time schedule (520)

Cumulative Hours Worked (month 1…n) / Cumulative hours in a full-time schedule (173.33)

Table 7. Build Metrics – Jobs Created and Retained

Job Reporting by Category and Smart Grid Project Classification (FTEs)							
Job Category	Customer Systems	AMI	Electric Distribution	Electric Transmission	Equipment Manufacturing	Regional Demonstration	Energy Storage
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	-	-	-	-	-	-	-

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

The Impact Metrics outlined in Table 8 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. DOE will use the Impact Metrics to conduct a quantitative benefits analysis.

In order to ensure consistent reporting, quantification, and monetization of benefits, DOE will apply a benefit analysis framework (see Appendix C). This framework serves as the starting point for a dialogue between the DOE Metrics and Benefits Team and each Project Team to determine the best approach for calculating benefits based on advanced grid functionality that comes from each project. DOE has developed a set of algorithms for calculating benefits based on Impact Metrics and will provide these to the Project Teams. These algorithms will be customized so that the Impact Metrics finalized between the DOE and the Project Team can be used to most appropriately calculate project benefits. DOE expects to iterate with each of the Project Teams 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. Measurements will be required for the baseline condition (i.e., prior to smart grid project implementation) as well as for after implementation for each Impact Metric and benefit that applies to a project.

Table 8. 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 8. Impact Metrics (Continued)

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).

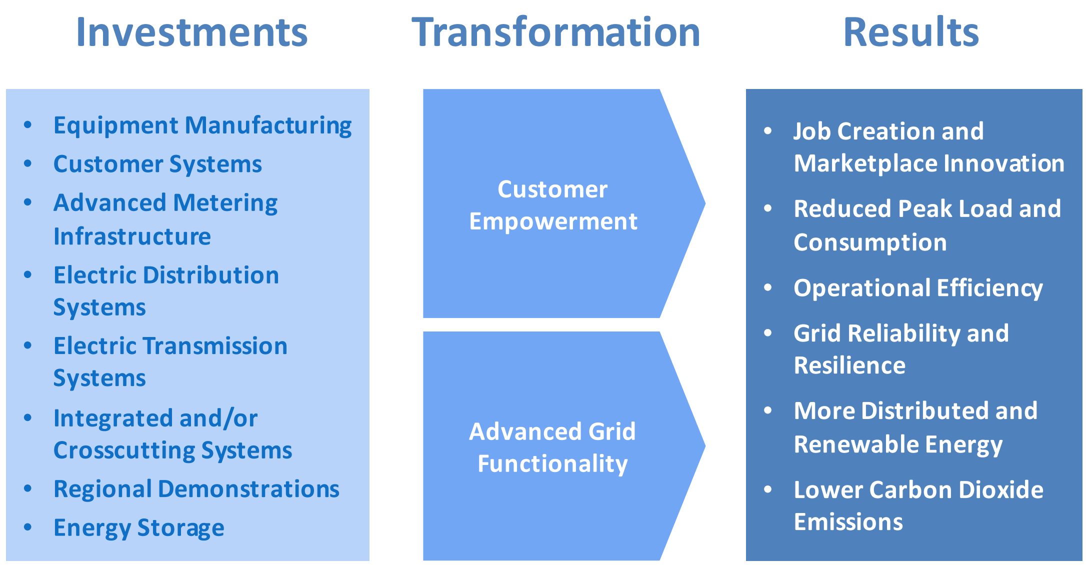


Figure 2. Smart Grid Program Investments, Transformation, and Results

DOE will use the data collected from Project Teams to track investments, monitor and measure transformation, and report the results of the smart grid investments. DOE will analyze the individual project data as well as 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 was reduced, or what the reliability impacts were, 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 should focus. These topics will also help to 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

DOE will track the total investment for the eight Smart Grid project categories areas over the next three years. This will include the cost share or match funding provided by Project Teams.

Table 9. Investments by Smart Grid Project Categories

Smart Grid Project Categories	Investment in millions			
	2010	2011	2012	Total
Customer Systems	$ -	$ -	$ -	$ -
Advanced Metering Infrastructure	$ -	$ -	$ -	$ -
Electric Distribution	$ -	$ -	$ -	$ -
Electric Transmission	$ -	$ -	$ -	$ -
Integrated and/or Crosscutting Systems	$ -	$ -	$ -	$ -
Equipment Manufacturing	$ -	$ -	$ -	$ -
Regional Demonstrations	$ -	$ -	$ -	$ -
Energy Storage	$ -	$ -	$ -	$ -

The investments made by the Smart Grid Programs will fund the deployment of technologies and tools that contribute to the development of a modernized transmission and distribution system. Assets will also be deployed to enable the active participation of customers. The Smart Grid Programs will accelerate the spread of these customer-related and grid related assets throughout the U.S. (Figure 3). DOE will measure the penetration rates of smart grid technologies, tools and techniques resulting from Smart Grid Program projects.

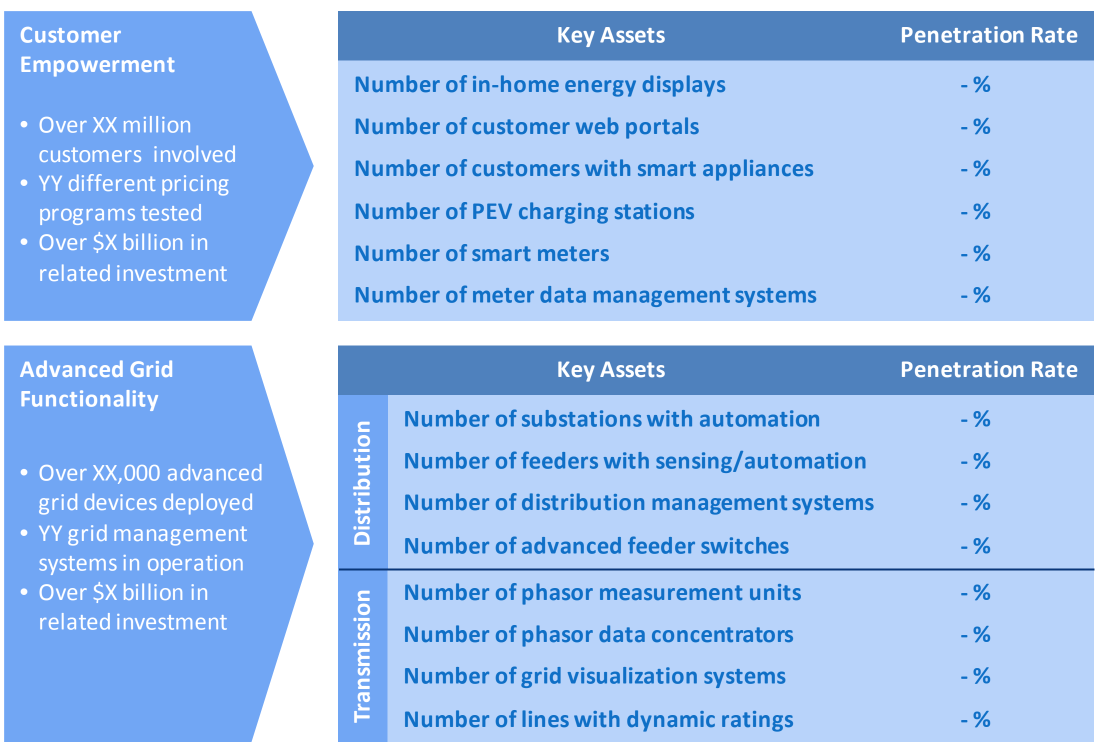


Figure 3: Assets Deployed for Customer Empowerment and Advanced Grid Functionality

4.2 Transformation of the Electric Power Sector

The assets that are deployed as part of the Smart Grid Programs will help empower electricity customers and enable advanced grid functionality for utilities. Both sides of the supply-demand relationship will gain a significant degree of information and control with which to increase the value of electricity. DOE will work with each of the Project Teams to identify the grid functionality and customer programs that will support the transformation to a modern grid. This is intended to be a collaborative process, and even though DOE has tried to be comprehensive, there may be some ideas proposed by the Project Teams that go beyond what DOE had envisioned. In such a case, DOE will work to develop a new function to describe the capability. Transformations brought about by deploying smart grid technologies fall into two major categories: electricity customer empowerment and advanced grid functionality, as shown in Figure 3, above.

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. DOE will work with these Project Teams 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.

Some Project Teams that plan to offer dynamic pricing have not planned any "controlled" evaluation of response. In such cases, DOE expects to receive aggregate participation figures (as proposed in Table 6 of the Guidebook) as well as Impact Metrics (as proposed in Table 8 of the Guidebook). However, in discussions between DOE and the Project Teams, opportunities to collect more disaggregated data might be identified. Other Project Teams have proposed evaluations of the effects of different rate, technology, and information options on consumers' electricity consumption. As indicated above, for such an approach to be successful, projects must be designed in such a way that these effects can be quantified with the necessary level of statistical precision, while also considering the nature of the data being requested.

Appendix D provides detail about the approach for evaluating the results of projects that involve advanced metering and pricing programs to better understand consumer behavior.

Advanced Grid Functionality

In addition to customer empowerment, DOE will monitor the transformation of the grid in terms of the advanced functionality realized and the related benefits. As described in Section 3 and Appendix C, DOE 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 DOE would categorize as "Demand Response".

4.3 Results

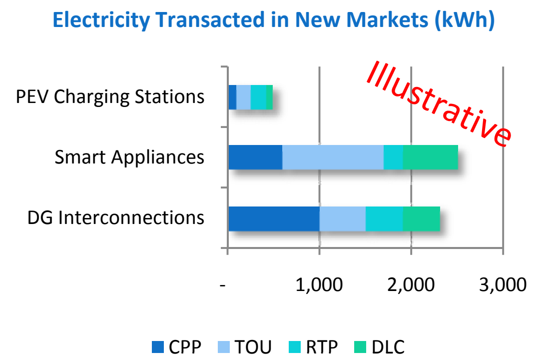
The customer empowerment and advanced grid functionality supported by the Smart Grid Programs will deliver results that DOE will communicate within six topics. These are illustrated in the following sections.

Job Creation and Marketplace Innovation

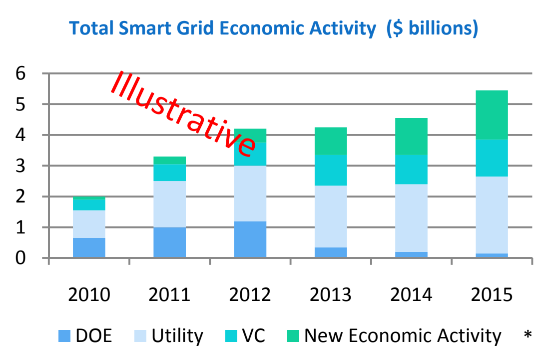
Key metrics track the economic impact of the DOE Smart Grid Programs

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

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



DOE investment has stimulated significant new economic activity

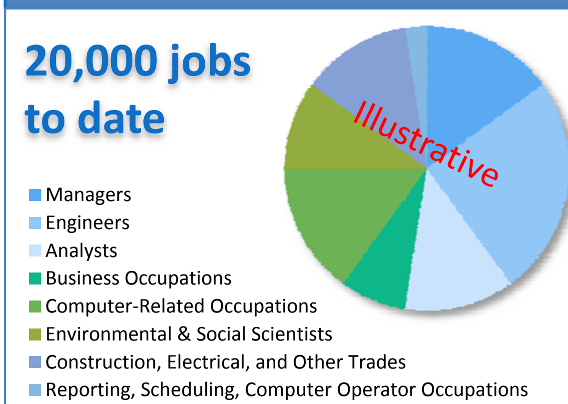


*Transaction revenue from PEVs, DG, and other new products.

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.

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

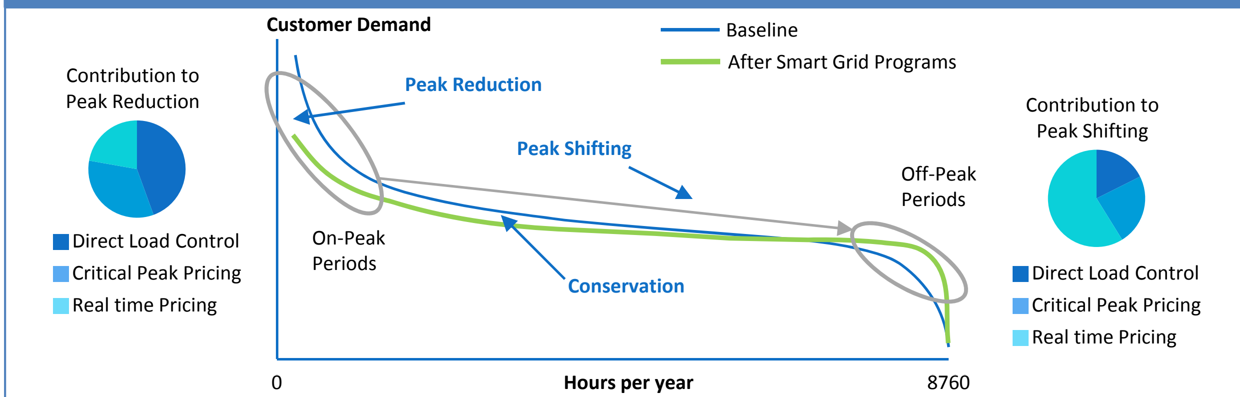


Peak Demand and Electricity Consumption

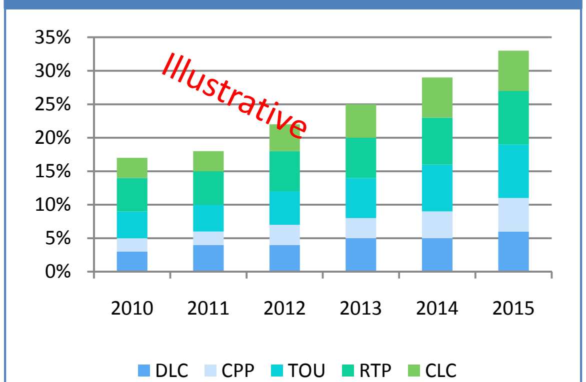
Key Assets and Customer Devices that will contribute to Demand Management	
Smart meters *(units)*	X,XXX,XXX
Customer energy displays or customers with portal access (number)	X,XXX,XXX
Distribution Automation Systems (number)	X,XXX
Grid-responsive, non-generating demand-side devices purchased *(units)*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

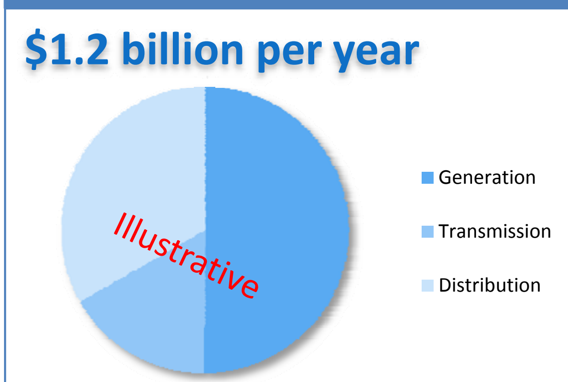
Technologies and pricing programs designed to reduce peak demand and electricity consumption have modified the load curve



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

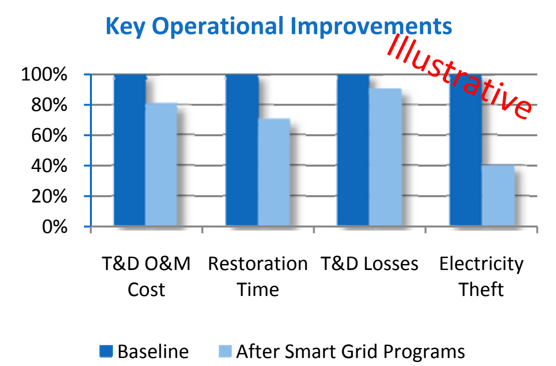
Key assets enable improvements in Operational Efficiency

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

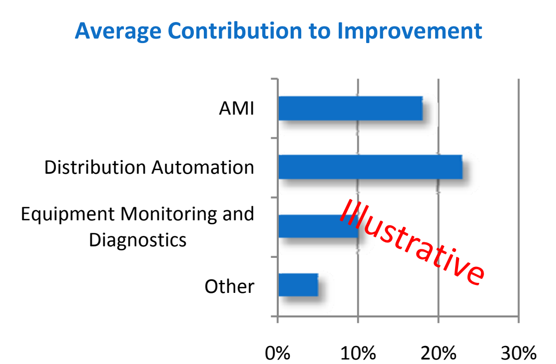
Illustrative

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 DOE-funded projects have supported this.

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

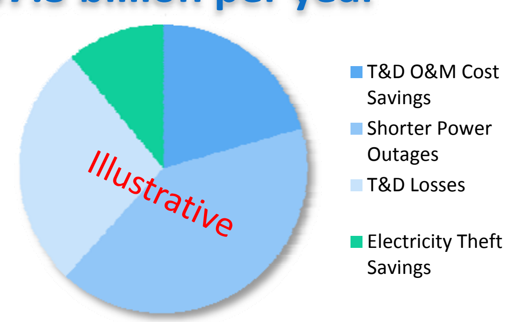


AMI and distribution automation are the major contributors to operational efficiency



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

$7.3 billion per year

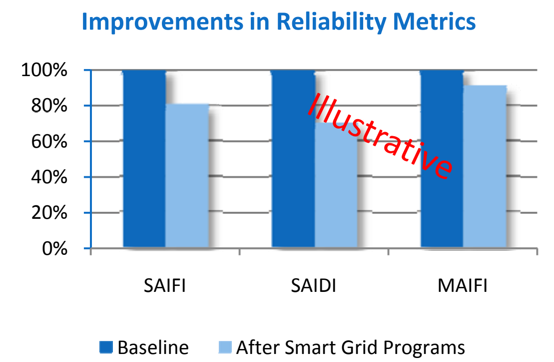


Grid Reliability and Resilience

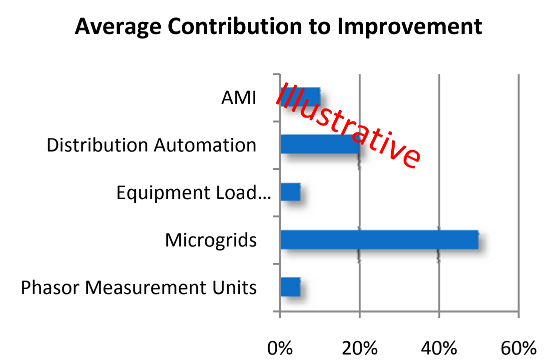
Key assets support Grid Reliability and Resilience	
Customer end-points monitored *(number of smart meters)*	2,500,000
Feeders with remote or automated switching *(number of feeders)*	123
Load served within microgrids *(MW)*	245
Phasor monitoring points on transmission *(number of PMUs)*	82
System elements 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 projects have shown reliability improvements of about 20%

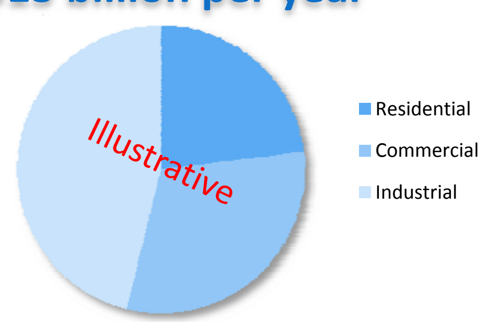


Distribution automation and microgrids make the greatest contribution to improved reliability



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

$13 billion per year



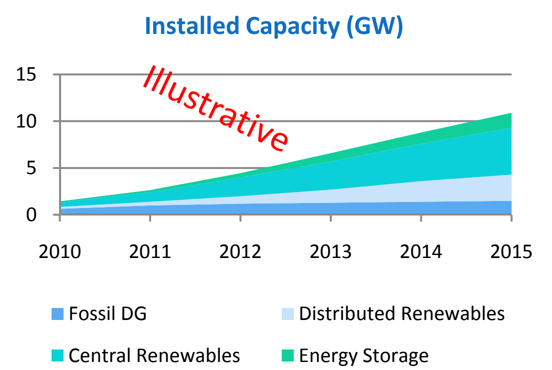
Distributed Energy Resources and Renewable Energy

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

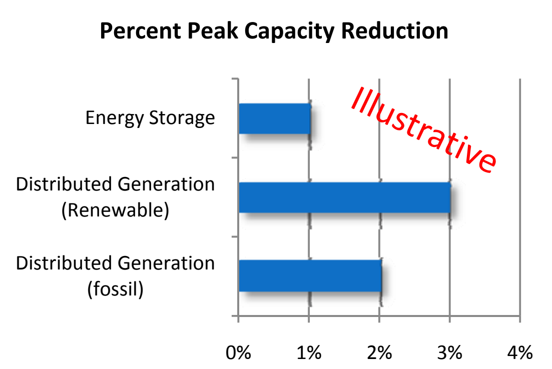
The monitoring, coordination and control capabilities supported by smart grid technologies will enable power grids to accommodate an increased number and variety of generation (including distributed renewable energy and combined heat and power, and central and remote renewable energy systems) and storage 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.

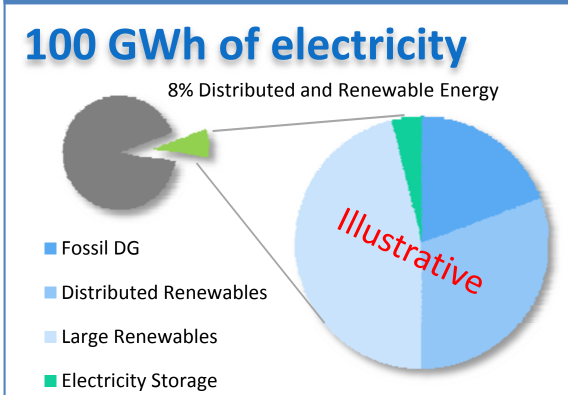
The installed capacity of distributed generation and renewable energy has increased by 270%



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



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



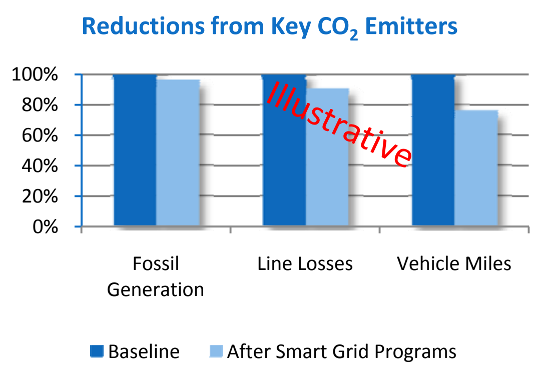
Carbon Dioxide Emissions

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

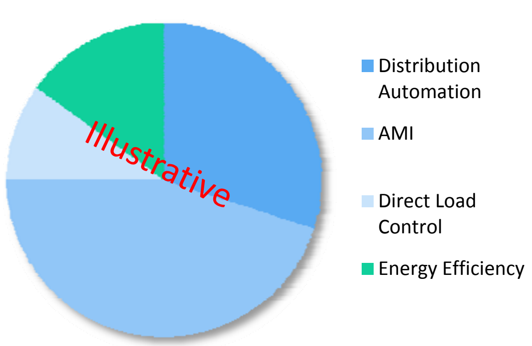
The smart grid will play a key role in facilitating the reduction of carbon dioxide (CO_2) emissions. This will be accomplished by enabling higher penetrations of renewable energy, reducing utility vehicle emissions through automation, improving the ability of utilities to manage demand thereby reducing 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.

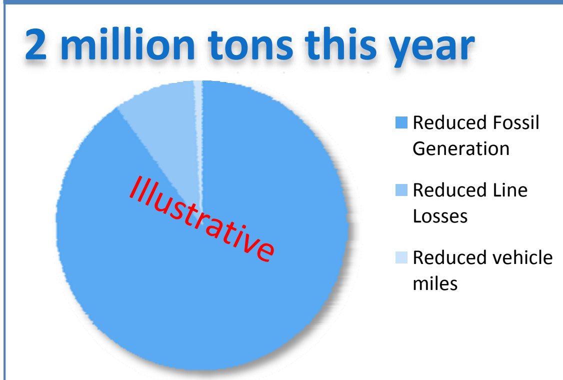
Smart Grid projects are demonstrating progress toward reducing CO_2 emissions



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 DOE's Smart Grid programs this year



Appendix A: Data Collection and Reporting Templates

Build Metrics and Impact Metrics will be reported for all projects. However, Project Teams will be expected to report only those metrics that are relevant for their project. DOE will work with each project to develop customized reporting requirements. Standard information reporting templates are provided for three types of projects:

- Advanced Metering Infrastructure and Customer Systems (Tables A-1.1 to A-1.4)
- Electric Distribution Systems (Tables A-2.1 to A-2.3)
- Electric Transmission Systems (Tables A-3.1 to A-3.2)

Projects will select the relevant metrics from these templates for reporting. DOE will provide support to projects to develop appropriate customized reporting plans. Integrated and Crosscutting projects will report information using one or more of these templates depending on the nature of the project. Customized information reporting requirements will be developed for Equipment Manufacturing projects.

In addition, standardized templates will be developed for SGD program projects (i.e., Regional Demonstrations, and Energy Storage Demonstrations) once these projects have been selected.

Table A-1. Advanced Metering Infrastructure and Customer Systems

Build Metrics

A-1.1. BUILD METRICS: AMI and Customer Systems Assets		
Metric	**Value**	**Remarks**
End-Points (meters) - Total	#	Total meters in planned implementation
End-Points (meters) - Project	#	Meters deployed as part of SGIG project
Portion of Customers with AMI		
Residential	%	Customers with AMI by class
Commercial	%	
Industrial	%	
Metering Features		
Interval reads of 1 hour or less	Interval	Indicate the read interval of meters
Remote Connection/Disconnection	Yes/No	Indicate if meters will be used for this purpose
Outage Detection/Reporting	Yes/No	
Power quality monitoring	Yes/No	
Tamper detection	Yes/No	
Backhaul Communications Network	Description	Network characteristics from collectors to head-end
Meter Communications Network	Description	Network characteristics from collectors to meters
Home Area Network	Description	Network characteristics within customer premise
Headend system	Description	Characteristics of system
Meter Data Management System	Description	Characteristics of system
Meter data analysis systems	Description	Software for analyzing and manipulating meter data
Enterprise systems integration		
Billing	Yes/No	Indicate if AMI will be integrated with system
Customer information system	Yes/No	
Outage management system	Yes/No	
Distribution management system	Yes/No	
Others	Yes/No	
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
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	Numbers of other customer devices or systems

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

A-1.3. BUILD METRICS: Distributed Energy Resources		
Metric	**Value**	**Remarks**
Distributed Generation	# MW MWh	Number of units, total installed capacity and total energy delivered
Energy Storage	# MW MWh	Number of units, total installed capacity and total energy delivered
DG Interface	Description	Characteristics of DG interface or interconnection, including information and control capability for utility
Others		Characteristics of DERs

Impact Metrics

A-1.4. Advanced Metering Infrastructure and Customer Systems		
Metric	**Value**	**Remarks**
Metrics Related Primarily to Economic Benefits		
Hourly Customer Electricity Usage	kWh $/kWh	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	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	Specify intermittent generation by type and amount
Peak Load and Mix	MW Mix	Specify controllable load by type
Annual Generation Cost	$	Total cost of generation to serve load
Hourly Generation Cost	$/MWh	Aggregate or market price of energy in each hour
Annual Electricity Production	MWh	Total electricity produced by central generation
Ancillary Services Cost	$	Total cost of ancillary services
Meter Operations Cost	$	Includes operations, maintenance, reading and data management
Truck Rolls Avoided	#	Could include trips for meter reading, connection/disconnection, inspection and maintenance
Meter Operations Vehicle Miles	Miles	Total miles accumulated related to meter operations
Metrics Related Primarily to AMI System Performance		
Meter Data Completeness	%	Portion of meters that are online and successfully reporting in
Meters Reporting Daily by 2AM	%	Portion of daily meter reads received by 2AM the following day

Table A-2. Electric Distribution Systems

Build Metrics

A-2.1. BUILD METRICS: Electric Distribution Systems Assets		
Metric	**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	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	Indicate if DA will be used for these purposes
Voltage Optimization	Yes/No	
Feeder Peak Load Management	Yes/No	
Microgrids	Yes/No	
Other Applications	Yes/No	
Distribution Management System		
Integration with AMI	Yes/No	Including loading, voltage and power quality sensing and reporting from meters
Integration with Outage Management System	Yes/No	Includes outage detection and reporting from OMS
Integration with transmission management system	Yes/No	Interface with high voltage energy management system
Integration with distributed energy resources	Yes/No	Interface with customer energy management systems and DERs
Fault Current Limiter	#	
Other Distribution devices	#	Characteristics of Distribution devices

A-2.2. BUILD METRICS: Electric Distribution Systems Distributed Energy Resources		
Metric	**Value**	**Remarks**
Distributed Generation	# MW MWh	Number of units, total installed capacity and total energy delivered
Energy Storage	# MW MW	Number of units, total installed capacity and total energy delivered
DG Interface	Description	Characteristics of DG interface or interconnection, including information and control capability for utility
Plug-in Electric Vehicle Charging Points	#	Number of charging points, capacity, and total energy transacted

Impact Metrics

A-2.3. IMPACT METRICS: Electric Distribution Systems		
Metric	**Value**	**Remarks**
Metrics Related Primarily to Economic Benefits		
Distribution feeder or equipment overload incidents	#	The total time during the reporting period that feeder or equipment loads exceeded design ratings
Distribution feeder load	MW MVAR	Real and reactive power readings for those feeders involved in the project. Information should be based on hourly loads.
Deferred Distribution Capacity Investments	$	The value of the capital project(s) deferred, and the time of the deferral
Equipment failure incidents	#	Incidents of equipment failure within the project scope, including reason for failure
Distribution Equipment Maintenance Cost	$	Activity based cost for distribution equipment maintenance during the reporting period
Distribution Operations Cost	$	Activity based cost for distribution operations during the reporting period
Distribution Feeder Switching Operations	#	Activity based cost for feeder switching operations during the reporting period
Distribution Capacitor Switching Operations	#	Activity based cost for capacitor switching operation during the reporting period
Distribution Restoration Cost	$	Total cost for distribution restoration during the reporting period
Distribution losses (%)	%	Losses for the portion of the distribution system involved in the project. Modeled or calculated.
Distribution power factor	pf	Power factor for the portion of the distribution system involved in the project. Modeled or calculated.
Metrics Related Primarily to Reliability Benefits		
SAIFI	Index	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	
MAIFI	Index	
Outage response time	Minutes	Time between outage occurrence and action initiated
Major Event Information	Event Statistics	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	#	Faults cleared that could be designated as high impedance or slow clearing
Metrics Related Primarily to Environmental Benefits		
Truck Rolls Avoided	#	Estimate of the number of times a crew would have been dispatched to perform a distribution operations or maintenance function
Distribution Operations Vehicle Miles	Miles	Total mileage for distribution operations and maintenance during the reporting period
CO2 Emissions	tons	Could be modeled or estimated
Pollutant Emissions (SOx, NOx, PM-10)	tons	Could be modeled or estimated

Table A-3. Electric Transmission Systems

Build Metrics

A-3.1. BUILD METRICS: Electric Transmission Systems		
Metric	**Value**	**Remarks**
Portion of transmission system covered by Phasor Measurement systems	%	Including lines, transmission substations, and key equipment
Phasor Measurement Systems		
PMUs	# and 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	# and Description	Make and model, security measures, consistency NASPI and synchrophasor standards, number of PMUs networked
Communications Network	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	Indicate if Phasor Measurement Systems will be used for these purposes
Post-mortem Analysis (including compliance monitoring)	Yes/No	
Voltage Stability Monitoring	Yes/No	
Thermal Overload Monitoring	Yes/No	
Improved State Estimation	Yes/No	
Steady-State Model Benchmarking	Yes/No	
DG/IPP Applications	Yes/No	
Power System Restoration	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

Impact Metrics

A-3.2. IMPACT METRICS: Electric Transmission Systems		
Metric	**Value**	**Remarks**
Metrics Related Primarily to Economic Benefits		
Peak Generation and Mix	MW Mix	Specify intermittent generation by type and amount
Peak Load and Mix	MW Mix	Specify controllable load by type
Annual Generation Cost	$	Total cost of generation to serve load
Hourly Generation Cost	$/MWh	Aggregate or market price of energy in each hour
Annual Generation Dispatch	MWh	Total electricity produced by central generation
Ancillary Services Cost	$	Total cost of ancillary services
Congestion (MW)	MW	Total transmission congestion during the reporting period
Congestion Cost	$	Total transmission congestion cost during the reporting period
Transmission line or equipment overload incidents	#	The total time during the reporting period that line loads exceeded design ratings
Transmission line load	MW MVAR	Real and reactive power readings for those lines involved in the project. Information should be based on hourly loads.
Deferred Transmission Capacity Investments	$	The value of the capital project(s) deferred, and the time of the deferral.
Equipment failure incidents	#	Incidents of equipment failure within the project scope, including reason for failure
Transmission Equipment Maintenance Cost	$	Activity based cost for transmission equipment maintenance during the reporting period
Transmission Operations Cost	$	Activity based cost for transmission operations during the reporting period
Transmission Restoration Cost	$	Total cost for transmission restoration during the reporting period
Transmission losses	%	Losses for the portion of the transmission system involved in the project. Could be modeled or calculated.
Transmission power factor	pf	Power factor for the portion of the transmission system involved in the project. Could be modeled or calculated.
Metrics Related Primarily to Reliability Benefits		
SAIFI	Index	Index calculated for the portion of the transmission system involved in the project.
SAIDI/CAIDI	Index	
MAIFI	Index	
Metrics Related Primarily to Environmental Benefits		
Truck Rolls Avoided	#	Estimate of the number of times a crew would have been dispatched to perform a transmission operations or maintenance function
Transmission Operations Vehicle Miles	Miles	Total mileage for transmission operations and maintenance during the reporting period
CO_2 Emissions	Tons	Could be modeled or estimated
Pollutant Emissions (SOx, NOx, PM-10)	Tons	Could be modeled or estimated

A-3.2. IMPACT METRICS: Electric Transmission Systems		
Metric	**Value**	**Remarks**
Metrics Related Primarily to Energy Security Benefits		
Event Capture and Tracking		
Type and size	Cause Load lost	Causes could include line trips, generator trips, or other disturbances
Duration	Minutes	
PMU dynamic data	PMU Data	From related PMUs
Detection	Application	Application that detected the event
Events Prevented	#	Include reason for prevention
Metrics Related Primarily to PMU/PDC System Performance		
PMU Data Completeness	%	Portion of PMUs that are operational and successfully providing data
Network Completeness	%	Portion of PMUs networked into regional PDCs
PMU/PDC Performance	Reliability Quality	
Communications Performance	Availability	
Application Performance	Description	Usefulness of applications, including reliability improvements, markets and congestion management, operational efficiency

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 and Benefits

While every project may have a different way of approaching the smart grid, and may articulate functionality that projects provide using different terms, DOE will apply a common terminology to compare and report the efforts 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 for that team. 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, portal) and a program where they are sending pricing signals or commands to customers. In DOE's terms, both projects would involve "Real Time Load Measurement & Management" as a function. Both of the projects would also involve a policy/program that DOE would call "Demand Response".

DOE will work with Project Teams to determine which standard functions they support. This is intended to be a collaborative process, and even though DOE has tried to be comprehensive, there may be some ideas proposed by the Project Teams that go beyond what DOE had envisioned. In such a case, DOE will develop a new function to describe the capability. However, DOE recognizes that even though each project will have unique aspects, most of the time different utilities are really pursuing similar ideas but using different words. Therefore, DOE will work to find the common areas so that key impacts and effects can be clearly articulated across the smart grid program.

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:

- Fault Current Limiting
- Wide Area Monitoring and Visualization and Control
- Dynamic Capability Rating
- Power Flow Control
- Adaptive Protection
- Automated Feeder Switching
- Automated Islanding and Reconnection
- Automated Voltage and VAR Control
- Diagnosis and Notification of Equipment Condition
- Enhanced Fault Protection
- Real-time Load Measurement and Management
- Real-time Load Transfer
- Customer Electricity Use Optimization

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-2.) 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-3 presents the linkage between assets and functions. Table C-4 shows the relationship between the functions and the benefits realized. All benefits will require an approach for calculating the baseline value to be used for comparison and Project Teams 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 Project Teams 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 Project Teams will be required to collect and assimilate raw data and then report the outcome, as project benefits to DOE. However, in a few predetermined cases, the Project Team will be required to report raw data and DOE will process it to determine what the outcome was. DOE 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.

The complete methodology used to determine the benefits as a result of smart grid systems is presented in a report entitled, "Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects". This report will be provided to all Project Teams and will be publically available.

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 distributed generation (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	This function provides real-time measurement of customer consumption and management of load through Advanced Metering Infrastructure (AMI) systems (smart meters, two-way communications) and embedded appliance controllers that help customers make informed energy use decisions via real-time price signals, time-of-use (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.
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. Smart Grid Benefits

Benefit Category	Benefit Sub-category	Benefit
Economic	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)
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)

Table C-3. 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-4. 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	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		•	•													

Appendix D: Consumer Behavior Study Approach (involving Dynamic Pricing with Randomization)

This appendix provides additional information concerning the metrics DOE expects to collect specifically from dynamic pricing projects that may include technology, education/information delivery and content, and other aspects enabled by the implementation of the smart grid, in order to ensure the study design appropriately includes data collection efforts necessary to calculate and report these metrics in a consistent and accurate manner.

General DOE Approach to Study Electricity Consumption Behavior

DOE is interested in an approach to dynamic pricing projects that will produce a better understanding of how the smart grid, the technologies it enables, and the information it provides affect electricity consumption behavior.

The Smart Grid Programs provide guidance for advanced metering and dynamic pricing.[4] DOE will work with each Project Team to ensure the framework of the proposed study design is consistent with the intent of the guidelines included in the Funding Opportunity Announcement. For example, study designs should include descriptions of approaches for achieving acceptable levels of statistical accuracy and precision (e.g. minimum size for control and treatment groups given various factors) in the subsequent analysis and metrics that are produced. Ideally, the study designs proposed by Project Teams should have statistical accuracy and precision of no less than 90% confidence level and 10% relative precision. Treatment and control groups should include customers with similar characteristics and attributes; Project Teams will have to demonstrate that their sample has been appropriately stratified to achieve the desired level of statistical precision.

Data Collection

In consultation with DOE, Project Teams will evaluate the feasibility of compiling the data required for subsequent analysis of their dynamic pricing project, and will make plans for how that data will be collected and organized. Hourly sales and retail electricity price data are necessary, at a minimum, to do any assessment of consumer response to changes in price. However, to broaden the Project Team's and industry's understanding of how individual or cohorts of customers are reacting to the information provided by smart meters and to dynamic pricing in general, a disaggregated level of detail is required (i.e., customer level data). If the project is able to help address research questions such as, for example, an evaluation of response due to different forms and penetration of smart grid enabled technology, then the timing, stock, and use of this technology should be collected for each participant in the study.

[4] Smart Grid Investment Grant Program, Funding Opportunity Number: DE-FOA-0000058, "Special Instructions for Applications Involving Advanced Metering with Dynamic Pricing and Randomization."

Furthermore, there may be unobservable differences among customers (or similar groups of customers) that may drive acceptance and responsiveness to dynamic pricing. In this regard, DOE strongly advocates for Project Teams to seriously consider collecting household demographic and/or company characteristic data as well as other key information as part of the project plan to allow the subsequent analysis to better explain differences in consumption and drivers of behavior.

Data Reporting

DOE needs to fully understand how taxpayers' money is facilitating the expansion of smart meters and dynamic pricing and how consumer behavior is influenced by the range of options the smart grid enables. To that end, DOE will expect Project Teams to comply with specific data reporting requirements.

In all cases, DOE expects to receive aggregate participation figures (as proposed in Table 7 of the Guidebook) as well as Impact Metrics (as proposed in Table 9 of the Guidebook) on a regular basis. A more detailed set of Impact Metrics will also be collected from projects involving advanced metering with dynamic pricing and randomization in order to assess more detailed effects (Table D-1).

DOE strongly urges all Project Teams to include in their evaluation plan the estimation of a fully-specified consumer demand model from which elasticity estimates can be derived. However, it is expected that some Project Teams may instead focus solely on estimating load impacts from event-based dynamic pricing projects because they are simply implementing dynamic pricing that the Smart Grid now enables. In those latter cases, the Project Team will not be expected to report the elasticity metrics, but will be still be responsible for providing the other dynamic pricing metrics listed. The peak demand and electricity consumption dynamic pricing Impact Metrics should be reported both in actual terms (i.e., what was observed or derived during the project) as well as weather-normalized for 1 year in 10 and 1 year in 2 weather patterns.[5]

DOE expects the dynamic pricing projects being funded through the Smart Grid Programs will allow the industry to gain a better understanding of, among other things, the distribution of price response among customers, what characteristics are associated with customer responsiveness to dynamic pricing, if these characteristics are common across the broad range of Smart Grid projects with dynamic pricing that DOE is funding, and if these cohorts exhibit uniform or diverse impacts across projects. To achieve this goal, each Project Team will be expected to collect detailed customer information about each of its participants in the dynamic pricing project.

DOE strongly prefers Project Teams report all detailed dynamic pricing Impact Metrics and customer characteristic data at the individual customer-level, which will more readily allow DOE to answer the distributional questions cited above. If the Project Team is unable to do so

[5] Ideally, the weather normalization methodology would be consistent with the approach identified in the California Public Utility Commission's decision adopting protocols for estimating demand response load impacts (Rulemaking 07-01-041). See http://docs.cpuc.ca.gov/published/FINAL_DECISION/81972.htm for more details.

because of the modeling approach undertaken, the dynamic pricing Impact Metrics must be reported for each of the customer characteristic levels (i.e., cohorts) described above. This way the dynamic pricing Impact Metrics can be readily and easily compared at the cohort level across all Project Teams, either because they were reported to DOE that way or will be rolled-up by DOE after-the-fact from the customer-level data provided to DOE.

Tables D-2 and D-3 present the characteristics and associated attributes of residential and commercial/industrial customers that DOE wishes to collect. Table D-4 presents the data fields that are applicable to consumer behavior studies and will be reported to DOE.

Table D-1. Dynamic Pricing Impact Metrics

IMPACT METRICS: Dynamic Pricing		
Metric	**Value**	**Remarks**
Elasticity of Substitution		
Own-Price Elasticity of Demand		
Cross-Price Elasticity of Demand		
Daily Demand Elasticity		
Impact on system coincident peak demand (% and MW)	% MW	Single hour where system coincident peak demand occurs
Impact on future reliability requirement (% and MW)	% MW	Over time period determined by local reliability rules for setting future reserve margins and capacity requirements
Average hourly impact on consumption over all events or peak period (% and MWh/Hour)	% MWh	Time period will depend on rate design
Standard error of hourly impact on consumption over all events (% and MWh/Hour)	% MWh	Time period will depend on rate design
Average annual impact on consumption (% and MWh)	% MWh	Ideally based on 12 consecutive months, but may need to limit depending upon the duration of the project
Standard error of annual impact on consumption (% and MWh/Hour)	% MWh	Ideally based on 12 consecutive months, but may need to limit depending upon the duration of the project

Table D-2. Characteristics and Associated Attributes of Residential Customers

Residential Customers	
Characteristics	**Attribute Levels**
Average Daily Use	• <50% of class average • 50%-150% of class average • >150% of class average
Education Level (Head of Household)	• High School degree or less • College education with associates and/or bachelors degree • College education with advanced degree (more than four years; masters or PHD)
Annual Income Level (Household)	• < $30,000 • $30,000 - $70,000 • >$70,000
Housing Type	• Single-family detached/attached and multi-family (1-4 units) • Multi-family (> 4 units)
Number of Occupants	• 1 • 2 • 3 or more
Owner/Renter	• Owner of residence • Renter of residence
Air-Conditioning	• None • Room A/C • Central A/C
Swimming Pool	• Yes • No
Spa/Hot Tub/Whirlpool	• Yes • No
Retail Rate Design and Rate Level	• Flat • Flat with Critical Peak Pricing • Flat with Peak Time Rebate • Tier • Tier with Critical Peak Pricing • Tier with Peak Time Rebate • Time-of-Use • Variable Peak Pricing • Time-of-Use with Critical Peak Pricing • Time-of-Use with Peak Time Rebate • Real-Time Pricing • Real-Time Pricing with Critical Peak Pricing • Real-Time Pricing with Peak Time Rebate
Enabling Technology	• Programmable Controllable Thermostat • In-Home Display • In-Home Energy Management System • Web Portal • Smart Appliances • Direct Load Control
Educational/Information Material	• Delivery Method - Paper (e.g., bill inserts, mailers) - Electronic (e.g., email messages, social networking) • Timing of Information - Near Real-time feedback - Delayed feedback (1 hour or more) • Level of Detail - End-use - Aggregate household/meter

Table D-3. Characteristics and Associated Attributes of Commercial and Industrial Customers

Commercial and Industrial Customers	
Characteristics	**Attribute Levels**
Average Daily Use	• <50% of class average • 50%-150% of class average • >150% of class average
Business Class	• 2-digit NAICS
On-site Generation	• Yes • No
Square Footage	• <15,000 sq. ft. • 15,000 to 100,000 sq. ft. • >100,000 sq. ft.
Retail Rate Design and Rate Level	• Flat • Flat with Critical Peak Pricing • Flat with Peak Time Rebate • Tier • Tier with Critical Peak Pricing • Tier with Peak Time Rebate • Time-of-Use • Variable Peak Pricing • Time-of-Use with Critical Peak Pricing • Time-of-Use with Peak Time Rebate • Real-Time Pricing • Real-Time Pricing with Critical Peak Pricing • Real-Time Pricing with Peak Time Rebate
Enabling Technology	• Energy Management and Control Systems • Direct Load Control (e.g., peak load controllers for specific equipment) • Programmable Controllable Thermostat
Education/Information Material	• Delivery Method - Paper (e.g., bill inserts, mailers) - Electronic (e.g., email messages, social networking) • Timing of Information - Near Real-time feedback - Delayed feedback (1 hour or more) • Level of Detail - End-use - Aggregate meter

Table D-4. Specific Data Fields Applicable to Consumer Behavior Studies

Field	Description
Hourly Data	
Customer_ID	Unique identifier given to every participant in the dynamic pricing project. This should act to mask the actual customer account number.
Meter_ID	Unique identifier given to every meter that reports data to be used in the dynamic pricing project.
Date	Date for which this interval observation is valid.
Hour-Ending	Hour-ending for which this interval observation is valid.
Energy	Interval energy consumption (kWh)
Tariff_Rate_ID	Unique identifier given to the tariff rate this customer was on during this interval
Applicable Retail Rate	Tariff rate that customer was billed on during this interval ($/kWh)
THI	Temperature heat index in degrees Fahrenheit
Dry_bulb	Average hourly dry bulb temperature (degrees fahrenheit) of nearest weather station to meter
Wet_bulb	Average hourly wet bulb temperature (degrees fahrenheit) of nearest weather station to meter
Wind_Speed	Average hourly wind speed (knots) of nearest weather station to meter
Cloud_Cover	Average cloud cover (%) at nearest weather station to meter
Tariff Data	
Tariff_Rate_ID	Unique identifier given to the tariff rate this customer was on during this interval
Start_Date	Start date for which this tariff record applies
Cust_Chg	Monthly customer charge ($/Customer)
Dmd_Chg	Monthly demand charge ($/kW)
Energy_Flat_Chg	Charge for incremental energy consumption ($/kWh)
Energy_CPP_Chg	Charge for incremental energy consumption during Critical Peak Pricing events ($/kWh)
Energy_PTR_Crdt	Credit for incremental energy reduction during Peak Time Rebate events ($/kWh)
Energy_TOU1_Chg	Charge for incremental energy consumption during TOU Period 1 ($/kWh)
Energy_TOU2_Chg	Charge for incremental energy consumption during TOU Period 2 ($/kWh)
Energy_TOU3_Chg	Charge for incremental energy consumption during TOU Period 3 ($/kWh)
Energy_TOU4_Chg	Charge for incremental energy consumption during TOU Period 4 ($/kWh)
Energy_TOU5_Chg	Charge for incremental energy consumption during TOU Period 5 ($/kWh)
Energy_TOU6_Chg	Charge for incremental energy consumption during TOU Period 6 ($/kWh)
TOU1_Descr	Description of time covered by TOU Period 1
TOU2_Descr	Description of time covered by TOU Period 2
TOU3_Descr	Description of time covered by TOU Period 3
TOU4_Descr	Description of time covered by TOU Period 4
TOU5_Descr	Description of time covered by TOU Period 5
TOU6_Descr	Description of time covered by TOU Period 6

Table D-4. Specific Data Fields Applicable to Consumer Behavior Studies (Continued)

Field	Description
Residential Customer Data	
Customer_ID	Unique identifier given to every participant in the dynamic pricing project. This should act to mask the actual customer account number
Meter_ID	Unique identifier given to every meter that reports data to be used in the dynamic pricing project
Start_Date	Start date for data contained in this record
Avg_Daily_Use	Average daily use (as % of class average) for 12-month period prior to commencement in dynamic pricing project
Education	Education level of the head of household: 1)High school only; 2)Some college, AS, BA, BS; 3)Advanced
Income	Annual income level for entire household: 1)<$30,000; 2)$30,000 - $70,000; 3) >$70,000
Housing_Type	Type of housing for residence: 1) Single-family detached/attached or multi-family of 1-4 units; 2) Multi-family of > 4 units
Occupants	Number of occupants at residence: 1) 1;, 2) 2; 3) 3 or more
Owner_Renter	Type of occupancy arrangement: 1) Owner, 2) Renter
Pool	Swimming pool at residence: 0) No; 1) Yes
Spa	Spa at residence: 0) No; 1) Yes
AC	Air-condition at residence: 1) None; 2)Room A/C; 3) Central A/C
PCT	Possession of programmable controllable thermostat: 0) No; 1) Yes
IHD	Possession of in-home display: 0) No; 1) Yes
EMS	Possession of energy management system: 0) No; 2) Yes
Web	Possession of web portal: 0) No; 1) Yes
Smart_App	Possession of smart appliances: 0) No; 1) Yes
DLC	Possession of direct load control: 0) No; 1) Yes
Inf_Dlvry	Meter data and/or dynamic pricing Information delivery method: 1) Paper; 2) Electronic
Inf_Timing	Timing of meter data and/or other dynamic pricing information feedback: 1) Near real-time of less than 1 hour, 2) Delayed of 1 hour or more
Inf_Level	Level of detail of information feedback: 1) End-use; 2) aggregate household/meter
Non-Residential Customer Data	
Customer_ID	Unique identifier given to every participant in the dynamic pricing project. This should act to mask the actual customer account number
Meter_ID	Unique identifier given to every meter that reports data to be used in the dynamic pricing project
Start_Date	Start date for data contained in this record
Avg_Daily_Use	Average daily use (as % of class average) for 12-month period prior to commencement in dynamic pricing project
NAICS_2Digit	2-digit NAICS
OnSite_Gen	On-site generation is available for use in response to pricing: 0) No; 1) Yes
Sq_Ft	Square feet of space
PCT	Possession of programmable controllable thermostat: 0) No; 1) Yes
EMS	Possession of energy management system: 0) No; 1) Yes
DLC	Possession of direct load control: 0) No; 1) Yes
Inf_Dlvry	Meter data and/or dynamic pricing Information delivery method: 1) Paper; 2) Electronic
Inf_Timing	Timing of meter data and/or other dynamic pricing information feedback: 1) Near real-time of less than 1 hour, 2) Delayed of 1 hour or more
Inf_Level	Level of detail of information feedback: 1) End-use; 2) aggregate household/meter

Table D-4. Specific Data Fields Applicable to Consumer Behavior Studies (Continued)

Field	Description
Bill History	
Customer_ID	Unique identifier given to every participant in the dynamic pricing project. This should act to mask the actual customer account number.
Meter_ID	Unique identifier given to every meter that reports data to be used in the dynamic pricing project.
Bill_Start_Date	Start date for data contained in this record
Bill_End_Date	End date for data contained in this record
Energy	Total energy consumption for the billing period for the specified meter (kWh)
Demand	Maximum demand for the billing period, if specified, for the specified meter (kW)
Ratch_Demand	Ratched demand used for billing period, if specified, for specified meter (kW)
Cost	Total cost of electricity bill for the specified meter ($)
Ec_Dev_Cost	Total cost of electricity bill for the specified meter that corresponds with reduced cost electricity for economic development reasons ($)