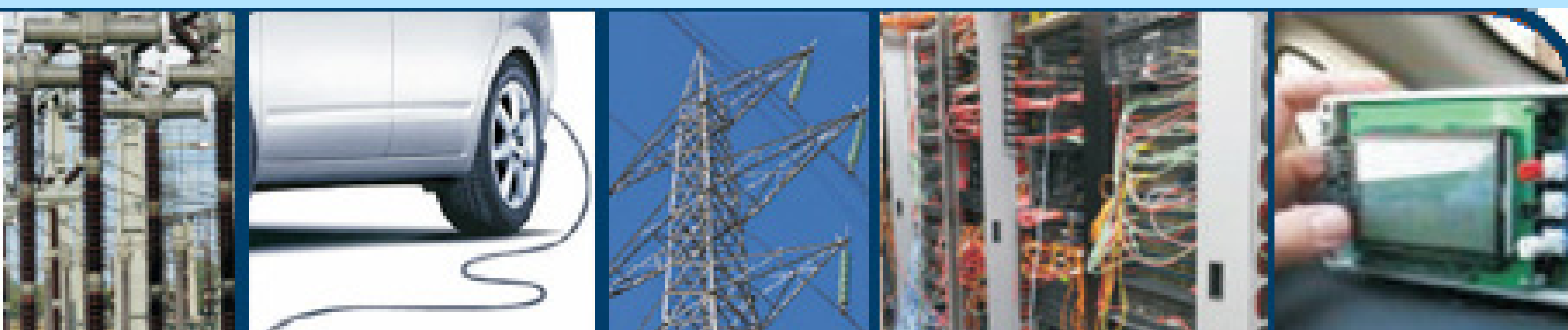
Metrics for Measuring Progress Toward Implementation of the *Smart Grid*

Results of the Breakout Session Discussions *at the* Smart Grid Implementation Workshop



Office of Electricity Delivery and Energy Reliability

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Prepared by
Energetics Incorporated
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Executive Summary

On June 19-20, 2008, the U.S. Department of Energy's (DOE) Office of Electricity Delivery and Energy Reliability (OE) held a technical workshop on metrics for measuring progress toward implementation of smart grid technologies, practices, and services. More than 140 experts from utilities, equipment manufacturers, state agencies, universities, and national laboratories attended. The aim was to identify metrics for each of the seven major smart grid characteristics, and to discuss data sources and measurement methods for assessing the degree to which smart grid technologies, practices, and services are being implemented by power companies, service providers, customers, and others.

Major Findings

- General agreement was reached among the major "thought leading" groups – GridWise Alliance, Electric Power Research Institute, Edison Electric Institute, Galvin Initiative, and the Modern Grid Strategy – on the seven major characteristics. Specifically, a properly planned, designed, implemented, and operated smart grid will:
    - Enable active participation by consumers
    - Accommodate all generation and storage options
    - Enable new products, services, and markets
    - Provide power quality for the range of needs in a digital economy
    - Optimize asset utilization and operating efficiency
    - Anticipate and responds to system disturbances in a self-healing manner
    - Operate resiliently against physical and cyber attack and natural disasters

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- Measuring progress toward implementation of smart grid involves identifying metrics, establishing baselines, and collecting data to track developments. In doing this there is need to account for the level of development and deployment that has already occurred and to recognize that the topology of each utility's transmission and distribution system may require its own baselines, targets, and measurement approaches. As a result, it is probably not appropriate to track smart grid implementation in the same way for every entity who adopts smart grid technologies, practices, and services.
- Examples of smart grid metrics for the seven characteristics listed above include:
    - Percentage of customers capable of receiving information from grid operators and the percentage of customers opting to make or delegate decisions about electricity consumption based on that information
    - Percentage of distributed generation and storage devices that can be controlled in coordination with the needs of the power system
    - The number of smart grid products for sale that have been certified for "end-to-end" interoperability
    - The number of measurement points per customer for collecting data on power quality, including events and disturbances
    - The amount of distributed generation capacity (MW) that are connected to the electric distribution system and are available to system operators as a dispatchable resource
    - The percentage of grid assets (e.g., transmission and distribution equipment) that are monitored, controlled, or automated
    - The percentage of entities that exhibit progressively mature characteristics of resilient behavior

Path Forward

- Further research and analysis is needed to refine the metrics and develop methodologies and data for establishing baselines and measuring progress toward implementation. DOE plans to use the metrics to define the research, development, demonstration, analysis, and technology transfer activities it will undertake as authorized by Title XIII of the Energy Independence and Security Act of 2007. Other stakeholders – including electric power companies, state agencies, equipment and software manufacturers and vendors, and consumer and environmental groups – are invited to use these metrics to plan, design, implement, and evaluate their own smart grid efforts.

- Because smart grid covers a variety of technologies, practices, and services—covering electric generation and storage, delivery, and consumption—misunderstandings about what it is (and what it is not) are common. There is an urgent need to provide educational materials about smart grid that contains consistent definitions and concrete examples. The key audiences today for these materials are state utility regulators, offices of consumer advocates, and environmental and consumer groups. To have the greatest impact, the information needs to be fact-based, unbiased, neutral, and non-promotional. In the future, as implementation proceeds, there is a larger educational need to train the next generation of electricity planners, operators, engineers, and technicians about all things smart grid.

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1. Enables Active Participation by Consumers

Successful smart grid implementation requires that electricity customers—residential, commercial, industrial, and institutional—have the information and the tools needed to participate in the market. Clear and consistent information, e.g., when the grid experiences peak demand, and effective tools, e.g., switches and smart appliances, enables informed and active customer participation in the smart grid. Service providers and others need to be encouraged to develop interoperable devices, programs, and other services on a timely basis to enable customers to participate in smart grid programs.[1] Customers need to see the "value proposition" for participating in the smart grid, and that their utility bills will be reduced. Levels of knowledge and quality of information will differ by region, utility, and delivery point on the grid; understanding these regional and local differences will impact the manner in which customers participate in smart grid decisions. Regulators, legislators, and others need to be educated on the opportunities provided by the smart grid, as well as the costs and benefits of smart grid investments. Cost recovery of these investments continues to be a barrier to implementation, which in turn affects customer participation in smart grid programs. Participation also hinges on the accurate design of electricity rates that reflect appropriate economic realities. This type of rate design is occurring in many areas across the country, and should continue. Finally, feedback on the impact of customer participation in the smart grid will be necessary to allow and improve coordination between the utility and its customers, to minimize customer disruptions, and improve customer service.

Suggested Revised Wording for the Characteristic: *Enables Informed Participation by Customers*

Key implementation metrics for enabling informed customer participation in the smart grid include:

- Percent of customers/premises capable of receiving information from the grid
- Percent of customers opting to make decisions and/or delegate decision-making authority
- Number of communication-enabled, customer-side of the meter devices sold
- Number of customer-side of the meter devices sending or receiving grid related signals
- Amount of load managed
- Measurable energy savings by customers

Percent of Customers/Premises Capable of Receiving Information from the Grid &
Percent of Customers Opting to Make Decisions and/or Delegate Decision-Making Authority

These two metrics are discussed together because they reflect both the *potential* and the *actual* effort required to equip customers and buildings/facilities with equipment, switches, and other enabling devices to send and receive information from the grid. If successful, customers will be able to make smart grid decisions themselves or delegate decision-making authority, the utility, or to a third party. The first step in the process is the purchase and installation of communication signaling infrastructure at the customer's place of residence or business. This "end use" device must be installed so that information can be gleaned and decisions then made. The grid and usage signals are then recognized and acknowledged by the user, and the customer then responds. Sources of information include the FERC Form 1 as well as trade groups, such as EEI, that can inform customers about the signaling infrastructure needed and the most effective manner for grid-related decision-making. To begin this process, two important pieces of data are required: the percentage of customers who already have devices and/or appliances with consumption and grid-related information available, and the percentage of customers that opt-in to participating in the smart grid.

Number of Communication-Enabled, Customer-Side of the Meter Devices Sold (Cumulative)

The first step in developing this metric is to define "communication-enabled." This may refer to imbedded electronic signaling software that allows customers to control the device, or that allows the utility or third party to

[1] The Energy Independence and Security Act of 2007 establishes a process for developing national smart grid interoperability standards under the National Institutes for Standards and Technology. The standards fall into two categories: 1) Mandatory interoperability standards under the federal Energy Regulatory Commission for wholesale electricity markets, and 2) voluntary interoperability standards for electrical products subject to the Energy Policy and Conservation Act (in other words those electrical products subject to national energy efficiency standards).

control it over the Internet. One issue that needs to be addressed is the life cycle of various products, such as water and space heaters, microwaves, refrigerators, etc. Because some of these products have longer product lives, the data stored in them may become distorted over time. In addition, identifying which types of products to include, and which not to include, is an important issue, particularly when considering the wide range of residential, commercial, industrial, and institutional facilities in which they are installed. Once these issues are settled, these devices must be labeled as “smart grid” or “peak load” devices, much like the ENERGY STAR label, with information/data on the labels provided by utilities, manufacturers, or other reliable entities. In order to determine the number of communication-enabled, customer-side devices sold, the challenge is to track them through the manufacturers’ own data and/or with the help of end-use customer sampling and point-of-sale data. It is assumed that no such devices have been sold (i.e., that the baseline is zero), but that going forward, sales can be tracked quarterly.

Number of Customer-Side of the Meter Devices Sending or Receiving Grid-Related Signals

This metric assumes that customer devices have been sold and installed, and that they are ready to send and receive grid-related signals. Once the devices are defined, the responsible entity for providing the data, or signals, needs to be identified. Whether it is the resident/owner of the building or facility, or a third-party, the responsibility for programming and managing the signals is a major one. The next steps in addressing this metric are to obtain reliable consumer demographic information/data, to track the number and location of installed devices, and then to identify the manner in which an actual count of customer devices will be accomplished. A statistical sampling of devices may be the most cost-effective way to track the number of devices, rather than an actual count. Finally, close tracking of devices, data, and results will be required.

Amount of Load Managed

The issues to be addressed in managing electric load so that customers can participate in smart grid programs include performing an accurate assessment of the impacts of demand response programs and obtaining accurate forecasts of weather-normalized electricity usage on the grid. Actual demand response impacts serve as the baseline for future load assessments, and thus provide a baseline for the costs and benefits of providing load information to customers. This type of data is available from utilities, regional transmission owners, and FERC. Accurate tracking of load managed is imperative, but must be clearly delineated as attributable to smart grid activities versus other efforts such as advertising (e.g., public service announcements when the grid is reaching capacity) or dynamic price signals.

Measurable Customer Energy Savings

The key ingredient to enabling informed participation in the future smart grid is accurate measurement of energy savings. Energy savings leads to cost savings, and customers are driven to participate by anticipated cost savings. The first step in measuring customer energy savings is to define it: is it dollars, kilowatt hours saved, or dollars per kilowatt hours saved? Once the savings metric is defined, new load additions need to be factored in, and distinctions clearly made between energy efficiency and smart grid savings. Examples of quantitative information needed include gas and electric usage compared with gross average utility consumption per customers, which is available from regulatory sources and other government agencies that track specific energy products, such as plug in hybrid electric vehicles (PHEVs). Key questions that have to be addressed to accurately track these data include determining the best unit metric, how best to quantify the benefits of the smart grid versus energy efficiency, and how distributed generation options such as photovoltaics (PVs) and the benefits of storage are factored into smart grid efforts.

Table 1.1. List of Participants

Name	Organization
Stacy Angel	EPA
Stan Blazewicz	National Grid
Mike Burns	ITRON
Fred Butler	NARUC/New Jersey Board of Public Utilities
Jim Crane	ComEd
Conrad Eustis	PGE
Erich Gunther	EnerNex/Gridwise Architecture Council/OpenHAN
Dave Hardin	Invensys/Gridwise Architecture Council
Becky Harrison	Progress Energy
Sue Kelly	APPA
Sila Kiliccote	LBNL
Matt McDonald	APPA
Bill Moroney	UTC
Jay Morrison	NRECA
Mike Oldak	EEP
Rich Sedano	Regulatory Assistance Project
Matt Smith	Duke Energy
Ron Smith	ESCO Technologies
Tom Sloan	Kansas State Legislator
Steve Widergren	PNNL
Jan Brinch, Facilitator	Energetics Incorporated

Table 1.2. Comments on the Characteristic

- Smart grid investments are appropriate and will receive regulators' and legislators' support when the value exceeds consumer costs.
- It is too early to presume targets for metrics.
- Technology will become available to fill needs.
- Participation in the smart grid must be designed to optimize electricity system resources.
- Customers must be provided with the options, capability, and information to manage their energy usage.
- Diversity of options may be unique to regions, utilities, and delivery points.
- Rates must be designed to reflect appropriate economic signals.
- Feedback loops must be provided to allow and improve coordination between the utility and its customers, to minimize customer disruptions, and improve customer service.
- **Suggested Revised Wording**: Enabling Informed Participation by Customers

Table 1.3. Metrics
(Diamonds indicate the number of votes received to identify the top five priorities)

Information Availability and Actions Taken	Societal Metrics	Measurable Energy Savings	Participation Rates	Amount of Load Managed	Customer Satisfaction
▪ Percent of premises or customers capable of receiving information from the grid (Potential) ◆◆◆◆◆◆◆ ◆◆◆◆◆◆◆ ◆	▪ Number of communication-enabled devices sold and installed (Cumulative/ Potential) ◆◆◆◆◆◆◆ ◆◆◆◆◆	▪ Measurable energy savings by customers - Per capita energy usage (per region) - Percent or absolute changes in a specified value element per customer (kWh/ customer) ◆◆◆◆◆◆◆◆ ◆◆◆	▪ Percent of customers who have changed their participation as a result of usage information ◆◆◆◆◆	▪ Amount of load (peak, normal) managed ◆◆◆◆◆◆	▪ ACSI points increased (customer satisfaction) - Fewer customer complaints on billings options for energy usage ◆◆◆
▪ Amount (percent) of customers participating in 2-way, time-based metering (Actual) ◆◆◆◆◆◆	▪ Number of options available for participating in the smart grid (for varying levels of involvement by customers) ◆◆◆		▪ AMI Market Penetration	▪ MW of demand response - Number of customers enrolled in demand response and/or distributed generation programs ◆◆◆◆◆	
▪ Percent of customers opting to make decisions and/or delegate decision-making authority (Actual) ◆◆◆◆◆	▪ Percent of successful rate recovery on smart grid investments ◆			▪ MW of distributed generation - Number of DG units integrated with distributed systems ◆	
	▪ Elasticity of demand in regional wholesale power markets ◆				
	▪ Reduction in CO_2 ◆				

Table 1.4. Measurement Issues

Number of Customers/Premises Capable of Receiving Information from the Grid and Number of Customers Opting to Make Decisions and/or Delegate Decision-Making Authority	Number of Communication-Enabled Customer-Side Devices Sold (Cumulative)	Number of Customer Devices Sending or Receiving Grid Related Signals	Amount of Load Managed	Measurable Customer Energy Savings
Issues: 1) Utility's communication signaling infrastructure to the customer or end-use device 2) Acknowledgement of signals 3) Customer's actual response. Overall technical penetration and standards development Information Sources and Methods: 1) Utility reporting: FERC Form 1 (if smart grid information is Incorporated 2) Trade groups Key Analysis Questions: 1) Percentage of customers who already have infrastructure 2) (infrastructure has to be defined) 3) Percentage of enabled customers: ▪ What is their response? ▪ How is it measured?	Issues: 4) Definition of "communication-enabled" (interoperability?) 5) Varying product life cycles distort cumulative data 6) What device types to include? Information Sources: 1) Manufacturing trade groups 2) Data from utilities 3) Statistical sampling of end-use customers Methods: 1) Define device label, then obtain count of devices sold with label category from trade organizations Key Analysis Questions: 1) Baseline assumed to be zero 2) Tracking progress requires quarterly updates with adjustments for product life cycles	Issues: 1) Who is responsible for providing the data? 2) Definition of metric itself 3) Need to relate demographic information to device data Information Sources and Methods: 1) Need other information about premise or customer where devices are installed (e.g. PCO class), size of home/facility, load size 2) Obtain count from entity responsible for device enrollment (LSE, RTO, ANL, REP) 3) Absolute count (census) versus statistical sample Key Analysis Questions: 1) Demographic breakout of results? 2) Types of devices? 3) Quality of the data?	Issues: 1) Forecasted business as usual (peak/normal load) 2) Expected impact of providing information to customers (cost-benefit, literature search, etc.) 3) Measure actual demand response Information Sources and Methods: 1) Utility, RTO, FERC data Key Analysis Questions: 1) How much accuracy is necessary? 2) What effect is attributable to smart grid vs. other forces (i.e., public service announcements, prices, etc.) 3) What is incremental benefit of smart grid?	Issues: 1) How do you define the savings ($, KWh, cost/KWh) 2) How do you account for new load additions? PHEV? All energy? Gas, gasoline, electric footprint? 3) EE vs. smart grid savings? Information Sources and Methods: 1) Gross average/utility/customer segment ▪ Gas ▪ Electric 2) DMV-PHEV stats 3) Regulators Key Analysis Questions: 1) Determine best unit metric 2) How do you measure what smart grid delivers vs. energy efficiency 3) How does DG get factored in – PV, PHEV, storage

2. Accommodates All Generation and Storage Options

One of the characteristics of a smart grid is its ability to accommodate all generation and storage options. The smart grid would seamlessly integrate all types and sizes of electrical generation and storage and simplify interconnection processes analogous to “plug and play.” In addition, it would accommodate:

- Large central power plants including environmentally friendly sources, such as wind, solar, and advanced nuclear plants
- An increasing number of smaller decentralized sources
- All generation and storage models

Accommodating distributed resources requires balancing the interests of a full range of stakeholders including consumers, third party developers (aggregators or service providers), regulators, and utilities. Accommodating all technologies will most certainly require an evolution in which new challenges are addressed as they arise, while the integration and balancing of emerging and traditional technologies continues to occur. Interconnecting distributed resources of all sizes across all technologies is a tremendous challenge, even though the information technology side of “plug and play” is evolving significantly for many technologies. As far as the range of technologies, “size matters” and decision makers will need to look at categories and sizes of the generation sources as well as which side of the meter they are on. As distributed resources are tracked, measuring various subcategories such as renewables, storage, etc. is important. Storage goals are varied, both long and short-term, such as shifting off-peak generation to relieve on-peak loads, shifting loads to off-peak periods, and system regulation. MicroGrids are another issue that needs to be raised in relation to how changes are accommodated.

There are “game changers” that need to be considered throughout the conversation about this characteristic including:

- Climate change
- Energy Security, particularly domestic manufacturing capabilities
- Reducing U.S. dependence on oil imports
- The accommodation of PHEV and other emerging technologies

Level of Deployment of Generation and Storage on the Distribution System and the Level of Deployment of Renewable Resources on the Transmission. System

Key implementation metrics include:

- Information structure—percent of grid that is networked to standard
- Percent of real-time generation of DG and storage that can be controlled
- Penetration—percent of load as measured by kWh served by distributed resources
- Storage—percent of systems accommodating off peak renewable energy PMD dispatching on peak through storage
- Deployment process applications—number of days from initial application to build distributed resources to operation (split by size class of the distributed resource)
- Improvements in load factors (the average load divided by the peak load) for electricity production, delivery, and consumption, at various points in the electric system, and at various levels of aggregation

Foundational Standards—Percent of Grid that is Networked to According to Adopted Standards

A key metric in measuring the build out of the smart grid will be the percentage of the grid that is networked to the adopted standards. Standards need to be defined to support the information network and then power companies need to adopt them. Once defined the standards need to be developed and adopted to address the requirements. Information needs to be gathered on the rate of adoption for all stakeholders including utilities, manufacturers, developers, and equipment owners and operators. The existence of these standards is a foundational metric for determining how quickly and effectively the industry is moving forward and is establishing processes and requirements in accordance with stakeholder requirements and responsibilities. Once the standards are in place, it will be possible to determine the extent of installations that meet them.

Percent of Real-Time Generation of DG and Storage that Can Be Controlled

The first step in developing this metric is to determine the location and operational status of DG and storage. The communication system architecture would also be part of this initial assessment. In developing quantitative information, direct communications with those organizations involved with devising interoperability standards will be central. A remaining question is to define the type of R&D data needed for large scale deployments.

Penetration—Percent of Load as Measured by kWh Served by Distributed Resources

There are several issues to consider including the verification of DR output overall and by various types (e.g., renewables and storage), data warehousing, and defining and capturing the data to produce information on percent of load served by DR at required times frames. In gathering data for this area, the utilization of two-way communications, AMI meters and modeling tools will be critical to success. In performing this data collection, there are several areas for further analyses including a clear definition of the baseline as well as segmenting DR. It may be necessary to measure percent renewables versus total kWh served or percent batteries versus total kWh served.

Storage—Percent of Systems Accommodating Off Peak Renewable Energy PMD Dispatching on Peak through Storage

Fundamental issues related to storage include knowing that the renewable energy is there, determining its location, and determining whether it is dispatchable. Quantifying this metric will involve the number of applications (size and location), measurement of availability, and profitability (with or without a subsidy). There will be analytical areas to resolve such as measuring and reporting performance of the storage systems and how to obtain the data on the number of applications involved.

Deployment Process Applications—Number of Days from Initial Application to Build a Distributed resource to Operation (Split by Size Class of the Distributed resource)

One effective method for scoping out the elements of this metric is to identify the number of locations applications are submitted for, determine the number of rejected or abandoned applications, and obtain a valid operational date. Once the data are defined it would be important to create a single application website. It would be useful to have access to building code permit application databases and larger distributed resource interconnection requests at ISO/RTO/utilities. Significant areas of unknowns exist with this metric, including the following areas: abandoned applications, state-to-state variances, and data aggregation.

Improvements in Load Factors

Load factor is a comparison of the average load to the peak load and measures the disparity of the peak from typical or average usage. As the load factor increases toward unity, it is an indicator of operational efficiency in managing loads and hence is a metric of the extent of Smart Grid deployments or "grid intelligence." Information on load factors is available through utilities for estimating values at the level of customer, feeder, and other levels of aggregation throughout the system, including substations, transmission lines, and operating companies and for any time period, including daily, monthly, or annually. There is a need to develop standard approaches for the level of detail and time period for comparing load factors on a consistent basis.

TABLE 2.1. LIST OF PARTICIPANTS

Name	Organization
Bruce Baccei	SMUD
Dick DeBlasio	NREL
Ward Bower	Sandia National Laboratories
James Calore, Group Spokesperson	PSE&G
J. Larry Dickerman, Expert Leader	American Electric Power
Doug Houseman	Capgemini
Ken Huber	PJM Interconnection
Mike Jung	Silver Spring Networks
Stanley Klein	Open Secure Energy Control Systems, LLC
David Michel	California Energy Commission – PIER
Michael Montoya	Southern California Edison
David Nichols	Rolls Royce Fuel Cell (US)
Brad Roberts	S&C Electric Company
Merrill Smith	U.S. Department of Energy
Morghan Transue	DOE (observer)
Hunter Hunt	Hunt Power LP
Robert Thomas	Cornell University
Joseph Waligorski	FirstEnergy Service Company
Tammy Zucco	ABB Inc.
Bonnie Ram, Facilitator	Energetics Incorporated

TABLE 2.2. COMMENTS ON THE CHARACTERISTIC

- This area is very broad and must focus not only on the technology and the industry, but the consumers. Should evaluate "whom" the smart grid is trying to accommodate. This would include: third party developers; regulators; utilities; aggregators (service providers).
- Also need to consider all generation and storage options as well as anywhere on the transmission and distribution system. The options would include the following: Large conventional generation (both utility owned and IPP owned); wind farms; solar farms; process steam; house level solar; small CHP; large CHP; small wind; PHEV; large compressed air storage; MW-sized storage (on T&D); small residential storage; MW-sized traditional; gas peaking; emergency diesels & backup ICE; fuel cells
- Recognize that the grid currently accommodates large central station generation and large scale storage (e.g., pumped water storage).
- Other central issues to consider include: Which side of the meter is it on? Who regulates? What is the size? How should storage and generation be split?
- Serious consideration for revised wording to, *"Accommodating all generation and storage options on the distribution system and renewable resources and storage on the transmission system,"* but decided to remain with the original characteristic.

Table 2.3. Metrics
(Diamonds indicate the number of votes received to identify the top five priorities)

Information Infrastructure	Real Time Operation	Penetration	Storage	Deployment: Process Application	Renewable Energy	Improve System Load Factor	Coverage
▪ Percent completion of communication infrastructure to accommodate DG and storage ◆◆◆◆ ▪ Foundational - Define/ determine common information to be exchanged - Define/ determine information exchange protocols/ standards ▪ Ability to sense and measure physical effects of each unit of DER on utility grid system ◆◆◆◆◆◆ ▪ Percentage penetration of smart grid protocols in equipment and AEPSO's ◆◆ ▪ Build metrics/ establish available two way communication - Adaptive logic - Time of (rates) - Security - Automatic response - Standards - Protocols by 2015	▪ Percent of DG and storage that can be controlled ◆◆◆◆◆◆ ▪ Electric power flow planning and real time control ◆◆◆ ▪ Ability for scheduling and forecasting - Percent of electric power flow management - Percent of electric load management - Percentage of electric energy Storage - Percent of DG penetration optimization - Percent DG penetration optimization ◆ ▪ Ability to accommodate 50% non-dispatchable generation by 2020 ◆	▪ Ability to detect and monitor number and type of all utility-connected forms of DERs ▪ Ability to sense and measure physical effects ◆◆◆◆◆ ▪ Percent of load served by energy efficient DG ◆◆◆◆◆ ▪ Percent of network registered nontraditional generation ◆◆ ▪ Assumes interconnection application required ▪ Connect X% of generation and renewables applications to T&D system ◆ ▪ Percent penetration of all-source distributed resources to distribution (energy security) ▪ Percent components of smart grid (Two way meters/ receptor/ AMI and T&D) ▪ Percent load reduction - EE and RE	▪ Percent of system accommodate off-peak RE and dispatch on-peak through storage ◆◆◆◆ ◆◆ ▪ Total MWs of off peak renewable energy captured and dispatched on peak (capacity factor improvement) ◆◆ ▪ Address intermittency of renewable such as PV ◆	▪ Number of days from application to build to operation by size class ◆◆◆◆◆◆	▪ Total MWs of fossil fuel generation permanently retired from the grid ◆ ▪ Percent renewables (At T and at D)	▪ Improve load factor – consumption and production ◆◆◆◆◆◆ ◆	▪ Coverage factor on a library of use cases ◆ ▪ Functionality percent of various types of DG and storage covered by the modern grid ◆ ▪ Number of devices certified for application at various voltages

TABLE 2.4. MEASUREMENT ISSUES

Metric	Top Three Issues	Information and Methodologies	Key Analysis Questions
Information Structure (Percent of grid that is networked to standard)	1. Standards to be defined for information network 2. Power companies' adoption of standards 3. Deployment to standards	▪ Aggregate power company data re: actual interconnection to standard ▪ Gather data re: power flow, generation attributes from standards-connected facilities/ demonstrations	▪ Should FERC get in the business of measuring data re: information networks in power sector? ▪ How do we access and manage data from non-IOU DERs?
Percent of Real-Time Generation of DG and Storage That Can Be Controlled	1. Location of DG and Storage 2. Operational status of DG and storage 3. Communication system architecture	▪ Direct communications with all devices ▪ Interoperability standards ▪ Optimization of system operation	▪ What R&D for data for large scale deployments?
Penetration Percent of Load as Measured by kWh Served by Distributed Resources	1. Verification of DR output overall and by various types (e.g., renewables, storage, etc.) 2. Data warehousing 3. Define and capture the data to produce information on percent of load served by DR at required time frames (year, month, day, hour, etc.)	▪ AMI meters ▪ Two way communications ▪ Modeling tools	▪ Defining the baseline – does it include existing generation that is not dispatchable? ▪ How to handle customer owned DR that nets out before the meter? ▪ What segmentation of distributed resources will be necessary to utilize as submetrics such as: - Percent renewables versus total kWh served - Percent batteries versus total kWh served
Storage (Percent of systems accommodating off peak renewable energy PMD dispatching on peak through storage)	1. Knowledge that the RE is there? 2. Dispatchability – Can it be scheduled and controlled? 3. Location of the RE sources	▪ Number applications (size and location) ▪ Measurement of availability ▪ Profitability (with or without subsidy)	▪ How do you get the data on the number of applications? ▪ How is the performance of the storage systems measured and reported? ▪ Is fast response storage more valuable to grid operation?
Deployment (Number of days from initial application to build a DER to operation (split by size class of the DER)	1. Number of locations applications are submitted to 2. Number of rejected or abandoned applications 3. Getting a valid operational date	▪ Creation of a single application website ▪ Building code permit application databases ▪ For larger DER interconnection requests at ISO/RTO/ utilities	▪ Can the data be aggregated? ▪ How to deal with abandoned applications? ▪ How to deal with state to state variance? ▪ How to deal with variance in types of DER (e.g., a local government liked PV but dislikes wind)? ▪ How to deal with the fact that many people may be part of the chain and the start date and operation date may come from different sources and have different levels of quality? ▪ How to deal with the impact of state and local incentives on volume and number of trained people in the process?
Improving System Load Factor *(Note: A 6th priority was added because of the high number of votes)*	1. Proper level to measure/ metering availability at that level (T-line, substation, distribution CKT, customer) 2. Impact from various sources (DG storage, demand response efficiency, PHEV, etc.)	▪ Metering of lines/subs (RTO/ISO and utility)	▪ Determine/establish parameters – base time period (past years, rolling time period, seasonal, etc.) ▪ Availability/identification of measuring points ▪ Ability to differentiate impact of sources (DG, storage, DR, efficiency, PHEV, etc.)

3. Enables New Products, Services, and Markets

A key characteristic of a smart grid is that it will support new markets by enabling new products and services. This will be marked by several developments, including:

- Emergence of the end-use customer as a purchaser of new technologies and services
- Creation of secondary electricity markets and support of competitive retail markets
- Stimulation of small and startup firms that bring new innovation into the market

New products and services that support a smart grid certainly will be implemented by utilities, independent power producers, ISOs and RTOs, who traditionally have been the main purchasers and deployers of energy resources for the grid. However, consumers themselves must be added to this value chain in order to support smart grid maturation. A "mass market" for smart grid technologies and services is foreseen, in which individual electricity customers are active participants. As such, providers of new products and services will need to focus on the needs and wants of the end-use consumer. The creation of "secondary" electricity markets also will involve non-traditional or non-utility players such as brokers, integrators, and aggregators. In other words, markets will become further "segmented" as consumer participation increases and choices become diversified. Finally, small companies, with their tradition of innovation, will be crucial in getting much of the R&D from the lab to the marketplace. Importantly, this new environment assumes that there is regulatory support. As a potential limiting factor in smart grid development, the regulatory environment to which these new products are subjected must be auspicious, and there must be stipulations for regulatory recovery.

Key metrics for measuring progress include:

- The degree to which there is the provision for regulatory recovery for alternative solutions
- The number of new smart grid-related companies that achieve revenues of at least $100M
- The number of products with end-to-end interoperability certification
- The amount of venture capital (VC) put into smart grid startups
- The number of new residential products that were not available two years prior

The Degree to which there is Regulatory Recovery for Alternative Solutions

The first step in developing this metric is to define "alternative solution" and "smart grid investment." Further, developing this metric will require the availability of a national database of timely information on regulatory decisions and the ability to factor in Federal power authorities as well as municipal utilities and cooperatives. This information can be developed by DOE, FERC Form 1, a survey of state commissions, the APQC Maturity Model, NARUC/FERC Smart Grid and Gridwise Alliances, and the Federal Smart Grid Task Force. Analysis is needed to define "regulatory recovery" (including rate-based, incentives, and tax instruments) and the period of time to monitor. Additional analysis should determine if non-electric utilities should be included, as well as whether to track utility requests to calculate percentage approved.

The Number of New Smart Grid-related Companies that Achieve Revenues of at least $100M

New companies will be important players, and the growth of these companies is a key metric. The first step in developing this metric is to identify related companies that got to where they are solely due to the smart grid as well as to define the words "new" and "company" (business unit of existing company, public vs. private, etc.). Data sources include 10-Q sources, prospectuses to venture capitalists, chambers of commerce, news releases, and CEO interviews. Analysis will determine if revenues are related to smart grid deployment, and this analysis will often rely on obtaining proprietary information from companies.

The Number of Products with End-to-End Interoperability Certification

The first step in developing this metric is to determine who the interoperability certification bodies are, the scope as it relates to standards and/or product interface definitions, and how the interoperability criteria are validated. These data may be obtained via industry market surveys (such as Chartwell, Scott Report and Newton-Evans), trade associations like NEMA and Utilimetrics, and surveys/polls done by vendors and utilities. Analysis is needed to assess the value and quality of the accreditation, what historical data are important for establishing a baseline, the statistic used to measure, and to assess any "feedback loop."

The Amount of Venture Capital (VC) put into Smart Grid Startups

The amount of seed money that investors are putting into startup operations that are dedicated to smart grid-related technologies and services is a straightforward metric. Yet the credibility of the source of the data and the quality of the data are important in accurately gauging progress on this front. Two very important sources for the data are New Energy Finance and the National VC Association. While the metric here is dollars, it will be important to determine what to include and exclude in the analysis.

The Number of New Residential Products That Were Not Available Two Years Prior

The initial steps involve establishing a definition for a new product from two years prior, e.g., according to revenue, sales, market share, or other quantification. It must also be decided which public product agency/entity tracks or certifies new residential products (i.e., UL or Consumer Reports) and which agency will track the new products over time specific to smart grids. Sources of information include retailers, particularly the Consortium for Energy Efficiency (CEE). HVAC/residential control companies, as well as lighting manufacturers and associations may also be able to provide key information. Analysis in this area will differentiate between completely new products and those products that have been enhanced or modified. Further analysis will involve tracking a baseline for the overall industry against new products, and will ideally be framed in terms of market share, not simply number of new products.

TABLE 3.1. LIST OF PARTICIPANTS

Name	Organization
William Anderson	NIST
Philip Bane	Global Smart Energy
John Caskey	NEMA
Jim Crane	Exelon
Richard Drake	NYSERDA
Joe Franceschi	Pegasus Capital
Chuck Goldman	LBNL
Ed Gray	Elster
Chris Hickman	Site Controls
Jonathan Hou	ABB ESC
Wade Malcolm	Accenture
Jack McGowan	Energy Control Inc.
Spero Mensah	Areva T&D
Terry Mohn	Sempra Energy
Terri Moreland	California ISO
George Potts	Pepco Holdings, Inc.
Al Sarria	Austin Energy
Chris Tinkham	BAE Systems
Tom Schneider	TRS Energy
Thomas Standish	Centerpoint Energy
Stephen Waslo	DOE
Eric Woychik	Comverge, Inc.
Thomas Yeh	Ennovasion Group
Brad Spear, Facilitator	Energetics Incorporated

TABLE 3.2. COMMENTS ON THE CHARACTERISTIC

- Characteristic is too general and broad; it needs to be disaggregated
- Frames of reference for this disaggregation: Existing customers vs. IPPs/RTOs/ISOs vs. new participants
- Break users down between customer classes and utilities. Include participants in non-utility areas.
- Services and products need to be broken out from markets, including products and services that are not already available through other means.
- Focus on the complete supply chain and segment this appropriately
- Stress the value chain focused on the customer and customers' wants and needs
- Include an emphasis on small firms and new contractors (such as architects who design buildings with smart grid features)

TABLE 3.3. METRICS
(DIAMONDS INDICATE THE NUMBER OF VOTES RECEIVED TO IDENTIFY THE TOP FIVE PRIORITIES)

Market Indicators and Innovation Opportunities	Cost and Energy Savings	Standards and Regulations	Environmental Benefits	Publicity, Awareness and Education
▪ Number of new companies with ≥ $100M revenue ◆◆◆◆◆◆ ▪ Amount of venture capital put into smart grid startup companies ◆◆◆◆◆ ▪ Number of new energy using residential products that were not available two years prior ◆◆◆◆◆ ▪ Number of households with home area networks ◆◆◆◆ ▪ Number of consumer owned generation types ◆◆◆ ▪ # of MW saved and business models capitalizing on savings ◆ ▪ Number of new business startups offering power/energy products and services ◆ ▪ Percentage of utility substations that have SCADA systems communicating back to the operator ▪ Magnitude of entry barrier to offering new products/services ▪ Number of new "non-core" services offered by utilities ▪ Microgrids deployed	▪ Expected availability of service (uptime) ◆◆◆ ▪ Per capita use of electricity ◆◆◆ ▪ Cost-Benefit in Net Present Value (NPV) terms (Business Case analysis) ◆◆ ▪ # of PHEVs that charge off peak ◆ ▪ Option value: Blackman-Scholes option analysis - beyond NPV of a scenario regarding benefits/costs ◆ ▪ Consumption efficiency by categories of users ◆ ▪ Expected Total Cost of Ownership (TCO) of product/service offering	▪ Regulatory recovery for alternative solutions ◆◆◆◆◆◆◆◆◆◆ ▪ Number of products with end-to-end interoperability certification ◆◆◆◆◆◆ ▪ # of new standards (IEEE, NEMA, NERC, IEC) ◆ ▪ Levels of end-to-end interoperability for a sector (generation to end use) ▪ # of Title 13 related proceedings adopting grid modernization plans and cost recover for smart grid deployments	▪ Per capita amount or total tons of greenhouse gasses avoided ◆◆◆◆	▪ National goal for EE, DR, AMI and new base load ▪ Consistent suite of customer products defined at the national level vs. everyone making up their own ▪ # of times Smart Grid is mentioned in national elections

Market Indicators and Innovation Opportunities	Cost and Energy Savings	Standards and Regulations	Environmental Benefits	Publicity, Awareness and Education
▪ Yearly increase in offerings to consumers to provide choice in terms of alternatives to conventional service ▪ Yearly increase in new markets defined and developed in the regions				

TABLE 3.4. MEASUREMENT ISSUES

The Degree to Which There is Regulatory Recovery for Alternative Solutions	The Number of New Smart Grid-related Companies that Achieve Revenues of ≥ $100M	The Number of Products with End-to-End Interoperability Certification	The Amount of Venture Capital (VC) Put into Smart Grid Startups	The Number of New Residential Products That Were Not Available Two Years Prior
▪ Issue: Who will pay for a National database of regulatory decisions? ▪ Issue: Is the information in such a database timely? ▪ Issue: What is the definition of "alternative solutions" and what is considered a smart grid investment? ▪ Issue: How do we factor in Federal power authorities and county/munis/co-ops? ▪ Data from: DOE, FERC Form 1, a survey of state commissions, the APQC Maturity Model, NARUC/FERC Smart Grid and Gridwise Alliances, and the Federal Smart Grid Task Force ▪ Analysis: Define alternative solutions re: smart grid ▪ Analysis: Define "regulatory recovery" ▪ Analysis: Define period of time to monitor ▪ Analysis: Who will pay for it? ▪ Analysis: Are there non-electric utilities that should be considered? ▪ Analysis: Do we want to track original utility requests to calculate percentage approved?	▪ Issue: Identifying related companies that got there solely due to the smart grid ▪ Issue: Defining the word "new" in the metric ▪ Issue: Defining "company" (i.e., whether existing company that has a new business unit, public vs. private) ▪ Data from: 10-Q Sources, prospectus to venture capitalists, chamber of commerce, news releases, CEO interviews ▪ Analysis: Determine if revenues are related to smart grid deployment ▪ Analysis: Obtain proprietary information from companies	▪ Issue: Who are the certification bodies? ▪ Issue: What is the scope as defined by standards, and/or product and interface definitions? ▪ Issue: How is the interoperability criteria validated? ▪ Data from: Industry market surveys (Chartwell, Scott Report, Newton-Evans, etc.) ▪ Data from: Trade associations (NEMA, Utilimetrics, etc.) ▪ Data from: Vendor and utility polls and surveys ▪ Analysis: What is the value and quality of the accreditation? ▪ Analysis: What historical data is available that is credible for baselining? ▪ Analysis: What statistic should we use to measure? ▪ Analysis: Feedback loop	▪ Issue: Source and quality of data ▪ Data from: New Energy Finance and the National VC Association ▪ Analysis: What $ data to include and what to exclude	▪ Issue: How to define new product from 2 years prior, e.g., revenue, sales, or number ▪ Issue: Which public product agency tracks or certifies new residential products i.e., UL or Consumer Reports? ▪ Issue: What agency will track the new products over time specific to smart grids? ▪ Data from: Appliances – retailers follow market share i.e., Consortium of Energy Efficiency ▪ Data from: HVAC/residential control companies (Johnson, Siemens, Honeywell) ▪ Data from: Lighting manufacturers and Associations ▪ Analysis: At what point does it mean to define a new product (enhancement vs. new product) ▪ Analysis: For each info source one needs to track baseline for overall industry against new product ▪ Analysis: This metric needs to move to market share vs. just number of new products

4. Provides Power Quality for the Range of Needs in a Digital Economy

Power quality is a broad term that means different things to different customers. However, it has been well defined by organizations such as IEEE and multiple definitions exist based on the customer class.

What is not well defined is how the smart grid can enhance power quality. The determination of metrics for power quality will largely depend on the entity that is considering the metric. For example, metrics used by the U.S. Department of Energy will be different than the metrics used by regulators, city officials, and utilities. Another important factor is the scale (i.e., city, state, nation) at which the metrics will be used.

Cost is an important aspect of power quality and it is difficult to track and measure. There are costs associated with implementing power quality devices and there are potential costs associated with not having power quality equipment (i.e., customer interruption, cost of outages to sensitive loads). One power quality level doesn't fit all customers, and varying grades of power quality offered at several pricing levels should be considered. While a specific cost metric was not developed by the group, it was identified as a key factor in the implementation of power quality devices and cross-cuts all the metrics developed. It was suggested that charter organizations should be formed to report on the costs of various power quality levels (on both implementation and impact costs). There have been studies conducted on the costs of power quality events but they have mainly been circulated among utilities and industry stakeholders. There should be an effort to educate a broader group of stakeholders including consumer groups and regulators about the impact costs and how the smart grid can affect power quality.

Suggested Revised Wording for the Characteristic: *Provides Power Quality for the Range of Needs in the 21st Century Economy*

Key implementation metrics for power quality include:

- Number of devices divided by improvement in reliability indices
- Number of power quality measurement points divided by number of customers
- Number of power quality incidents that one can identify and anticipate over time
- Number of states that have defined electric rate structures based on power quality service level
- Number of customer complaints regarding power quality issues

Number of Devices Divided by Improvement in Reliability Indices

The first step in developing this metric is to determine the number of available power quality devices (e.g., energy storage systems) as well as the type and quantity of installed devices. Reliability indices already exist and are well known to industry such as SAIDI, SAIFI, and CAIDI can be used in this metric without the need for creating new ones. Potential data sources to gather this information include regulatory bodies and industry surveys. Analysis is needed to develop a clear definition of device types and categories, to compare devices with different functions, and to develop a methodology and scalability across stakeholder boundaries for calculating effectiveness.

Number of Power Quality Measurement Points Divided by Number of Customers

The first step in developing this metric is to determine a methodology for extracting useful information from large quantities of power quality data. It will also be necessary to determine the penetration of useful measurement tools (such as meters). Potential data sources to gather this information include utilities, meter manufacturers, and trade organizations such as NEMA. Analysis is needed to ensure data interchangeability and keeping data at a high enough level so that it is manageable.

Number of Power Quality Incidents that One Can Identify and Anticipate Over Time

The first step in developing this metric is to determine what the definition of a power quality incident is—which will vary depending on customer perspective—and to determine what caused the power quality event. Potential data sources to gather this information include EPRI, EEI, universities, IEEE, and the national laboratories. There is a lack of resources to accomplish this and additional personnel, funding, and tools will need to be allocated to be able to establish a baseline and track progress for this metric.

Number of States that Have Defined Electric Rate Structures Based on Power Quality Service Level

The first step in developing this metric is to determine how many states have defined electric rate structures based on power quality service level and how many states have initiated and established electric rate structures based on power quality service level. Potential data sources for gathering this information include public utility commissions, NARUC, NRECA, industry groups, and FERC. Analysis is needed to better define aggregation level (state versus utility, etc.) and determine focus (IOU, muni, co-op); determine what defines power quality service level; and investigate the availability of power quality rates versus customer adoption.

Number of Customer Complaints Regarding Power Quality Issues

The first step in developing this metric is to determine the most appropriate definition of power quality; this definition depends on customer class, (i.e. industrial, commercial, or residential). Next, it will be necessary to determine how to attribute customer satisfaction improvements to the smart grid. Gathering this information could entail having focus groups, utility marketing groups, and advocacy groups use questionnaires targeted at each defined power quality customer class to obtain data. Potential issues include who pays for and administers these surveys and being sure to collect an adequate amount of customer responses in order to have a large enough data set to examine.

Table 4.1. List of Participants

Name	Organization
Hawk Asgeirsson	DTE Energy
Clayton Burns	National Grid
Joe Bucciero	KEMA, Inc.
Lawrence Carter	Bonneville Power Administration
Steve Hauser	GridPoint
Eric Hsieh	NEMA
Ward Jewell	Wichita State University
Mladen Kezunovic	Texas A&M University
Tom King	Oak Ridge National Laboratory
Ben Kroposki	National Renewable Energy Laboratory
Bob Lash	USDA-RUS
Arshad Mansoor	Electric Power Research Institute
Merv McInnis	Emerson
Joe Schatz	Southern Company
Richard Schomberg	Electricity de France
Le Tang	ABB, Inc.
Chuck Whitaker	BEW Engineering
Terry Winter	American Superconductor
Brian Marchionini, Facilitator	Energetics Incorporated

Table 4.2. Comments on the Characteristic

- **Suggested Revised Wording**: *Provides power quality for the range of needs in the 21st Century economy.*

Table 4.3. Metrics

(Diamonds indicate the number of votes received to identify the top five priorities)

Sense	Communicate	Process	Control/Action	Impacts
▪ Number of power quality measurement points divided by number of customers ◆◆◆◆◆◆◆◆◆ ▪ Number of devices sold and installed to measure power quality ◆◆◆◆	▪ % of circuit miles (or customers) monitored and communicating power quality information to a central location ◆◆◆◆ ▪ Number of devices that are necessary measurement and communications equipment contributing to open architecture ◆◆◆	▪ Number of power quality incidents that you can identify and anticipate over time ◆◆◆◆◆◆ ◆◆◆◆	▪ Number of devices divided by improvement in reliability indices ◆◆◆◆◆◆◆◆◆◆ ◆ - Determining how many controllable devices have been sold and installed - Number of power quality control points divided by number of customers - Number of customers with service interruptions at all households, businesses in a service territory - Number of points that control power quality factor ▪ % of sensitive loads that have built in immunity (for example-ride through capability) ◆◆◆◆◆◆◆ ▪ The DG capacity level (how small) at which voltage regulation is effective/effected economically ◆◆◆ ▪ Number of instances where generators have to operate outside of their target efficiency range ◆◆ - Controlling flicker within local standard - Provide voltage per standard to the customer	▪ Number of states that have defined electric rate structures based on power quality service level ◆◆◆◆◆◆◆◆ ▪ Number of choices a customer has for various levels of power quality at various costs ◆◆◆◆◆ - Varying grades of power quality at different pricing levels ▪ Number of customer complaints regarding power quality issues ◆◆◆◆◆◆◆ - Level of customer satisfaction on a scale of 1-10 - Duration of resolution to power quality complaint ▪ Minimum cost to economy $power quality/GDP/time ◆◆ - Number of people seriously affected because of power quality disturbances

TABLE 4.4. MEASUREMENT ISSUES

	Number of Devices Divided By Improvement in Reliability Indices	Number of Power Quality Measurement Points Divided By Number of Customers	Number of Power Quality Events That You Can Identify and Anticipate Over Time	Number States That Have Defined Electric Rate Structures Based On Power Quality Service Level	Number of Customer Complaints Regarding Power Quality Issues
Key Analysis Questions	▪ Determine the number of available devices as well as the kind and quantity of installed devices	▪ Determine what is useful information ▪ Determine what is penetration of useful measurement tools (meters)	▪ What is the definition of a power quality incident (varies depending on perspective) ▪ What caused the power quality event ▪ Are there applicable standards	▪ How many states have defined electric rate structures based on power quality service level ▪ How many states have initiated and established electric rate structures based on power quality service level	▪ What is definition of power quality- depends on customer class, i.e., industrial, commercial, residential ▪ Attributing customer satisfaction improvements to the smart grid ▪
Sources of Information and Methodologies	▪ Regulatory bodies and industry surveys	▪ Utilities and co-ops ▪ Meter manufacturers ▪ Trade organizations (NEMA, NRECA)	▪ EPRI, EEI, universities, IEEE, national laboratories	▪ PUCs, NARUC, NRECA, Industry groups, FERC	▪ Focus groups- utility marketing groups ▪ Questionnaires ▪ Advocacy groups ▪ Utility customer service division
Top 3 Issues	▪ Clear definition of device types and categories ▪ Comparing devices with different number of functions ▪ Methodology and scalability across stakeholder boundaries of calculating effectiveness	▪ Data interchangeability ▪ Keeping data at a high enough level to be manageable ▪ Verifiable information	▪ Lack of resources - Personnel - Funding - Tools	▪ Better define aggregation level (state vs. utility, etc.) and determine focus (IOU, muni, co-op) ▪ What defines power quality service level ▪ Availability of power quality rate vs. customer adoption	▪ Who pays for surveys ▪ Who administers the surveys ▪ Number of customer responses

5. Optimizes Asset Utilization and Operating Efficiency

A smart grid will be able to employ information technologies, advanced materials and equipment, and automated metering and monitoring to continually optimize capital assets while minimizing operation and maintenance costs. A key outcome of smart grid will be existing assets that are more efficient, longer-lasting, and less prone to unscheduled maintenance. "Replacing iron with bits" will also reduce or defer the need for additional power plants, power lines, substations, and transformers, while maintaining the same or improved power output and quality. This can be accomplished in a number of ways, including using demand response programs to shave peak loads, real-time condition monitoring and diagnostics, active voltage and VAR control, smart sensors and meters, and advanced materials and technologies that can expand the capacity of power lines and other electric capital assets. Both "smart" (computer-based) and "dumb" (physical equipment and materials) technologies will be part of the solution.

Different areas of the electric delivery system (transmission, distribution, and end-use/consumer) have different assets and operating characteristics. Therefore, "build metrics" to measure progress on implementing the characteristic of "optimizing asset utilization and operating efficiently" need to be identified for each area. Table 1 describes key implementation metrics for this characteristic, grouped into the three categories.

TABLE 5.1: KEY IMPLEMENTATION METRICS ("BUILD METRICS")

Transmission	Distribution	Consumer
▪ # of assets deferred and period of deferral (better use of existing assets) ▪ # of transmission MW that involve voltage and VAR controls ▪ % of transmission assets with real-time condition monitoring and diagnostics ▪ # of lines with dynamic rating capability ▪ # of miles of line with expanded transmission capacity through advanced materials and devices, e.g., superconductors, fault current limiters, and composite conductors	▪ # of MW of distributed generation/storage connected to grid as dispatchable assets ▪ % of smart grid enabled switches/reclosers/ capacitor banks ▪ # of distribution MW that involve voltage and VAR controls ▪ % of distribution assets with real-time condition monitoring and diagnostics ▪ # of customers connected per automated circuit segment	▪ # of smart meters ▪ # of customers utilizing real time pricing ▪ # of MW of dispatchable demand response
Crosscutting Metrics (Transmission, Distribution and Consumer)		
▪ # of IEDs (smart sensors) deployed ▪ % of IEDs with communications that allows the IED to perform its function ▪ # of operational information technology applications that are integrated		

While these build metrics are very useful for tracking progress, the "value metrics"—which track the *outcome* of smart grid implementation—will ultimately have the greatest relevance to regulators and ratepayers. Key value metrics that will measure progress for this characteristic include:

- Total amount ($ and MW) of deferred generation
- Overall electric delivery system efficiency, e.g., amount of energy consumed divided by amount of energy sold
- Overall system level of asset utilization or load factor (peak load/average load)

Some combination of value metrics and build metrics should be used to communicate the progress towards the goal (value metric)—which could take some time to achieve—and the leading indicators of that progress (build metrics).

There are also a number issues associated with defining smart grid metrics for this particular characteristic. First, optimizing asset utilization and operating efficiently depends on the proper integration of technologies with business processes and associated information technology. In a sense, this characteristic is an outcome of successful implementation of other smart grid characteristics and operating "philosophies." Second, build metrics are not static, and will need to be updated regularly as new technologies are developed. Third, build metrics should not be technology prescriptive or result in narrowing technology options for policy and decision makers considering smart grid investments. Rather, they should strive to be "technology neutral" and create an environment that encourages innovation and entrepreneurship.

TABLE 5.2. LIST OF PARTICIPANTS

Name	Organization
Sandy Aivaliotis	Nexant
David Andrejcak	FERC
Steve Ashworth	LANL
David Cohen	Grid Agents
Reza Ghafurian	Con Edison of NY
Erin Hogan	NYSERDA
Jonathan Hou	ABB, Inc.
Bernard Lecours	GE Energy
David Kreiss	Current Group
Dominic Lee	ORNL
Jack McCall	American Superconductor
Mark McGranaghan	EPRI
Ed Matthews	Kansas City Power & Light
Joe Miller	Horizon Energy Group
Rob Pratt	PNNL
George Rodriguez	Southern California Edison
Bob Saint	NRECA
Dave Sharma	FERC
Jeff Varney	APQC
Heber Weller	SAIC/Modern Grid Strategy
Pat Williams	East Mississippi Electric Power Auth.
Shawna McQueen, Facilitator	Energetics Incorporated

TABLE 5.3. COMMENTS ON THE CHARACTERISTIC & ASSOCIATED METRICS

- Optimizing asset utilization and operating efficiently depends on proper integration of technologies with business processes and associated IT
- Advanced materials and equipment, local communications, and local intelligence are also part of the solution for smart grid
- Build metrics need to differentiate between statistics measuring number of deployed widgets/data versus having the widgets/data available for use
- Build metrics will be different for transmission, distribution and consumer parts of the "*optimizing asset utilization and operating efficiently*" smart grid characteristic

Table 5.4. Metrics
(Diamonds indicate the number of votes received to identify the top five priorities)

Sensors & Devices	Putting Data/Info into Use (Applications)	Technology Penetration	Communication (# Bits and Bytes)	Data Management and Integration	Process Changes
▪ Number/MW feeders with remotely operated communicating switches ◆◆◆◆◆◆◆ ◆◆◆◆◆ ▪ % smart grid enabled switches/ reclosers/ capacitor banks ◆◆◆◆◆◆◆ ◆◆◆ ▪ Number of smart meters deployed ◆◆◆◆◆◆◆ ◆ ▪ Number of IEDs (smart sensors) deployed ◆◆◆◆◆◆◆ ▪ Number of phasor measurement units and digital fault monitors installed ◆◆◆◆ ▪ Number or % of distribution transformers with remote monitoring ◆◆◆ ▪ Number remote connect/ disconnect ◆◆ ▪ % deployment of infrared system monitoring ▪ % deployment of antenna arrays for electromagnetic noise detection	▪ % of assets that have real data trend analysis (condition-based maintenance or CBM) ◆◆◆◆◆◆◆ ◆◆◆◆◆◆◆ - # of critical assets monitored for CBM ▪ MW-MVAR volt - variance control ◆◆◆◆◆◆ ▪ # of self-generated work orders—proactive fault detection and repair (incipient/ anticipated) ◆◆◆◆◆ ▪ Number/MW feeders operated with dynamic voltage/ loss optimization ◆◆◆◆ ▪ Demand response: call vs. response ◆◆◆◆ ▪ % reduction in operator interference with the grid, thus increasing reliability ◆ ▪ Volume of reactive maintenance activities	▪ MW of distributed generation connected to grid as a dispatchable asset ◆◆◆◆◆◆◆◆◆◆ ◆◆◆◆◆◆ ▪ Number of customers with real or near-real timing pricing ◆◆◆◆◆◆◆◆◆ ▪ Number of new assets deferred, period of deferral ◆◆◆◆◆◆◆◆ ▪ % of critical transmission lines utilizing thermal ratings to optimize existing asset utilization ◆◆◆ ◆◆◆ ▪ Increase in right of way/ power delivery increase to accommodate load growth ◆◆◆◆◆ ▪ Number of miles of superconducting cables ◆◆◆◆◆ ▪ Number of customers or MW of demand response: 1) demonstrated, 2) deployed to displace ancillary services ◆◆◆◆◆ ▪ % of customers with accurate connectivity models ◆◆◆◆ ▪ Number MW of island-able load ◆◆◆◆ ▪ MW of price-responsive demand response deployed (residential, commercial, industrial) ◆◆◆ ▪ Number of customers/MW with demand response used for transmission congestion relief ◆	▪ % of system with 2-way secure communication infrastructure available ◆◆◆◆◆◆ ◆◆◆◆◆◆ ◆◆ ▪ Communication latency ◆◆◆ ▪ Communication bandwidth	▪ Level of implementation of an extensible common information model and integration bus ◆◆◆◆◆◆ ◆ ▪ % deployed decision support systems (using new sensors) ◆◆◆◆◆◆	▪ Change in the percent of load balanced ▪ Capital improvement costs vs. demand and energy (load factor) - for capacity planning ▪ Increase in capacity divided by cost ($) ▪ T&D losses (total energy delivered divided by total energy generated) ▪ Equipment life increase (in years)

Sensors & Devices	Putting Data/Info into Use (Applications)	Technology Penetration	Communica-tion (# Bits and Bytes)	Data Management and Integration	Process Changes
		▪ Number of customers/MW with demand response used for distribution capacity management ◆ ▪ Number of units of a technology/approach deployed per year in different regions in the US ◆			

Table 5.5. Measurement Issues with Crosscutting (Transmission, Distribution, and Consumer) Metrics

of IEDs (smart sensors) Deployed
▪ Issues: ▪ Easiest to measure ▪ Should be used as the baseline ▪ What should be the end point ▪ Break into categories: 1) asset monitors, 2) power monitors, 3) meters, 4) controllers ▪ There will be a different (unique) metric for each area of the power system (Transmission, Distribution, and Consumer)

Table 5.6. Measurement Issues with Transmission Metrics

# of assets deferred and period of deferral	% of assets with real time condition monitoring and diagnostics	Amount of active voltage and VAR control on transmission systems
▪ Issue: This is investment that is deferred while still maintaining the same result (e.g., reliability/ performance) through better utilization of existing assets ▪ Issue: Assets need to be tracked by category (large investment items) - Transmission lines - Substations - Substation transformers	▪ Issue: Need to track according to each category of asset - Substation transformers - Circuit breakers - Static Var systems, FACTs devices - Capacitor banks, Shunt reactors, series capacitors - Transmission lines (e.g., dynamic line rating) - this was listed as a separate index but can be included in this set of indices - Surge Arrestors - Insulators - Towers ▪ Issue: Need to define the criteria that qualifies as real-time condition monitoring and diagnostics - Communications - Diagnostics - Notification/alarming - Etc.	▪ Issue: What technologies are included - FACTS - SVC - Series capacitors - HVDC ▪ Issue: What is metric? - MVAR of compensation/active control (could include storage) - Increase in transmission capacity (MW) - % of MW or MVAR that are controlled with advanced equipment

TABLE 5.6 (CONT'D). MEASUREMENT ISSUES WITH TRANSMISSION METRICS

Number of Miles of Line With Technologies for Expanded Transmission Capacity	Number of IEDs (smart sensors) deployed	Level of Implementation of Extensible Common Information Model and Integration Bus
▪ Issue: Need to identify examples of technologies that are included in this metric - Superconducting cables - Composite conductors - Distributed transmission line VAR compensation - FCLs mentioned as technology to consider but may not be appropriate for this specific metric – this could be a separate metric related to advanced fault management ▪ Issue: Miles of line may not be the best metric for measuring the increased transmission capacity - if we used another metric like the increased capacity itself, we could include technologies like FACTS, FCLs, etc.	▪ Issue: There are multiple categories of devices - Voltages, currents, powers, etc. - Physical quantities (temperature, pressure, wind, etc.) - Analytical quantities (gas analysis, etc.) ▪ Issue: We should track these by elements of the system that are being monitored - Transformers - Lines - Breakers ▪ Issue: Criteria for including - Communications - Intelligence	▪ Issue: This is an infrastructure metric ▪ Issue: It needs to be measured with some kind of matrix of the applications that are integrated with interfaces that are standardized - EMS/SCADA (%) - GIS (%) - Asset Management Systems (%) - Etc. (need a full list for tracking)

TABLE 5. 7. MEASUREMENT ISSUES WITH CONSUMER METRICS

Number of smart meters	Number of customers with dynamic pricing	Number of MW dispatchable
▪ Issue: Percentage of meters with - 2-way communications - Open protocol ("plug and play") - Load management capability - Home area network enabled - Information Source: Utilities/meter companies	▪ Issue: Percentage of meters with - Time of use - Real time/dynamic pricing (enabled and utilized) for both ▪ Information Source: SECF ▪ Information Source: Utilities	▪ Issue: Percentage of meters participating ▪ Issue: Available kW/meter ▪ Issue: Realized kW/meter ▪ Analysis: Participation dynamics ▪ Analysis: Factors driving predictability ▪ Information Source: Utilities

6. Addresses and Responds to System Disturbances in a Self-Healing Manner

One of the characteristics of a smart grid is having the ability to address electric system disturbances in a more automated manner than is being done today. Achieving this involves new technologies, tools, and techniques for:

- Prevention of disturbances in the first place
- Containment of disturbances to limit their impact on the system
- Restoration of the system after disturbances so that the impact on customers is less

To make progress, changes to several aspects of grid planning and operations will be required, including investment in new devices and equipment and implementation of new standards, procedures, and business practices. For example, new designs for electric transmission and distribution systems will be needed, including configuration of lines, substations, and power flow pathways. New monitoring systems that collect and process large volumes of data on the operational status of various systems, subsystems, and components will also be needed. It will be necessary to develop and use new analysis tools for assessing grid conditions and identifying alternative courses of action to address problems and maintain system stability and reliability. New control systems and automated processes will be needed to accelerate response times and reduce human error. It will also be necessary to deploy new communications standards for rapid data exchange, interoperability of equipment, wider area coverage, and closer to real time operations.

Suggested Revised Wording for the Characteristic: *Addresses Disturbances through Automated Prevention, Containment, and Restoration*

Key implementation metrics include:

- The percentage of grid assets that are monitored, controlled, or automated
- The percentage of network nodes and customer interfaces that are monitored in “real time”
- The level of deployment of common communications infrastructure
- The percentage of the system that can be “fed” from alternative sources
- The geographic coverage, numbers, and MW of phasor measurement units and networks

The Percentage of Grid Assets that are Monitored, Controlled, or Automated

The first step in developing this metric is to define which types of electric system assets are considered to be “smart grid assets.” One consideration is the appropriate level of “granularity” to use, which means the extent to which the metric is applied to specific customers, feeder lines, substations, groups of substations, utility service areas, regional systems, or entire interconnections. There are a variety of potential data sources including utility tax records, circuit maps, and EMS, DMS, or SCADA systems. Analysis is needed to determine appropriate baselines and conduct benchmarking studies to help ensure comparability and consistency of data across utilities.

The Percentage of Network Nodes and Customer Interfaces that are monitored in “Real Time”

The first step in developing this metric is to establish common definitions for what is meant by “nodes” and “real time.” All utilities have achieved some level of this already and thus baselines will need to reflect the fact that each utility will have its own starting point. The best approach for obtaining this information is to survey the utilities and establish protocols and data definitions so that metrics and targets are comparable across companies and regions. Analysis is needed to establish baselines and procedures to normalize based on factors such as value drivers, customer density, and system topology.

The Level of Deployment of Common Communications Infrastructure

The first step in developing this metric is to determine definitions for “common communications infrastructure.” One issue involves the broad-based need for communications standards for the interoperability of equipment across utilities, regions, and the country. Sources of data include the utilities, independent system operators, equipment vendors, and government agencies. Analysis to determine baselines could include inventories of the deployment of SCADA systems and the number of miles of fiber optic cables in service by utilities to support communications for grid operations.

The Percentage of the System that can be "Fed" from Alternative Sources

There are several issues to consider regarding this metric. One issue is that the target for this metric will differ depending on the topology of each utility system. Also, the costs to implement this metric will also vary considerably by utility. Data for this metric may be difficult to obtain because it involves specific information on power flows and grid design that is available from utilities in principle, but record keeping across utilities is inconsistent. Analysis is needed to determine baselines and to determine the extent of loading on alternative sources. Once baselines have been established, progress can be measured by the percentage change against the baseline or as percentage progress toward a specific target or goal.

The Geographic Coverage, Numbers, and MW Coverage of Phasor Measurement Units and Networks

The first step is to determine the extent to which existing phasors are networked and providing used and useful information to support grid operations. Data on existing phasor deployments can come from NERC, the three major interconnections—east, west, and Texas. One issue is the degree to which actual phasor data will be shared among utilities and with others. Analysis is needed to identify potential smart grid applications that rely on phasor data and to assess whether existing coverage is sufficient for the application. Information to collect includes the number of smart grid applications that use phasors, the number of grid operations centers that use phasor data and the types and numbers of uses to which the data is applied.

TABLE 6.1. LIST OF PARTICIPANTS

Name	Organization
Tom Bialek	San Diego Gas and Electric
Witold Bik	S&C Electric
Wayne Boyer	Idaho National laboratory
Merwin Brown	University of California
Vikram Budhraja	Electric Power Group
ML Chan	Quanta Technology LLC
Jerry Fiedler	CoServ Electric
Jerry FitsPatrick	National Institutes of Standards and Technology
John Garrity	GE Research
Michaeil Gouge	Oak Ridge National Laboratory
Arthur Kressner	Con Edison
Trudy Lehner	Superpower Inc.
Ryan Lewellyn	FirstEnergy
Kieran McLoughlin	IBM
Patrick Murphy	Department of Homeland Security
Bert Nelson	Zenergy Power
Phil Overholt	U.S. Department of Energy
Stewart Ramsey	Zenergy/Sequentric
Joe Rostron	Southern States LLC
Bob Reedy	Florida Solar Energy Center
Mark Simon	ComEd
Zolaikha Strong	Edison Electric Institute
Wes Sylvester	Siemens Energy
Don Von Dollen, Group Spokesperson	Electric Power Research Institute
Rich Scheer, Facilitator	Energetics Incorporated

Table 6.2. Comments on the Characteristic

- Covers both the transmission and distribution system – from generation to consumption
- Covers all types of disturbances including voltage spikes and sags, frequency oscillations, etc.
- Priority is avoidance of disturbances and to lessen consequences for consumers when they do occur
- Better monitoring and visibility is key for preventing issues from becoming problems
- How much autonomy is enough?
- Response times must be appropriate. For example, if millisecond response is not needed, why provide it?
- The term self healing has a certain "public relations" appeal, but it is not very accurate and could be misleading
- **Suggested Revised Wording**: *Addresses Disturbances through Automated Prevention, Containment, and Restoration*

Table 6.3. Metrics

(Diamonds indicate the number of votes received to identify the top five priorities)

Monitoring and Analysis	Automation and Controls	Communications	Electric System Design	Societal/Industry Values "lagging build metrics"
▪ % of network nodes and customer interfaces monitored in "real time" ◆◆◆◆◆◆◆◆◆◆◆◆◆ - # of grid components capable of sending or receiving actionable info. - # of smart meters ▪ Coverage %, #, and MW of phasor measurement units and networks ◆◆◆◆◆◆◆◆◆ ▪ Amount of focused disturbance locating ◆◆◆◆ ▪ Extent of condition-based maintenance ◆ ▪ Db level of 5th (or 7th) order harmonics ◆ ▪ Methods of knowing that operating parameters are trending into danger ◆	▪ % of assets controlled and/or automated ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ - Amount of automation deployed - % of system with SCADA - $ invested per line mile or customer ▪ # of MW participating in RTP and/or DSM programs ◆◆◆ ▪ # of automated grid operations that would otherwise require manual intervention ◆◆ - # of regulators approving "nega-watt" programs	▪ Level of deployment of common communications infrastructure ◆◆◆◆◆◆◆◆◆◆◆◆◆◆ - Common communications protocol (yes or no) ▪ Amount of system visibility ◆◆◆ ▪ Extent of data exchange across utilities ◆ ▪ Extent of data exchange and interoperability within a utility system	▪ % of the system that is able to be "fed" from alternative sources ◆◆◆◆◆◆◆◆◆◆◆◆ ▪ (N-X) reliable where X=large integer <N ◆◆◆◆ ▪ % of load or # of MW of storage in the system ▪ Amount of networked distribution systems ◆◆ ▪ Smart grid design blueprint (yes or no) ◆◆ ▪ # of breaker cycle faults per year ◆◆ ▪ % of circuits with >1 tie switch ▪ # of line sections that provide disturbance isolation capabilities ▪ % change versus today of the ability to electrically connect across systems	▪ Restoration time ◆◆◆ ▪ # of prevented disturbances ◆◆ - # of customers affected - # of customers that avoided an outage ▪ The sum over the # of outages per year of the number of affected customers times the duration of the outage per customer ◆◆◆ - # of customer minutes out of service ▪ Level of customer satisfaction ▪ # of regional outages ▪ # of customers disconnected in error ▪ Level of system efficiency ▪ Feeder level composite quality factor - Feeder level equivalent availability factor ▪ Maintenance cost per unit of availability time - # reduction of maintenance costs

TABLE 6.4. MEASUREMENT ISSUES

% of Network Nodes and Customer Interfaces Monitored in "Real Time"	% of Assets Controlled and/or Automated	Level of Deployment of Common Communications Infrastructure	% of the System that is Able to be "Fed" From Alternative Sources	Coverage %, #, and MW of Phasor Measurement Units and Networks
▪ Issue: All utilities will have different starting points ▪ Issue: There is need to develop common definitions for nodes, monitoring, and real time ▪ Issue: Standards are needed for quality, communications, and reliability data ▪ Data from: Utilities, equipment providers, and installation contractors ▪ Methods: Surveys, utility records, standardized compliance units ▪ Analysis: Satisfactory time line ▪ Analysis: Normalization for saturation based on different value drivers; customer density; and system topology/design	▪ Issue: What assets are considered SG assets? ▪ Issue: There is need for consistent definitions in the metrics (e.g., SCADA) ▪ Issue: The level of granularity needs to be determined (e.g., system versus feeder line) ▪ Data from: Asset registries, tax books, circuit maps, industry "best practices," EMS/SCADA systems; DMS/SCADA systems; SA systems ▪ Analysis: Determine appropriate baselines/starting points ▪ Analysis: Estimate rate of change for key parameters ▪ Analysis: Set targets to match expectations ▪ Analysis: Assess consistency across different data collection entities, i.e., benchmarking	▪ Issue: Defining what constitutes a "common communications infrastructure" ▪ Issue: Determining what standards are needed ▪ Analysis: Determine current level of deployment of SCADA and the amount of fiber optic lines to substations ▪ Analysis: Determine how much of what is currently in place is "compliant" with the common communications infrastructure ▪ Analysis: Define what it means to be in compliance	▪ Issue: Target will vary on the grid topology for each utility ▪ Issue: The costs to implement will also vary greatly ▪ Issue: Alternative sources may not be attractive if they are heavily loaded ▪ Data from utilities ▪ Analysis: Determine the baseline as the % that is currently able to be fed from available alternative sources and track changes as the "delta" from the baseline, or the % of progress toward a target or goal	▪ Issue: Definition of when a phasor is "in service"—installed, networked, and production system ▪ Issue: What is the extent of the coverage across the Interconnection in terms of data sharing and the distributed footprint ▪ Data from: NERC (WECC, ERCOT, EI, HQ) and transmission owners and operators ▪ Analysis: Do we have the right coverage to implement smart grid phasor applications? ▪ Analysis: Is there adequate communications coverage? ▪ Analysis: What about the following metrics for phasor applications: # of applications, # of control rooms using them, types of uses such as load monitoring, RenRes monitoring, PIHV

7. Operates Resiliently Against Physical and Cyber Attacks and Natural Disasters

One of the characteristics of a smart grid is having the ability to operate resiliently against physical and cyber attacks and natural disasters. The issues and priorities associated with improving operating resiliency against such incidents are in many cases similar to those associated with improving resiliency against other hazards; accordingly, an all-hazards approach to improving operating resiliency is appropriate. Further, whether an incident that threatens resiliency is deliberate (i.e., an attack) or inadvertent, the activities utilities can take to improve their protective posture and response are in many cases the same. Therefore, the group proposed to expand this characteristic to include resilient operations against all hazards, including physical and cyber interruptions, intentional or inadvertent.

While many of the metrics that can be useful in establishing baseline operating resiliency and tracking progress toward improved resiliency over time apply to either cyber or physical assets, many also apply equally well to both types of assets.

Suggested Revised Wording for the Characteristic: *Operates Resiliently Against All Hazards*

Key implementation metrics include:

- The percentage of operating entities that exhibit progressively mature characteristics of resilient behavior, as measured by high ratings on a resiliency scale
- A measure of the number of alternative paths of supply to any load point on the distribution grid
- Quantified operating margin that is needed to ensure resiliency (i.e., safe limits)
- Adjusting standard metrics currently used (e.g., SAIDI, SAIFI, CAIDI) to capture those incidents initiated by physical and cyber attacks

To avoid unfairly penalizing high-potential targets or the largest asset owners, metrics that measure the number of attacks or incidents should be normalized to the number of assets and the level of risk for the utility.

The Percentage of Operating Entities that Exhibit Progressively Mature Characteristics of Resilient Behavior

This metric provides two measures of progress toward a smart grid that operates resiliently against physical and cyber attacks and natural disasters. First, the magnitude of focus on this issue among the electricity sector can be measured by increases in the number of operating entities who go through the process of either rating themselves or being rated on a resiliency scale. Second, improvements in entities' ratings over time can track progress toward a more resilient posture. The first step in pursuing this metric is to develop a rating scale that will be accepted and used by all parts of the electricity industry. One approach is to modify existing scales (e.g., SEI resiliency engineering framework or APQC survey) to suit the needs of this metric.

A Measurement of the Number of Alternative Paths of Supply to Any Load Point on the Distribution Grid

This metric is a measurement of the number of available paths to supplying customers with electricity in the event of a physical or cyber attack or natural disaster. As the smart grid enables greater flexibility in grid operations (e.g., through greater distributed generation capacity), this metric should improve with time and increase the resiliency of the grid as a whole. This concept of alternative paths must extend back through the entire electricity supply chain to ensure resilient operations for all hazards. For example, the metric should consider alternative supply pathways for coal in even in the event of an attack on railways delivering coal to power plants.

Quantified Operating Margin that is needed to Ensure Resiliency (i.e., Safe Limits)

One of the primary advantages of the smart grid is the ability for utilities to operate the grid in a more dynamic, responsive way, thereby maximizing capacity and reducing the need for reserve capacity to handle peak demands. As operating margins push higher, however, the "buffer" that can be tapped in the event of a disruption caused by an attack or natural disaster diminishes, while the need for an accurate measure of that buffer increases. To ensure the balance between higher operating margins and operating resiliency is achieved, safe limits of operating margin should be quantified. Once those safe limits are known, utilities can progress with the smart grid and reap the rewards of improved operating margins within the limits required for resiliency, even in the event of a catastrophic natural disaster or widespread cyber attack.

Adjusting Standard Metrics Currently Used (e.g., SAIDI, SAIFI, CAIDI) to Capture those Incidents Initiated by Physical and Cyber Attacks

The electricity sector already uses several metrics to track reliability and interruptions in service. Adjusting the processes and data collection methods used to gather these metrics in order to capture incidents initiated by physical and cyber attacks can provide a near-term opportunity for data collection in a highly leveraged way.

TABLE 7.1. LIST OF PARTICIPANTS

Name	Organization
Ron Ambrosio	IBM Research/GWAC
Sharla Artz	SEL, Inc.
Frances Cleveland	Xanthus Consulting
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Patrick Duggan	Con Edison of NY
Steve Ecroad	EPRI
Ali Feliachi	West Virginia University
Gary Finco	Idaho National Laboratory
Steven Goldsmith	Sandia National Laboratory
Darren Highfill	EnerNex
Sarah Mahmood	DHS/S&T Support
Van Holsonback	Georgia Power/Southern Co.
Wayne Longcore	Consumers Energy
Austin Montgomery	Software Energy Engineering Institute
Erik Newman	Surmeitzer Engineering Labs
Terry Oliver	BPA
Michael Peters	FERC
Bacgyn Sadan	Ampericon
Paul Wang	E2RG
Ross Brindle, Facilitator	Energetics Incorporated

TABLE 7.2. COMMENTS ON THE CHARACTERISTIC

- The characteristics of resilient operations can be extended to apply to all hazards and both inadvertent and deliberate incidents
- “Resiliency” includes designing in resiliently, policies, procedures, etc.
- Natural disasters may merit special consideration apart from physical and cyber attack
- Appropriate levels of security are needed - risk assessment with cost considerations
- Islanding, demand management, distributed generation – these aspects of the smart grid enable increased resiliency
- The trade-offs between security and efficiency create tension
- This characteristic includes “ground-up” security, not just encryption
- The characteristic does not reduce the threat, but it does reduce vulnerability and consequences
- **Suggested Revised Wording for the Title**: *Operates Resiliently Against All Hazards*

TABLE 7.3. METRICS

(DIAMONDS INDICATE THE NUMBER OF VOTES RECEIVED TO IDENTIFY THE TOP FIVE PRIORITIES)

	Deterrent	Detective	Preventive	Reactive	Recovery	Risk Assessment
Addresses Cyber Security	▪ Training (type of training needed vs. number trained)	▪ # of successful cyber attacks (scales to importance of asset) ◆◆◆◆ ▪ # of events when investigated shows people poorly or improperly trained	▪ % of domains (systems + devices) subjected to yearly penetration test ◆◆◆◆◆ ▪ # of CIPs addressing smart grid issues (transmission and distribution grids) ◆◆ ▪ Compliance with requirements vs. known treats per standards (e.g., NERC CIP) and rapid identification of new threats to all for appropriate countermeasures and future standards ◆◆ ▪ % of controllable devices that have remote programming capabilities and % that meet CIP standards regardless of operating voltage		▪ Hours to repair (zero day) security issue at end of business case life heterogene-ous network state ◆◆◆◆	
Addresses Physical Security	▪ Number of urban substations inter-connected at distribution voltage	▪ Speed of identification of a physical threat (e.g., video SCADA) ◆◆ ▪ # of attempts to break into substation or tamper with meter over time	▪ A measure of the number of alternative, independent paths of supply to any load point on the distribution grid (e.g., primary feeder, alternate feeder, DG) ◆◆◆◆◆◆◆◆◆ - Must also go upstream through the supply chain ▪ % of distribution facilities that are physically hardened ◆ ▪ % of DG/DR automation capacity vs. base generation/transmission capacity for a (portion) of the distribution grid (assumes DG = more resilient) ▪ This is measurement of heterogeneous resources, which may correlate with resiliency	▪ Reduction in critical load disruption "outage" ◆		

	Deterrent	Detective	Preventive	Reactive	Recovery	Risk Assessment
Addresses Both Cyber & Physical Security	▪ % of operating entities exhibit progressively mature characteristics of resilient behavior (more organizations rating higher on resiliency scale) ◆◆◆◆◆◆◆ ▪ Cyber system metrics - adopt DOD metrics for mission-critical IT (e.g., DIACOP) ◆	▪ # of failures due to conflict in operating procedures across companies ◆◆ - % of joint operating agreements that are formalized across companies ▪ # of hazard events detected, based on theoretical number of events ◆ - Measured at inner and outer rings to measure (1) detection ability and (2) success of outer rings	▪ System availability % (higher means less vulnerability to catastrophic disruption) ◆◆◆◆	▪ Adjust standard metrics (SAIDI, SAIFI, CAIDI) to capture those incidents initiated by physical and cyber attacks ◆◆◆◆◆◆ ▪ Threats communicated with actionable information in a timely manner to the right people ▪ Measurement of breadth of outage caused by physical or cyber event (Smart grid should have reduced physical or cyber footprint)	▪ Degree to which recovery from event is enhanced, as measured by fewer customers without power and faster time to recovery ◆◆◆◆ ▪ % of successful root cause analyses based on forensics ◆ ▪ Time to recover service resulting from an event ◆◆ ▪ Reduction in extent of impact and recovery time for characterized events ◆	▪ Quantified operating margin (safe limits) that is needed to ensure resiliency ◆◆◆◆◆◆ ▪ # of assets (physical and information) for which risk assessment has been truly performed ◆◆◆◆◆◆ ▪ Dollar loss per thousand hours operation or lives lost per thousand hours operation ◆ ▪ # of secondary assets affected by "event" on primary asset (target) (total MVA affected)

TABLE 7.4. MEASUREMENT ISSUES

Adjust Standard Metrics Currently Used (e.g., SAIDI, SAIFI, CAIDI) to Capture Those Incidents Initiated by Physical and Cyber Attacks	A Measure of The "Number of Alternative Paths of Supply" to Any Load Point on The Distribution Grid (e.g., Primary Feeder, Alternate Feeder, DG)	The Percentage of Operating Entities That Exhibit Progressively Mature Characteristics of Resilient Behavior, as Measured by High Ratings on A Resiliency Scale	Quantified Operating Margin That Is Needed to Ensure Resiliency (i.e., Safe Limits)
▪ Issue: Getting agreement on use of new cause codes and contrast ▪ Issue: Data use and reporting ▪ Issue: Privacy concerns ▪ Data from: existing SAIDI, SAIFI, and CAIDI ▪ Data from: Agreed upon new cause codes for physical or cyber attacks ▪ Data from: Forum to make this a commonly understood as existing SAIDI, etc. ▪ Data from: Link to standards (CIP) to identify as breach of requirement/procedure or new issue to be addressed ▪ Analysis question: Is an incident a violation of existing requirement or a new issue? ▪ Analysis question: How best to address or mitigate new standards and other alternatives ▪ Analysis question: To what extent are broad-based risk complexities considered?	▪ Issue: Data availability ▪ Issue: Data correctness (e.g., feeder mapping) ▪ Issue: Developing baseline scenarios and achieving consensus ▪ Methods: ▪ Contingency analysis ▪ Power flow analysis ▪ Data from: AMI, Nameplate, DA (feeder metering), EMS, AM/FM ▪ Analysis question: Determine the contingencies and prioritization ▪ Analysis question: How best to assess possible contingencies and conduct cost/benefit analysis of solutions	▪ Issue: Quantitative measures need to be tailored to specific sectors ▪ Issue: Willingness to respond to survey (and risk looking bad) - Should survey be blind, or have that option? ▪ Issue: Does the utility own and maintain its own systems? ▪ Data from: SEI resiliency engineering framework ▪ Data from: APQC survey ▪ Data from: UNITE survey (IT centric) ▪ Analysis question: What defines operational resiliency for a utility? ▪ Analysis question: Does the target scale change or evolve with time? ▪ Analysis question: What are the "growth stages" and how does "age" impact expectations for maturity?	▪ Issue: What is the ultimate capability of the system (difficulty determining)? ▪ Issue: Understanding real-time state of the system (complexity challenge) ▪ Issue: Information and responsibility sharing (across regions, industry, functions) ▪ Data sources: - Synchrophasors - Real-time dynamic simulation - Dynamic line rakings - Network monitoring - Smart field equipment - Bandwidth communications ▪ Analysis question: Understanding what the reserve margin is and tracking it over time ▪ Analysis question: Is the data integrity adequate? ▪ Analysis question: How best to overcome cultural and regulatory barriers

8. Crosscutting Themes and Potential Next Steps

The concept of a “smart grid” covers the entire electric transmission and distribution system and involves advances in digital and information technology for enhanced operational monitoring, control, intelligence, and connectivity. Many groups have been developing smart grid technologies, tools, and techniques over the past several years and have used a variety of different names to describe their aims and activities.

Title XIII of the Energy Independence and Security Act of 2007 states that “It is the policy of the United States to support modernization of the nation’s electricity transmission and distribution system to maintain reliable and secure electricity infrastructure that can meet future demand growth…” and to achieve the potential benefits of a smart grid. Title XIII also gives DOE, FERC, and NIST new responsibilities for supporting implementation activities. In addition, providers of smart grid technologies, tools, and techniques such as advanced metering infrastructure and phasor measurement units are installing their equipment in ever increasing numbers.

As a result, the timing is right for expanded government and industry cooperation and coordination on smart grid implementation activities.

Measuring progress toward implementation of smart grid technologies, tools, and techniques involves identifying metrics, establishing baselines, and collecting data to track developments. In doing this there is need to account for the level of development and deployment that has already occurred and to recognize that the topology of each utility’s transmission and distribution system may require its own baselines, targets, and measurement approaches. As a result, it is probably not appropriate to track smart grid implementation in the same way for every utility.

Because smart grid covers a variety of technologies, tools, and techniques—from electric generation to consumption—misunderstandings about what it is and what it is not are common. There is an urgent need to provide educational materials about smart grid that contain consistent definitions and concrete examples. The key audiences today for these materials are state utility regulators, offices of consumer advocates, and environmental and consumer groups. In the future, as implementation proceeds, there is a larger educational need to train the next generation of electricity planners, operators, engineers, and technicians about all things smart grid.

Table 8.1. Comments During the Closing Plenary

Crosscutting Themes

- While there is need to make the grid ‘smarter,’ let’s not lose sight of the fact that the physical assets themselves need to be upgraded and modernized.
- In considering the speed of response as a metric for the smart grid, remember that there are limits and avoid spending resources to achieve faster response than specific situations warrant.
- The interdependencies among the various characteristics are enormous and there is need for systems analyses to optimize properly.
- The implementation of the smart grid on a national or North American scale may be the most significant systems engineering effort ever attempted.
- Tools will be needed to handle the large quantity of data that will be generated and communicated throughout the supply chain; effective integration of this data is paramount.
- There is a need to have data, models, and processes for recognizing the societal benefits of smart grid in state regulations and to standardize the value.
- An “avalanche” of power plants and T&D construction is expected over the next 20 years and—in order to be relevant—smart grid technologies, tools, and techniques need to be a part of this.
- The setting of standards will require extensive utility involvement and there needs to be funding to support the standard-setting process.
- A lot of misunderstanding and confusion currently exists about smart grid; there is a need to strive for greater accuracy to build credibility.
- The results of this workshop are highly relevant to smart grid development efforts around the world.
- There is a need to educate about smart grid at all levels, e.g., public officials, interest groups, the general public, and the next generation of planners, operators, engineers, and technicians.
- Smart grid R&D needs to be defined and focused on critical gaps and points of leverage.

Table 8.1. Comments During the Closing Plenary

Possible Next Steps

- Coordination of existing and upcoming smart grid demonstrations would be useful so that results can be comparable and sharable and duplication can be kept to a minimum.
- As smart grid deployments proliferate, it is critical to measure and document results – failures as well as success stories.
- IT requirements and standards need to be more fully explored and discussed.
- Models and tools in use currently by grid operators need to be evaluated and upgraded to include smart grid data and features.
- Smart grid business models, where they have been shown to be profitable or cost effective, need to be documented and shared so success can be replicated.
- There is an urgent need to educate public utility commission regulators on smart grid basics and to make key aspects tangible (e.g., describing a home network).
- Results of this workshop need to be shared with all stakeholders and interested parties, particularly those with limited representation at this workshop (e.g., environmental groups and consumer groups).