White Paper- The Smart Grid and the Evolution of the Independent System Operator

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The global electric utility industry and its customers are faced with a set of challenges which are unparalleled since the advent of widespread electrification. Challenges including the increased likelihood of a carbon constrained future, significant requirements for new infrastructure investment, and increasing energy prices are converging to drive fundamental change in the way that energy is produced, delivered and used.

The electricity system of the future has to produce and deliver electricity that is reliable, affordable and clean. To accomplish these goals, both the electric grid and the existing regulatory system need to get smarter. This paper explores the smarter grid, the broader vision of a smart grid in the United States, and the role that the standards making process has in helping Independent System Operators (ISOs) evolve to meet the challenges facing the grid.

Most smart grid development in the US has been focused on regional issues related to utility deployment of AMI and other basic foundational systems. While this effort is important, placing meters at end user locations is only the first step in the development of a smart grid. A much more specific effort is needed in order to create the interoperable smart grid that has been envisioned by US federal policy. To realize this vision, every participant in the electric grid, from the consumer to the generator, needs to be engaged in a fully transactive system. This new, more transactive system will require the facilitation of millions, perhaps even billions, of new transactions by ISOs. This system is a logical extension of existing electricity markets, but it represents a monumental change in policy.

What is a Smart Grid?

Defining a smart grid is not a simple task. The smart grid is more than just technology upgrades to the existing electric grid. It is a comprehensive vision that combines physical assets, operating systems, and new engineering design standards with economic, policy, and consumer behavioral changes. These system changes are dependent upon both the existing utility infrastructure and the existing regulatory environment. The US is a patchwork of both infrastructure and regulation that is surprisingly diverse. Because of this diversity, the most valuable way to define a smart grid is in terms of what it is capable of, often referred to as the grid's functional capabilities.

The US Department of Energy' Office of Electricity Delivery and Energy Reliability and its Modern Grid Strategy Team, among others, have been working for several years in the US to build consensus on a definition of smart grid and more recently to implement smart grids through Title XIII of the federal *Energy Independence and Security Act of 2007*. ("EISA07")[1] At a national smart grid workshop in June 2008, participants agreed on seven defining characteristics of a smart grid, noting that, "a properly planned, designed, implemented, and operated smart grid will:[2]

(i) Enable active participation by consumers;
(ii) Accommodate all generation and storage options;
(iii) Enable new products, services, and markets;
(iv) Provide power quality for the range of needs in a digital economy;
(v) Optimize asset utilization and operating efficiency;
(vi) Anticipate and respond to system disturbances in a self-healing manner;
(vii) Operate resiliently against physical and cyber attack and natural disasters.

These smart grid characteristics can be subdivided into two broad categories of functional capabilities:

(1) those that enable *informed customer participation* in markets and intelligent and informed customer use of energy,

(2) those that support *improved utility performance*.

The first four defining characteristics of a smart grid involve informed customer participation in markets, and are particularly relevant to the societal goals of increased efficiency, affordability and competition; and the last three characteristics relate to improved utility performance, and are most relevant to utility system reliability. The following figure provides an overview of the characteristic transformations of the electric grid of today into the smart grid of the future.[3]

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[1] *See e.g.*, J. Miller, US DOE Modern Grid Strategy Team, "What is the Smart Grid," presentations to Illinois Smart Grid Initiative, June 3, 2008 and July 8, 2008, Chicago, IL. Also see discussion of Title XIII in the following sections of this report.

[2] www.oe.energy.gov/DocumentsandMedia/Smart_Grid_Workhsop_Report_Final_Draft_08_12_08.pdf

[3] http://www.netl.doe.gov/moderngrid/docs/MGI%20Vision%20Summary.pdf

FIGURE 1: Characteristics of a Smart Grid

Today's Grid	Principal Characteristic	Modern Grid
Responds to prevent further damage. Focus is on protection of assets following system faults.	**Self-heals**	Automatically detects and responds to actual and emerging transmission and distribution problems. Focus is on prevention. Minimizes consumer impact.
Consumers are uninformed and non-participative with the power system.	**Motivates & includes the consumer**	Informed, involved and active consumers. Broad penetration of Demand Response.
Vulnerable to malicious acts of terror and natural disasters.	**Resists attack**	Resilient to physical and cyber attack. Less vulnerable to natural disasters rapid restoration capabilities.
Focused on outages rather than power quality problems. Slow response in resolving Power Quality (PQ) issues.	**Provides power quality for 21st century needs**	Quality of power meets industry standards and consumer needs. Various levels of Power Quality (PQ) at various prices.
Relatively small number of large generating plants provide majority of generation. Numerous obstacles exist for interconnecting Distributed Energy Resources (DER).	**Accommodates all generation and storage options**	Very large number of diverse distributed generation and storage devices deployed to complement the large generating plants. "Plug-and-play" convenience. Significantly more focus on and access to renewables.
Limited wholesale markets still working to find the best operating models. Not well integrated with each other. Transmission congestion separates buyers and sellers.	**Enables markets**	Mature wholesale market operations in place; well integrated nationwide and integrated with reliability coordinators. Retail markets flourishing where appropriate. Minimal transmission congestion.
Minimal integration of limited operational data with asset management processes and technologies. Siloed business processes. Time based maintenance.	**Optimizes assets and operates efficiently**	Greatly expanded sensing and measurement of grid conditions. Grid technologies deeply integrated with asset management processes to most effectively manage assets and costs. Condition based maintenance.

It is useful to note that the smart grid vision really consists of two different stages. As the US Department of Energy noted in its booklet, Smart Grid: An Introduction[4], there are in fact two grids to keep in mind as we think about the smart grid. The first is a "smarter grid" which consists of technologies that can be deployed within the very near future, or are already deployed today. In the short term, this smarter grid could enable increased efficiency and the ability to contain rising energy cost through the integration of distributed energy resources. The second is a broader vision of the smart grid which represents the longer-term promise of an intelligent network. The broader vision of the smart grid is expected to spur the kind of

[4] http://www.oe.energy.gov/DocumentsandMedia/DOE_SG_Book_Single_Pages(1).pdf

transformation that the internet has brought to daily life, although that is universally considered a decade or more away.

I. Smart Grid Activity

As a result of policy direction from Federal and State policymakers, many utilities are moving toward smart grid implementation. There are two key classes of smart grid projects under way in the United States. The first is the deployment of foundational technologies, such as Advanced Metering Infrastructure (AMI), in different areas around the country. The second is the development of smart grid technology standards.

1. Deployment of Foundational Technologies

US smart grid deployment is focused primarily on foundational technologies such as AMI, because it is a necessary but not sufficient condition for a smarter grid. Figure 2 shows the penetration of advanced meters by US state, and how that penetration has changed in recent years.

Uses of Advanced Metering

An installed meter is really only as good as the way it is used. So, just having meters installed is not a sufficient metric to determine the penetration of a smarter grid in the US. The 2008 FERC Survey asked respondents how they use advanced metering, beyond interval meter reading collection. Figure 3 shows the results for 2006 and 2008. There is an increased use of newer types of advanced metering functionality, especially the use of advanced metering to perform remote outage management and to remotely upgrade firmware on the advanced meters.

2. Standards Making (i.e., Interoperability and Security)

The Energy Independence and Security Act of 2007 (EISA) calls for the National Institute of Standards and Technology (NIST) to coordinate the development of a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems. NIST has stated that it believes that the full development and implementation of the broader smart grid actually hinges on the accomplishment of interoperability among devices across the entire electricity value chain – generation, transmission, distribution, and even end-use. According to NIST, given the regulatory framework which governs the North American electric system, including differences in market structures, regional planning, and state and local priorities, it is realistic to expect public policies and business practices for the smart grid and interoperability to evolve incrementally. However, the pace of this incremental evolution can be affected, if not accelerated, if policy officials and business executives use consistent definitions, terminology, and analysis methods and if they understand the implications of their policies and practices for smart grid and interoperability.

Interoperability is a complex topic that decision makers need to understand in a practical way if they are to develop effective policies and practices. The complexities of interoperability can be seen in Figure 4 below. [5]

Within this framework, NIST has orchestrated a three-phase approach to help develop common understanding, standards and tools that are needed to achieve interoperability.
NIST's has argued that this three-phase approach will:

- Further engage utilities, equipment suppliers, consumers, standards developers and other stakeholders to achieve consensus on Smart Grid standards. This process will include a stakeholders' summit scheduled for May 19-20 in Washington, D.C. By early fall, the process will deliver:
  - the Smart Grid architecture;
  - priorities for interoperability and cybersecurity standards, and an initial set of standards to support implementation; and
  - plans to meet remaining standards needs.
- Launch a formal partnership to facilitate development of additional standards to address remaining gaps and integrate new technologies.
- Develop a plan for testing and certification to ensure that Smart Grid equipment and systems conform to standards for security and interoperability.

NIST recently contracted with the Electric Power Research Institute, Inc. (EPRI) to help the agency develop an interim report on Smart Grid architecture and a standards roadmap. Headquartered in Palo Alto, Calif., EPRI is an independent, nonprofit, noncommercial organization that conducts research and development relating to the generation, delivery and use of electricity. EPRI also will support consensus-building activities to create an initial slate of Smart Grid standards. By the end of 2009, NIST plans to submit these standards for review and approval by the Federal Energy Regulation Commission, which has jurisdiction over interstate distribution and sales of electric power. By August 15, 2009 EPRI will release an Interim Standards Roadmap (Interim Report) that identifies parties responsible for standards development and harmonization with a summary of unresolved issues.

Interim Roadmap Process and Development Timeline

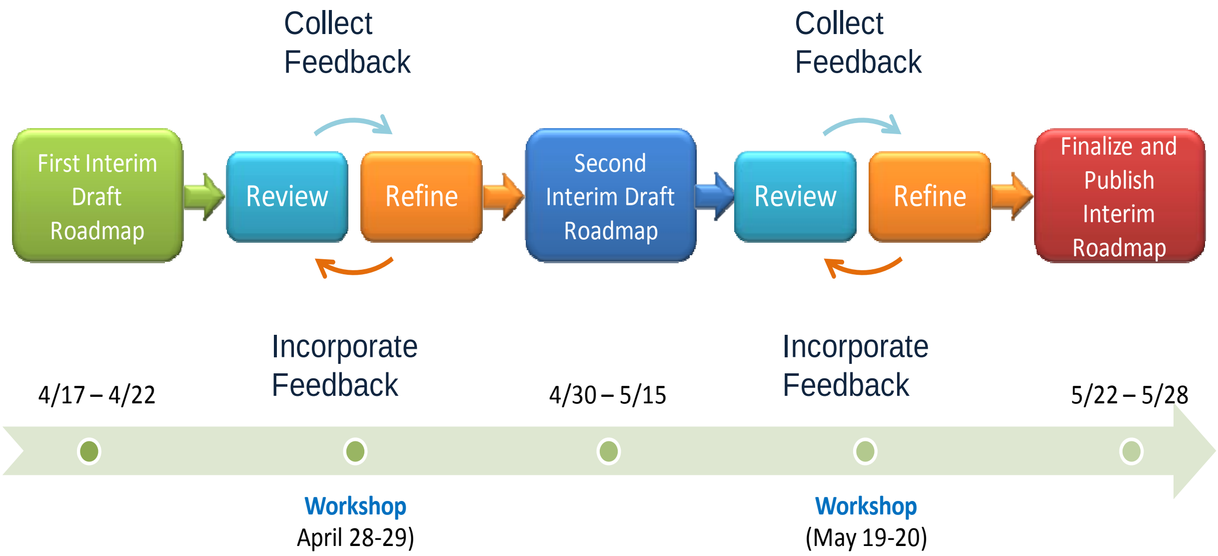
NIST has developed the following goals for the Interim Report[6]:

- Capabilities
- Priorities
- Architecture
- Standards
- Release Plan
- Responsibilities
- Governance
- Testing and Certification

[5] http://www.nist.gov/smartgrid/NIST_GI08_Foundation%20Session%20Slides_final.pdf

[6] NIST Smart Grid Standards Roadmap Project Goals, George W. Arnold, Eng.Sc.D. National Coordinator for Smart Grid Interoperability, National Institute of Standards and Technology, April 28, 2009

Figure 5 – NIST Timelines[7]



EPRI'S Draft Interim Roadmap Report

As of the Drafting of this white paper, EPRI's Draft Interim Roadmap Report was still in preliminary draft form[8]. However enough information had been released to provide an initial summary of its contents.

> The Interim Roadmap provides a starting point to bring stakeholders together to work toward common goals and visions of what the smart grid needs to become. In addition the Interim Roadmap initiates some of the processes and work activities necessary to accelerate the adoption of an open infrastructure to enable the smart grid to become manifest. It should be noted that this work is intended to augment the Standards and Consortia work that is taking place across various stakeholder communities. The focus on architecture concepts also recognizes the need to see the big picture of how the smart grid infrastructure will need to become integrated not only within the power industry but across all the industries and markets that will have key roles in the development, implementation, and management of the smart grid. The smart grid will require cooperation on unprecedented levels to achieve the visions of interoperable systems that are not

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[7] Ibid.

[8] Interim Smart Grid Roadmap, Draft prepared for April 22, 2009 Delivery, Draft Report, 4/23/2009 8:32:00 PM: available at http://collaborate.nist.gov/twiki-sggrid/pub/_SmartGridInterimRoadmap/InterimRoadmap/Interim_Smart_Grid_Roadmap20090423Final.doc

only supplied by hundreds of companies but can be effectively integrated, secured and managed in a way that inspires public trust and confidence.

This document serves as an initial roadmap for the high-level architecture of the Smart Grid moving forward. In doing so, this document describes the principles and interface design, current status of the Smart Grid, issues and priorities for interoperability standards development and harmonization between stakeholders. This document is divided into the following major sections:

Smart Grid Vision. This section provides understanding as to what we consider to be the "Smart Grid". It also gives insight into development planning and deployment of Smart Grid components including the associated organizational drivers, opportunities and challenges.

Smart Grid High-level Architecture. This section defines Smart Grid in terms of architecture from a high level including the scope, security, destinations and metrics, supporting principles and methods.

Architecture Requirements and Interfaces. This section delves into the requirements driven approach to architecting the Smart Grid and the integration between interfaces.

Smart Grid Standards and Recommended Practices Development. This section evaluates the current and emerging standards and best practices relevant to the Smart Grid, including the identification of gaps.

Prioritized Actions and Timelines to Address Identified Issues. This section discusses the NIST-focused Action Plan for resolving the gaps identified in the previous section

II. A Vision for the Future

As described above, most smart grid development in the US has been focused on regional issues related to utility deployment of AMI and other basic foundational systems. While this effort is important, it is only the first step. A much more specific effort is needed in order to create the interoperable smart grid, envisioned by US federal policy. To realize this vision, every participant in the electric grid, from the consumer to the generator, needs to be engaged in a fully transactive system. This system is a logical extension of existing electricity markets, but it represents a monumental change in policy. For example, today PJM interconnection manages endpoint connections that number in the thousands, but that number will increase by many millions as more information becomes available from the electric gird. Identifying and incorporating this new information will be a critical Independent System Operator function in the near future. The current ongoing efforts by NIST and EPRI will help advance this goal.

A Smart Experiment

One experiment in the United States has tested idea of a transactive electric gird. In Washington State, the GridWise Olympic Peninsula Project was designed to test both smart grid technologies, and smarter market rules, in more than a hundred homes. The project, which was managed by the Pacific Northwest National Laboratory and funded by the U.S. Department of Energy, lasted from March 2006 through March 2007.

The GridWise Olympic Peninsula Project examined how customers respond to real time electricity pricing, how they change their purchasing behavior in response to price changes, and how those decisions can be automated and simplified for consumers through the use of market mechanisms.

The 112 households in the study were equipped with technology that allowed them to automate their responses to price changes. This technology included smart appliances such as communicating thermostats, water heaters, and clothes dryers. These appliances were programmed to respond to changes in price of electricity. Consumers also had the ability to change their settings (and override them) to reflect their preferences. The project also included incentives to reflect the actual costs of producing and delivering electricity. The goal of this incentive was to motivate consumers to reduce their electricity consumption at times of peak demand. The project tested the theory that consumers' behavioral response to prices will increase grid reliability and efficiency, and that decentralized coordination could be accomplished among consumers and generators in the market, without the need for centralized utility control.

Results

On average, consumers saved approximately 10 percent on electricity bills. At the same time, peak demand was reduced by 15 percent. Some argue that the significance of these two findings alone show that upgrading today's electricity grid can delay or even eliminate the need for future power plants, transmission lines, and so on.

The project's key finding is that a market-based network of consumers and local generation is feasible using existing price-responsive digital technologies. The primary barriers to widespread adoption of such an approach are regulatory, not technological.

Smart grid technology enhances electric grid reliability and reduces outages by reducing peak demand. As a result, smart grid technologies could lead to smaller electricity bills for consumers, while at the same time helping to alleviate the need for additional infrastructure. Furthermore, because smart grid technologies allow consumers to change their use based on pricing, they make it easier for power companies to incorporate renewable resources like wind and solar power.

Actualizing this Vision

The smart grid creates many new opportunities. For example, using only existing technology even small consumers could participate in demand response (DR) or distributed energy resource (DER) programs which when aggregated, can become a market commodity. While this is possible using today's technology, the incorporation of economic DR and DER into wholesale markets is only at its beginning stages. The smart grid will increase the flow of information and enable more customer participation in markets, which should help to increase the effectiveness of DR and DER programs. Increased information flow will help reduce transactions costs for programs, and will help increase reliance on DR and DER as a system resource. As the interface between generation, transmission and distribution grid functions, Independent system operators are in the best position to help actualize the value of this information to send clear signals about the price and usefulness of DR and DER.

In addition to securing the reliability and efficiency of day-to-day operations, and assuring continued improvement as a regional planner, ISOs can and should play an important role as a coordinator and enabler of the "smart grid" of the future. Over the next five to ten years, the grid will be in the process of evolving to a truly intelligent 21st Century grid. To help achieve this goal, the ISO should serve coordination and planning functions that will enable such a transformation. However, the ISOs have said very little about their actual role in this process. The primary reason for this is that ISO operational systems integrate the systems of load serving entities, transmission owners, and power producers operating within their footprint. Because of this legacy role, the ISO's primary functions have been systems integration, and not on the development of broader standards.

This can be seen clearly in a report released in early March of 2009 by the New England ISO titled "Overview of the Smart Grid: Policies, Initiatives, and Needs." After reviewing the national smart grid policy, the report concludes:

> In the long run, the EISA Smart Grid initiative will have a significant impact on ISO New England and its market participants. The implementation of the Smart Grid will likely require ongoing changes to the market rules and will significantly increase operational complexity. Because Smart Grid devices are capable of making intelligent decisions about energy consumption and supply, the ISO's ability to co-optimize these smart devices with existing grid infrastructure will require more sophisticated tools than those in use today. Accompanying the implementation of the Smart Grid could be the exponential growth in the number of assets under ISO control, especially if and when PHEV and distributed generation technology reach critical mass. Smart Grid applications also are expected to significantly increase the volume of data that will need to be gathered and analyzed, which will require more sophisticated solutions than those presently in use. New software programs and algorithms will be needed for energy balancing and control functions. Operators will require a new breed of visualization tools to aid situational awareness and improve decision making and response time. System planners will need "Smart-Grid-aware" tools that extract efficiencies from existing infrastructure when new "smart devices" are used.
>
> Relatively few formal standards and business practices exist at present upon which to build Smart Grid tools and capabilities. The DOE's Electricity Advisory Committee and Smart Grid Task Force are working diligently to provide a strategy and direction for Smart-Grid-related developments. NIST has recently begun an initiative to develop Smart Grid standards and business practices. Expert domain groups are being established to develop standards for building-to-grid, industrial-to-grid, home-to-grid, and transmission and distribution functions.
>
> The success of the EISA Smart Grid depends on several critical characteristics and a collaborative effort across the electricity supply chain. These characteristics include the following:
>
> - A ubiquitous, reliable, and secure communications infrastructure
> - A Smart Grid interoperability framework, which contains communication and control protocols that operate across the entire electricity supply chain (i.e., generators, transmission operators, distribution companies, consumers, marketers, regulators)
> - Long-term investment and implementation commitments across the entire supply chain
> - Ubiquitous and timely deployment of Smart-Grid-enabled infrastructure
> - A methodical and practical transition and implementation plan
> - Practical regulations that satisfy the needs of stakeholders across the entire electricity supply chain

> Significant research and development efforts also are needed to create the technical and business practice standards that will facilitate a successful Smart Grid as envisioned in the Energy Independence and Security Act of 2007. Presently, the most urgent needs are for educational programs, knowledge sharing, and close coordination among the parties that are helping to create Smart Grid policies, regulations, standards, and project plans.

As the New England ISO has realized, it will take the guidance of an interoperable open systems architecture, which is being developed by NIST, to realize the fully transactive smart grid. The creation of clear interoperability standards will go a long way towards streamlining the deployment of this fully transactive system by minimizing the uncertainty in future systems investments. This transactive system will require a grid network−not unlike the nerves in a human body−that provides the communication interface, as well as the standards to guide the operation. This grid network would represent a common approach to moving the industry forward. It would be a set of technologies, standards, services and initiatives with the key principles of creating an evolving technology strategy, using open systems architecture and standards for two-way communications from generator to consumer.

III. Conclusion

In conclusion, the Modern Grid Initiative and the research conducted through the PNNL GridWise Demonstration Project have created a vision for the role that ISOs could play in the architecture of the smart grid. However, US ISO visions about their roles remain relatively vague. The primary driver of this is the lack of clear standards for interoperability at a national level. This significant challenge must be addressed in order to actualize the smart grid vision and bring the promised benefits to fruition within the United States. In short, clear standards are absolutely necessary if the vision of a smarter grid is actually going to be attained.

Figure 2– Penetration of advanced metering by state in 2006 and 2008 [9]

	2006			2008		
State	AMI meters	Total meters	Penetration	AMI meters	Total meters	Penetration
Pennsylvania	18,200	6,053,110	0.3%	1,443,285	6,036,064	23.9%
Idaho	29,062	739,199	3.9%	105,933	769,963	13.8%
Arkansas	75,118	1,494,383	5.0%	168,466	1,488,124	11.3%
North Dakota	29	367,776	0.0%	33,336	375,473	8.9%
South Dakota	7	484,728	0.0%	41,191	475,477	8.7%
Oklahoma	60,273	2,024,592	3.0%	161,795	1,875,325	8.6%
Texas	28,200	10,195,134	0.3%	868,204	10,870,895	8.0%
Florida	8,479	9,679,565	0.1%	765,406	9,591,363	8.0%
Georgia	73,312	4,404,447	1.7%	342,772	4,537,717	7.6%
Missouri	8,986	3,087,821	0.3%	204,498	3,098,055	6.6%
Vermont	1	331,161	0.0%	20,755	375,202	5.5%
Alabama	89,702	2,738,519	3.3%	139,972	2,774,764	5.0%
Kentucky	27,501	2,225,485	1.2%	105,460	2,161,142	4.9%
South Carolina	19,655	2,007,339	1.0%	114,619	2,373,047	4.8%
Kansas	18,913	1,430,953	1.3%	61,423	1,426,832	4.3%
Wisconsin	19,882	2,983,075	0.7%	117,577	3,039,830	3.9%
Wyoming	0	272,033	0.0%	12,268	318,282	3.9%
Arizona	5,521	2,783,083	0.2%	96,727	2,810,224	3.4%
North Carolina	29,411	4,681,178	0.6%	143,093	4,771,479	3.0%
Iowa	110	1,591,985	0.0%	46,407	1,714,774	2.7%
Washington	477	3,061,233	0.0%	69,377	2,987,355	2.3%
New Mexico	1	875,393	0.0%	20,776	904,861	2.3%
Oregon	2,960	1,821,710	0.2%	39,797	1,890,423	2.1%
Louisiana	44	1,037,355	0.0%	44,103	2,186,249	2.0%
Indiana	13,137	3,217,359	0.4%	61,551	3,115,205	2.0%
Illinois	43,043	5,510,470	0.8%	112,410	5,701,533	2.0%
Tennessee	426	3,165,211	0.0%	60,385	3,160,551	1.9%
Colorado	39,274	2,263,873	1.7%	39,873	2,246,184	1.8%
Montana	162	529,135	0.0%	8,979	549,136	1.6%
Hawaii	45	465,314	0.0%	6,550	405,228	1.6%
Minnesota	11,780	2,537,414	0.5%	37,071	2,542,113	1.5%
Michigan	31,254	4,877,345	0.6%	73,948	5,311,570	1.4%
California	40,153	14,253,873	0.3%	170,896	14,595,958	1.2%
Nebraska	1,520	937,148	0.2%	8,630	970,774	0.9%
Nevada	17	1,193,873	0.0%	10,835	1,292,331	0.8%
Ohio	1,958	6,307,050	0.0%	28,042	5,544,353	0.5%
Connecticut	3,862	1,580,365	0.2%	5,838	1,600,768	0.4%
New Jersey	25,222	3,884,140	0.6%	9,866	3,900,716	0.3%
District of Columbia	0	809,412	0.0%	1,348	809,412	0.2%

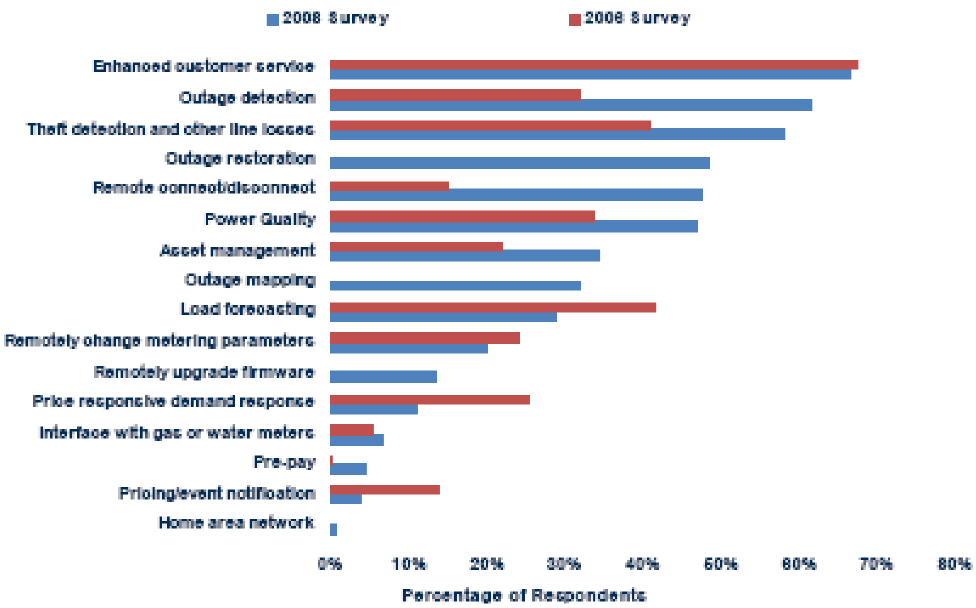
[9] http://www.ferc.gov/legal/staff-reports/12-08-demand-response.pdf

New York	3,071	7,906,309	0.0%	12,778	7,811,335	0.2%
Virginia	5,016	3,412,011	0.1%	6,448	3,965,584	0.2%
Massachusetts	6,940	3,244,778	0.2%	3,907	3,077,679	0.1%
Maine	716	773,164	0.1%	426	780,748	0.1%
New Hampshire	306	759,514	0.0%	260	763,683	0.0%
Rhode Island	398	480,275	0.1%	148	480,135	0.0%
Alaska	6	305,949	0.0%	18	315,419	0.0%
Utah	1	1,036,605	0.0%	37	1,056,718	0.0%
West Virginia	17	1,234,035	0.0%	10	1,183,513	0.0%
Maryland	130	1,972,886	0.0%	8	1,938,948	0.0%
Mississippi	82	1,015,493	0.0%	3	1,454,275	0.0%
Delaware	16	421,331	0.0%	0	438,020	0.0%
Virgin Islands	0	53,628	0.0%	0	53,628	0.0%

Source: 2006 FERC Survey and 2008 FERC Survey

Notes: The number of meters is extrapolated to account for less than 100 percent response rate.

Figure 3. Reported uses of advanced metering in 2006 and 2008 [10]



Source: 2006 FERC Survey and 2008 FERC Survey

[10] Ibid.

Figure 4 GridWise Architecture Council Standards Reference Model, Shown with Cross-Cutting Issues