GRIDWISE ALLIANCE Advocating for a Smarter Grid

HANDBOOK FOR ASSESSING SMART GRID PROJECTS

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The GridWise® Alliance – Advocating for a Smarter Grid

The GridWise Alliance, founded in 2003, is a consortium of public and private stakeholders which include utilities, IT companies, equipment vendors, new technology providers and academic institutions. The Alliance members are aligned around a shared vision of a smarter electric system that integrates the infrastructure, processes, devices, information, and market structure. This integration will ensure that energy can be generated, distributed, and consumed more efficiently and cost effectively resulting in a more resilient, secure and reliable energy system

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I. Introduction

About

This *Handbook for Assessing Smart Grid Projects* was developed for the GridWise Alliance, a diverse group of smart grid stakeholders that includes system operators, utilities, manufacturers, universities, software and communications companies, investors, and consultants. KEMA, Inc. took a lead in writing the handbook with a great deal of input from Alliance members as well as the Edison Electric Institute and their members.

This handbook is designed to serve as a reference tool for those organizations and entities that are developing and/or assessing a high quality smart grid project. The handbook provides a legislative background and citations, and lays out a series of metrics that could be considered when developing or assessing a project.

This handbook does not seek to be the sole source of understanding smart grid deployment, but should be used as guidance for those who wish to gain a better understanding of the costs and benefits of their project. Care should be taken to follow any project development and reporting procedures required by funding entities such as the Department of Energy.

Purpose

As smart grid projects begin massive deployment with Federal, private, public, and rate-based funds, questions will be asked as to the efficacy of those projects. The GridWise Alliance undertook this project in an effort to identify metrics that were important to evaluating the benefits of smart grid projects. Data collection, measurement and verification will all be important as Federal and state energy and climate policy takes shape and the electric grid begins its transformation to a cleaner, more intelligent ecosystem. This handbook was prepared by KEMA, Inc. with the GridWise Alliance to identify key metrics that smart grid projects should meet in order to be deemed high quality projects. The purpose of this paper is:

- To suggest key metrics for project developers to use when developing smart grid projects.
- To describe a process allowing stakeholder participation in meeting these metrics and for identifying weighting of metrics.
- To recommend a process for monitoring and reporting on effective use of smart grid funding, whether through the Federal, State or private investments.

- To ensure efficiency in contracting procedures, whether done on a Federal or State level.

II. Approach

To develop the suggested metrics, the American Recovery and Reinvestment Act of 2009 (Recovery Act) was thoroughly analyzed to understand its objectives and to identify all provisions that relate to the development of a Smart Grid. This led to an examination of the Smart Grid programs in Title XIII of Energy Independence and Security Act of 2007 EISA, which was amended and funded under the Electricity Delivery and Energy Reliability provision in the Recovery Act. The Initial Implementing Guidance for the Recovery Act from the Office of Management and Budget (OMB) was a key resource for understanding the planning and implementation requirements for various aspects of the Recovery Act.

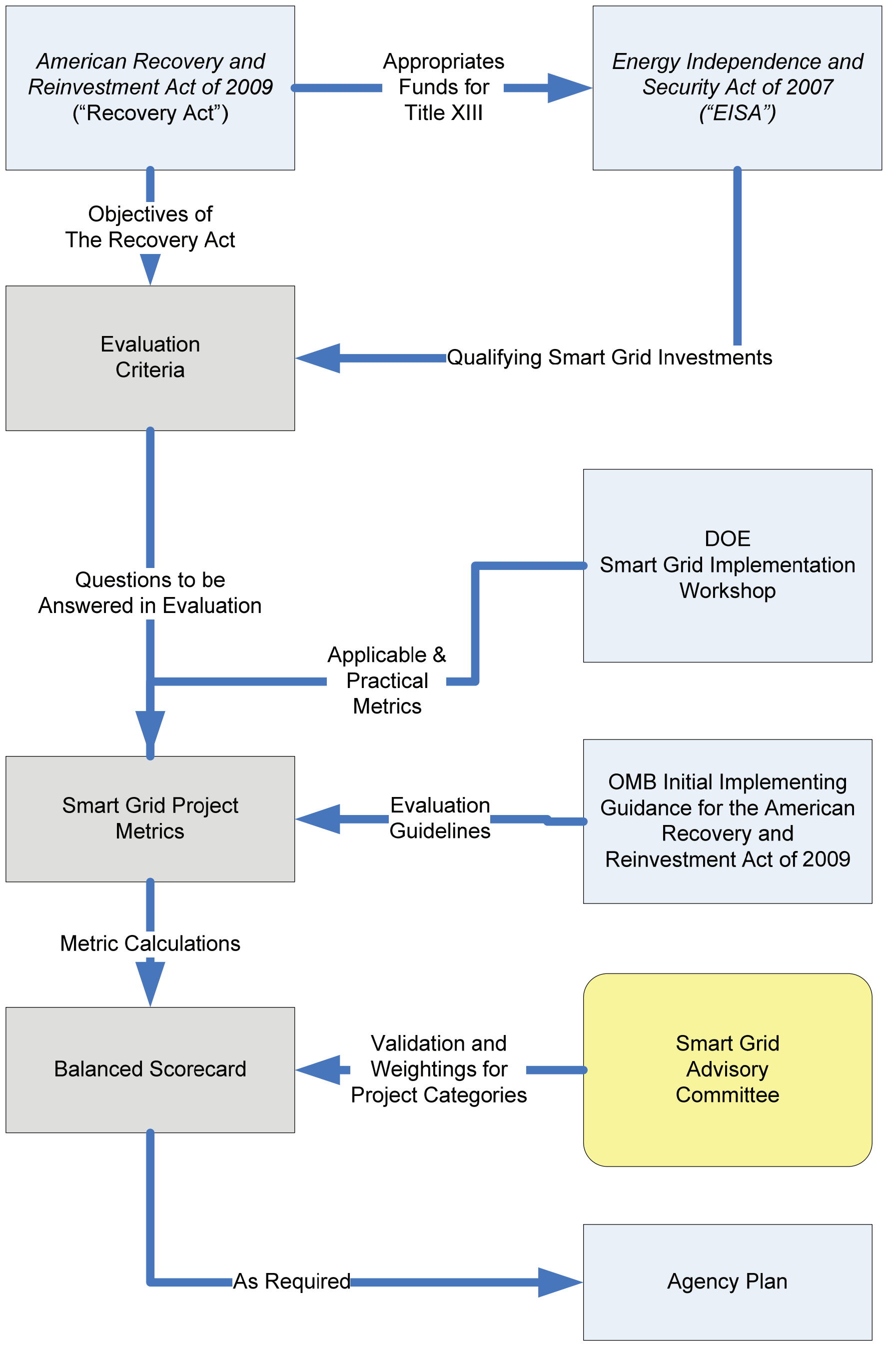
Prior and ongoing Smart Grid program efforts by the Department of Energy (DOE) and other stakeholder groups, were also leveraged, including the National Energy Technology Laboratory's (NETL) Modern Grid Initiative and work on key Smart Grid implementation metrics completed in June 2008 at the DOE's Smart Grid Implementation Workshop. From the workshop's key Smart Grid implementation metrics, metrics were selected that are applicable and practical for the purpose of evaluating project applications. Smart Grid business cases, regulatory filings, and ongoing utility performance reporting were drawn upon to identify relevant metrics.

To aid with comparative evaluations, a method for weighting the metrics is needed. Rather than suggest weightings, this paper suggests a proven methodology for developing weightings when complex metrics are in use and when different stakeholders have different perceptions of the relative importance of each metric.

This handbook also describes a process for publishing the metrics and weightings, applying them to grant applications, and disseminating results at a high level. Finally, a summary is provided on which metrics can be monitored and reported by project contractors and grant recipients and how these can be reported by DOE or other oversight agencies.

Exhibit 1 provides an overview of the approach used to develop the recommended metrics for assessing Smart Grid projects.

Exhibit 1: Metrics Development Approach



III. Using the Metrics

Few, if any, Smart Grid projects are likely to impinge on all the areas that the metrics in Appendix A cover. While a broad regional "demonstration" project might conceivably address all aspects of Smart Grid from "behind the meter" to the generator, the typical project will be focused on one or two of the domains. Going forward, utility project initiatives, which must be funded by state or municipal bodies via a regulatory approval process, are likely to be focused on specific domains.

Therefore, the metrics have to be selected for use in a given project business case in light of the purpose of the project.

Additionally, these are not metrics for a "scorecard" use where 100 is perfect and 65 is a pass-fail threshold. Rather, they are a compilation of the benefits and impacts that can be claimed and assessed in a project business case.

The DOE's Smart Grid Clearinghouse and other initiatives in the states will begin to collect project implementation data that can help build a picture of numerics typical of these metrics, thus continually informing the process.

IV. Defining and Categorizing Smart Grid Projects

Developing relevant and effective metrics for evaluating Smart Grid projects requires that the meaning of a Smart Grid be clearly defined. Though many Smart Grid definitions exist, for the purposes of evaluating Smart Grid projects, this paper draws upon the definitions provided in EISA, Section 1301; Section 1306(b) - Qualifying Smart Grid Investments; and Section 1306(d) - Smart Grid Functions.

EISA, Section 1306 enumerates nine categories of expenditures that are authorized and eligible for matching funds. This paper focuses on the metrics that apply to Utility Investment Projects which are generally complex with many cost-benefit factors and frequently where multiple Smart Grid technologies and project types come together.

The GridWise Alliance recommends that smart grid projects could consist of:

- Retrofits to transmission apparatus with Smart Grid capabilities;
- Transmission monitoring, control, and optimization including sensors, communications, and computer systems and software;
- Distribution monitoring, control, and optimization including sensors, communications, and computer systems and software;
- Smart Grid technologies focused on renewables facilitation;
- Advanced Metering including advanced meters, communications infrastructure, and computer systems and software;
- Communications infrastructure to support Smart Grid including distribution automation and advanced metering;
- Microgrids capable of high reliability/resiliency and islanded operation;
- Integration of Distribution Automation (DA), Feeder Automation (FA), Advanced Metering Initiatives (AMI), and microgrid technologies;
- Technologies to assist in the efficient integration of plug-in hybrid vehicles;
- Consumer integration into energy markets and grid operations;

- IT, communications, and field automation projects concentrated on achieving compliance with Cyber Security standards.

Appendix B provides additional definition of these categories.

V. Technological Subsets of Smart Grid Initiatives

Implicit in the Recovery Act and prior DOE work on Smart Grid is recognition of different categories of Smart Grid technologies and applications ranging from new transmission apparatus and controls to smart meters and integration with home area networks (HAN). The different technological categories focus on achieving different objectives of the Recovery Act to varying degrees; that is, not all technologies address all objectives in a comparable fashion. How can project evaluators ensure that funding is sufficiently and fairly allocated so as to appropriately cover the broad universe of Smart Grid technologies?

The GridWise Alliance membership broadly supports all variations of Smart Grid projects and that it is important to deploy projects that span the broad domain of Smart Grid technologies.

VI. Evaluation Metrics

i. *Relationship of Smart Grid Technologies to Evaluation Factors*

Different Smart Grid projects with varying content in different categories of activity will match up with different evaluation factors and criteria differently. A set of criteria and corresponding metrics that span all of the Smart Grid project categories and qualifying Smart Grid investments identified in EISA, Section 1306 have been developed. Project evaluators may develop weighting factors or other mechanisms for selecting which metrics are best used for different kinds of projects. Not all metrics are applicable to all types of projects.

EISA, Sections 1304(b) and 1306 both stipulate that eligible investments must use open protocols and standards when available.

ii. *Metrics Development*

The recommended metrics for guiding Smart Grid project funding were developed using the results of the DOE's Smart Grid Workshop report on national Smart Grid metrics, which were assessed for applicability to this initiative and categorized within the evaluation factors from the legislation. Included in these recommendations were considerations for the practicality of applying quantitative metrics to track, assess, and report. Many of the workshop criteria were intended to measure success levels of the penetration and development of Smart Grid on a regional or national scale and are not applicable to a single project. Examples include measures of venture capital funding, and development of companies exceeding $100M in market capitalization. Others are useful measures of Smart Grid project impacts (e.g., improvement in System Average Interruption Duration Index (SAIDI)) for the purposes of developing metrics. Also considered was whether the particular metric was already included in Smart Grid business case development and/or regulatory filings. Metrics that are familiar to the Smart Grid community and already calculated in an intensive review process for large-scale projects are more likely to be successfully applied and submitted with proposals in a timely manner. Those which have too many issues identified in the workshop report and which are not typical today are likely to delay project proposals and evaluations. An assessment of the workshop metrics for this purpose is shown in Appendix C.

Some of the legislative objectives in the Recovery Act are simply not in the workshop results or, in some cases, in typical business case and filings. However, these are also likely among the most critical of the Recovery Act's objectives – particularly job creation, environmental impact (in terms of renewables facilitation and energy delivery efficiency), and the engagement and participation of the consumer. With these metrics, it is important that project evaluators provide guidance as to their definition and direction as to how to apply them in developing and measuring a project.

Using this process, a suggested list of metrics under each objective has been created. This is shown in Exhibit 2 and the detailed explanation of each metric development is shown in Appendix A.

Exhibit 2: Results

Evaluation Criteria	Metric
Economic Stimulus Effect	
Job creation plans and estimates	
Timing of job creation	Direct jobs and wages retained and/or created; normalized to #jobs/$000 of project cost
	Indirect supply chain jobs and wages as above
Impact on local economy	Wages and purchases spent in local economy times multiplier effect
Stimulation of a Smart Grid business ecosystem	Quantitative but subjective and hard to assess on a project basis
Impact on energy costs to consumers	% and $ decrease in consumer energy costs
	Consumer savings- average $ and % change in consumer annual bill by class
Number or extent of new programs/services being offered	Qualitative
Number of existing smart grid implementations in the state (to encourage geographic dispersion)	Qualitative
Other	As proposed
Energy Independence and Security	
Facilitation of renewable energy	Additional capacity for accommodating incremental renewables - MW and % peak MW and & energy; probably best described qualitatively
	% of DG / renewables that can be sensed and controlled
	Facilitation of distributed renewables - projection - MW, % peak MW; % energy
	MW and % increase in maximum remote renewable resource capacity the system can accommodate when possible to quantify
Electric Vehicle / Plug-in Hybrid Electric Vehicle integration	Qualitative

Evaluation Criteria	Metric
	# PHEV charging connected to V2G services
	Projected impact in terms of # of PHEV added
Demand Response management	# customers and coincident peak MW participating
	MWH saved at coincident peak
	MW reduction at coincident peak
	Market price impact
System Efficiency	% improvement in losses
	$ and % improvement in costs of failed equipment
	Improvement in system congestion costs when possible to evaluate.
Forecast of customer participation in demand response and conservation programs	# of customers and MW
Greenhouse gas emissions reduction potential	Tons GHG and per MWH; also tons GHG / customer
Power System reliability impacts	SAIDI improvement
	Reduced restoration time from major disruptions
	Reduction in major outages
	Improvement in Loss of Load Probability
Amount of transmission, distribution and substation automation in project	Increase in IED penetration integrated to SA and control systems
	# / % of lines, feeders and stations to be automated
Integration and Interoperability	
Links to the state energy assurance plan (required of all governors)	% fulfillment
Integration with state/local energy efficiency and conservation programs	Qualitative
Degree to which direct consumer participation is encouraged	Attractiveness of customer value proposition
	Open protocols and open business model to 3rd party products / services
Plans for measurement of customer participation and adoption	Qualitative
Interoperability of smart grid technologies	Qualitative

Evaluation Criteria	Metric
Use of Open Protocols	Qualitative
	% improvement in # of IEDs and controllable apparatus using open protocols
	Compliance to Security needs
Business Plan Robustness	
Completeness of technology plan and maturity of chosen technologies	Qualitative
Outcome of cost-benefit analysis which includes qualitative factors such as benefits to society	Qualitative
Plans for interim reporting on progress	Not a metric; specified by DOE
Implementation plan	Assess per FAR
	Risks - cost, schedule

VII. Evaluation Process

In order to apply these metrics to a proposed project and arrive at a balanced scorecard result suitable for comparing project proposals, project evaluators will need to develop weightings for each metric appropriate to the Smart Grid category being proposed.

One approach to developing the weightings (and gaining some acceptance of the metrics) for DOE to consider is the "Analytical Hierarchical Process" or AHP. AHP is a process for developing weightings of multi-factor metrics that are not easily quantified and where different stakeholders have different perceptions of the importance and value of each metric. AHP has an accepted theoretical background, is widely used in project evaluations in a number of domains, and has been applied to Smart Grid and related project assessment criteria development in the past. It is supported by a number of commercially available software tools. It is a transparent process wherein stakeholders interact to develop relative comparative pairwise weightings and then which rationalizes those weightings in a logical and mathematical framework. Appendix D provides additional details on AHP.

VIII. Reporting

The OMB Guidance spells out periodic agency reporting requirements on agency programs under the Recovery Act. The Guidance also points to existing Federal regulations and procedures for monthly cost and progress analysis and reporting by contractors and grantees. This paper does not attempt to amplify on these well-understood processes.

This paper, however, suggests that on some basis the funding recipient report on project performance against the evaluation criteria. The evaluation metrics that are calculated in the original project application and audited/modified/accepted by project evaluators should be derived from a set of calculations and assumptions that were transparent in the application and consistent with accepted definitions and Federal and state guidance. As such, they are subject to change as inputs to those calculations change. After deployment, the funding recipient should assess the system performance metrics (reliability, costs, consumer participation, etc) that were derived and report on planned versus actual results. A final report should include a reconciliation of planned versus actual metrics and scorecard results.

The Federal government in coordination with states should establish a database of metrics and scorecard results on proposed and awarded projects plus the evolution of metrics through the project and as finally reported. This database can be used to accomplish a number of beneficial results:

- Publication of it allows likely future project business cases, whether applying for Federal or state funding or not, to fine tune their proposed metrics and scorecards and to understand where the assumptions and calculations have changed with events.
- DOE will ultimately possess a database of planned and actual metrics that will be useful to the industry in future Smart Grid project planning on a commercial basis. This will also be useful in future regulatory processes.
- DOE will have a basis for periodic agency reporting of the planned and actual metrics and scorecards on an overall basis for analysis.

IX. Summary

A set of metrics for grant application evaluation and scoring were adapted from the results of recent DOE workshops with industry stakeholders that developed broad Smart Grid implementation success factors. Typical technical and economic metrics already well understood and developed in Smart Grid business case development and regulatory filings are used and mapped to the relevant workshop metrics. A process of ratifying the metrics and developing weightings for them is described that would make use of an accepted scorecard development methodology, the Analytical Hierarchical Process.

X. References

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Appendix A – Recommended Metrics

Evaluation Criteria	Metric	Description	Applicability
Job creation plans and estimates			
Timing of job creation	Direct jobs and wages created; #jobs/$000 of project cost	Net new jobs and wages of utility and project contractor employees, linked to project tasks and durations. Example: installation of 200,000 meters at 4 hrs/meter over 6 months results in 800 installers and 40 supervisors. Result should be in # of jobs and # of jobs / project cost. Profile of jobs and wages over time to be provided.	Typical with Major AMI Projects; less applicable to T&D projects
	Indirect supply chain jobs and wages as above	Suppliers estimate that project will result in XX incremental jobs over a time period incrementally greater than if project had not gone forward. Example: manufacturing, test, and delivery of 200,000 meters at 0.25 hours /meter over 6 months results in 100 jobs and 10 supervisors. Jobs are net of avoided layoffs and new hires/ contractors.	Multiplier times Procurement content in project

Evaluation Criteria	Metric	Description	Applicability
Impact on local economy	Wages and purchases spent in local economy times multiplier effect	DOE should publish Federally accepted multipliers for local regions. Proposing entities should use these for utility, contractor, and supplier jobs and wages to estimate additional regional jobs.	Broadly applicable as economic multiplier
Stimulation of a Smart Grid business ecosystem	Quantitative but subjective	If the project is expected to create / sustain direct and indirect supplier businesses, this should be described and quantified where possible. Examples could include factors such as % increase of revenues of Smart Grid technology/product supplier (jobs already counted above, note) or stimulation of NN local business enterprises / franchises installing consumer side products (PV, example). This latter may or may not be already counted in the local economic multiplier effect based on uniqueness of procurement and business opportunity. DOE will have to develop a process for scoring these claimed impacts.	Not applicable to most projects

Evaluation Criteria	Metric	Description	Applicability
Impact on energy costs to consumers	Projected % and $ decrease in consumer energy costs	Should be weighted more heavily if a proposed tariff than if a projected change. Also, rate increases are negative factors.	Typical for Demand Response Projects Only
	Projected Consumer savings- average $ and % change in consumer annual bill by class	Projected on a per consumer basis by class as is typical in regulatory filings today	Typical for Demand Response Projects Only
Number or extent of new programs/services being offered	Qualitative	Proposal should describe new services offered and an estimate of the consumer acceptance/participation. DOE will develop a methodology for scoring such	Applies to AMI / DR Projects integrated with behind the meter resources
Other	As proposed	Freedom for proposer to identify other economic benefits. Example: improved reliability reduces exodus of high technology firms. Reduced rates attract additional business.	Should encourage applicants to identify new types of benefits
Facilitation of renewable energy	Additional capacity for accommodating incremental renewables - MW and % peak MW and & energy	Could be as a result of increased transmission capacity (or reduced stability limit derating); could be as a result of peak reduction on distribution feeder; whatever rationale and calculation that can be	Difficult to do except in special cases today.

Evaluation Criteria	Metric	Description	Applicability
		supported	
	% of DG / renewables that can be sensed and controlled	Renewables and DG need to be integrated with Smart Grid and system operations via sensing, communications, control, and integration with system computer systems	Applies to SCADA, AMI, Distribution Automation
	Facilitation of distributed renewables - projection - MW, % peak MW; % energy	Calculation/estimate of additional distributed renewables as a result of technical support, integration technologies, consumer business propositions and value. Also fossil fuel offset	Applies to Above plus new planning and operations systems
	MW and % increase in maximum remote renewable resource capacity the system can accommodate	Increased transmission capacity to access remote renewables due to Smart Grid technologies. (this metric will only be applicable in selected instances)	Difficult to know except in special cases (example – special wide area protection)
Electric Vehicle / Plug-in Hybrid Electric Vehicle integration	Qualitative	Description of specific programs / customer participation offerings to attract PHEV	Applicable to EV/PHEV aspects of AMI and DA projects

Evaluation Criteria	Metric	Description	Applicability
	Projected # PHEV charging connected to V2G services	Projection of how many PHEV will be connected to Vehicle to Grid functionality for managed charging	Applicable to EV/PHEV aspects of AMI and DA
	Projected impact in terms of # of PHEV added	Programs to support / enable projected # of PHEV where projection source is regional, auto industry, governmental	Applicable to EV/PHEV aspects of AMI and DA
Demand Response management	Projected # customers and coincident peak MW participating	Per existing program filings. Calculated by revenue class	Applicable to AMI, DA, and behind the meter integration
	Projected MWH saved at coincident peak	Per existing filing methodologies, calculated by revenue class	Applicable to EV/PHEV aspects of AMI and DA
	{Projected MW reduction at coincident peak	Per existing filing methodologies, calculated by revenue class	Applicable to EV/PHEV aspects of AMI and DA
	Projected Market price impact	Per market simulations using accepted methodologies	Typical of Demand Response Projects in Deregulated Markets
System Efficiency	% improvement in losses	Reduction in losses via voltage control, peak reduction, use of storage, etc.	Typical of distribution volt/var control

Evaluation Criteria	Metric	Description	Applicability
	Projected $ and % improvement in costs of failed equipment	This metric summarizes the economic impacts of condition monitoring, condition based maintenance, asset management, and other operational techniques relying on sensors, systems integration, and advanced applications software	Goal of asset management programs utilizing condition monitoring
Projected reduction in congestion costs	Congestion Costs $$	Reduction in Congestion Costs as a result of increased limits via monitoring / calculations or via new algorithms	Difficult except in special cases
Forecast of customer participation in demand response and conservation programs	# of customers and MW	As per today's typical filings	Applicable to AMI, DR, and behind the meter projects
Greenhouse gas emissions reduction potential	Tons GHG and per MWH; also tons GHG / customer	Weighted per GHG norms; includes loss reduction, renewables increase, effect of conservation, and secondary effects such as reduced utility truck mileage	Applicable to demand response and energy efficiency; also to projects that alter system generation dispatch
Power System reliability impacts	SAIDI improvement	Per filings today	Applicable to many T&D automation and demand

Evaluation Criteria	Metric	Description	Applicability
			response projects
	Reduced restoration time from major disruptions	Projected from utility applicant experience and/or benchmark data; expressed as % reduction in the total major disruption customer outage hours (area under duration curve)	Applicable to Distribution automation
	Reduction in major outages	Not quantifiable today as incidents are too infrequent. Description of how outages will be avoided and why; relation to historical where possible; projected additional threat due to load growth, renewables growth, etc	Applicable to transmission optimization and control
	Improvement in Loss of Load Probability	Calculated improvement in system reliability due to Smart Grid technologies at the transmission level, including Synchrophasor, FACTS and other technologies, advanced software systems, asset management, and other technologies	Applicable to transmission optimization and control
Amount of transmission, distribution and substation automation in project	Increase in IED penetration integrated to SA and control systems	Increase in digital vs. analog/electromechanical technology and full utilization via comms and	Applicable to transmission and distribution

Evaluation Criteria	Metric	Description	Applicability
		integration per Smart Grid workshop discussions	automation projects
	# / % of feeders and stations to be automated	Comment: projects that deploy IEDs w/o substation, comms, and back office systems do not qualify	Applicable to transmission and distribution automation projects
Links to the state energy assurance plan (required of all governors)	% fulfillment	Exposition of contribution of renewables, demand management, and reliability projections to state plan. Could measure extent to which project fulfills state objectives but is not a comparable metric	Broadly applicable in a descriptive sense. Quantitative for demand response and renewables
Integration with state/local energy efficiency and conservation programs	Qualitative	Exposition of how project fulfills state objectives. And how to avoid double counting	Applicable to demand response, behind the meter integration
Plans for measurement of customer participation and adoption	Qualitative	Description of plans for end use consumption measurement; total household/business measurement; and statistical analysis of same	Applicable to demand response, behind the meter integration
Interoperability of smart grid technologies	Qualitative	Description of standards to be employed; justification of any	Applicable to all Smart Grid projects

Evaluation Criteria	Metric	Description	Applicability
		standards not embraced; plans to validate the interoperability; description of any new integration points or techniques. Decision not to use standards should weigh very negatively	
Use of Open Protocols	Qualitative	Binary yes / no; need a commitment to future open standards when available	Applicable to all Smart Grid Projects
	% improvement in # of IEDs and controllable apparatus using open protocols	The relative % of system IEDs and controllable apparatus that are integrated via open protocols	Applicable to transmission and distribution automation
	Compliance to Security needs	Assurance of levels of security consistent with industry practices and emerging standards	Applicable to transmission and distribution automation
Degree to which direct consumer participation is encouraged	Attractiveness of customer value proposition	Financial value to customer; extent to which is market tested; extent of hurdles to customer participation	Applicable to Distribution automation, AMI, and behind the meter integration
	Open protocols and open business model to 3rd party products / services	Qualitative description of provisions for 3rd party products and services (also part of ecosystem above)	Applicable to AMI and behind the meter integration

Evaluation Criteria	Metric	Description	Applicability
Outcome of cost-benefit analysis which includes qualitative factors such as benefits to society	Qualitative	BCA per filings. Include description of benefits, avoided costs, and costs borne by stakeholders to achieve benefits	
Plans for interim reporting on progress	Not a metric; specified by DOE		
Implementation plan	Assess per FAR		
	Risks - cost, schedule		

Appendix B – Smart Grid Project Categories Definitions

- **Retrofit of transmission apparatus with Smart Grid capabilities**: flexible AC transmission technologies; high-efficiency technologies (e.g., low-loss or superconducting technologies); high-speed switchgear; new voltage transient suppression technologies; environmentally-friendly technologies (lower profile transmission towers, oil-free or gas-free apparatus) new technologies targeted at renewables integration (e.g., novel undersea cables for offshore wind). Storage is explicitly called out in the Recovery Act and is both a technology that can be applied as a generation, transmission, distribution, or customer resource.

- **Transmission monitoring, control, and optimization**: sensors, communications, automation systems, asset-condition monitoring systems, planning and control room applications, including computer systems and software.

- **Distribution monitoring, control, and optimization**: sensors, automation systems, asset-condition monitoring systems, planning and control room applications, including computer systems and software including: feeder and substation automation with particular provisions for reducing peak and off-peak energy consumption; integrating high renewable levels, integrating consumer-side resources and demand response; improving reliability; reducing losses; improving resiliency against major disturbances – physical and cyber, natural, accidental, and deliberate. Also apparatus with new controllability, efficiency, or environmental-direct benefits.

- **Smart Grid technologies focused on renewables facilitation**: there are a number of technology "gaps" associated with support for high levels of renewable resources ranging from apparatus (inverters capable of providing voltage var support, governor response, and power system stabilization) to protection/automation systems (specific wide-area protection schemes aimed at high RP levels); feeder and station protection and automation systems developed for high local renewables penetration, and protection systems developed for high behind the meter or distributed renewables on distribution circuits), and analytic applications (forecasting, scheduling, and optimization tools which are developed for the high levels of uncertainty associated with some renewable portfolio projections).

- **Advanced Metering**: two-way metering capable of a variety of functionality including real-time pricing; remote connect/disconnect; integration of electric vehicles (EVs) and home area networks (HAN) at some level; power quality sensing and communications.

- **Communications infrastructure projects** associated with enabling utility-wide coverage for distribution automation, advanced metering, distributed generation, storage, and other resources. Distribution communication networks for smart grid capabilities: facilitating a network dedicated to the increased use of sensors installed throughout the distribution grid and other real-time, automated, interactive technologies required by the smart grid. For communications concerning grid operations and status, distribution automation, integration of renewable, Advanced Metering and microgrids.

- **Microgrids capable of high reliability/resiliency and islanded operation**: Advanced microgrids integrated with distributed generation and storage, bridge distribution systems, and consumer technologies.

- **Integration of Distribution Automation (DA), Feeder Automation (FA), Advanced Metering Initiatives (AMI), and microgrid technologies**: microgrids that are integrated operationally with utility Smart Grid systems.

- **Technologies to assist in the efficient integration of Plug-In Hybrid Vehicles**. Charging control, communications, computer systems and software, and distribution automation associated with PHEV integration with grid and market operations.

- **Consumer integration into energy markets and grid operations**: systems that communicate market information to customers and enable them to make decisions which impact markets as well as facilitating integration of grid operations with consumer decision making. Systems for integrating EVs with Smart Grid fall under this category.

- **Cyber Security projects** involving IT technologies, communications, and field smart grid components that are specifically targeted at achieving system compliance with cyber security standards.

Appendix C – Smart Grid Workshop

Smart Grid Workshop Metric	Rating	Issues In Workshop	Factor In AMI / SG Filings Today	Issue For DOE SG Metrics	DOE Stimulus Scorecard Basis
Enables Informed Participation by Customers					
% of customers capable of receiving information from the grid	H	Communications infrastructure acknowledgement of signals customer actual response technical penetration and standards	Yes	Yes	High
% of customers opting "in" or delegating authority	H	Definition, sources, demographics	Forecast as part of Benefit Cost Analysis (BCA)	Maybe	Medium
# of comms enabled behind the meter devices	H	Definition, product life cycles, what to include	Not under utility control at all	No	No
# of customer side devices interacting with the grid	H		Could be forecast for renewables and Electric Vehicle (EV)	Maybe	Medium/High
Amount of load managed	M	vs. business as usual, impact of information availability, measurement	Forecast as part of BCA	Yes	Yes
Measurable energy savings by customers	H	Definitions, load growth, EE vs. SG savings	Forecast as part of BCA	Yes	Yes
% of customers on 2-way TOU metering (actual)	M		Yes	Yes	Yes
# of participation options available to customers	M		Tariff issue often not addressed in SG filings	Yes	Yes
AMI Mkt penetration	M		Not relevant	No	No
MW of demand response / # of customers with DR	L		Forecast as part of BCA	Yes	Yes

Smart Grid Workshop Metric	Rating	Issues In Workshop	Factor In AMI / SG Filings Today	Issue For DOE SG Metrics	DOE Stimulus Scorecard Basis
% of successful rate recovery on smart grid investments	L		No	No but PUC endorsement needed	Yes as PUC endorsement
MW of DG / # of customers with DG	L		Forecast as part of BCA	Yes	Yes
Elasticity of demand in regional markets	L		Not Usually Today	Maybe	???
Reduction in CO2	L		Not Usually Today	Yes	Yes
ASCI point improvement	L		No	No	No
Accommodates all Generation and Storage Options					
% of grid networked to standards	M	Standards, FERC participation, non-IOU DER	No	Yes	Yes
% of Real Time (RT) DG & storage that can be controlled	M	Standards, data definition, needed R&D	No	Yes	Yes
% of load (energy) served by DG/renewables	M	Defining baseline, data management, validation	No	Yes	Yes
# of days to process DG applications	M	Single data base, many procedural issues	No	No	No
% of off system renewables served by storage	H	Visibility of Renewable; operational status of storage			
Improvement in load factors	M	Metering, multiple impacts, data validation	Usually Part of BCA	Yes	Yes
% completion of comms infrastructure to support DG and storage	M		Yes	Yes	Yes
Ability for scheduling and forecasting	L		No	Not for SG projects	No

Smart Grid Workshop Metric	Rating	Issues In Workshop	Factor In AMI / SG Filings Today	Issue For DOE SG Metrics	DOE Stimulus Scorecard Basis
Ability to accommodate 50% non-dispatchable generation by 2020	L		Not Usually	Link to any National RPS Goal	Maybe
Capacity of fossil gen retired	L				
Ability to sense DG presence	L		No	Yes	Yes
Ability to sense and measure DG physical effects	L		No	Yes	Yes
Address intermittency	L		No	No	No
Enables New Products, Markets, Services					
Degree of Regulatory Recovery for Alternative Solutions	H	Data base and funding, definition, non IOU,	No	PUC Endorsement	Yes - PUC Endorsement
Number of New SG related $100M enterprises	M	SG as sole driver; definitions; sources of data; proprietary data	No Applicable	No	No
# of products with end to end interoperability certification	M	Who certifies; scope of standards; validation; source of data	Not Applicable	No	No
Amount of VC funding for SG startups	M	Source and validity of data; what to count	Not Applicable	No	No
# of New Residential products vs 2 yrs prior	M	Definitions; who tracks;	Not Applicable	No	No
Expected availability of service	M		No	No	Yes
Venture Capital (VC) funding	M		Not Applicable	No	No
# households with Home Automation Network (HAN)	M		No	No	No
# consumer owned generation types	L		Yes	Yes	Yes

Smart Grid Workshop Metric	Rating	Issues In Workshop	Factor In AMI / SG Filings Today	Issue For DOE SG Metrics	DOE Stimulus Scorecard Basis
n# of MW saved and business models capitalizing on savings	L		Usually in BCA	Yes	Yes
Per capita electricity use	L		No	No	No
BCA and NPV of project	L		Yes	Yes	Yes
# of EV charging off peak	L		No	Maybe	Maybe
Optionality value of savings	L		No	No	No
Consumption efficiency by users	L		Yes	No	No
# new standards	L		Not Applicable	No	No
# of title 13 related generization plans	L		Not Applicable	No	No
Per capita avoidance of GHG	M		No	Yes	Yes
Provides Power Quality Needs for Digital Economy					
#Devices/Reliability Improvement	H	Definitions and determination	Yes	Could be in BCA	Maybe
# Power Quality Measurements per customer	H	What is actually useful	Yes	No	No
# Power Quality Incidents that can be anticipated and identified	H	Definition; cause, standards	Yes	No	No
# States with Power Quality performance rates	M		Not Applicable	No	No
# customer complaints re Power Quality	H	Definition, attribution to SG	Yes	No	No
# PQ devices sold and installed	M		No	No	No
Open architecture of devices	L		No	No	No
$ of sensitive loads with immunity	M		No	No	No

Smart Grid Workshop Metric	Rating	Issues In Workshop	Factor In AMI / SG Filings Today	Issue For DOE SG Metrics	DOE Stimulus Scorecard Basis
# customer choices for PQ levels	M		No	No	No
DG level where VR is economic	L		No	??	??
Cost to economy of PQ	L		No	??	??
Optimizes Asset Utilization and Operating Efficiency					
Transmission					
# assets deferred and timing	H	Tracking; must maintain performance	Sometimes in BCA	Yes	Yes
# of MW involving V / VAR control	M	Definitions, what technologies	No	Yes	Yes
# assets with condition monitoring an diagnostics	H	Tracking by category; definitions	No	Yes	Yes
# lines with dynamic ratings	M		No	Yes	Yes
3 miles of line with advanced materials and devices increasing capacity	M	Definitions, better metrics	No	Yes	Yes
Distribution					
MW of DG as dispatchable assets	H		Yes	Yes	Yes
% SG enabled apparatus	H		No Usually	Yes	Yes
# MW with V VAR controls	M		Not Usually	Yes	Yes
# customers connected per automated segment	M		No	Maybe	Maybe
Consumer					
# smart meters	H	% two way; openness; functionality	Yes	Yes	Yes

Smart Grid Workshop Metric	Rating	Issues In Workshop	Factor In AMI / SG Filings Today	Issue For DOE SG Metrics	DOE Stimulus Scorecard Basis
# customers with TOU rates	L	Link to meter deployment; available vs. utilized	Yes	Yes	yes
MW dispatchable demand response	M	Available vs. utilized	Yes	Yes	Yes
General					
# IEDs deployed	M	Definitions; track by assets monitored	No	Yes	Yes
# IEDs with full communications	M		No	Yes	Yes
# IT applications integrated	M		No	No	No
# of Phase Measurement Units (PMUs) deployed	M		No	Yes	Yes
Addresses Disturbances via Automated Prevention, Containment, and Control					
% of assets that are monitored, controlled, or automated	H	Variations; definitions; standards	Yes	Yes	Yes
% of nodes and customer interfaces that are monitored	H	What assets qualify; definitions; standards; variations	Yes	Yes	Yes
Level of deployment of common communications infrastructure	H	Definitions; standards development; current state	Yes	Yes	Yes
% of system that can be fed from alternative sources	H	Variations; not always a valid approach	No	Yes	Yes
geographic coverage, numbers, MW covered by PMU	H	Definitions; actual usage	No	Yes	Yes
Amount of focused disturbance location	M		Yes	Yes	Yes
Extent of cbm	L		No	Yes	Yes
Db level of 5th & 7th harmonics	L		No	No	No

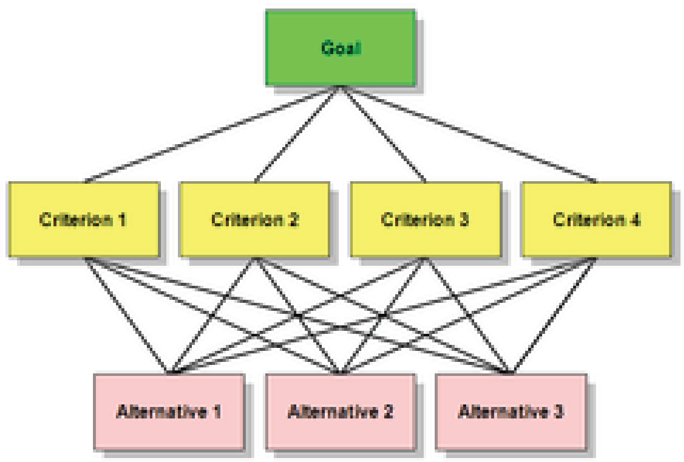
Smart Grid Workshop Metric	Rating	Issues In Workshop	Factor In AMI / SG Filings Today	Issue For DOE SG Metrics	DOE Stimulus Scorecard Basis
MW in RTP and DSM	L		Yes	Yes	Yes
# of automated grid operations	L		Can be in BCA	No	No
Amount of system visibility	M		Not Explicit	Yes	Yes
extent of data exchange/interoperability	L		No	Yes	Yes
(N-X) reliability	M		No	No	No
% of load /MW of storage	M		No	Yes	Yes
Amount of networked distribution	L		No	No	No
Smart Grid roadmap	L		No	Yes	Yes
# breaker cycle faults/yr	L		No	No	No
% of circuits > 1 switch	L		No	No	No
# sections w dist loc	L		No	No	No
Restoration time	M		No	No	No
# prevented disturbances	L		No	No	No
# outages/duration	M		Usually in BCA	Yes	Yes
Customer sat	L		No	No	No
# regional outages	L		No	No	No
Operational errors (disconnects)	L		No	No	No
System efficiency	L		Loss reduction in BCA	Yes	Yes
Feeder lvl quality metrics	L		No	No	No
Maintenance cost per unit availability	L		Sometimes in BCA	Yes	Yes
Resilient against all hazards					
% operating entities that exhibit progressively mature resiliency behavior	H	Specificity; willingness to respond; who actually owns/maintains affected systems;	No	No	No

Smart Grid Workshop Metric	Rating	Issues In Workshop	Factor In AMI / SG Filings Today	Issue For DOE SG Metrics	DOE Stimulus Scorecard Basis
Measure of # alternative paths of supply	H	Data availability and validity; baseline;	Sometimes in BCA	Yes	Yes
Qualified operating margin that is needed to ensure resiliency	H	Knowing ultimate capacities; knowing real time state; information sharing	No	No	No
Adjusting standard metrics to capture physical/cyber attacks	H	Agreement re new codes; privacy and reporting issues;	No	No	No
DOD cyber system metrics	L				
Training	L				
# interconnected urban substations	L				
# successful cyber attacks	M				
# domains penetration tested	M				
# CIP standards addressing SG	L				
NERC CIP compliance	L				
# devices meeting CIP	L				
Cyber security issue repair time	L				
Physical threat identification time	L				
# physical threat attempts	L				
# physically hardened distribution facilities	L				
Reduction in critical load outages	L				
% of DG/DR automation	L				
Failures to conflicting procedures	L				
# hazard events detected	L				

Smart Grid Workshop Metric	Rating	Issues In Workshop	Factor In AMI / SG Filings Today	Issue For DOE SG Metrics	DOE Stimulus Scorecard Basis
System availability	M				
Enhanced recoveries via SG	M				
Event impact reduction	L				
# of assets for which risk assessment is done	H				
Dollar loss per unit time	L				
# secondary assets affected	L				
Additional Stimulus SG Metrics					
Stimulus Effects					
Utility jobs lost/created	H		Yes	Yes	Yes
Contractor jobs	H		Yes	Yes	Yes
Supplier jobs	M		No	Yes	Yes
Expense timing	H		Yes	Yes	Yes
Retraining	M		Sometimes	Yes	Yes
Facilitation of Renewables					
Facilitation of EV/PHEV					

Appendix D – Analytical Hierarchical Process

The Analytic Hierarchy Process (AHP) is a structured technique for helping people deal with complex decisions. Rather than prescribing a "correct" decision, the AHP helps people to determine one that suits their needs and wants. Based on mathematics and psychology, it was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. The AHP provides a comprehensive and rational framework for structuring a problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions. It is used throughout the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, and education.



A Simple AHP Hierarchy

Several firms supply computer software to assist in using the process.

Users of the AHP first decompose their decision problem into a hierarchy of more easily comprehended sub-problems, each of which can be analyzed independently. The elements of the hierarchy can relate to any aspect of the decision problem—tangible or intangible, carefully measured or roughly estimated, well- or poorly-understood—anything at all that applies to the decision at hand.

Once the hierarchy is built, the decision makers systematically evaluate its various elements, comparing them to one another in pairs. In making the comparisons, the decision makers can use concrete data about the elements, or they can use their judgments about the elements' relative meaning and importance. It is the essence of the AHP that human judgments, and not just the underlying information, can be used in performing the evaluations. [1]

The AHP converts these evaluations to numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. This capability distinguishes the AHP from other decision making techniques.

In the final step of the process, numerical priorities are derived for each of the decision alternatives. Since these numbers represent the alternatives' relative ability to achieve the decision goal, they allow a straightforward consideration of the various courses of action.