About This Document:

Report to NIST on the Smart Grid Interoperability Standards Roadmap—**Post Comment Period Version**

Under the Energy Independence and Security Act (EISA) of 2007, the National Institute of Standards and Technology (NIST) has "primary responsibility to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems…" [EISA Title XIII, Section 1305]

In late March 2009, NIST awarded the Electric Power Research Institute (EPRI) a contract to engage Smart Grid stakeholders developing a draft interim standards roadmap. On June 17, EPRI delivered its *Report to NIST on the Smart Grid Interoperability Standards Roadmap.* This document contained material gathered, synthesized, and refined by the contractor using its technical expertise. This deliverable was not a formally reviewed and approved NIST publication. Rather, it is one of many inputs into the ongoing NIST-coordinated roadmapping process.*

In a notice published in the Federal Register on June 30, 2009, NIST solicited public comment on the EPRI-prepared report. All comments received as of July 30, 2009, the end of the comment period, were divided among the EPRI technical team for resolution and response. Corresponding modifications of the original EPRI document (June 17, 2009) were refined and integrated into this revised version, delivered to NIST on August 10, 2009.** This revised document, along with the original comments, will serve as resources as NIST progresses further in developing of the NIST Smart Grid Interoperability Standards Framework, as required under the Energy Independence and Security Act (EISA) of 2007. The initial release of the NIST framework document is planned to be available in September 2009.

NIST no longer is accepting comments on EPRI-prepared documents, except those from parties who believe their comments on the June 17, 2009, report were not addressed. Comments and responses are not indicated in this revised version. These can be found at: http://collaborate.nist.gov/twiki-sggrid/bin/view/_SmartGridInterimRoadmap/InterimRoadmapFinal.

Send questions to smartgrid@nist.gov.

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Report to NIST on the Smart Grid Interoperability Standards Roadmap

(Contract No. SB1341-09-CN-0031—Deliverable 10)

Post Comment Period Version Document

This document contains material gathered and refined by the Electric Power Research Institute using its technical expertise. It has been submitted as a deliverable to the National Institute of Standards and Technology under the terms of Contract No. SB1341-09-CN-0031.

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EXECUTIVE SUMMARY

President Obama has made a smart electrical grid a key element of his plan to lower energy costs for consumers, achieve energy independence and reduce greenhouse gas emissions. A smart grid would employ real-time, two-way communication technologies to allow users to connect directly with power suppliers. The development of the grid will create jobs and spur the development of innovative products that can be exported.

The electricity grid can only get so smart without a framework for interoperability. This framework will identify a suite of standards that enable the integration of diverse technologies. The Energy Independence and Security Act (EISA) of 2007 gave the U. S. Department of Commerce, National Institute of Standards and Technology (NIST) the "primary responsibility to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems…"

This report provides an Interim Roadmap for the development of the Interoperability Framework. It describes the current status, issues, and priorities for interoperability standards development and harmonization. The report also describes the high-level architecture for the smart grid including a conceptual model, architectural principles and methods and cyber security strategies.

A broad range of stakeholders were engaged in the development of this Interim Roadmap. Over 1000 stakeholders participated in two workshops to achieve consensus on the critical standards and standards development activities needed for the Smart grid.

In section 1, this report provides a general overview of this project.

In section 2, this report summarizes the efforts to date to define the smart grid and describes the ongoing governance process that will be required to develop the smart grid.

Section 3 defines a conceptual model for thinking about the smart grid and its implementation. It discusses the architectural principles that will enable the smart grid to support new technologies and support new business models.

One can best understand interactions between the domains through looking closely at key cross-cutting applications. Section 4 of this report introduces the applications Automated Metering Infrastructure (AMI), Demand Response (DR), Plug-In Electric Vehicles (PEV), Cyber Security, Wide Area Situation Awareness (WASA), Market Communications, and Distributed Generation and Energy Storage (DG).

Section 5 discusses the security requirements of the smart grid. As the smart grid relies on business interactions as much as it does upon the physical processes of delivering electricity, security for the smart grid must consider interference or disruption of business communications as much as it does disruption of the delivery of electricity. Matters of identity and authorization are paramount, as are privacy and appropriate access concerns for handling personal information of customers.

Section 6 presents the near-term actions that NIST can take in advancing the Interoperability Framework. The highest priority actions include:

- Developing a common semantic model - NIST should work with the appropriate standards development organizations to form a common representation of information models for the smart grid
- Developing a common pricing model standard - NIST should work with the relevant standards development organizations to develop an approach for developing a common pricing model to traverse the entire value chain.
- Developing a common semantic model for advanced metering, demand response and electric transportation – NIST should coordinate the various industry activities to accelerate the development and adoption of a unified semantic model for these high-priority applications.
- Conducting an analysis to select Internet Protocol Suite profiles for smart grid applications - NIST should commission a group to perform a comprehensive mapping of smart grid application requirements to the capabilities of protocols and technologies in the Internet Protocol Suite to identify Internet protocol Suite subsets as important for various applications in the various smart grid domains.
- Investigating Communications Interference in Unlicensed Radio Spectrums - NIST should commission a group of experts to study the issue of communications interference in unlicensed radio spectrums for smart grid applications.
- Developing common time synchronization and management - NIST should work with the appropriate standards development organizations to develop or adopt application or role based time synchronization guidelines
- Coordinating efforts across Standards Development Organizations – NIST should coordinate cross-SDO efforts for harmonizing and extending their standards and addressing new standards requirements.

The Appendices to this report present a detailed guide to existing standards developed from the workshops and from expert opinion. It is not a cookbook; rather it outlines the issues, overlaps and gaps that exist in the current standards.

In undertaking these key actions and the many subsidiary actions that are identified in this report, NIST will help provide the Interoperability Framework needed to build the smart grid and meet President Obama's energy and environmental goals.

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1 Purpose and Scope

1.1 Background

This document is the result of a focused project that is a part of an overall mandate laid out in the Energy Independence and Security Act (EISA) 2007 Federal Legislation. EISA states that NIST:

> "…shall have primary responsibility to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems…"

As called out by EISA, NIST has solicited input and cooperation from key stakeholders, including, but not limited to, GridWise Architecture Council, the Institute of Electrical and Electronic Engineers, the National Electric Reliability Organization recognized by the Federal Energy Regulatory Commission, and National Electrical Manufacturer's Association.

The goals of Interim Roadmap project can be summarized as follows:

- Develop an Interim Roadmap that describes the high-level Smart Grid architecture, principles and interface design.
- Describe the current status, issues, and priorities for interoperability standards development and harmonization including an action plan that addresses these issues.
- Rapidly build consensus for the Interim Roadmap among the various Smart Grid stakeholders.

Everything already on the grid is legacy, and must be supported for years. Existing systems and components must be encapsulated and re-engineered to be compatible with new standards and new innovations. The most significant challenge of interoperability is, and will continue to be, interoperability with the installed legacy systems, while addressing interfaces between new and yet to be established devices, systems and domains constituting the Smart Grid.

This roadmap document identifies the short term and long term plans for Architecture Development and associated standards and infrastructure development for the Smart Grid. This draft distills a set of recommended processes and actions from individuals with broad experience in the utility and related industries working as part of the NIST Domain Expert Working Groups (DEWGS) and a focused document team from NIST and EPRI, along with a sequence of two workshops designed to discuss and inform the work by the direct involvement of hundreds of stakeholder participants.

The interim roadmap will identify a set of standards that can be applied directly in projects and as necessary further developed into a Smart Grid infrastructure. A set of standards actions and recommendations are included in chapter 6.

1.2 Context of this Document

This document provides a context for assessing the status of standards and protocols for smart-grid-related information exchange. It identifies the issues in coordinating the development of a framework that involves participation with and ownership by the principle stakeholders. It identifies an initial set of architecturally significant interfaces and their relationship to existing standards as defined primarily, by stakeholders engaged through workshops. It also identifies and prioritizes the interoperability standards activities required to support the integration of smart devices and systems in the electric system.

This document is divided into the following major sections:

1.0 Purpose and Scope	
2.0 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.
3.0 Smart Grid High-Level Architecture	Here a conceptual model of the Smart Grid is presented that illustrates the landscape of applications across this extensive notion.
4.0 Smart Grid Applications Requirements	Through Use Case analysis and using the priority functionalities identified by FERC, a set of example applications are investigated to expose key interfaces and requirements.
5.0 Cyber Security Requirements	This section presents a high level view of critical infrastructure cyber security requirements for the Smart Grid.
6.0 Prioritized Actions and Timelines	This section discusses the recommendations for resolving the gaps identified in the previous section.

1.3 NIST Role and Plans

As the Nation's measurement and standards institute, NIST is making a unique contribution to the establishment of the Smart Grid. Recognizing the benefit of focusing NIST's technical expertise and industry-oriented mission on what is one of the Nation's most pressing issues, Congress called on NIST in the **Energy Independence and Security Act (EISA) of 2007** to take a leadership role in ensuring an interoperable, secure, and open energy infrastructure that will enable all electric resources, including demand-side resources, to contribute to an efficient, reliable electricity network.

NIST is uniquely qualified to undertake this task because of its technical capability, industry knowledge, standards and testing expertise, and international influence. Ensuring interoperability of the Smart Grid requires the integration of technical expertise in numerous disciplines. NIST brings 1) knowledge of the electric utility industry through its research in supporting measurement technology and testing; 2) expertise in advanced networking technology; 3) expertise in industrial controls and their interfaces to the electrical infrastructure; 4) expertise in the technology of buildings and their interfaces to the electric grid, and, of critical importance, 5) expertise in computer and network security. NIST has a long track record of working closely with industry and standards development organizations to develop consensus standards for use by industry, and where needed, for regulatory agencies. NIST has extensive experience in establishing testing and certification programs in critical areas including cyber security. Finally, NIST has strong presence and leadership in key international standards organizations and the ability to effectively represent U.S. interests in the international arena.

Responding to Congress's mandate, in 2008 NIST initiated a government/industry effort, in collaboration with the Department of Energy, to establish an Interoperability Framework and engage the many Smart Grid stakeholders in a more coordinated approach. NIST's effort was intensified in early 2009 and actions taken to accelerate progress toward industry consensus on Smart Grid standards. Once the Federal Energy Regulatory Commission (FERC) judges that there is sufficient consensus, EISA instructs it to institute a rulemaking proceeding to adopt the standards and protocols that may be necessary to ensure that there is Smart Grid functionality and interoperability in interstate transmission of electric power, and in regional and wholesale electricity markets.

The priority that the Administration has placed on the Smart Grid in its plans to move the nation toward energy independence, coupled with the investments contained in the American Reinvestment and Recovery Act of 2009 to spur its development, demands that the development of standards be expedited.

In April 2009 NIST announced a 3-phase plan to fast-track the development of consensus on an initial suite of Smart Grid standards while establishing a robust framework for the longer-term development and evolution of additional standards. By year-end 2009, after engaging utilities, equipment suppliers, trade organizations, consumers, and others, NIST plans to:

1. Publish a report that documents stakeholder consensus on: the Smart Grid architecture, standardization priorities for securing and assuring the interoperability of Smart Grid components, an initial set of standards (Smart Grid Release 1), and a roadmap for addressing remaining standards needs.

2. Launch a formal public-private partnership to coordinate and facilitate development and evolution of additionally needed standards; and

3. Develop an overall plan for testing and certification to ensure that Smart Grid devices and systems conform to standards for both cyber security and interoperability.

The first phase of this program involves the development of the standards roadmap described in this document.

NIST has responded to the nation's priority to transition to the Smart Grid with a program that will expedite the development of key standards while providing a robust foundation for development and evolution of additional standards.

1.4 Summary of Interim Roadmap Project

Over a thousand people have contributed to this effort. Hundreds of participants representing a wide variety of perspectives, including transmission & distribution, markets, storage, smart buildings, smart homes, business, finance, and policy makers. These stakeholders met in two Smart Grid roadmap workshops designed to identify existing candidate Smart Grid standards for today, and identify standards requirements, gaps, and issues for future Smart Grid interoperability. Hundreds more stakeholders have participated in the NIST Domain Expert Workgroups (DEWGs) since last summer, contributing their expertise, and building consensus on standards priorities.

Some patterns emerged:

- A great deal of knowledge and experience is represented by the participants from varied perspectives.
- Each participant, typically, values and understands a small set of standards, which are often different from other stakeholders.
- Few participants have a detailed knowledge of a significant number of these standards.
- Participants with detailed understanding of one standard often do not have similar understanding of other standards.
- Preservation of existing assets and business processes based on adopted standards are often stronger drivers for standards selection than technical merit or enabling innovation.
- Not all stakeholders are necessarily represented, and the best path forward cannot be determined based on a simple vote, due to unbalanced representation.

These patterns make rapid consensus difficult. So, it is appropriate that these results be built upon through further analysis and refinement. NIST desires to accommodate existing technology while relying on technical experts that aid in successfully developing a standards roadmap to achieve an innovative smart grid. It is expected that this further analysis and refinement will occur in subsequent phases of the NIST 3-phase plan [20] which will set up governance and deep coordination with SDOs to achieve the appropriate level of depth and openness that this work merits.

A key benefit from infusing the smart grid with a high degree of interoperability is that it will open up every aspect of the generation, distribution, and use of energy to innovation. Innovation will create change, and change will increase diversity. Diversity is always, and always will be, one of the greatest challenges not only to initial integration, but to maintenance management and to operational integrity of the grid.

Today's utilities manage risk and complexity and cost by limiting diversity. This drives the passion that binds one business to one standard and another to a second, creating conflict for interoperability across geographic and participant boundaries on the grid. These standards, and their often proprietary roots, limit diversity and so reduce complexity. Mere identification of standards "brands" through workshops such as these will not deliver interoperability.

The great challenge, then, for Smart Grid interoperability, and for the standards that support it, will be to support diversity and innovation. This requires loosely coupled standards that enable shallow integration of diverse technologies. These standards will support diversity of business models through symmetry, transparency, and composition. These standards require enterprise-class cyber security at each interface. These standards are not ready today.

Deployments must be made, and will always be made, to meet today's business needs. Everything already in the field is based upon legacy standards interacting with legacy technology. There is no clear path to the future Smart Grid for every technology and every capital investment made in the past. Everything already in the field will require support for many years. Those technologies deployed next year, using next year's standards, will then also be part of the legacy environment, requiring support for many years. Encapsulation of existing systems for interoperation with the Smart Grid will remain a significant challenge. Yet this challenge must be met gracefully and steadily.

2 Smart Grid Vision

This section presents a consensus derived from a variety of stakeholders on what a smart grid should be. It describes the destination for the technological and architectural paths that are described in this roadmap.

2.1 What is the Smart Grid?

The Smart Grid as defined here is based upon the descriptions found in the Energy Independence and Security Act of 2007. The term "Smart Grid" refers to a modernization of the electricity delivery system so it monitors, protects and automatically optimizes the operation of its interconnected elements – from the central and distributed generator through the high-voltage transmission network and the distribution system, to industrial users and building automation systems, to energy storage installations and to end-use consumers and their thermostats, electric vehicles, appliances and other household devices.

The Smart Grid will be characterized by a two-way flow of electricity and information to create an automated, widely distributed energy delivery network. It incorporates into the grid the benefits of distributed computing and communications to deliver real-time information and enable the near-instantaneous balance of supply and demand at the device level.

2.2 Smart Grid Characteristics: Drivers and Opportunities

The definition of the smart grid builds on the work done in EPRI's IntelliGrid [2] program, in the Modern Grid Initiative (MGI) [8], and in the GridWise Architectural Council (GWAC) [6]. These considerable efforts have developed and articulated the vision statements, architectural principles, barriers, benefits, technologies and applications, policies, and frameworks that help define what the Smart Grid is. This section describes some of these widely accepted principle characteristics that will be the basis for the 21st Century grid we are striving to achieve.

2.2.1 Smart Grid Benefits

Smart Grid benefits can be categorized into 5 types:

- **Power reliability and power quality**. The Smart Grid provides a reliable power supply with fewer and briefer outages, "cleaner" power, and self-healing power systems, through the use of digital information, automated control, condition-based maintenance and autonomous systems.

- **Safety and cyber security benefits**. The Smart Grid continuously monitors itself to detect unsafe or insecure situations that could detract from its high reliability and safe operation. Higher cyber security is built in to all systems and operations including physical plant monitoring, and privacy protection of all users and customers.

- **Energy efficiency benefits.** The Smart Grid is more efficient, providing reduced total energy use, reduced peak demand, reduced energy losses, and the ability to induce end-user use reduction instead of new generation in power system operations.

- **Environmental and conservation benefits**. The Smart Grid is "green". It helps reduce greenhouse gases (GHG) and other pollutants by reducing generation from inefficient energy sources, supports renewable energy sources, and enables the replacement of gasoline-powered vehicles with plug-in electric vehicles.

- **Direct financial benefits**. The Smart Grid offers direct economic benefits. Operations costs are reduced or avoided. Customers have pricing choices and access to energy information. Entrepreneurs accelerate technology introduction into the generation, distribution, storage, and coordination of energy.

2.2.2 Stakeholder Benefits

The benefits from the Smart Grid can be categorized by the three primary stakeholder groups:

- **Consumers**. Consumers can balance their energy consumption with the real time supply of energy. Variable pricing will provide consumer incentives to install their own infrastructure that supports the Smart Grid. This infrastructure is necessary to not only take advantage of lower-priced energy in off-peak hours, but also to minimize consumption of higher-priced energy in peak conditions. Smart grid information infrastructure will support additional services not available today.
- **Utilities.** Utilities can provide more reliable energy, particularly during challenging emergency conditions, while managing their costs more effectively through efficiency and information.
- **Manufacturers.** Manufacturers must produce and service the myriad components that actually comprise the Smart Grid. The burst of innovation in products will propel producers to new business developments and existing business enhancements.
- **Society.** Society benefits from more reliable power for governmental services, businesses, and consumers sensitive to power outage. Renewable energy, increased efficiencies, and PHEV support will reduce environmental costs, including carbon footprint.

A benefit to any one of these stakeholders can in turn benefit the others. Those benefits that reduce costs for utilities lower prices, or prevent price increases, to customers. Lower costs and decreased infrastructure requirements ameliorate social justice concerns around energy to society. Reduced costs increase economic activity which benefits society. Societal benefits of the Smart Grid can be indirect and hard to quantify, but cannot be overlooked.

Other stakeholders also benefit from the Smart Grid. Regulators can benefit from the transparency and audit-ability of Smart Grid information. Vendors and integrators benefit from business and product opportunities around Smart Grid components and systems.

2.2.3 Modern Grid Initiative Smart Grid Characteristics

For the context of this section, characteristics are prominent attributes, behaviors, or features that help distinguish the grid as “smart”. The MGI developed a list of seven behaviors that define the Smart Grid. Those working in each area of the Smart Grid can evaluate their work by reference to these behaviors. These behaviors match those defined by similar initiatives and workgroups.

2 1BSmart Grid Vision

Figure 1 – MGI's Principle Characteristics are part of their Smart Grid system vision for measuring success

The behaviors of the Smart Grid as defined by MGI are:

- **Enable Active Participation by Consumers.** The Smart Grid motivates and includes customers, who are an integral part of the electric power system. The smart grid consumer is informed, modifying the way they use and purchase electricity. They have choices, incentives, and disincentives to modify their purchasing patterns and behavior. These choices help drive new technologies and markets.
- **Accommodate All Generation and Storage Options.** The Smart Grid accommodates all generation and storage options. It supports large, centralized power plants as well as Distributed Energy Resources (DER). DER may include system aggregators with an array of generation systems or a farmer with a windmill and some solar panels. The Smart Grid supports *all* generation options. The same is true of storage, and as storage technologies mature, they will be an integral part of the overall Smart Grid solution set.
- **Enable New Products, Services, and Markets.** The Smart Grid enables a market system that provides cost-benefit tradeoffs to consumers by creating opportunities to bid for competing services. As much as possible, regulators, aggregators and operators, and consumers can modify the rules of business to create opportunity against market conditions. A flexible, rugged market infrastructure exists to ensure continuous electric service and reliability, while also providing profit or cost reduction opportunities for market participants. Innovative products and services provide 3rd party vendors opportunities to create market penetration opportunities and consumers with choices and clever tools for managing their electricity costs and usage.
- **Provide Power Quality for the Digital Economy.** The Smart Grid provides reliable power that is relatively interruption-free. The power is "clean" and disturbances are minimal. Our global competitiveness demands relatively fault-free operation of the digital devices that power the productivity of our 21st century economy.

- **Optimize Asset Utilization and Operate Efficiently.** The Smart Grid optimizes assets and operates efficiently. It applies current technologies to ensure the best use of assets. Assets operate and integrate well with other assets to maximize operational efficiency and reduce costs. Routine maintenance and self-health regulating abilities allow assets to operate longer with less human interaction.
- **Anticipate and Respond to System Disturbances (Self-heal).** The Smart Grid independently identifies and reacts to system disturbances and performs mitigation efforts to correct them. It incorporates an engineering design that enables problems to be isolated, analyzed, and restored with little or no human interaction. It performs continuous predictive analysis to detect existing and future problems and initiate corrective actions. It will react quickly to electricity losses and optimize restoration exercises.
- **Operate Resiliently to Attack and Natural Disaster.** The Smart Grid resists attacks on both the physical infrastructure (substations, poles, transformers, etc.) and the cyber-structure (markets, systems, software, communications). Sensors, cameras, automated switches, and intelligence are built into the infrastructure to observe, react, and alert when threats are recognized within the system. The system is resilient and incorporates self-healing technologies to resist and react to natural disasters. Constant monitoring and self-testing are conducted against the system to mitigate malware and hackers.

2.3 Smart Grid Challenges

The Smart Grid poses many procedural and technical challenges as we migrate from the current grid with its one-way power flows from central generation to dispersed loads, toward a new grid with two-way power flows, two-way and peer to peer customer interactions, and distributed generation. These challenges cannot be taken lightly – the Smart Grid will entail a fundamentally different paradigm for energy generation, delivery, and use.

2.3.1 Procedural Challenges

The procedural challenges to the migration to a smart grid are enormous, and all need to be met as the Smart Grid evolves:

- **Broad Set of Stakeholders.** The Smart Grid will affect every person and every business in the United States. Although not every person will participate directly in the development of the Smart Grid, the need to understand and address the requirements of all these stakeholders will require significant efforts.

- **Complexity of the Smart Grid.** The Smart Grid is a vastly complex machine, with some parts racing at the speed of light. Some aspects of the Smart Grid will be sensitive to human response and interaction, while others need instantaneous, automated responses. The smart grid will be driven by forces ranging from financial pressures to environmental requirements.

- **Transition to Smart Grid.** The transition to the Smart Grid will be lengthy. It is impossible (and unwise) to advocate that all the existing equipment and systems to be ripped out and replaced at once. The smart grid supports gradual transition and long coexistence of diverse technologies, not only as we transition from the legacy systems and equipment of today, but as we move to those of tomorrow. We must design to avoid unnecessary expenses and unwarranted decreases in reliability, safety, or cyber security.

- **Ensuring Cyber Security of Systems.** Every aspect of the Smart Grid must be secure. Cyber security technologies are not enough to achieve secure operations without policies, on-going risk assessment, and training. The development of these human-focused procedures takes time—and needs to take time—to ensure that they are done correctly.

- **Consensus on Standards.** Standards are built on the consensus of many stakeholders over time; mandating technologies can appear to be an adequate short cut. Consensus-based standards deliver better results over.

- **Development and Support of Standards.** The open process of developing a standard benefits from the expertise and insights of a broad constituency. The work is challenging and time consuming but yields results more reflective of a broad group of stakeholders, rather than the narrow interests of a particular stakeholder group. Ongoing engagement by user groups and other organizations enables standards to meet broader evolving needs beyond those of industry stakeholders. Both activities are essential to the development of strong standards.

- **Research and Development.** The smart grid is an evolving goal; we cannot know all that the Smart Grid is or can do. The smart grid will demand continuing R&D to assess the evolving benefits and costs, and to anticipate the evolving requirements.

- **Regulatory and Policy.** To maintain a consistent regulatory and energy policy framework over a transition period that will be lengthy. Further, to achieve a National modernization of the distribution grid since the regulation of the grid is delegated to local and statewide authorities.

2.3.2 Technical Challenges to Achieving the Smart Grid

Technical challenges include the following:

- **Smart equipment**. Smart equipment refers to all field equipment which is computer-based or microprocessor-based, including controllers, remote terminal units (RTUs), intelligent electronic devices (IEDs). It includes the actual power equipment, such as switches, capacitor banks, or breakers. It also refers to the equipment inside homes, buildings and industrial facilities. Smart Equipment also includes previously electromechanical switches, reclosers, voltage controllers, and other actuated hardware that have been retrofitted with sensors and controls used to monitor state, transmit that state to an external analysis point, and execute control commands returned from that point. Some of these packages are outfitted with local intelligence, used to carry out analysis and instructions when remote analysis is unnecessary or not economical. This embedded computing equipment must be robust to handle future applications for many years without being replaced.

- **Communication systems**. Communication systems refer to the media and to the developing communication protocols. These technologies are in various stages of maturity. The smart grid must be robust enough to accommodate new media as they emerge from the communications industries and while preserving interoperable, secured systems.

- **Data management**. Data management refers to all aspects of collecting, analyzing, storing, and providing data to users and applications, including the issues of data identification, validation, accuracy, updating, time-tagging, consistency across databases, etc. Data management methods which work well for small amounts of data often fail or become too burdensome for large amounts of data – and distribution automation and customer information generate lots of data. In many cases entirely new data models and techniques (such as data-warehousing and data-mining) are being applied in order to handle the immense amount of synchronization and reconciliation required between legacy and emerging databases. Data management is among the most time-consuming and difficult task in many of the functions and must be addressed in a way that will scale to immense size.

- **Cyber Security**. Cyber security addresses the prevention of damage to, unauthorized use of, exploitation of, and, if needed, the restoration of electronic information and communications systems and services (and the information contained therein) to ensure confidentiality, integrity, and availability.

- **Information and Data privacy.** The protection and stewardship of privacy is a significant concern in a widely interconnected system of systems that is represented by the Smart Grid. Data integrity and non-repudiation is needed for succinct, reliable communication across the grid. Additionally, care must be taken to ensure that access to information is not an all or nothing at all choice since various stakeholders will have differing rights to information from the Smart Grid.

- **Software applications**. Software applications refer to programs, algorithms, calculations, and data analysis. Applications range from low level control algorithms to massive transaction processing. Application requirements are becoming more sophisticated to solve increasingly complex problems, are demanding ever more accurate and timely data, and must deliver results more quickly and accurately. One of the most prominent software development evolutions is shifting from a peer-to-peer integration environment to a services oriented architecture (SOA) built upon on a robust analysis, simulation, and data management infrastructure. Software engineering at this scale and rigor is still emerging as a discipline. Software applications are at the core of every function and node of the Smart Grid.

2.3.3 Government drivers: Planning Assumptions

The Smart Grid is vital component of President Obama’s comprehensive energy plan, which aims to reduce U.S. dependence on foreign oil, create jobs, and help U.S. industry lead in the global race to develop and apply clean energy technology. The President has set ambitious short and long-term goals, necessitating quick action and sustained progress in implementing the components, systems, and networks that will make up the Smart Grid.

For example, the President’s energy policies are intended to double renewable energy generating capacity, to 10 percent, by 2012—an increase in capacity that is enough to power 6 million

American homes. By 2025, renewable energy sources are expected to account for 25 percent of the nation's electric power consumption.

The American Recovery and Investment Act includes $11 billion in investments to "jump start the transformation to a bigger, better, smarter grid."[1] These investments and associated actions to modernize the nation's electricity grid will result, for example, in more than 3,000 miles of new or modernized transmission lines and 40 million "smart meters" in American homes.[2] In addition, progress toward realization of the Smart Grid will contribute to accomplishing the President's goal of putting one million plug-in hybrid vehicles on the road by 2015.[3]

Over the long term, the integration of the power grid with the nation's transportation system has the potential to yield huge energy savings and other important benefits.

A Department of Energy study found that the idle capacity of today's electric power grid could supply the equivalent of 70 percent of today's cars and light trucks without adding to generation or transmission capacity—*if the vehicles charged during off-peak times.*[4] Estimates of associated potential benefits include:

- Displacement of about half net oil imports;
- Reduction in U.S. carbon dioxide emissions by about 25 percent; and
- Reductions in emissions of urban air pollutants of 40 percent to 90 percent.

While the transition to the Smart Grid may unfold of over many years, incremental progress along the way can yield significant benefits. In the United States, electric-power generation accounts for about 40 percent of human-caused emissions of carbon dioxide, the primary greenhouse gas.[5] If the current power grid were just 5 percent more efficient, the resultant energy savings would be equivalent to permanently eliminating the fuel consumption and greenhouse gas emissions from 53 million cars.[6]

President Obama has called for a national effort to reduce, by 2020, the nation's greenhouse gas emissions to 14 percent below the 2005 level and to about 83 percent below the 2005 level by

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[1] "The American Reinvestment and Recovery Plan—By the numbers," http://www.whitehouse.gov/assets/documents/recovery_plan_metrics_report_508.pdf.

[2] Ibid.

[3] The White House, Office of the Press Secretary, "President Obama Announces $2.4 Billion in Funding to Support Next Generation Electric Vehicles." March 19, 2009.

[4] M. Kintner-Meyer, K. Schneider, and R. Pratt, "Impacts Assessment of Plug-in Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids." Part 1: Technical Analysis. Pacific Northwest National Laboratory, U.S. Department of Energy, 2006.

[5] Energy Information Administration, U.S. Department of Energy, "U.S. Carbon Dioxide Emissions from Energy Sources, 2008 *Flash* Estimate." May 2009.

[6] U.S. Department of Energy, *The Smart Grid: an Introduction*.

2050.[7] Reaching these targets will require a combination of improvements in grid efficiency and power management optimization, which will aid in the reduction of greenhouse gases. The execution of a Smart Grid interoperability strategy will enable the pursuit and measurement of that reduction.

Progress in developing the Smart Grid will strongly and broadly support the Administration's policies to advance energy and climate cyber security, while promoting economic recovery efforts. Specifically, steps toward realizing of the Smart Grid will help to:[8]

- Create new jobs in a "clean energy economy" by spurring development of new green manufacturing opportunities,
- Promote U.S. competitiveness in the global economy,
- Enable and foster innovation in next-generation energy technologies;
- Break U.S. dependence on oil by promoting development of the next generation of cars and trucks and the alternative fuels that will power them;
- Enhance U.S. energy supplies through responsible development of domestic renewable energy, fossil fuels, advanced biofuels and nuclear energy;
- Promote energy efficiency and reduce energy costs in the transportation, electricity, industrial, building and agricultural sectors; and.
- Develop an economy-wide emissions reduction program to reduce greenhouse gas emissions and secure the greatest benefits at the lowest cost for families and businesses.

2.4 The Initial Project Application Areas

The Roadmap development process maintains that new applications and extensions to existing systems need to be developed across the scope of the Smart Grid. These include many new areas that need to be further developed across all the major domains. This project is meant to serve as a set of directions and an interim roadmap to the future. To this end a limited set of initial applications are selected as examples that can be worked through within the timeframe of this initial interim roadmap and the series of workshops planned to augment its development. The initial focus of the roadmap is on applications identified as higher priority by the Federal Energy Regulatory Commission (FERC) in its Proposed Smart Grid Policy [11] released for comments on March 19, 2009. We note here that development solely in these priority areas is not sufficient enough to meet fully the needs and goals of the Smart Grid Architecture.

These areas are introduced here and more extensively described in Chapters 4, 5, and 6.

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[7] Office of Management and Budget, *A New Era of Responsibility, Renewing America's Promise.* U.S. Government Printing Office, Washington, D.C. 2009.

[8] Citation from: FACT SHEET: President Obama Highlights Vision for Clean Energy Economy,April 22, 2009, http://www.whitehouse.gov/the_press_office/Clean-Energy-Economy-Fact-Sheet

FERC identified four (4) Smart Grid functional priorities that include:

1. Wide Area Situational Awareness
2. Demand Response
3. Electricity Storage
4. Electric Vehicles

Additionally, the team pursued two additional categories of applications:

5. Distribution Grid Management Initiatives
6. Advanced Metering Infrastructure

2.5 The Landscape of the Smart Grid Roadmap

Although the final destinations of the smart grid roadmap are not known, much that is needed on the way there is. Requirements must continue to be developed. Standards that allow interoperation and innovation must be ready. The business processes of today and tomorrow must be supported. Development of the tools and work force that will build and maintain the smart grid must be pursued.

The Smart Grid effort is unprecedented in its scope and breadth. It will demand unprecedented levels of cooperation to achieve. Along the way, solutions must be developed for each of the issues in this section.

2.5.1 Requirements Must Be Mature

Requirements that drive and specify the functions and how they are applied are foundational to the realization of the Smart Grid. Requirements define what the Smart Grid is and does. The following are some of the key requirements:

- Industry policies and rules of governance are well developed, mature, and can be consistently applied.
- Requirements are well-developed by domain experts and well documented following mature systems-engineering principles.
- Requirements define support for applications and are well developed enough to support their management and cyber security as well.

Chapter 4 provides examples of use cases and a description of the process for using them to build requirements. The use case process is a mature, industry-accepted practice for describing system behavior as requests are made from it. Use cases provide a “who does what in what order” analysis. Use cases are a means to an end, in that they drive requirements which are rational, comprehensive, and defensible.

2.5.2 Well-Developed Standards Are in Place

Standards are critical to enabling interoperable systems and components. Mature, robust standards are the foundation of mature markets for the millions of components that will have a role in the future Smart Grid. Standards enable innovation where components may be constructed by thousands of companies. They also enable consistency in systems management and maintenance over the life-cycles of components. Metrics can be further developed around the following:

- Open stable and mature industry-level standards developed in consensus processes from standards development organizations (SDOs) are available.
- Standards are integrated and harmonized with complementing standards across the utility enterprise through the use of an industry architecture that documents key points of interoperability and interfaces.
- The standards were thoroughly evaluated both from focused technical review as well as through the development of reference designs and implementations that were subsequently tested rigorously.
- Standards are robust and can be extended as necessary to meet future requirements and applications as needs arise.
- There is a mechanism in place such as a user group to support and evolve the definition of the standard as the requirements of the stakeholders evolve.
- Standards conformance testing suites are thorough and are complemented with interoperability and performance testing suites.

2.5.3 Mature Architectures Guide Development

Architectures define how systems and components interact. Architectures assist in technical and management governance and direct ongoing development work. Architectural concepts integrate technical and non technical features and components of systems. Each domain within the Smart Grid, or even smart grids within the Smart Grid, may have its own architecture or architectures.

The architectures of the Smart Grid must be well defined, well documented and robust. Desired attributes of architectures for the Smart Grid include:

- Architecture artifacts include well-defined interfaces across industries external to the utility industry.
- Modern system-modeling tools and techniques are used to manage the documentation and complexity of the system.
- Architectural interfaces are well-defined. Each architectural element must be appropriate for the applications which reside within it. The architectures must support development of massively scaled, well-managed and secure networks with life-spans of 30 years or more.
- The infrastructure supports third party products that are interoperable and can be integrated into the management and cyber security infrastructures.

- The architecture must be flexible enough to incorporate evolving technologies.
- Architectures must also support interfacing with legacy applications and devices in a standard way, avoiding as much additional capital investment and/or customization as possible.

2.5.4 Support Infrastructure must be Ready

Each application, technology, and architecture requires its own support infrastructure. Not only must each be well defined, documented and implemented, but the necessary economic and societal structures must be in place to support their use. These include:

- Up-to-date system-modeling tools to manage both the documentation and the complexity of the system.
- Independent vendors are able to produce components that can interoperate.
- Workforces are educated and can support all aspects of the lifecycle of Smart Grid systems.
- Educational resources are in place to support workforce development and renewal[9].
- Well defined specification and requirements documents for procurement of smart grid components.

2.5.5 Smart Grid Networking

The Smart Grid is a network of networks. That is, many networks with various ownership and management boundaries are interconnected to provide end to end services between stakeholders and in and among intelligent electronic devices (IEDs).

[9] Pervasive Security and Complex Systems Architecture are two areas of education that will require particular ongoing development and attention.

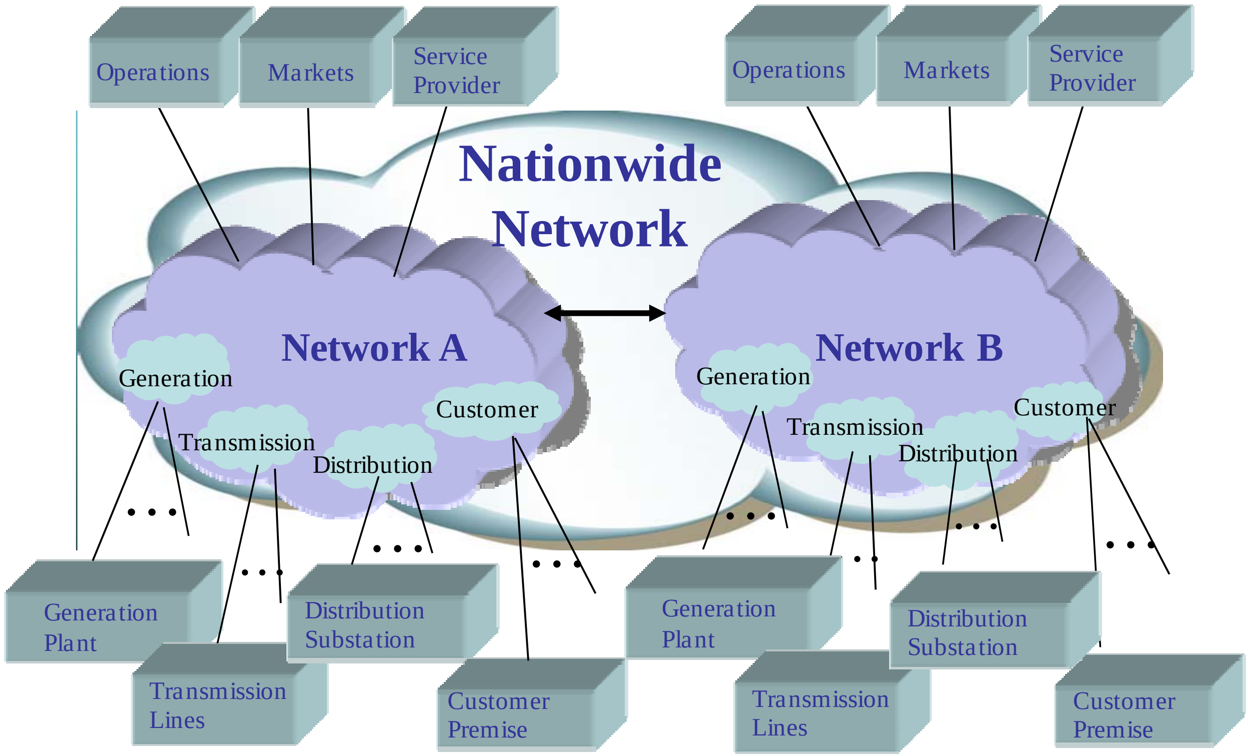

Figure 2 – Smart Grid Networks for Information Exchange

Figure 2 is a high level view of the information network for the Smart Grid. It handles the two-way communication between the network end points residing in their respective domains. By domain, here, we mean the unique distributed computing environments in which communicating end points can be found (see Figure 3 – Smart Grid Conceptual Model – Top Level in the next section). Thus, any domain application could communicate with any other domain application via the information network, subject to the necessary network access restrictions and quality of service requirements[10].

The applications in each domain are the end points of the network as shown on the top and bottom of Figure 2. For example, an application in the Customer domain could be a smart meter at the customer premise; an application in the Transmission domain could be a phasor measurement unit (PMU) unit on a transmission line or in a Distribution domain at a substation; an application in the Operation domain could be a computer or display system at the operation center. Each of these applications has a physical communication link with the network. The smaller clouds within the network represent sub-networks that may be implementing unique functionality. The networking function in the Operations, Market, Service Provider domains may not be differentiable from normal information processing networks; therefore no unique clouds are illustrated.

- [10] Note the concept of domains is expanded and detailed in subsequent sections of this document.

This information network may consist of multiple interconnected networks as shown in Figure 2, where two backbone networks, A and B are illustrated. The physical links within these two networks and between the network and the network end points could utilize any appropriate communication technology currently available or yet to be developed in the future.

Additional requirements for the information network are as follows:

- management functionality for network status monitoring, fault detection, isolation, and recovery,
- secure protocols to protect Smart Grid information in transit and authenticate infrastructure components,
- cyber security countermeasures,
- addressing capability to entities in the network and devices attached to it,
- routing capability to all network end points,
- quality of service support for a wide range of applications with different latency and loss requirements.

2.6 Smart Grid Interoperability Standards Governance

The Smart Grid is recognized as a key strategic infrastructure needed for consumers, utilities, service providers, operators and the country. Whether Smart Grid deployments are being driven by legislative and regulatory policies, realizing operational efficiencies, or creating customer value, the motivation and pressure to produce has caused the industry to perform Smart Grid implementations in fragmented efforts with limited or no stakeholder coordination or agreed-upon standards. As the technology and interoperability standards mature and gain consensus, some early adopters may be faced with “sunk costs” or, at the very least, some serious integration and interoperability issues going forward.

According to a recent article in SmartGridNews.com authored by the Open Smart Grid Subcommittee and the Utility Smart Grid Executive Working Group, there are three challenges facing broad Smart Grid standards adoption [9]:

1. The large number of stakeholders, different considerations, number and complexity of standards available (and missing) requires a more formal nationally-driven governance structure.
2. Since Smart Grid efforts are underway, and in some cases complete, standards adoption must consider work already completed and underway.
3. Interoperability discussions and definitions should be expanded to focus on standards across systems (inter-system) rather than just within systems (intra-system).

A governance model for standards would accelerate the implementation of a secure, intelligent, interoperable, and a fully-connected smart grid. Early identification and development of standards for interoperability and for device specification will ensure that pending deployments will offer lasting and extensible value.

NIST will nurture a Smart Grid Panel and governance process to identify and guide the development of smart grid standards. This effort will be part of the interoperability Phase 2 effort that begins in mid-August, 2009. Many of the foundational standards for the Smart Grid already exist. Organizations including the GridWise Architecture Council (GWAC), and Open Smart Grid (OpenSG) Subcommittee of the Utility Communications Architecture International Users Group (UCAIug) have already created wide awareness, engaged a large cross-section of the stakeholders, and begun identifying and refining interoperability standards.

Ongoing governance of smart grid standards should include key stakeholder representatives, including (breaking down into greater detail the primary stakeholder groups described in section 2.2.2):

- Utilities
- RTOs, ISOs, and aggregators.
- Equipment suppliers and systems developers from each domain of the Smart Grid.
- Consumer advocates
- Information technology and e-commerce
- Standards organizations
- User groups
- Industry technical advisory workgroups
- New market participants as they are identified

The governance process:

- Promotes participation, openness, accountability, and transparency
- Ensures balanced stakeholder representation for voting actions
- Prioritizes standards development and adoption based on consensus and value
- Encourages inclusion, open participation, and early publication to provide transparency of efforts and to encourage collaboration among stakeholders.
- Publishes deliberations and standards selection criteria early and often for free-of-charge public web access to ensure the process is open, unbiased, and fully documented.
- Meets in publicly announced summits and workshops in diverse locations to encourage easy participation of all stakeholders, interested parties.
- Documents decisions and results from all workshops and summits for timely publishing in a free public location.

3 Smart Grid Conceptual Model

This Section provides a conceptual model for discussing the Smart Grid. The Smart Grid is a system of systems, each with its own architecture. The high level conceptual model will define the principles, cyber security strategies, and methodologies that will be used in developing the architectures of the domains. Compliance with the architectural principles will assure that the domains that comprise the Smart Grid will work together effectively and efficiently.

3.1 Principles

As we define the Smart Grid architecture we must evaluate each substantive decision against the core principles: "Does what we're doing enable markets? Motivate and include the customer? Optimize assets and operate efficiently?"[11] The GridWise Architecture Council[6] (GWAC) has developed a framework for understanding interoperability and interfaces, notably in the Interoperability Constitution [5] and the "GWAC Stack." These provide the business, policy, and technology context for developing the Smart Grid.

A critical goal of the Smart Grid is to enable new technologies and support new business models, just as the Internet generated new technologies and business models a decade ago, and just as it continues to do today. Like the Internet, the Smart Grid is a system of systems that embraces diversity of technology, operators, and connection. The composition of these systems will change as technology evolves, generating new businesses and new interactions. To support this generative quality, the systems of the Smart Grid must not demand great intimacy with each other—they must interact with each other using minimum amounts of mutual information. This approach requires:

- *Loose coupling* is a design tenet for scalable, high performance architectures, used in enterprise software and device component design today. It increases the likelihood and speed of integration and reuse, as well as presenting opportunities for unforeseen innovation. Loose coupling helps create a flexible platform on which genuine, valid bilateral and multilateral transactions can occur without elaborate pre-arrangement in each instance.[12]
- *Layered systems* exist all around us—standards to browse a web site form several distinct layers with separation of function and loose coupling. We can think of layers as a collection of conceptually similar functions that provides services to the layer above and receives services from the layer below. Understanding and applying layering helps avoid placing unnecessary restrictions on one layer because of the implementation of adjacent layers.
- *Shallow integration*, driven by the requirement for *minimum knowledge*, extends the reach of each standard, and enhances the value of composition. The market operations

[11] Adapted from the Modern Grid Strategy, Department of Energy

[12] Note that while this is true for the general case, for critical infrastructure controls, tight coupling will often be required.

and load curtailment for (say) electricity and natural gas might be the same. Management, discovery or profiling of components may avoid deep knowledge of the managed or configured components.

- *Scalability* is a necessary design criterion which cannot be overemphasized. The Smart Grid applications, components, and participants are expected to grow rapidly as standards mature and infrastructure is modified or added. System performance should not be detrimentally affected as components and capabilities are added.

For the evolving Smart Grid, each interface must also honor the principles of *symmetry*, *transparency*, and *composition* while addressing management and *cyber security*:

- *Symmetry* is the principle that each action can run both ways: buyers of power at one moment can be sellers at the next. Symmetry is a fundamental characteristic of Net Zero Energy buildings. Integrating Distributed Energy Resources need attention to symmetry for energy flow and management.
- *Transparency* goes hand in hand with symmetry and the emergence of options in every market. Do you want to buy a certain class of power as part of a carbon strategy, in a multiparty marketplace? There needs to be a transparent and auditable chain of transactions showing that the markets actually cleared in each class of power.
- *Composition*, the building of complex interfaces from simpler interfaces, enables diversity. Composition enables interoperation among diverse, multi-sourced, multiplatform devices and data. We cannot demand universal database models across all domains prior to proceeding; and if we had such models they would be a barrier to innovation. For example, standards for metering can be separated from those for bidding and negotiations. As long as the model and each standard are scalable and designed for upward compatibility, pairs of actors can use only the subsets appropriate to their needs.
- *Cyber security* is critical and must be managed over the life-cycle of the systems deployed. Cyber security is fundamentally about managing risk. Security must be commensurate with the vulnerabilities and exposures from any given application. Security must be considered at the time the application requirements are being developed since the domain experts are in the best position to understand what is at stake.

3.2 The Smart Grid Conceptual Model

The Smart Grid Conceptual Model is a set of views (diagrams) and descriptions that are the basis for discussing the characteristics, uses, behavior, interfaces, requirements and standards of the Smart Grid. This does not represent the final *architecture* of the Smart Grid; rather it is a tool for describing, discussing, and developing that architecture. The conceptual model provides a context for analysis of interoperation and standards, both for the rest of this document, and for the development of the architectures of the Smart Grid. The top level of the conceptual model is shown in Figure 3.

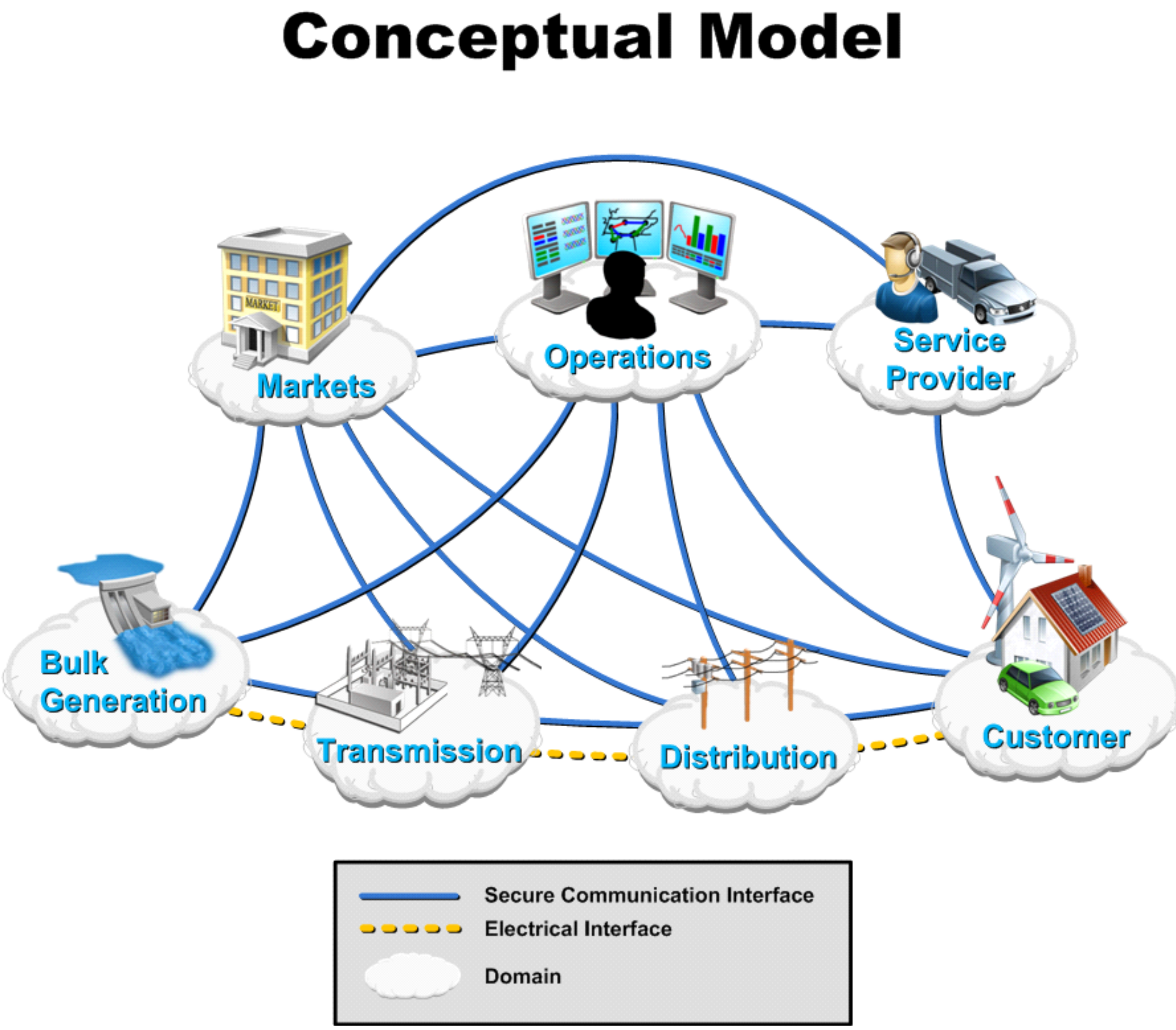

Figure 3 – Smart Grid Conceptual Model – Top Level

The conceptual model consists of several *domains*, each of which contains many *applications* and *actors* that are connected by *associations*, which have *interfaces* at each end*:*

- **Actors** may be devices, computer systems or software programs and/or the organizations that own them. Actors have the capability to make decisions and exchange information with other actors through interfaces.
- **Applications** are the tasks performed by the actors within the domains. Some applications are performed by a single actor, others by several actors working together.
- **Domains** group actors to discover the commonalities that will define the interfaces. In general, actors in the same domain have similar objectives. Communications within the same domain may have similar characteristics and requirements. Domains may contain other domains.

- **Associations** are logical connections between actors that establish bilateral relationships. At each end of an association is an *interface* to an *actor*.
- **Interfaces** show either electrical connections or communications connections. In Figure 3, the electrical interfaces are shown as yellow lines and the communications interfaces are shown in blue. Each of these interfaces may be bi-directional. Communications interfaces represent an information exchange between two domains and the actors within; they do not represent physical connections. They represent logical connections in the smart grid information network interconnecting various domains (as shown in Figure 2).

The domains of the Smart Grid are listed briefly in Table 1 and discussed in more detail in the sections that follow. In Figure 3, domains are shown as clouds.

Table 1 – Domains in the Smart Grid Conceptual Model

Domain	Actors in the Domain
Customers	The end users of electricity. May also generate, store, and manage the use of energy. Traditionally, three customer types are discussed, each with its own domain: home, commercial/building, and industrial.
Markets	The operators and participants in electricity markets
Service Providers	The organizations providing services to electrical customers and utilities
Operations	The managers of the movement of electricity
Bulk Generation	The generators of electricity in bulk quantities. May also store energy for later distribution.
Transmission	The carriers of bulk electricity over long distances. May also store and generate electricity.
Distribution	The distributors of electricity to and from customers. May also store and generate electricity.

It is important to note that domains are NOT organizations. For instance, an ISO or RTO may have actors in both the Markets and Operations domains. Similarly, a distribution utility is not entirely contained within the Distribution domain – it is likely to also contain actors in the Operations domain, such as a Distribution Management System, and in the Customer domain, such as meters

The Smart Grid Conceptual Model is presented as successive diagrams of increasing levels of detail, as shown in Figure 4. Users of the model are encouraged to create additional levels or identify particular actors at a particular level in order to discuss the interaction between parts of the Smart Grid.

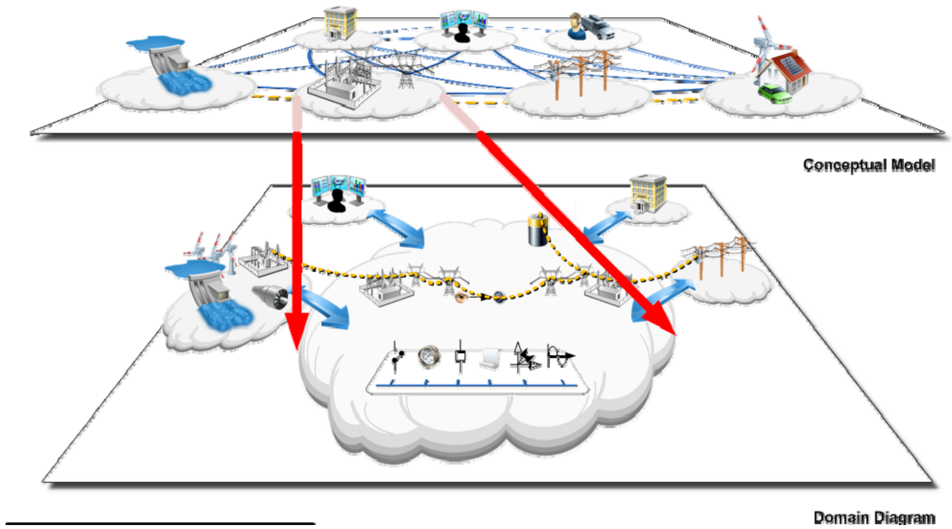

Figure 4 – Examining the Model in Detail

Later sections of this document will present several priority **use cases**. A use case is a story, told in structured and detailed steps, about how actors work together to reach a goal. A use case would be represented in the conceptual model by a path connecting several actors across multiple domains, as illustrated in Figure 5.

An example is the use case "Customers reduce demand in response to a price change". This type of demand response use case would involve actors in the Markets, Operations, Customer and possibly the Service Provider domains. Figure 5 depicts a hypothetical use case involving the Generation, Transmission and Distribution domains.

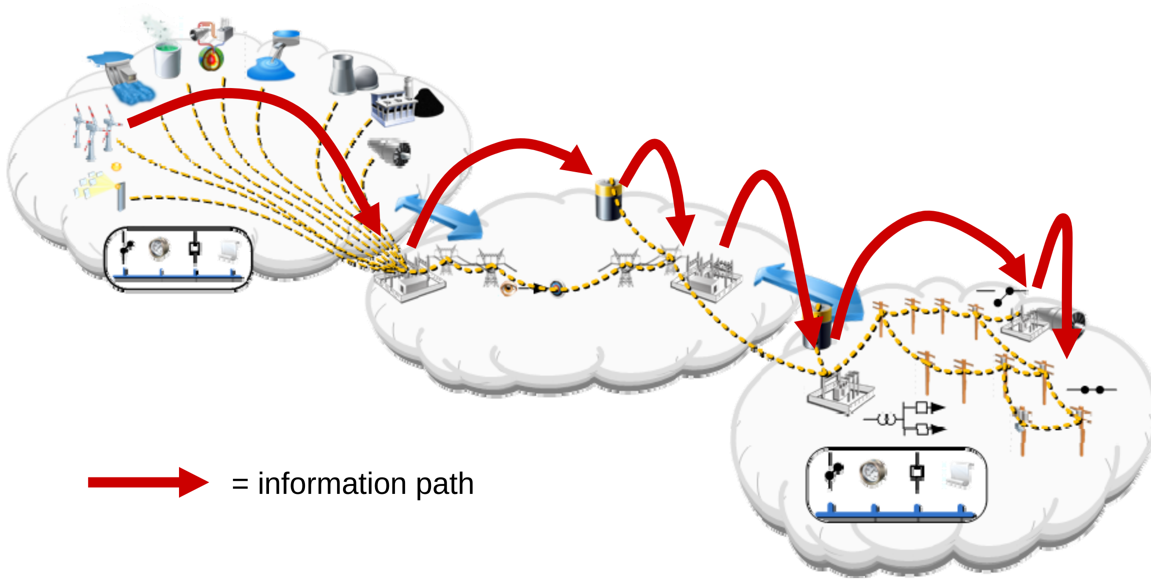

Figure 5 – A Smart Grid Use Case Represented by a Path through the Conceptual Model

The purpose of the conceptual model is to provide a framework for discussing both the existing power system and the evolving Smart Grid. The sections which follow describe the details of this model: first the overall scope, and then each of the domains individually.

Note that the Conceptual Model, as presented, is not intended to be comprehensive in identifying all actors and all paths possible in the Smart Grid. This achievement will only be possible after additional elaboration and consolidation of Use Cases is achieved by stakeholder activities that are ongoing.

3.2.1 Scope of the Conceptual Model

It is important to note that the conceptual model of the Smart Grid is not limited to a single domain or a single application or use case. The use of the term "Smart Grid" has been applied in some circles to only distribution automation or in others to only advanced metering or demand response, for example. The conceptual model assumes that "Smart Grid" includes a wide variety of use cases and applications, especially (but not limited to) the four functional priorities identified by FERC.

The scope also includes cross cutting requirements including cyber security, network management, data management, and application integration, as described in the GridWise Architecture Council Interoperability Context-Setting Framework [3]. As illustrated in Figure 6, the layers of this framework can be pictured as underlying the actors, domains and interfaces pictured in the model.

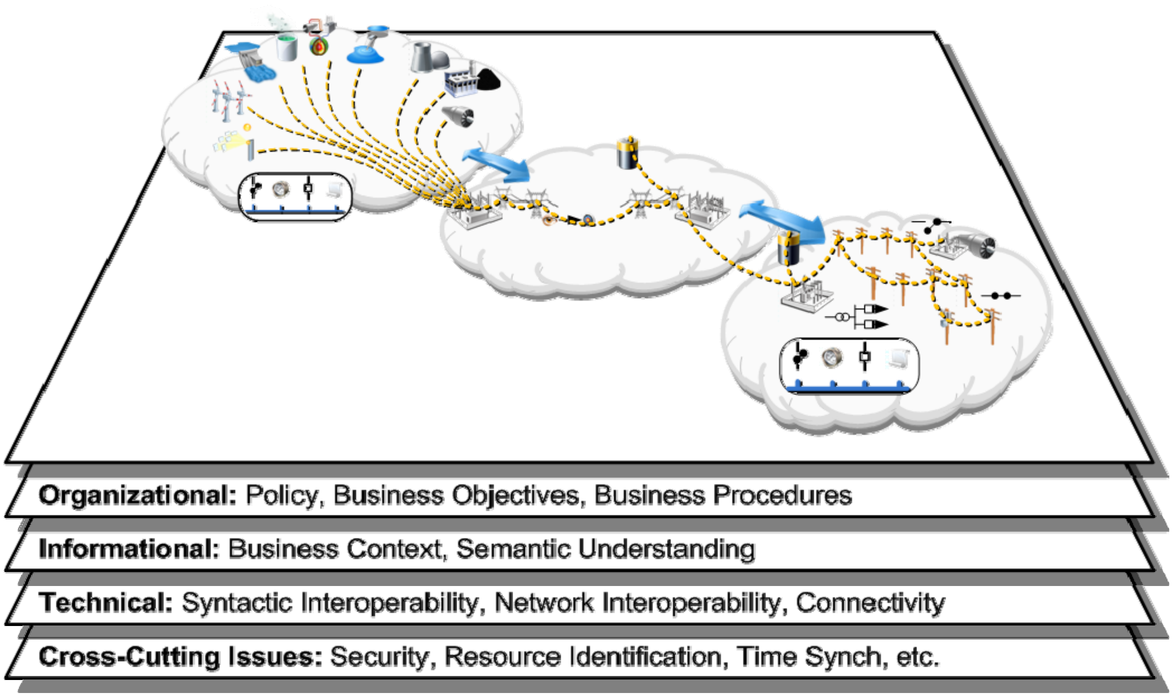

Figure 6 – The Conceptual Model and the GWAC Interoperability Framework

3.2.2 Customer Domain

Actors in the Customer domain enable customers to manage their energy usage and generation. Some actors also provide control and information flow between the customer and the other domains. The boundaries of the Customer domain are typically considered to be the utility meter and the Energy Services Interface (ESI). The ESI provides a secure interface for Utility-to-Consumer interactions [14]. The ESI in turn can act as a bridge to facility-based systems such as a building automation system (BAS) or a customer's energy management system (EMS)[13].

The Customer domain is usually segmented into sub-domains for home, commercial/building, and industrial. The energy needs of these sub-domains are typically set at less than 20kW of demand for Home, 20-200kW for Commercial/Building, and over 200kW for Industrial.

Each sub-domain has multiple actors and applications, which may also be present in the other sub-domains. Each sub-domain has a meter actor and an ESI that may reside in the meter or on the EMS or in an independent gateway. The ESI is the primary service interface to the Customer domains.

The ESI may communicate with other domains via the AMI infrastructure or via another means, such as the Internet. The ESI communicates to devices and systems within the customer premises across a Home Area Network or other Local Area Network. There may be more than one EMS—and therefore more than one communications path—per customer. The EMS is the entry point for such applications as remote load control, monitoring and control of distributed generation, in-home display of customer usage, reading of non-energy meters, and integration with building management systems and the enterprise. The EMS may provide auditing/logging for cyber security purposes.

The Customer domain is electrically connected to the Distribution domain. It communicates with the Distribution, Operations, Market, and Service Provider domains.

[13] Note that a customer EMS is often used by Use Cases dealing with the customer site. However, this term also conflicts with the meaning with the transmission system where is pertains to the state model of the power system.

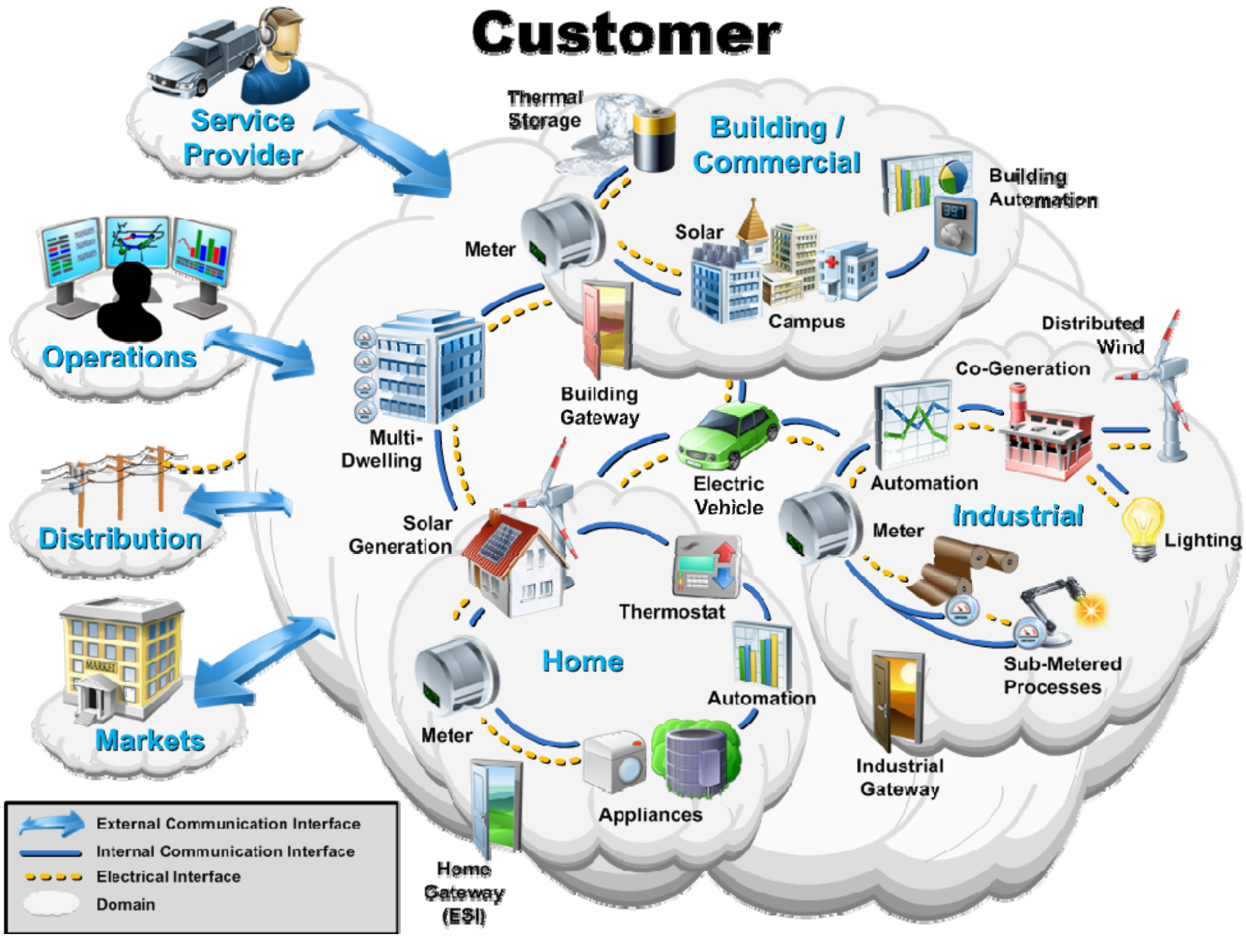

Figure 7 – Overview of the Customer Domain

Table 2 – Typical Applications within the Customer Domain

Application	Description
Building / Home Automation	A system that is capable of controlling various functions within a building such as lighting and temperature control.
Industrial Automation	A system that controls industrial processes such as manufacturing or warehousing.
Solar Generation	Harnesses solar energy for electricity at a customer location. May not be monitored, dispatched, or controlled via communications.
Wind Generation	Harnesses wind energy for electricity at a customer location. May not be monitored, dispatched, or controlled via communications.

3.2.3 Markets Domain

Actors in the Markets domain exchanges price and balance supply and demand within the power system. The boundaries of the Market domain include the edge of the Operations domain where control happens, the domains supplying assets (e.g. generation, transmission, etc) and the Customer domain.

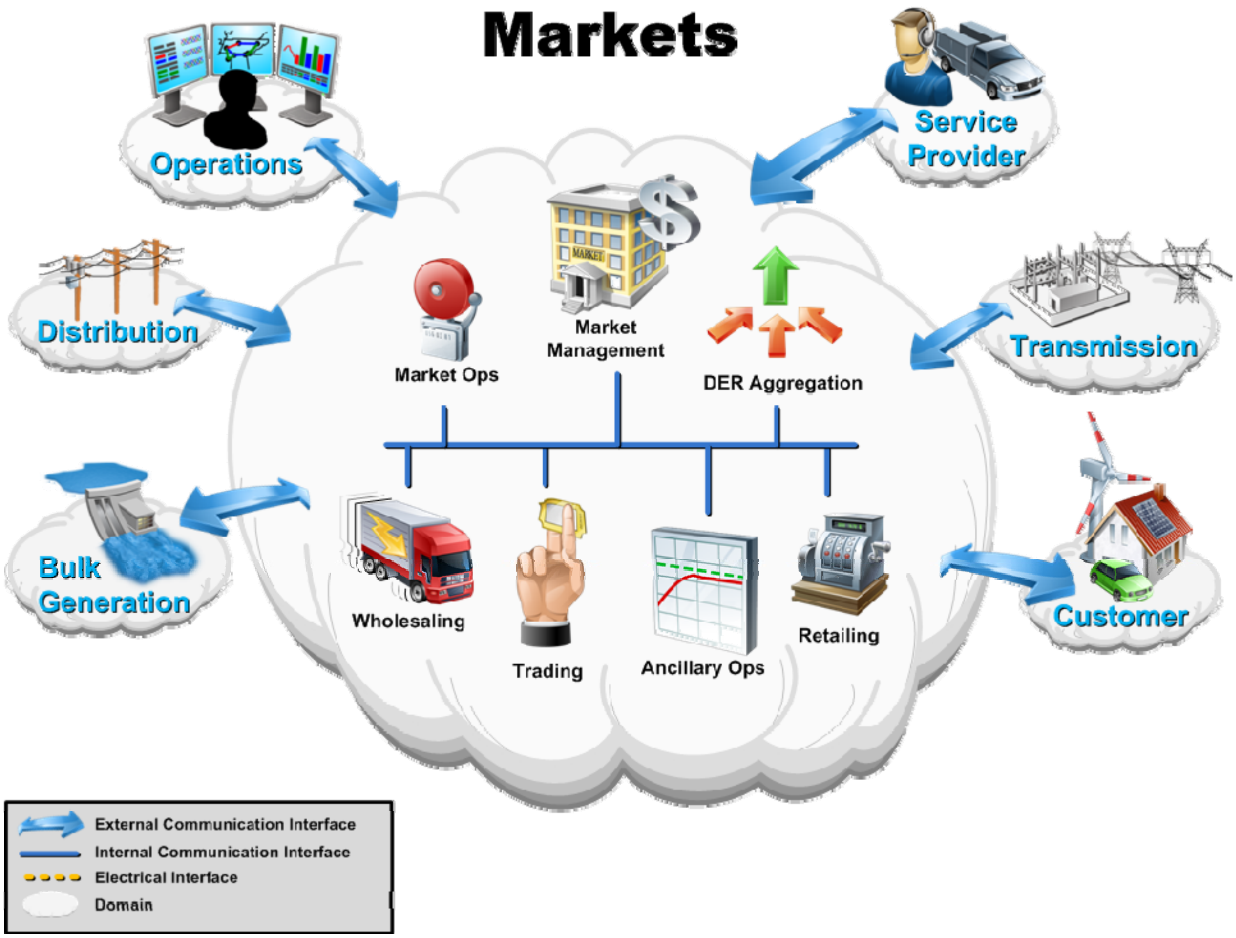

Figure 8 – Overview of the Markets Domain

Communication between the Market domain and the domains supplying energy are critical because efficient matching of production with consumption is dependent on markets. Energy supply domains include the Bulk Generation domain and Distributed Energy Resources (DER). DER resides in the Transmission, Distribution, and Customer domains. NERC CIPs consider suppliers of more than 300 megawatts to be Bulk Generation; most DER is smaller and is typically served through aggregators. DERs participate in markets to some extent today, and will participate to a greater extent as the Smart Grid becomes more interactive.

Communications for Market interactions must be reliable. They must be traceable and auditable. They must support e-commerce standards for integrity and non-repudiation. As the percentage of energy supplied by small DER increases, the allowed latency in communications with these resources must be reduced.

The high-priority challenges in the Markets domain are: extension of price and DER signals to each of the Customer sub-domains; simplification of market rules; expanding the capabilities of aggregators; interoperability across all providers and consumers of market information; managing the growth (and regulation) of retailing and wholesaling of energy, and evolving communication mechanisms for prices and energy characteristics between and throughout the Market and Customer domains.

Table 3 – Typical Applications in the Markets Domain

Example	Description
Market Management	Market managers include ISOs for wholesale markets or NYMEX for forward markets in many ISO/RTO regions. There are transmission and services and demand response markets as well. Some DER Curtailment resources are treated today as dispatchable generation.
Retailing	Retailers sell power to end customers and may in the future aggregate or broker DER between customers or into the market. Most are connected to a trading organization to allow participation in the wholesale market.
DER Aggregation	Aggregators combine smaller participants (as providers or customers or curtailment) to enable distributed resources to play in the larger markets.
Trading	Traders are participants in markets, which include aggregators for provision and consumption and curtailment, and other qualified entities. There are a number of companies whose primary business is the buying and selling of energy.
Market Operations	Make a particular market function smoothly. Functions include financial and goods sold clearing, price quotation streams, audit, balancing, and more.
Ancillary Operations	Provide a market to provide frequency support, voltage support, spinning reserve and other ancillary services as defined by FERC, NERC and the various ISO. These markets function on a regional or ISO basis normally.

3.2.4 Service Provider Domain

Actors in the Service Provider domain perform services to support the business processes of power system producers, distributors and customers. These business processes range from traditional utility services such as billing and customer account management to enhanced customer services such as management of energy use and home energy generation.

The service provider must not compromise the cyber security, reliability, stability, integrity and safety of the electrical power network when delivering existing or emerging services.

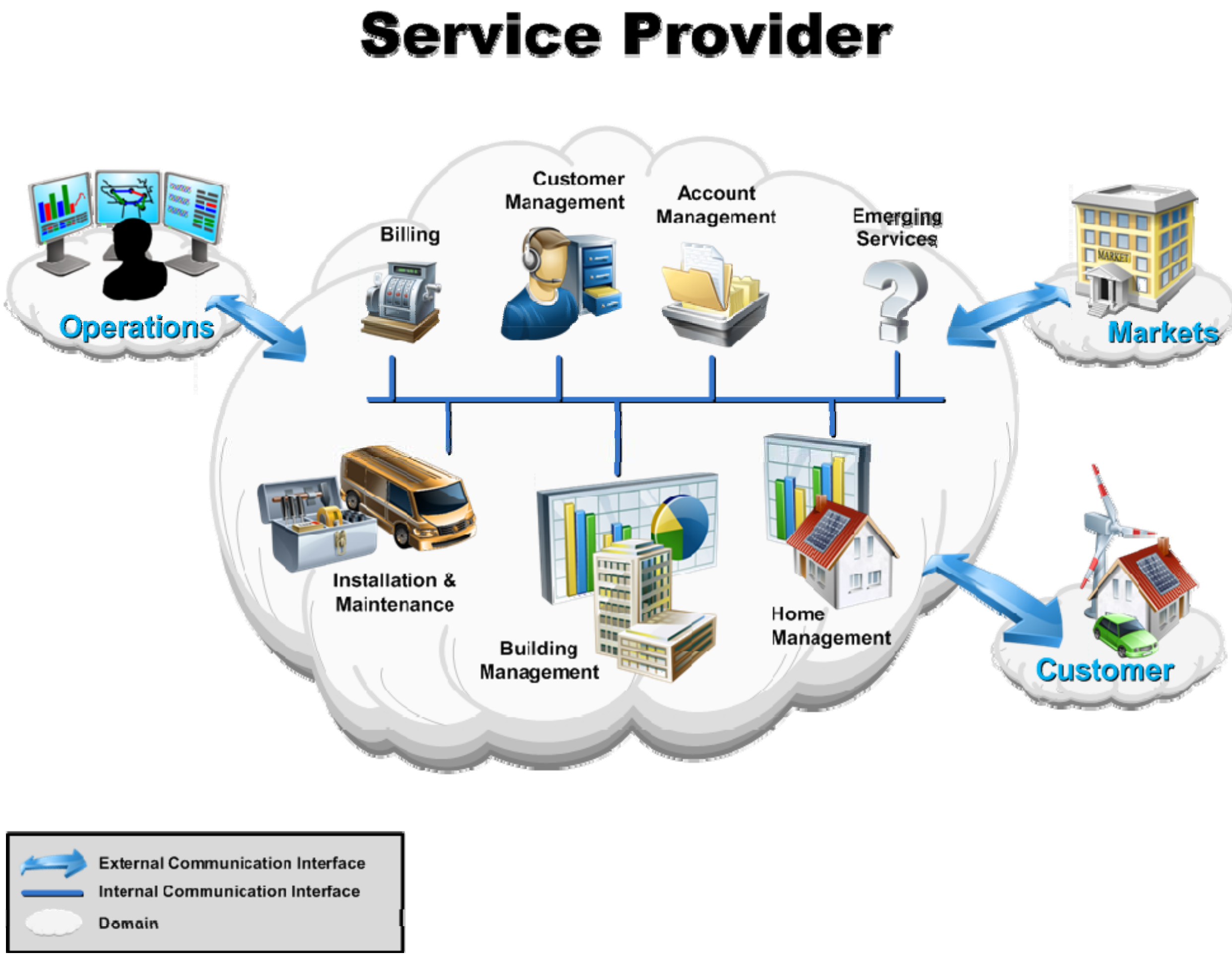

Figure 9 – Overview of the Service Provider Domain

The Service Provider domain shares interfaces with the Market, Operations and Customer domains. Communications with the Operations domain are critical for system control and situational awareness; communications with the Market and Customer domains are critical for enabling economic growth through the development of “smart” services. For example, the Service Provider domain may provide the interface enabling the customer to interact with the market(s).

Service providers will create new and innovative services and products to meet the new requirements and opportunities presented by the evolving smart grid. Services may be performed by the electric service provider, by existing third parties, or by new participants drawn by the new business models. Emerging services represent an area of significant new economic growth.

The priority challenge in the Service Provider domain is to develop the key interfaces and standards that will enable a dynamic market-driven ecosystem while protecting the critical power infrastructure. These interfaces must be able to operate over a variety of networking technologies while maintaining consistent messaging semantics.

Some benefits to the Service Provider domain from the deployment of the Smart Grid include:

1. The development of a growing market for 3rd parties to provide value-added services and products to customers, utilities and other stakeholders at competitive costs.
2. The decrease in cost of business services for other smart grid domains.
3. A decrease in power consumption and an increase in power generation as customers become active participants in the power supply chain.

Table 4 – Typical Applications in the Service Provider Domain

Example	Category	Description
Customer Management	Core Customer Services	Managing customer relationships by providing point-of-contact and resolution for customer issues and problems.
Installation & Maintenance	Core Customer Services	Installing and maintaining premises equipment that interacts with the Smart Grid.
Building Management	Enhanced Customer Services	Monitoring and controlling building energy and responding to Smart Grid signals while minimizing impact on building occupants.
Home Management	Enhanced Customer Services	Monitoring and controlling home energy and responding to Smart Grid signals while minimizing impact on home occupants.
Billing	Core Business Services	Managing customer billing information, sending billing statements and processing received payments.
Account Management	Core Business Services	Managing the supplier and customer business accounts.
Others	Emerging Services	All of the services and innovations that have yet to be created. These will be instrumental in defining the Smart Grid of the future.

3.2.5 Operations Domain

Actors in the Operations domain are responsible for the smooth operation of the power system. Today, the majority of these functions are the responsibility of a regulated utility. The smart grid will enable more of them to be outsourced to service providers; others may evolve over time. No matter how the Service Provider and Markets domains evolve, there will still be basic functions needed for planning and operating the service delivery points of a “wires” company. In transmission operations, Energy Management Systems (EMS) are used to analyze and operate the transmission power system reliably and efficiently, while in distribution operations, similar Distribution Management Systems (DMS) are used for analyzing and operating the distribution system.

Representative applications within the Operations domain are described in Table 5. These applications are derived from the IEC 61968-1 Interface Reference Model (IRM) for this domain[14].

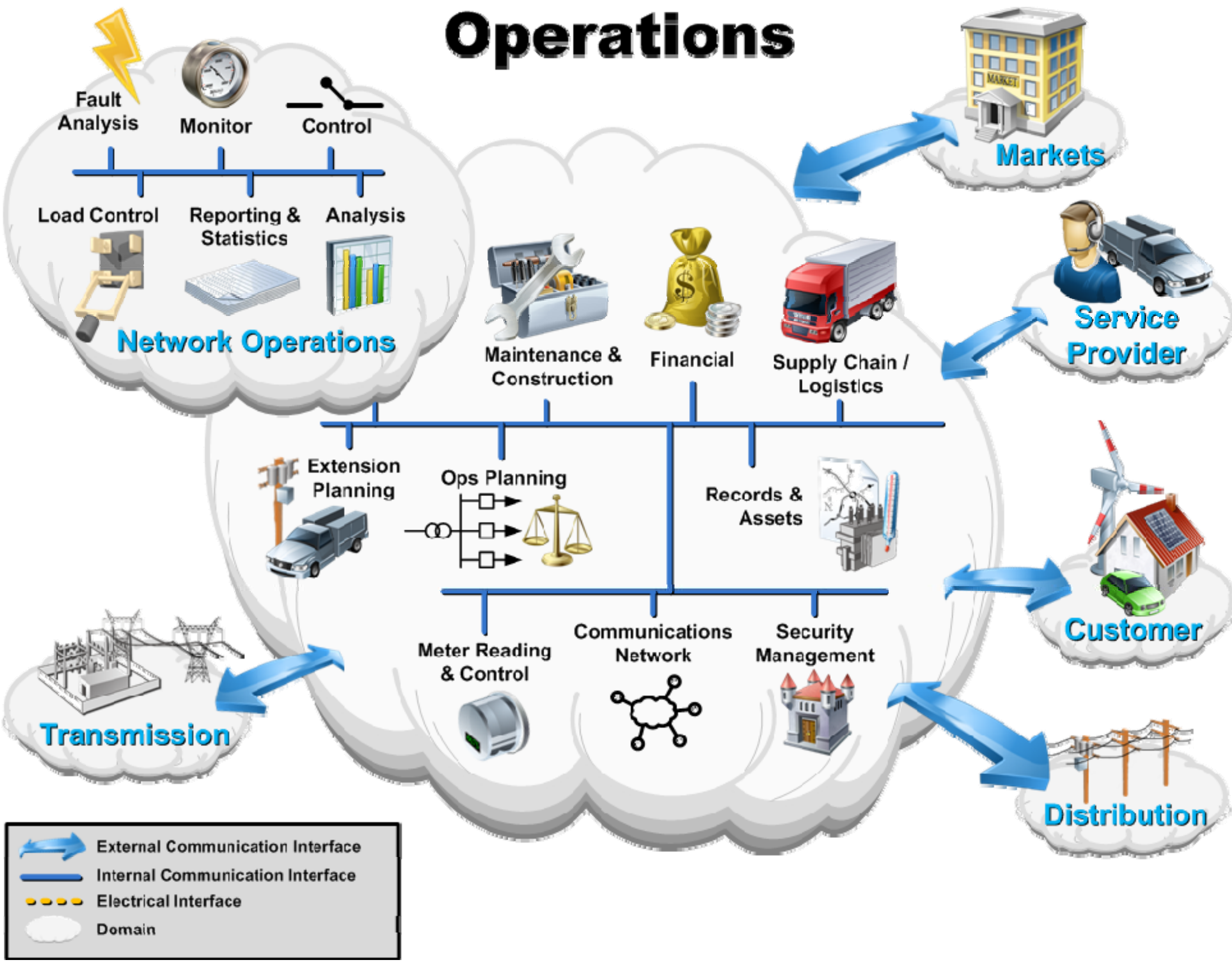

Figure 10 – Overview of the Operations Domain

Table 5 – Typical Applications in the Operations Domain

Application	Description
Network Operations	The Network Operations domain (actually a sub-domain) within Operations includes the applications:

[14] To review and comment on a more detailed breakdown of the IRM, please refer to the IEC 61968-1 document available under the Shared Documents directory at http://osgug.ucaiug.org/utilityami/AMIENT

Application	Description
Monitoring	Network Operation Monitoring actors supervise network topology, connectivity and loading conditions, including breaker and switch states, and control equipment status. They locate customer telephone complaints and field crews.
Control	Network control is coordinated by actors in this domain, although they may only supervise wide area, substation, and local automatic or manual control.
Fault Management	Fault Management actors enhance the speed at which faults can be located, identified, and sectionalized and service can be restored. They provide information for customers, coordinate with workforce dispatch and compile information for statistics.
Analysis	Operation Feedback Analysis actors compare records taken from real-time operation related with information on network incidents, connectivity and loading to optimize periodic maintenance.
Reporting and Stats	Operational Statistics and Reporting actors archive on-line data and to perform feedback analysis about system efficiency and reliability.
Calculations	Real-time Network Calculations actors (not shown) provide system operators with the ability to assess the reliability and security of the power system.
Training	Dispatcher Training actors provide facilities for dispatchers that simulate the actual system they will be using. (not shown on diagram)
Records and Assets	The Records and Asset Management actors track and report on the substation and network equipment inventory, provide geospatial data and geographic displays, maintain records on non-electrical assets, and perform asset investment planning.
Operational Planning	Operational Planning and Optimization actors perform simulation of network operations, schedule switching actions, dispatch repair crews, inform affected customers, and schedule the importing of power. They keep the cost of imported power low through peak generation, switching, load shedding or demand response.
Maintenance and Construction	Maintenance and Construction actors coordinate inspection, cleaning and adjustment of equipment, organize construction and design, dispatch and schedule maintenance and construction work, capture records gathered by field personnel and permit them to view necessary information to perform their tasks.
Extension Planning	Network Extension planning actors develop long term plans for power system reliability, monitor the cost, performance and schedule of construction, and define projects to extend the network such as new lines, feeders or switchgear.
Customer Support	Customer Support actors help customers to purchase, provision, install and troubleshoot power system services, and relay and record customer trouble reports.

Application	Description
Meter Reading and Control	Meter Reading and Control actors perform a variety of functions on the metering system including data collection, disconnect/reconnect, outage management, prepayment point of sale, power quality and reliability monitoring, meter maintenance and asset management, meter data management including validation, estimation and editing (VEE), customer billing, and load management, including load analysis and control, demand response, and risk management.
Supply Chain and Logistics	Supply Chain and Logistics actors manage the processes for acquiring necessary supplies; tracking acquired and ordered supplies; and allocating them.
Financial	Financial actors measure performance across the whole organization, including the evaluation of investments in capital projects, maintenance, or operations. They track risk, benefits, costs and impact on levels of service.
Communications Network	The planning, operations and maintenance of all communications network asset that are required to support Operations.
Security Management	The management of security policies, distribution and maintenance of security credentials, and centralized authentication and authorization as appropriate.
Premises	Information regarding the location of a service. This set of functions includes: Address management; Right of ways, easements, grants; and Real estate management.
Human Resources	Human Resources actors manage personnel information and activities including safety, training, benefits, performance, review, compensation, recruiting and expenses.
Business Planning and Reporting	These actors perform strategic business modeling, manpower planning, reporting, account management, and both assess and report on risk, performance and business impact.
Stakeholder Planning and Management	These actors perform track and manage the needs and concerns of various utility stakeholders by monitoring customer input, regulators, service standards, and legal proceedings.

3.2.6 Bulk Generation Domain

Applications in the Bulk Generation domain are the first processes in the delivery of electricity to customers. Electricity generation is the process of creating electricity from other forms of energy, which may vary from chemical combustion to nuclear fission, flowing water, wind, solar radiation and geothermal heat. The boundary of the Generation domain is typically the Transmission domain.

The Bulk Generation domain is electrically connected to the Transmission domains and shares interfaces with the Operations, Markets and Transmission domains. Communications with the

Transmission domain are the most critical because without transmission, customers cannot be served.

The Bulk Generation domain must communicate key performance and quality of service issues such as scarcity (especially for wind and sun) and generator failure. These communications may cause the routing of electricity onto the transmission system from other sources. A lack of sufficient supply may be addressed directly (via Operations) or indirectly (via Markets).

New requirements for the Bulk Generation domain include green house gas emissions controls, increases in renewable energy sources, provision of storage to manage the variability of renewable generation.

Actors in the Bulk Generation domain may include various devices such as protection relays, remote terminal units, equipment monitors, fault recorders, user interfaces and programmable logic controllers. They typically perform the applications shown in Figure 11 and discussed in the table below.

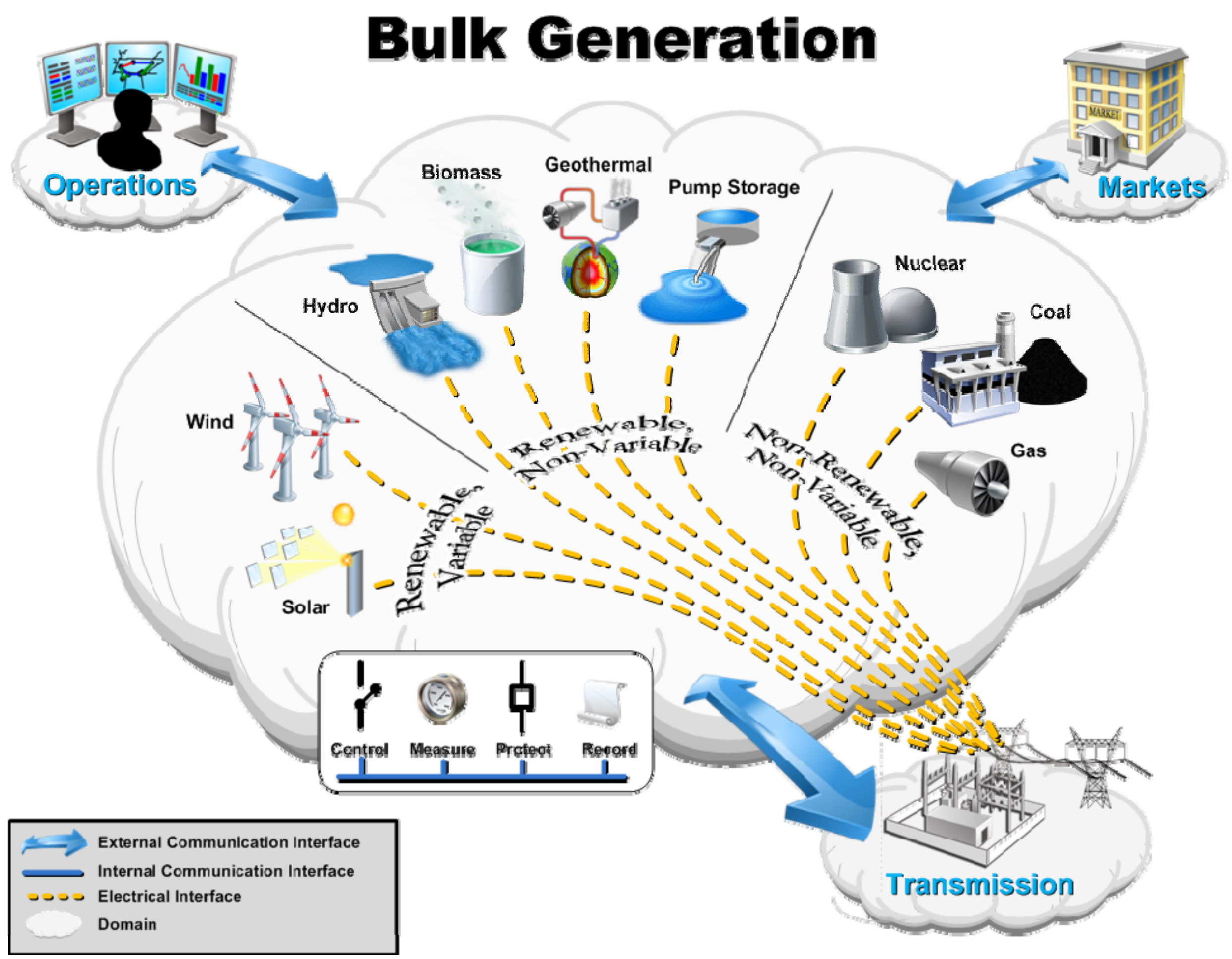

Figure 11 – Overview of the Bulk Generation Domain

Table 6 – Bulk Generation Categories

Category	Description
Variable	Generation from wind, sun, wave power, etc. that can vary with time.
Non-Variable	Generation from continuous process, coal, uranium, water, etc
Renewable	Generation from a source that can be replenished, e.g. wind, water, biomass
Non-Renewable	Generation from a source that cannot be replenished, e.g. coal, oil, uranium

Note that similarity exists in the common applications for Bulk Generation, Transmission, and the Distribution Domains. These common kinds of applications are summarized in Table 7 which follows. These applications, therefore, apply to each of the three power conduction path Domains.

Table 7 – Common Applications in Bulk Generation, Transmission, and Distribution Domains

Application	Description
Control	Performed by actors that permit the Operations domain to manage the flow of power and reliability of the system. An example would be the use of phase angle regulators within a substation to control power flow between two adjacent power systems
Measure	Performed by actors that provide visibility into the flow of power and the condition of the systems in the field. In the future measurement might be found in built into meters, transformers, feeders, switches and other devices in the grid. An example would be the digital and analog measurements collected through the SCADA system from a remote terminal unit (RTU) and provide to a grid control center in the Operations domain.
Protect	Performed by Actors that react rapidly to faults and other events in the system that might cause power outages, brownouts, or the destruction of equipment. Performed to maintain high levels of reliability and power quality. May work locally or on a wide scale.
Record	Performed by actors that permit other domains to review what has happened on the grid for financial, engineering, operational, and forecasting purposes.
Asset Management	Performed by actors that work together to determine when equipment should have maintenance, calculate the life expectancy of the device, and record its history of operations and maintenance so it can be reviewed in the future for operational and engineering decisions.

Application	Description
Stabilize and Optimize	Performed by actors that ensure the network is operating with the appropriate tolerances across the system. They may gather information to make control decisions that ensure reliable and proper operations (stability) or more efficient operations (optimization). Measurement and control form a feedback loop that allows grid operators to stabilize the flow of energy across the electric network or safely increase the load on a transmission path.

3.2.7 Transmission Domain

Transmission is the bulk transfer of electrical power from generation sources to distribution through multiple substations. A transmission network is typically operated by a Regional Transmission Operator or Independent System Operator (RTO/ISO) whose primary responsibility is to maintain stability on the electric grid by balancing generation (supply) with load (demand) across the transmission network.

Examples of actors in the transmission domain include remote terminal units, substation meters, protection relays, power quality monitors, phasor measurement units, sag monitors, fault recorders, and substation user interfaces. They typically perform the applications shown in the diagram (Figure 12) and described in Table 7 above.

The transmission domain may contain Distributed Energy Resources such as electrical storage or peaking generation units. Energy and supporting ancillary services (capacity that can be dispatched when needed) are procured through the Markets domain and scheduled and operated from the Operations domain, and finally delivered through the Transmission domain to the distribution system and finally to the Customer Domain.

Most activity in the Transmission domain is in a substation. An electrical substation uses transformers to change voltage from high to low or the reverse across the electric supply chain. Substations also contain switching, protection and control equipment. The figure depicts both step-up and step down sub-stations connecting generation (including peaking units) and storage with distribution. Substations may also connect two or more transmission lines. Transmission towers, power lines and field telemetry such as the line sag detector shown make up the balance of the transmission network infrastructure.

The transmission network is typically monitored and controlled through a Supervisory Control and Data Acquisition (SCADA) system composed of a communication network, monitoring devices and control devices.

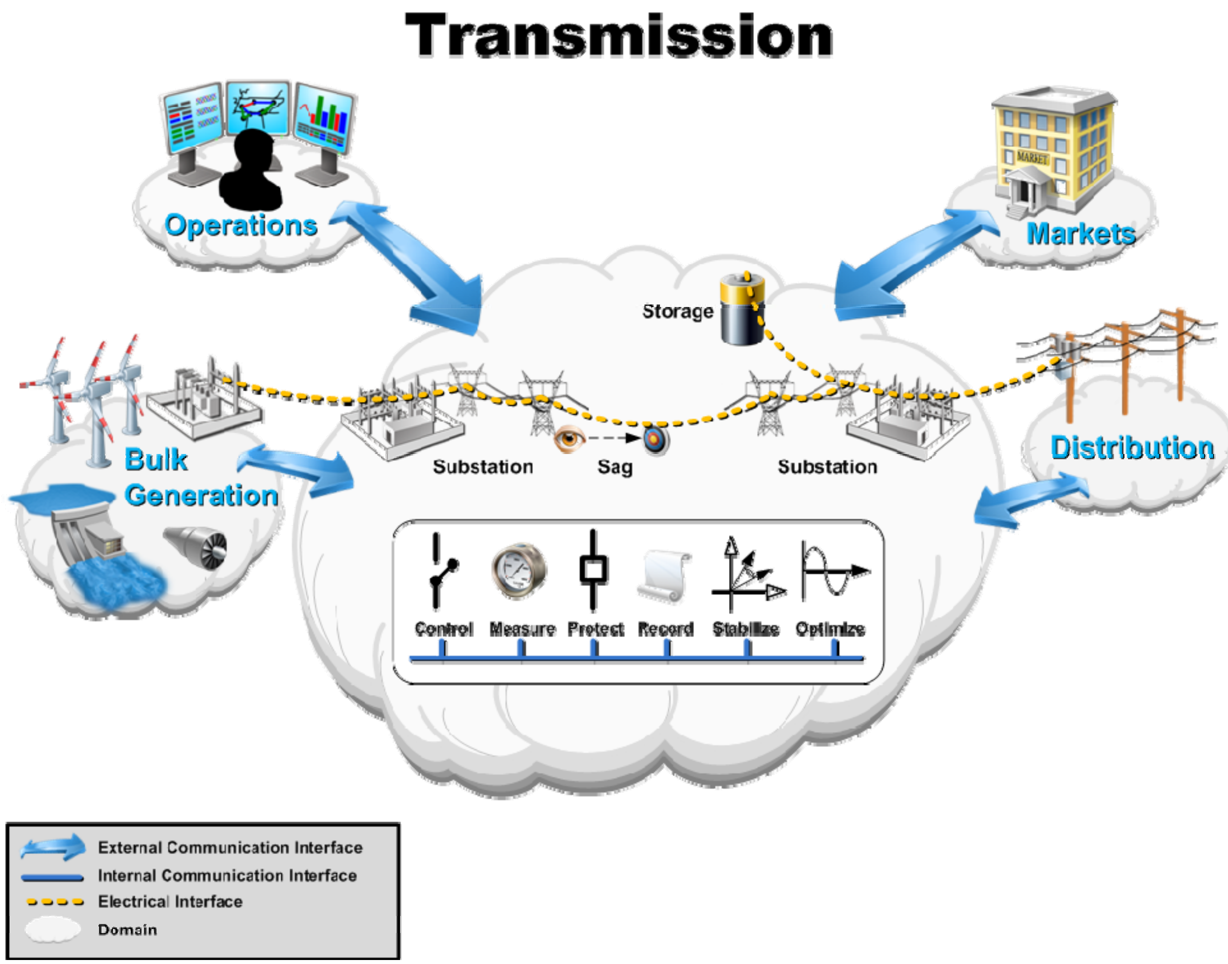

Figure 12 – Overview of the Transmission Domain

3.2.8 Distribution Domain

The Distribution domain is the electrical interconnection between the Transmission domain, the Customer domain and the metering points for consumption, distributed storage, and distributed generation. The electrical distribution system may be arranged in a variety of structures, including radial, looped or meshed.

The reliability of the distribution system varies depending on its structure, the types of actors that are deployed, and the degree to which they communicate with each other and with the actors in other domains. Historically distribution systems have been radial configurations, with little telemetry, and almost all communications within the domain was performed by humans. The primary installed sensor base in this domain is the customer with a telephone, whose call initiates the dispatch of a field crew to restore power.

Historically, many communications interfaces within this domain were hierarchical and unidirectional, although they now generally can be considered to work in both directions, even as the electrical connections are beginning to do. Distribution actors may have local inter-device (peer-to-peer) communication or a more centralized communication methodology.

In the smart grid, the Distribution domain will communicate more closely with the Operations domain in real-time to manage the power flows associated with a more dynamic Markets domain and other environmental and security-based factors. The Markets domain will communicate with Distribution in ways that will effect localized consumption and generation. In turn, these behavioral changes due to market forces may have electrical and structural impacts on the Distribution domain and the larger grid. Under some models, third party Customer Service Providers may communicate with the Customer domain using the infrastructure of the Distribution domain; such a change would change the communications infrastructure selected for use within the Domain.

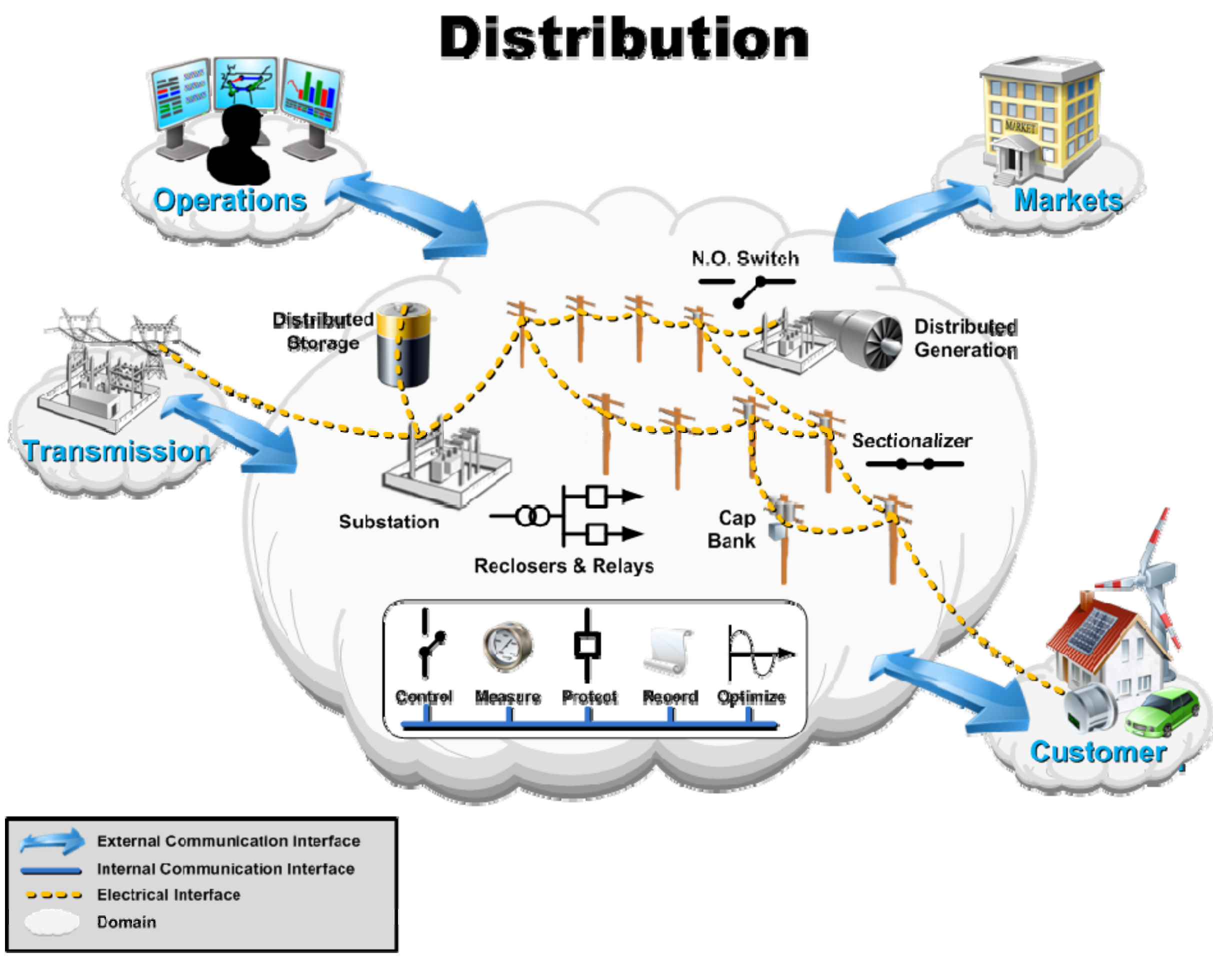

Figure 13 – Distribution Domain Diagram

Actors in the Distribution domain include capacitor banks, sectionalizers, reclosers, protection relays, storage devices, and distributed generators. They typically perform the applications shown in the diagram (Figure 13) and described in Table 7 above.

3.2.9 Use of the Conceptual Model within this Document

The remaining sections of this document will find the technical analysis infused with the concepts in the Conceptual Model.

Specifically, in section 4 summary descriptions of use cases were constructed to observe the requirements for standards in their implementation. In each use case, the scenario described sought to identify the actors in their domains, define the information exchanges that fulfilled the scenario, and finally specified the relevant standards that could carry these information exchanges.

In section 9 Appendix A: Standards Profiles by Domain, the standards are presented according to the GWAC Stack layered interfaces and is categorized via the domains in which the actors were discovered in the use case.

3.3 Cyber Security Risk Management Framework and Strategy

In the past, the energy sector concern was focused on managing the energy sector infrastructure; but now the information technology (IT) and telecommunications infrastructures are critical to the energy sector infrastructure. Therefore, the management and protection of systems and components of these infrastructures must also be addressed by the energy sector. This reliance on IT and telecommunications will increase with the implementation of the Smart Grid. The role of cyber security in ensuring the effective operation of the Smart Grid is documented in legislation and in the Department of Energy (DOE) Energy Sector Plan.

- *Energy, Critical Infrastructure and Key Resources, Sector-Specific Plan as input to the National Infrastructure Protection Plan*, May 2007. The vision statement for the energy sector is: "The Energy Sector envisions a robust, resilient energy infrastructure in which continuity of business and services is maintained through secure and reliable information sharing, effective risk management programs, coordinated response capabilities, and trusted relationships between public and private security partners at all levels of industry and government."
- As stated in the Energy Independence and Security Act of 2007, "It is the policy of the United States to support the modernization of the Nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth and to achieve each of the following, which together characterize a Smart Grid:

  (1) Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid.

  (2) Dynamic optimization of grid operations and resources, with full cyber security. ...."
- As specified in 18 CFR, Part 1 (Federal Energy Regulatory Commission (FERC)), Ch. 39, "*Reliable Operation* means operating the elements of the Bulk-Power System within equipment and electric system thermal, voltage, and stability limits so that instability, uncontrolled separation, or cascading failures of such system will not occur as a result of a sudden disturbance, including a cyber security Incident, or unanticipated failure of system elements."

Cyber security is a critical issue due to the increasing potential of cyber attacks and incidents against this critical sector as it becomes more and more interconnected. Cyber security must address not only deliberate attacks, such as from disgruntled employees, industrial espionage, and terrorists, but inadvertent compromises of the information infrastructure due to user errors, equipment failures, and natural disasters. Vulnerabilities might allow an attacker to penetrate a network, gain access to control software, and alter load conditions to destabilize the grid in unpredictable ways. The need to address potential vulnerabilities has been acknowledged across the Federal government including NIST, the Department of Homeland Security (DHS), the Department of Energy (DOE) and FERC.

Additional risks to the grid include:

- Increasing the complexity of the grid that could introduce vulnerabilities and increase exposure to potential attackers and unintentional errors;
- Interconnected networks can introduce common vulnerabilities;
- Increasing vulnerabilities to communication disruptions and introduction of malicious software that could result in denial of service or compromise the integrity of software and systems;
- Increased number of entry points and paths for potential adversaries to exploit; and
- Potential for compromise of data confidentiality, include the breach of customer privacy.

With the adoption and implementation of the Smart Grid, the IT and telecommunication sectors will be more directly involved. These sectors have existing cyber security standards to address vulnerabilities and assessment programs to identify known vulnerabilities in these systems; these vulnerabilities need to be assessed in the context of the Smart Grid. In addition, the Smart Grid has additional vulnerabilities due to its complexity, large number of stakeholders, and highly time-sensitive operational requirements.

4 Smart Grid Applications and Requirements

As described previously in 3.2 The Smart Grid Conceptual Model, use cases are a method through which to describe applications and through their description evidence the requirements needed to support them. This section describes at a high level the use cases that were the subject of the interim roadmap discussions and workshops, and, through which the actors (and their interfaces), information objects, and ultimately requirements and standards were derived. Subsequent work is recommended to further refine these results to normalize the nomenclature, the population of the Domains, and the summary of more detailed requirements as suggested in section 6.3.1 Completion of the NIST Standards Evaluation Process.

The Use Cases, therefore, are examples devised and extended by participants in the workshops and not definitive scenarios of the smart grid. As more extensive use cases are developed to enhance and complement these, the fuller extent of the interfaces for the actors in the Smart Grid will be visible. Note, also, that each Domain's actors has substantial overlap and duplication. Ultimately, these similarities need to be recognized and normalized as a Smart Grid clear set of actor definitions gets constructed in future work.

For each of the six application areas, define the following:

Description:	A description of the application area
Use Cases:	A summary of the use cases analyzed
Actors:	A table of the actors discovered in the use cases
Requirements drivers:	The significant drivers of requirements for use cases in the section
Communications diagram:	A summary diagram showing the actors and their interactions derived from the Use Cases in this application grouping.

Finally, a summary description of a subsequent requirements analysis that should be performed as one of the action results of this Interim Roadmap (see 6.3.1.1).

4.1 Diagramming Use Cases and Actors

The diagrams of the conceptual model shown in this document in section 3.2 are very detailed graphically and represent a top level and individual detail levels. However, it is often useful to focus on a single use case and the specific actors and their domains, and, the information exchanges in which they participate.

The figure below illustrates how a Smart Grid communications diagram for a use case involving actors in more than one domain could be represented in Unified Modeling Language (UML) [3] format, a common and standardized means for representing these concepts. Domains and actors are represented by rectangles. A line connecting two Actors is an Association or Connector representing the two Logical Interfaces (at each end of the line) to the Actors. A numbered arrow represents each message in the sequence of messages exchanged by the Actors.

Figure 14 – A Smart Grid Use Case Represented by a UML Communication Diagram shows a generic example of how to draw this kind of diagram. In a real use case, all the actors, interfaces and messages would also be labeled with their names. The UML specification defines “associations” and considers actors to be a type of “object”. The UML specification also has several other kinds of diagrams that can be used to represent use cases from the Smart Grid conceptual model, such as Use Case and Sequence diagrams.

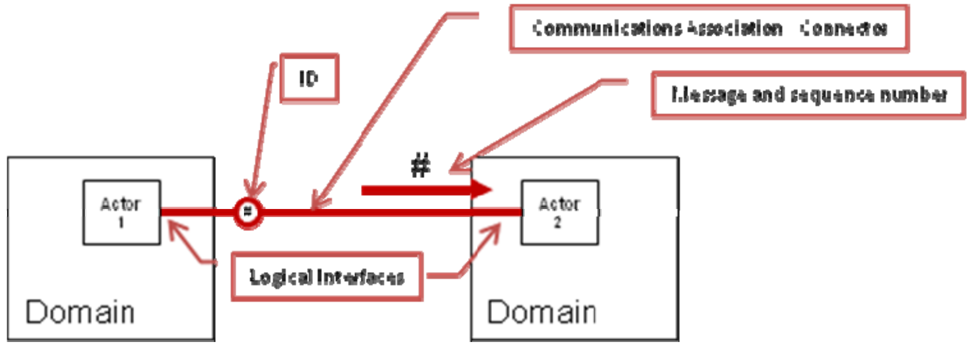

Figure 14 – A Smart Grid Use Case Represented by a UML Communication Diagram

In the sections which follow, diagrams of this form, with only Actors, Associations/Interfaces, and Domains are presented for each grouping of applications discussed.

4.2 Relevance of FERC Four Priority Functionalities to Smart Grid

Because of the limited time available to develop the Interim Roadmap, the project team is not able to study and analyze all smart grid applications but only a limited subset. The applications that the team has chosen to study are the "Four Priority Functionalities" that have been identified by FERC in their draft "Smart Grid Policy" issued March 19. These "FERC Four" functionalities are Wide-Area Situational Awareness (WASA), Demand Response, Electric Storage and Electric Transportation. In addition, AMI and Distribution Grid Management (DGM) were added as a result of stakeholder feedback, for a total of 6 functional priorities.

For each of the 6 functional priorities, use cases were collected, reviewed for “architectural significance”, and a representative subset was chosen. These use cases were rigorously exercised and introduced to workshop participants to modify and complete, and are included in this chapter. Workshop participants also performed requirements and gap analysis whose results are captured in the appendices:

- Appendix A: Standards Profiles by Domain
- Appendix B: Alphabetical Standards List
- Appendix C: Requirements, Standards Gaps, and Discussion Issues for the Action Plan

4.3 Wide-Area Situational Awareness (WASA)

4.3.1 Description

Wide Area Situational Awareness (WASA) represents the monitoring of the power system across wide geographic areas. These broad area perspectives are necessary to maintain system knowledge and decisions that go beyond conventions of individual companies or even regional transmission organization (RTO) boundaries. The requirements for WASA are architecturally significant from the standpoint of requiring uniformity across traditional systems operation boundaries. Enabling WASA based applications brings forward unique requirements and challenges for the Smart Grid infrastructure. WASA requirements are influenced by answers to questions that include:

- What is the state of the power system components? What is the state of the information system? This is situational awareness!
- What are the capabilities and behavior of the power system components? How does each relate to the entire power system state as a whole? How do you manage each? This is situational understanding!
- How will different situations and control commands affect the overall system? What are the optimal solutions to efficiently manage the system, correct system disturbances, or restore interrupted electrical services? This is situational prediction.

Modern power systems are extremely large and complex physical objects to control. They, in turn, consists of a number of also large and complex actors, such as bulk generation, transmission, distribution, and customer systems. These systems are interconnected and have strong interrelationships. With the significant advances of active components in the customer systems (DER, PEV, etc), the customer component will also significantly impact transmission system. The situational understanding of the transmission system cannot be comprehensive without information from the distribution and customer systems.

In order to properly define the requirements for the WASA we need to find the optimal proportion of the information, which should be provided to the automated monitoring and control systems and to the operator, which is always the "person in charge". In the sense of the volume of data, the automated systems will process the bulk of data, and the operators should be provided by concise and optimally visualized information to be able to direct the automated systems to the changing operational objectives within changing optimization constraints, remaining outside of the loop that is fast processing huge amount of data.

4.3.2 Use Cases

The following use cases are representative of architecturally-significant samples for WASA.

4.3.2.1 Contingency Analysis

Contingency analysis (CA) is an application that analyzes the security (i.e. the capability to withstand outages of element of the critical infrastructure) of a power system. It calculates, identifies, and prioritizes: current and power flow overloads in equipment, voltage violations at buses, and system stability problems that would occur if contingency events (i.e. equipment failures or outages) happen in the future. Contingency analysis simulates the effects of removing equipment and calculates the results using a model of the power system.

4.3.2.2 Inter-Area Oscillation Damping

Low frequency Inter-area oscillations are detrimental to the goals of maximum power transfer and optimal power flow. An available solution to this problem is the addition of power system stabilizers to the automatic voltage regulators on the generators. The damping provided by this technique provides a means to minimize the effects of the oscillations. Although Power System Stabilizers exist on many generators, they effect is only on the local area and do not effectively damp out inter-area oscillations. It can be shown that the inter-area oscillations can be detected through the analysis of phasor measurement units (PMU) located around the system. In a typical implementation, one or more of the generators in a system are selected as Remote Feedback Controllers (RFC). The RFC received synchronized phasor measurements from one or more remote phasor sources. The RFC analysis the phase angles from the multiple sites and determines if an inter-area oscillation exists. If an oscillation exists, a control signal is sent to the generator's voltage regulator that effectively modulates the voltage and effectively damps out the oscillations.

4.3.2.3 Wide Area Control System for Self Healing Grid Applications

The objective of the Wide Area Control applications is to evaluate power system behavior in real-time, prepare the power system for withstanding credible combinations of contingencies, prevent wide-area blackouts, and accommodate fast recovery from emergency state to normal state. The Wide area control system functions comprise a set of computing applications for information gathering, modeling, decision-making, and controlling actions. These applications reside in central and in widely distributed systems, such as relay protection, remedial automation schemes (RAS), local controllers, and other distributed intelligence systems. All these applications and system components operate in a coordinated manner and adaptive to the actual situations. The application is based on a consistent real-time model of the system topology and operational parameters validated by a State Estimator utilizing Wide-Area Measurement System (WAMS).

4.3.2.4 Voltage Security

The Voltage Security function is designed to detect severe low voltage conditions based on phasor measurements of Power and Voltage and upon detection, initiate corrective action such as load shed. The Voltage Security function also includes additional decision system inputs, including phasor measurements from other utilities, real time line capacity from SCADA/EMS, available customer dispatchable loads from DMS, available generation capacity from MOS, EMS, and DMS, and dispatchable VAR sources from EMS and DMS.

4.3.2.5 Monitoring Distribution Operations as a Part of WASA

The objectives of this function as a component of WASA are to monitor in the near-real time and in close look-ahead time the behavior of distribution operations under normal and emergency operating conditions, analyze the operations, and provide the transmission automated management systems and the transmission operator with the results of the analysis aggregated at the demarcation lines between distribution and transmission.

4.3.2.6 Voltage, Var, and Watt Control (VVWC)

The following objectives, relevant to WASA are supported by the application: Reduce load while respecting given voltage tolerance (normal and emergency); Conserve energy; Reduce or eliminate overload in transmission lines; Reduce or eliminate voltage violations on transmission lines; Provide reactive power support for transmission/distribution bus; Provide spinning reserve support; Minimize cost of energy.

The application calculates the optimal settings of voltage controller of LTCs, voltage regulators, Distributed Energy Resources, power electronic devices, capacitor statuses, and may enable demand response means for optimizing the operations following current objectives. The application takes into account operational constraints if both distribution and transmission operations, and, if so opted, it takes into account real-time energy prices, when the objective is cost minimization.

4.3.3 Actors

The following table is a summary of the key Actors and which domains they participate in.

Table 8 – Actors in Wide Area Situational Awareness

Actor	Domains	Description
RTO/ISO	Markets	RTO: An independent organization that coordinates, controls, and monitors the operation of the electrical power system and supply in a particular geographic area; similar to Independent System Operator. ISO: An independent entity that controls a power grid to coordinate the generation and transmission of electricity and ensure a reliable power supply.
Wholesale Market	Markets	Market for energy products, including bulk generation, distributed generation, electric storage, electric transportation, and demand response.
Aggregator	Service Provider	A person (company) joining two or more customers, other than municipalities and political subdivision corporations, into a single purchasing unit to negotiate the purchase of electricity from retail electric providers. Aggregators may not sell or take title to electricity. Retail electric providers are not aggregators.
Plant Control System	Bulk Generation	Distributed Control System for a generating plant.

Actor	Domains	Description
Customer ESI	Customer	Customer Energy Services Interface (ESI) can receive pricing and other signals to influence and manage the operation of customer systems and devices, including appliances, DER, electric storage, and PEVs.
IED	Distribution	A microprocessor-based controller of power system equipment, for monitoring and control of automated devices in distribution which communicates with SCADA, as well as distributed intelligence capabilities for automatic operations in a localized distribution area based on local information and on data exchange between members of the group.
IED	Transmission	A microprocessor-based controller of power system equipment for monitoring and control of automated devices in transmission which communicates with SCADA, as well as distributed intelligence capabilities for automatic operations.
Transmission Actuator	Transmission	Actuator device used for control of devices in the transmission system.
Power System Control Center	Operations	Power system central operations.
EMS	Operations	A system of computer-aided tools used by operators of electric utility grids to monitor, control, and optimize the performance of the generation and/or transmission system. EMS also provides DMS with transmission/generation-related objectives, constraints, and input data from other EMS applications.
SCADA	Operations	A computer system monitoring and controlling power system operations. SCADA database is updated via remote monitoring and operator inputs. Required scope, speed, and accuracy of real-time measurements are provided, supervisory and closed-loop control is supported.
Wide Area Measurement and Control System	Operations	Measurements from phasor measurement units located in a wide area of power systems and determining actions to perform with transmission actuators.
DMS	Operations	The system that monitors and controls the distribution system equipment based on computer-aided applications, market information, and operator control decisions.

4.3.4 Requirements Drivers

Phasor Measurement Units must have voltage (3-phase) and time synchronization in order to compute phasors. Time synchronization must be tight enough to maintain acceptable drift in local time keeping devices and maintained to IEEE 1588 Standards or better.

Wide area communications must meet latency and real-time applications requirements for WASA based applications.

Remote Feedback Controller must have valid secure communications from the remote sites; the controlled generator must be up and running with validation of status.

Topology and other processing must be able to integrate data from field equipment up to EMS systems and environments.

4.3.5 Communications Diagram

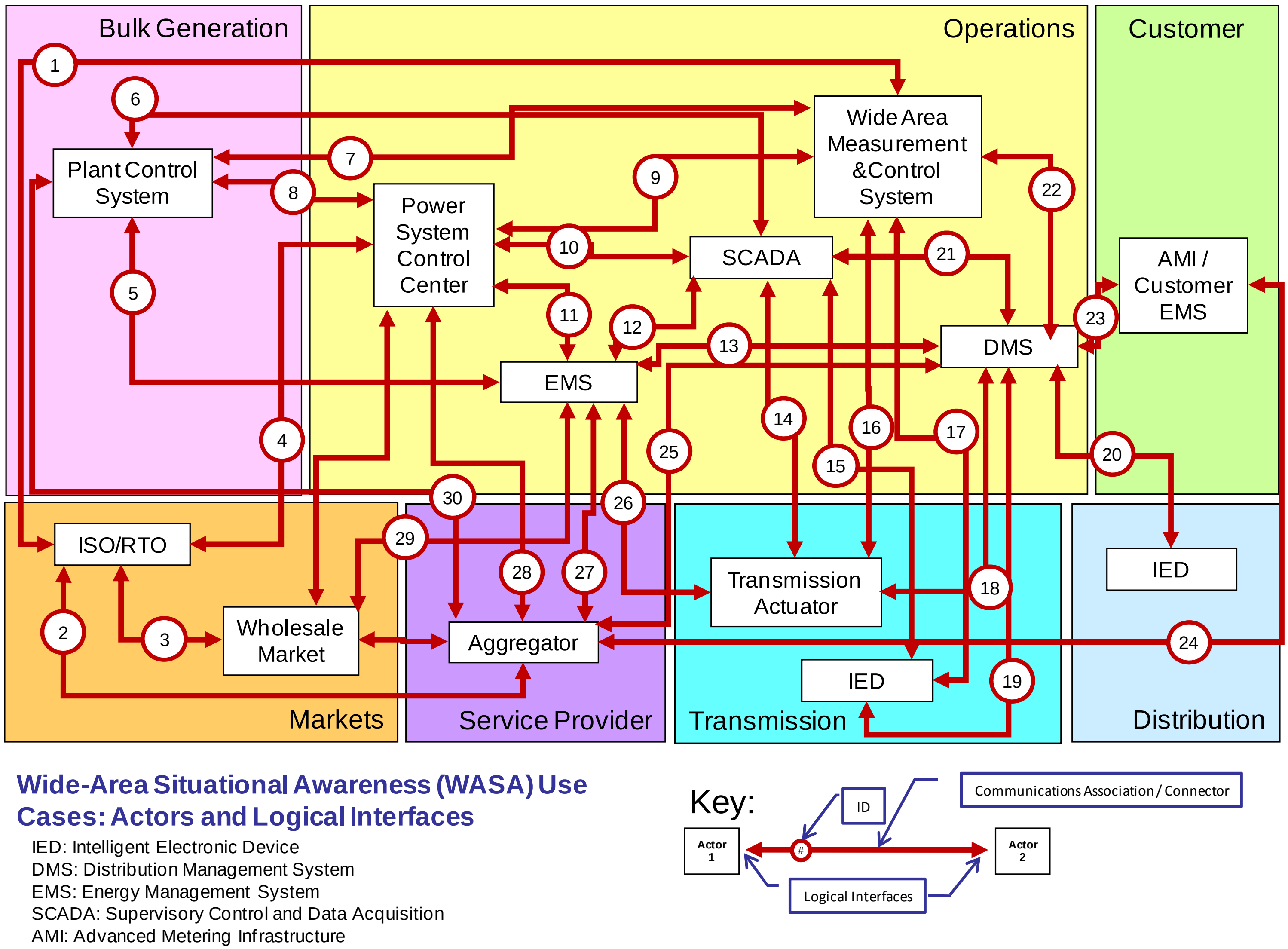

Figure 15 – Wide-Area Situational Awareness Applications Summary Communications Diagram

4.4 Demand Response

FERC states that further development of key standards around Demand Response will enhance interoperability and communications between system operators, demand response resources (also called curtailment resources), and the systems that support them. The following discussion on Demand Response supports FERC's request to identify use cases and relevant standards, particularly around dispatchable curtailment to address loss or unavailability of other resources and the potential for dispatchable Demand Response to increase power consumption during over-generation situations.

4.4.1 Description

Demand Response is a temporary change in electricity consumption by Demand Resources in response to market or reliability conditions. Demand Resources are loads or aggregation of loads capable of measurably and verifiably providing temporary changes in consumption. Distributed Energy Resources (DERs) are small-scale energy generation/storage sources capable of providing temporary changes in electricity supply. Demand Resources are sometimes clumped in with DERs in Smart Grid discussions. Both types of devices may be used to support electricity demand or supply management opportunities for reliability or economic reasons. By managing loads through Demand Response and supplies from non-traditional small-scale generation, the opportunity exists to:

- Engage the consumer by allowing market participation and consumption/billing choices;
- Introduce new markets for aggregators, micro-grid operators, distributed generation, vendors, and consumers;
- Control peak power conditions and limit or remove brownout/blackout instances;
- Flatten consumption curves and shift consumption times;
- Respond to temporary grid anomalies;
- Maximize use of available power and increase system efficiencies through time-of-use (TOU) and dynamic pricing models.

4.4.2 Use Cases

This section lists the architecturally significant use cases for Demand Response that were analyzed for the Interim Roadmap.

4.4.2.1 Direct Load Control

Studies indicate that customers want to know when direct load control measures are in effect. The DR solution shall provide the ability to manage direct load control programs. It accomplishes this by managing the transmission of direct load control actions to direct-load-control-enabled devices, shown as device, HAN device, and smart appliances. This solution will also provide interactions with customers to convey direct load control information.

Direct control presents critical risks to on-site safety in the operation of customer equipment, particularly in regard to automated start-up following load shedding. Each class of equipment and each customer environment may have its own safety and regulatory requirements. Smart grid communications must respect these requirements and work through agent interactions with the premises systems.

4.4.2.2 Demand Response Management System Manages Demand in Response to Pricing Signal

Studies indicate that customers who understand the cost of electricity reduce their usage, especially when prices are high. The DR solution shall provide the ability to manage pricing signal programs designed to reduce load. It accomplishes this by managing the transmission of price signal information to DR-enabled devices. This solution shall also provide interactions with customers to convey price signal information; communication is shown via the meter or the Facility Energy Services Interface (ESI).

4.4.2.3 Customer Reduces Their Usage in Response to Pricing or Voluntary Load Reduction Events

Customer awareness of energy scarcity and customer attention to energy use, each maintained by economic signals, are key benefits of the smart grid. The most expensive use of the grid is to cover short term shortages in energy supply. Today such shortages are caused as buildings respond to weather or as the grid responds to unplanned outages. Tomorrow, as we rely more on intermittent energy sources such as sun and wind, they will occur more frequently.

The grid can share responsibility for peak load management with customers by sharing economic incentives to reduce load. These incentives may be shared in advance by day-ahead pricing or in real time during a critical event. Energy customers will develop a variety of strategies to respond once the economic incentives are in place.

To enable customers to meet this need, the smart grid must provide them with timely price, event, and usage information. For competitive markets in software and equipment to assist customers, there must be national system market based upon information standards.

4.4.2.4 External Clients Use the AMI to Interact With Devices at Customer Site

The Smart Grid will enable third parties, such as energy management companies, to use the communication infrastructure as a gateway to monitor and control customer equipment located at the customer's premise. The communication will be required to enable on-demand requests and support a secure environment for the transmission of customer confidential information, and would take place via an AMI or communication through the Facility Energy Services Interface.

Automated interaction with premises equipment presents critical risks to on-site safety in the operation of customer equipment, particularly in regard to automated start-up following load shedding. Each class of equipment and each customer environment may have its own safety and regulatory requirements. Smart grid communications must respect these requirements and work through agent interactions that leave the premises systems, built with domain knowledge of particular needs in control.

4.4.2.5 Customer Uses an Energy Management System (EMS) or In-Home Display (IHD)

The Smart Grid will facilitate customers becoming actively involved in changing their energy consumption habits by connecting their personal control and display devices to the utility grid. This technology also makes it possible for the utility to obtain vital information to maintain power quality and reliability on their systems. There are a variety of programs that the customer can enroll in, that in conjunction with their Smart Appliances and Plug-in Electric Vehicles, enable them to better manage their energy usage and costs. Providing customers with the means to visually monitor information about their energy use from their residence or business helps them to make more educated energy related decisions. Customers with access to EMS and IHD are more inclined to install energy efficient equipment on their premises and participate in load reduction programs. This use case describes how customers and the utility use these new technologies for improved load management.

4.4.2.6 Utility procures energy and settles wholesale transactions

Operations for the Retail Market receives and prepares bids and offers into the wholesale energy market and evaluates the incoming bids from the wholesale market against the needs and the cost of operation. To facilitate this process, the Retail Market needs to know what resources, such as distributed generation or demand response, are available and for how long. Some time after a wholesale transaction has been completed, the Retail Market settles the transaction using actual usage data gathered by the metering system during the period specified in the transaction. The data is used to prepare bills and invoices to multiple parties involved in the transaction based on contracts and tariffs.

4.4.2.7 Dynamic Pricing— Energy Service Provider Energy and Ancillary Services Aggregation

A Demand Response Service Provider collects energy and ancillary services bids and offers from Dynamic Pricing and other DER subscribing customers. The Service Provider combines those bids into an aggregate bid into the market operations bid/offer system. When accepted, the Service Provider notifies the end customer of the status and requests scheduling of the services.

4.4.2.8 Customer Uses Smart Appliances

The Smart Grid allows customers to become actively involved in changing their energy consumption habits by connecting their personal Smart Appliances to the utility grid. This use case describes how the customer installs and begins using Smart Appliances to manage their energy usage and costs. Smart appliances have their own domain requirements, in particular safety requirements, and must manage their own behaviors in response to coordinating and economic signals. Communication is through the Facility Energy Services Interface or the metering system.

4.4.2.9 VVWC with DR, DER, PEV, and ES

The application calculates the optimal settings of voltage controller of Load Tap Changesr (LTCs), voltage regulators, DER, power electronic devices, capacitor statuses, and may enable Demand Response to amplify the effect of load-reducing volt/var control.

4.4.3 Actors

The following table is a summary of the key Actors and which domains they participate in.

Table 9 – Actors in Demand Response

Actor	Domains	Description
Retail Market	Market	The Retail Market clears bids and offers, or otherwise sets retail prices.
Aggregator	Markets	An Aggregator combines the curtailment or demand or DER of two or more customers into a single purchasing unit to negotiate the purchase or sale of electricity in the retail market. Aggregators act in retail and wholesale markets.
Grid Operations	Operations	Grid operations manage services for the distribution of electricity (and gas and water) to and from customers and may serve customers who do not choose direct access.
Distribution Management	Operations	Controls distribution of energy. May alternatively be considered part of Grid Operations in the Operations domain.
DR Service Provider	Service Provider	A Demand Response Service Provider may serve as an aggregator (in the Markets domain), or otherwise provide distribution of DR signals. The source of those signals is not shown in the diagram.
Meter	Customer	Unless otherwise qualified, a device used in measuring watts, vars, var-hours, volt-amperes, or volt-ampere-hours. Called a Smart Meter when part of an advanced metering infrastructure (AMI). Today typically located at the customer facility and owned by the distributor or retail provider.
Facility EMS/Gateway	Customer	A logical or physical device typically located at the customer facility and used as a communication gateway. The Energy Management System may or may provide the Gateway function. To simplify the exposition these two functions are labeled EMS in the diagram.
Display	Customer	An In-Home Display (for Homes) or facilities console for other customers (e.g. commercial buildings, industrial facilities, or vehicles) shows information related to energy management.
Distributed Generation	Customer	Distributed Generation, often called Distributed Energy Resources (DER), includes small-scale generation or storage of whatever form. This is in contrast to centralized or bulk generation and/or storage of electricity.

Actor	Domains	Description
Device, HAN Device, or Smart Appliance	Customer	Devices that can react to remote management, whether to price, grid integrity, or other energy management signaling. May be controlled by a Facility EMS, a Facility Gateway, though a Smart Meter (serving as a Facility Gateway), or other means such as direct communication of price or other information. Communication to the device might be via a Home-Area Network or other means; we use the terms interchangeably.

4.4.4 Requirements Drivers

Demand Response is characterized by interactions between the actors that must traverse many Domains in order to function. Information is exchanged between devices of varied complexity, ownership, and access rights.

4.4.5 Communications Diagram

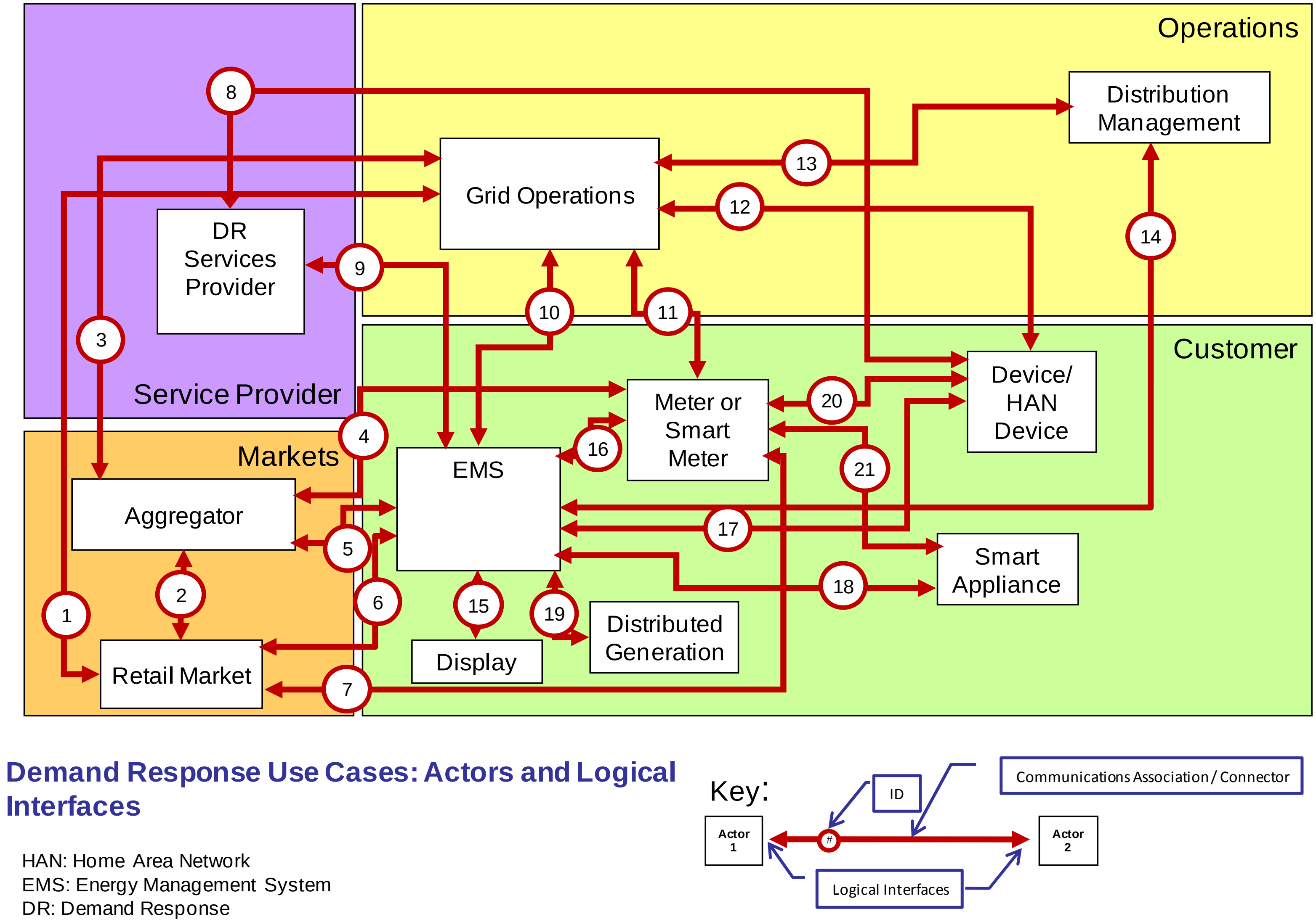

Figure 16 – Demand Response Applications Summary Communications Diagram

4.5 Electric Storage

FERC points out that investment in large amounts of electricity storage could ultimately address both the resource adequacy and resource management concerns, but that technical and economic issues remain to be addressed before such investment is likely to become significant. If electricity storage technologies could be more widely deployed, they would present another important means of addressing some of the difficult issues facing the electric industry. Electricity storage technologies can be deployed in a distributed manner (e.g. local storage that can be aggregated) or as bulk storage (direct interfaces to system energy management functions).

4.5.1 Description

To date, the only significant bulk electricity storage technology has been pumped storage hydroelectric technology. Distributed storage exists (e.g. local storage for UPS systems, etc.) but it is not aggregated or available for any system benefits. New storage technologies are under development and in some cases are being deployed, and could also potentially provide substantial value to the electric grid.

Electric storage is recognized to have value at all levels in the modern power system, from central generation to point of use. Examples of storage functionalities are:

- At Generation level – frequency control, spinning reserve, supply-ramping, demand-leveling, minimum loading
- At Transmission level – stability, VAR support, power quality and transfer-leveling, and reliability
- At Substation/Distribution – peak shaving, voltage support, power quality, capacity investment deferral, and reliability
- At End-Use level – demand control, interruption protection, voltage support and power quality

4.5.2 Use Cases

4.5.2.1 Energy Storage (ES) Owners Store Energy from the Power System

ES owners store energy when it is at its lowest cost and when it has least possibility to be detrimental to the power system operations.

4.5.2.2 Energy Storage (ES) Owners Discharge Energy into the Power System

ES owners discharge energy when it is economically advantageous to do so and/or when it can improve reliability, efficiency, or power quality of the power system operations.

4.5.2.3 Building Energy Usage Optimization using Electric Storage

Energy storage is used as one mechanism to optimize building energy usage in response to real-time pricing (RTP) signals. The RTP system provides the pricing schedule through email or direct transfer to the Building Automation System (BAS) that can perform the necessary activities to optimize the building energy usage.

4.5.2.4 RTO/ISO Directly Dispatches Electric Storage to Meet Power Demand

Using either market-based energy scheduling or emergency control capabilities, the RTO/ISO directly dispatches stored electric energy to meet local or regional power demand. The market-based energy schedule would include the electric storage devices that are under dispatch control of the RTO/ISO for the purpose of meeting scheduled demand.

Separately, depending upon the structure of the electric market, the RTO/ISO could also schedule and control the charging of the electric storage devices. The devices could also be controlled to provide for scheduled VAR demand.

4.5.2.5 Utility Dispatches Electric Storage to Support Intentional Islanding

A utility determines that an electric island (microgrid) could be intentionally established and dispatches electric storage as well as other DER generation and load management capabilities to support this islanding.

4.5.2.6 Electric Storage Used to Provide Fast Voltage Sag Correction

Electric storage provides fast voltage sag correction.

4.5.2.7 Impact on Distribution Operations of Plug-in Electric Vehicles as Electric Storage

The objectives of this use case are to demonstrate that the distribution monitoring and controlling functions a) take into account the near-real time behavior of the ES as loads and as Source of Energy and b) have the needed input information for the close look-ahead times reflecting the behavior of the ES as loads and as Source of Energy.

4.5.3 Actors

The following table is a summary of the key Actors and which domains they participate in.

Table 10 – Actors in Electric Storage

Actor	Domains	Description
Aggregator	Market	A person joining two or more customers, other than municipalities and political subdivision corporations, into a single purchasing unit to negotiate the purchase of electricity from retail electric providers. Aggregators may not sell or take title to electricity. Retail electric providers are not aggregators.
Utility EMS	Operations	The entities that continue to provide regulated services for the distribution of electricity (and gas and water) to customers and serve customers who do not choose direct access. Regardless of where a consumer chooses to purchase power, the customer's current utility will deliver the power to the consumer's home or business.

Actor	Domains	Description
Utility Energy Management Service	Operations	A service that provides supervisory storage management on behalf of the customers.
Meter	Customer	Unless otherwise qualified, a device of the utility used in measuring watts, vars, var-hours, volt-amperes, or volt-ampere-hours.
EMS	Customer	Customer owned energy management system
Storage System	Customer	Storage of electric energy at either the distribution grid level, often at customer sites, or at the transmission grid level, often connected in a substation.
PEV	Customer	A PEV can also be an element of energy storage.

4.5.4 Requirements Drivers

Effective applications of energy storage must have information on energy balance, requirements for ancillary services and related market values.

In the case of longer term storage (minutes to hours) for energy arbitrage, load following and ramping, market information on both the current value of energy and the expected future value will be required to effectively schedule changing and discharging. Since all storage systems will have both a capital and an operational cost component, its dispatch will depend primarily on capacity and on energy value. Also the capacity and energy limits of the storage systems will need to be communicated back to either a dispatcher or aggregator.

In the case of short-term storage (seconds to minutes) for ancillary services, including frequency regulation, reactive supply and voltage support, requires fast and secure communications that allow for automatic control of the resource. Storage acting as spinning or operating reserves will require communication to verify the requirement to operate and to confirm the available capacity in the seconds-to-minutes timeframe.

4.5.5 Communications Diagram

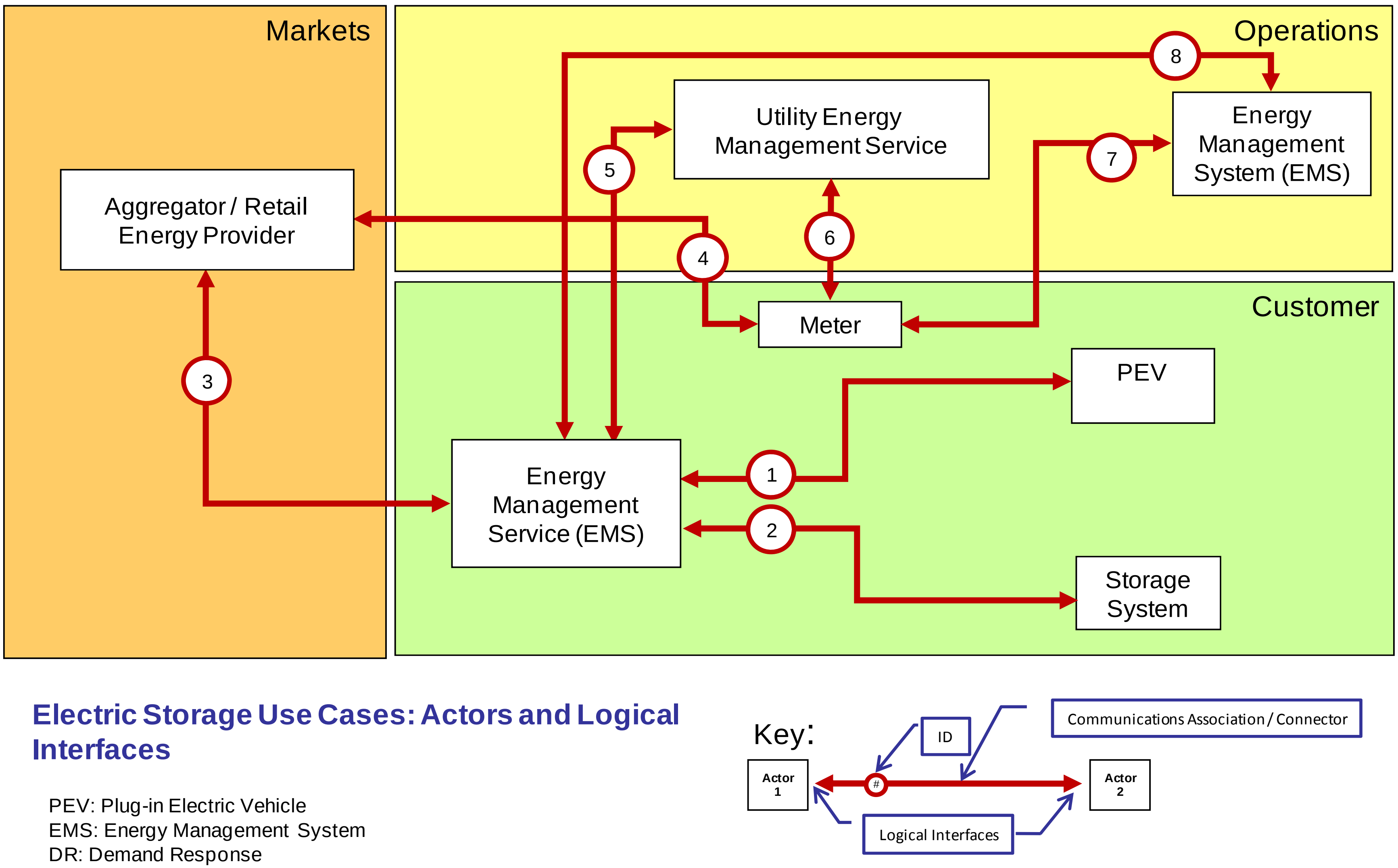

Figure 17 – Electric Storage Applications Summary Communications Diagram

4.6 Electric Transportation

Both FERC and the Obama administration recognize electric transportation as a key area of focus for the Smart Grid community. Electric transportation, to include PEVs and mass transit such as high speed electric rail, could significantly reduce our dependency on foreign oil, increase the use of renewable sources of energy, and also dramatically reduce our carbon footprint. The current grid and market infrastructure cannot support mass deployments of PEVs. There are very special issues to consider when designing for massive PEV support. The introduction of millions of mobile electricity charging and discharging devices provides unique challenges to every domain on the Smart Grid. A thorough and careful analysis of PEV introduction is necessary, and the Smart Grid architects and standards organizations must take special care to consider it in their designs.

4.6.1 Description

Two major scenarios are envisioned with the advent of plug-in electric vehicles (PEV), with one or the other or both actually playing out:

- PEV will add significantly to the load that the power system will have to serve, and if no regulation, coordination, and/or incentives are included, then PEV could significantly increase the cost of peak power.
- PEV, although still adding to the load, will help balance on- and off-peak loads through shifting when they are charged and also eventually by providing storage and discharging capacity. Additional ancillary services could also improve energy efficiency and power quality. These shifting strategies will result from carefully tailored pricing and market incentives.

Many stakeholders will be involved, with many interactions between them. The following use cases illustrate the types of interactions across these interfaces, and the interoperability standards, cyber security requirements, and system management that will be needed to realize these Smart Grid visions.

4.6.2 Use Cases

4.6.2.1 Customer Does Not Enroll in Any PEV-Specific Program

The customer plugs a PEV into electrical connections that do not have smart meters or any other communications capabilities. The PEV may or may not be registered in a program, but cannot take full advantage of it without a smart meter. The utility has neither direct knowledge of the PEV load nor any real-time or near-real-time information on PEV charging, due to the lack of communications.

The customer plugs a PEV into electrical connections that are interfaced to smart meters but do not include any PEV-specific interfaces such as the EVSE. Although possibly aware of incentives for enrolling in PEV-specific programs or that charging PEVs may have varying pricing during different time periods, some customers may still choose not to participate in any of these programs for any variety of reasons. The utility therefore has no direct knowledge of the PEV load, but can still monitor the overall customer load in real-time or near-real-time, and possibly make estimates on what the PEV load is.

4.6.2.2 Utility/ESP Develops Different Tariffs and Service Programs

The utility or Energy Services Provider develops a variety of PEV programs, based on different tariffs, different types and levels of services, different PEV response capabilities and requirements, as well as different rate structures for Time-of-Use (TOU), Real-Time Pricing (RTP), Critical Peak Pricing (CPP), Peak Demand Limited, Customer Demand Limited, Unlimited, Pre-Payment, No Roaming, etc.

4.6.2.3 PEV Charges After Customer Establishes Charging Parameters

PEV customers have different methods for establishing how and when their PEVs are charged, depending upon their location and constraints.

4.6.2.4 PEV Charges at Different Locations: Roaming Scenarios

The customer plugs the PEV into the grid at a location different from their "home" location. Different scenarios address who and how the PEV charging will be accounted for and billed. These roaming scenarios include:

- The customer connects their PEV to the energy portal at another premise. The premise customer pays for the energy use.
- The customer connects their PEV to the energy portal at another premise. The PEV customer pays for the energy use directly with the utility, such as with a credit or debit card. In this scenario, the customer would get billed at the rates in their PEV tariff.
- The customer connects their PEV to the energy portal at another premise outside the enrolled utility's service territory. In addition to the previous 2 scenarios, the customer could become a "guest" of the external utility and pay rates as such a guest, or could indicate the PEV program they are enrolled in at their "home" utility, and pay those rates. The external and "home" utilities would then make a settlement between them on any differences.
- The customer with a PEV that is not enrolled in any program (or cannot prove enrollment) connects their PEV to the energy portal at another premise. Either private party arrangements would be needed (first scenario) or "guest" arrangements (third scenario) would be used for payment.
- The customer connects their PEV to the energy portal at a public location, multi-family dwelling, or workplace infrastructure. Either private party arrangements (first scenario) or direct utility interactions (second scenario), or "guest" arrangements (third scenario) would be used for payment.

4.6.2.5 PEV Roaming, Assuming Unbundled Retail Electricity Reselling

One possible scenario may occur if regulators decide to unbundle retail electricity. This would permit customers to store electricity during low price times (e.g. at night) and resell it to PEVs during higher price times (e.g. during hot afternoons) for a profit

Another consideration could be the unbundling of the driver from the PEV, so that PEVs are not billed, but the driver of the PEV is billed – a scenario more in line with current practices for gasoline vehicles.

4.6.2.6 PEV for On-Premise Backup Power or Other Use of Storage

Customers may use the electric storage available from PEVs for uses other than powering the vehicle. These other applications include:

- V to G: Electric utility may be willing to purchase energy from customer during periods of peak demand
- V to H: Use of the PEV as a home generator during periods of electrical service outage
- V to L: Use of the PEV storage to provide power to a remote site or load that does not otherwise have electrical service. Examples include construction sites or camp sites.
- V to V: Use of the PEV storage to transfer electrical energy to another PEV

4.6.2.7 Utility Provides Accounting Services to PEV Customer

Based on the PEV program and tariff that the PEV customer has enrolled in, the utility or other accounting entity will issue bills to those PEV customers as well as providing other customer accounting services. These bills will be based on on-premise and off-premise meter (and/or sub-meter) readings for the appropriate time periods with the appropriate prices applied.

4.6.2.8 Impact of PEV as Load on Distribution Operations

Distribution operations will need to access all available sources of information on when, where, and how fast PEVs are charging, particularly as this load becomes increasingly more significant at local and more global levels. Sources of this information will include:

- AMI retrieval of near-time information on charging of PEVs that have communications interfaces to smart meters.
- Distribution feeder equipment sources, such as voltage regulators, capacitor banks, and automated switches. This load data will necessarily be aggregated, combining PEV charging loads with non-PEV loads.
- In the future, distribution transformers serving just a handful of customer might also be able to provide load information closer to the actual location of the load.
- Load forecasts, updated with estimates of where these mobile PEV might be charging, when they are expected to charge, what rate they will charge at, and the total charging needed.
- Up-to-date electrical connectivity models of the distribution system.
- State and measurements from power system equipment.

4.6.2.9 PEV Network Testing, Diagnostics, and Maintenance

As part of PEV Program services, the ESP provides services for testing, running diagnostics, and providing maintenance for the customer's PEV interface system (EVSE) and battery.

4.6.3 Actors

The following table is a summary of the key Actors and which domains they participate in.

Table 11 – Actors in Electric Transportation

Actor	Domains	Description
ISO/RTO	Operations	ISO: An independent entity that controls a power grid to coordinate the generation and transmission of electricity and ensure a reliable power supply. RTO: An independent organization that coordinates, controls, and monitors the operation of the electrical power system and supply in a particular geographic area; similar to Independent System Operator.
Federal Agency	Agency	Federal agency that requires information on interactions involving electric transportation
Energy Market Clearinghouse	Market	Market for energy products, including bulk generation, distributed generation, electric storage, electric transportation, and demand response.
Aggregator, Energy Services Company	Service Provider	A person or company combining two or more customers into a single purchasing unit to negotiate the purchase of electricity from retail electric providers or the sale to these entities. Aggregators may not sell or take title to electricity. Retail electric providers are not aggregators.
3rd Party	Service Provider	Any entity that has authorization to exchange information with customers and their systems.
SCADA/DMS	Operations	The system that monitors and controls the distribution system equipment based on Distribution Management System applications, market information, and operator control decisions.
Utility Apps	Operations	Software applications and models used to assess the impacts of electric transportation on distribution operations and help manage these devices through pricing and other signals.
Metering, Billing, Utility Back Office	Operations	The systems used for collecting metering information, validating it, settling bills across accounting entities, and issuing bills to customers.

Actor	Domains	Description
Meter	Customer	Unless otherwise qualified, a device of the utility used in measuring watts, vars, var-hours, volt-amperes, or volt-ampere-hours.
Energy Services Interface (ESI) /Gateway	Customer	Provides cyber security and, often, coordination functions that enable secure interactions between relevant Home Area Network Devices and the Utility. Permits applications such as remote load control, monitoring and control of distributed generation, in-home display of customer usage, reading of non-energy meters, and integration with building management systems. Provides auditing/logging functions that record transactions to and from Home Area Networking Devices. Can also act as a gateway.
Sub meter	Customer	A meter that measures a sub load, such as a plug-in electric vehicle.
End Use Measurement Device (EUMD)	Customer	End Use Measurement Device (EUMD) is a device that measures energy consumed by a PEV and communicates the information to the ESI.
Customer EMS	Customer	Customer Energy Management System can provide communication interface to PEV for communication of PEV status information (e.g. charging state, state-of-charge, charging rate, time to complete charge) on Customer viewable displays.
Electric Vehicle Service Element (EVSE)	Customer	The EVSE provides the direct interface with the PEV, including a charger and information exchange capabilities. The charger can either be on-board the vehicle or off-board. On-board chargers require AC energy transfer to the vehicle (either 120 or 240V single phase) and Off-board chargers are within the EVSE and require DC energy transfer to the vehicle.
PEV	Customer	Plug-in Electric Vehicle. Plugs into an Energy Portal (see actor definition below) at a premise to charge vehicle. A PEV is also an EV (Electric Vehicle) that relies only on electric propulsion. A PEV is also a PHEV (Plug-In-Hybrid Vehicle) that also includes an alternative source of propulsion power.

4.6.4 Requirements Drivers

PEVs will require reliable and secure communications with the equipment within customer premises and with utilities and energy service providers, in order to manage the different tariffs and service programs which would allow PEVs to participate in demand response and other interactive programs.

In addition to PEV management, distribution operations will need to access all available sources of information on when, where, and how fast PEVs are charging, particularly as this load becomes increasingly more significant at local and more global levels. Sources of this information will include:

- AMI retrieval of near-time information on charging of PEVs that have communications interfaces to smart meters.
- Distribution feeder equipment sources, such as voltage regulators, capacitor banks, and automated switches. This load data will necessarily be aggregated, combining PEV charging loads with non-PEV loads.
- In the future, distribution transformers serving just a handful of customer might also be able to provide load information closer to the actual location of the load.
- Load forecasts, updated with estimates of where these mobile PEV might be charging, when they are expected to charge, what rate they will charge at, and the total charging needed.
- Up-to-date electrical connectivity models of the distribution system.
- State and measurements from power system equipment.

Distribution operations will also need power system models and appropriate analysis tools. First the raw load data (and any load forecast data) must be mapped to the power system model. Then the analysis tools will need to estimate the real load (and power system topology and facilities connectivity). From this distribution operations model, many different analyses can be performed, such as:

- Contingency analysis to detect possible overloads, imbalanced phases, or other power system problems
- Voltage, Var and Watt management of feeders for improved efficiency
- Bus load modeling
- Multi-level feeder reconfiguration (MFR) assessment to determine if switching sections of feeders to other feeders could avoid overloads or other problems
- Thermal overload analysis: to what extent are component normal and emergency ratings exceeded (number of occurrences, typically overload asset classes, duration and magnitudes)
- Transformer loss of life analysis: how do the varying and mobile PEV loads affect the overall aging and loss of life of distribution and substation transformers?
- Harmonic analysis

- Statistical analysis

Additional distribution operational analysis functions can also help determine the effect of PEVs on the operation of the distribution system.

4.6.5 Communications Diagram

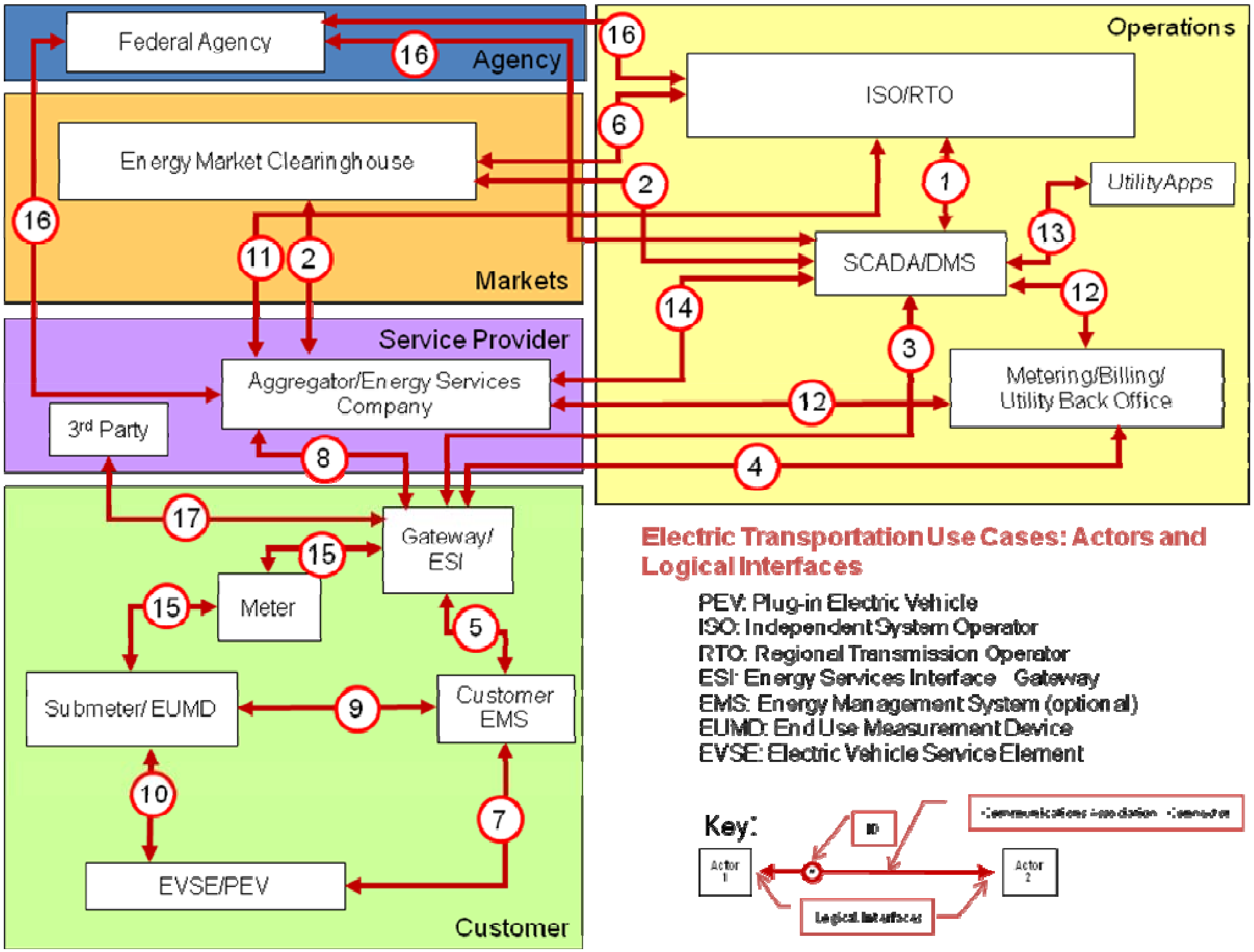

Figure 18 – Electric Transportation Applications Summary Communications Diagram

4.7 AMI Systems

4.7.1 Description

Advanced Metering Infrastructure (AMI) systems are the primary means for utilities to interact with their meters at customer sites. However, in addition to basic meter reading, AMI systems provide two-way communications that can be used by many functions and, as authorized, by third parties to exchange information with customer devices and systems.

4.7.2 Use Cases

4.7.2.1 External Clients Use AMI System to Interact with Devices at Customer Site

A third party vendor wants to identify what customer equipment (e.g. air conditioning, pool pumps, compressors, etc) is running and how much power each piece of equipment is drawing during a particular time of day. The vendor may also want to control or program specific equipment (e.g. turn on/off, adjust thermostat). The third party vendor makes an on-demand status and/or control request of the customer equipment. The monitoring or status request is received by the Customer EMS, the requestor and destination is authenticated and then the request is transmitted to the specific customer site. The customer equipment receives the request and provides a response back to the Customer EMS and the Customer EMS transmits the information back to the third party. If the on-demand request is a control request, the customer equipment will adjust operations as requested and provide an acknowledgement of receipt and processing through the Customer EMS back to the third party.

The third-party monitoring and control capabilities described in this use case may provide customers with increased options for programs and services that might not normally be provided by the utility and also may offset some of the AMI costs. These proposed services will enable customers to more easily participate in utility and non-utility demand reduction programs, by allowing third parties to help them monitor and control their equipment.

4.7.2.2 Demand Response Management System Manages Demand Through Direct Load Control

A major benefit of the Advanced Metering Infrastructure (AMI) is that it supports customer awareness of their instantaneous kWhr electricity pricing and it can support the utilities in the achievement of its load reduction needs. As we see increased electricity demand on the grid, it may result in energy shortages, therefore triggering the need for utilities to reduce energy consumption in support of grid stability. The AMI will help facilitate load reduction at the customer's site by communicating instantaneous kWhr pricing and voluntary load reduction program events to the customer and to various enabling devices at the customer's site. Voluntary load reduction events may be scheduled with a large amount of advanced notice (24 hrs) or near real-time. For the utility to receive the desired customer response, we must provide them timely pricing, event and usage information.

Related to this scenario is the measurement of the response to financial incentives, energy price adjustments and other voluntary demand response programs. The customer responses will be used to determine how and/or if they have responded to a pricing event, if the utility needs to launch other demand response events to achieve the needed demand reduction and help the utility determine how to structure future voluntary load reduction programs, to ensure the utility receives the best customer response.

4.7.2.3 Building Automation Software/System Optimization using Electric Storage

Energy storage, distributed generation, renewables, and demand response are used as mechanisms to optimize building loads in response to both dynamic pricing (DP) signals and system operational needs. The DP system provides the DP schedule through mechanisms such as email, pager, bulletin board, or direct transfer. The DP operator for the customer must enter the schedule into the building automation software (BAS) and perform the necessary optimization activities to implement the DP goals. The building operator may choose to adjust how their equipment responds to pricing and operational signals. Note that EMS or Energy Management System is often used interchangeably with BAS.

For example, a large industrial customer that can curtail large loads during peak hours will get a different rate than a small commercial customer with less ability to modify its load. The ESP and/or Grid operator sends signals (e.g. price / reliability) to the customers it serves, using the AMI system and receives information from the customer

The customer's Building Automation System (BAS) optimizes its loads and distributed energy resources (DER), based on the pricing and reliability signals it receives, the load requirements and constraints, and any DER requirements, capabilities, and constraints. The BAS understands the nature and opportunity for altering consumption based on economic and comfort drivers, and, the physical dynamics of the specific customer premises. The BAS then issues (or updates existing) schedules and other control mechanisms for loads and for DER generation. These control actions may be automatically implemented or may be reviewed and changed by the customer.

The BAS system uses the site-optimized algorithms to forecast its load and DER generation. It also determines what additional ancillary services it could offer, such as increased DER generation or emergency load reduction, and calculates what bid prices to offer these ancillary services at. The BAS then submits these energy schedules and ancillary services bids to the ESP (or Scheduling Coordinator, depending upon market structure), as input to the RTO/ISO market operations.

4.7.2.4 Outage Detection and Restoration using AMI

The AMI system should provide capabilities to detect and map outages to the customer portion of the power grid. It should provide interfaces to interact with the DA system to enable automated, remote restoration [or to confirm restoration occurred].

AMI System has to have access to a model of the connectivity of the system (or to provide it to an external system) to be able to detect and map outages.

- Power outage occurs, due to single customer problem, back hoe fade – small number of customers, transformer outage, phase outage, feeder outage, substation outage, transmission outage, cross-system outage.
- Detection begins via last gasp messages, DA (distribution automation) monitoring, customer report, polling (status system), triggered polling, control monitoring. There can be different durations and situations, including: momentary, short term outages, outages > 1 hour, false positives, critical customer, customer with backup power
- Mapping of extent occurs through "Hole detection" – who isn't responding to AMI? Power levels – feeder line drops from 5 to 1 MW, root cause analysis – where did it start?.
- Responsibility determined, although the outage may be large enough that AMI provides no immediately useful [too much] data for restoration. May bring it back in at end as part of restoration verification.
- Restoration begins with different situations, including prioritization, sub-outage restoration, and verification of restoration

4.7.3 Actors

The following table is a summary of the key Actors and which domains they participate in.

Table 12 – Actors in AMI Systems

Actor	Domains	Description
RTO/ISO	Market	RTO: An independent organization that coordinates, controls, and monitors the operation of the electrical power system and supply in a particular geographic area; similar to Independent System Operator. ISO: An independent entity that controls a power grid to coordinate the generation and transmission of electricity and ensure a reliable power supply.
Energy Market Clearinghouse	Market	Wide-area energy market operation system providing high-level market signals for operations.
3rd Party, External Systems (e.g. Weather)	Service Provider	Public information systems outside the utility, provides the utility with information on weather and major event relevant to utility operations.
Billing	Service Provider	Provides consolidated bills to customers

Actor	Domains	Description
Aggregator/Energy Services Company	Service Provider	A person or company combining two or more customers into a single purchasing unit to negotiate the purchase of electricity from retail electric providers, or the sale to these entities. Aggregators may not sell or take title to electricity. Retail electric providers are not aggregators.
Utility EMS	Operations	The entities that continue to provide regulated services for the distribution of electricity (and gas and water) to customers and serve customers who do not choose direct access. Regardless of where a consumer chooses to purchase power, the customer's current utility will deliver the power to the consumer's home or business.
DMS Applications	Operations	Calculation and analysis of power flow/state estimation results with the inclusion of distribution automation capabilities, demand response signaling, distributed energy resources, electric storage, PEVs, and load management
MDMS	Operations	Provides meter data validation and verification so that reliable information can be used at bill settlement.
Web Site	Operations	Provided to enable customer access to usage and billing records.
Metering System	Operations	The systems used for collecting metering information.
Load Management System (LMS)	Operations	Controlling DR, DER, PEV and ES charging/discharging; processing and storing data on load management programs, contracts, relevant historic information, creating behavioral models, collecting, processing, and storing customer-specific power quality and reliability characteristics, etc.
Geographic Information System (GIS)	Operations	Repository of distribution system assets, their relationships (connectivity), ownerships, and activities. AM/FM system contains the geographical information of the distribution power system circuit connectivity, as well as the parameters describing the power system facilities. Conceptually, the AM/FM/GIS database can contain transmission connectivity and facility data and relevant to distribution operations customer-related data.

Actor	Domains	Description
Customer Information System (CIS)	Operations	Repository of customer information related to distribution company services. CIS contains load data for customers that are estimated for each nodal location on a feeder, based on billing data and time-of-day and day-of week load shapes for different load categories.
Outage Management System (OMS)	Operations	Management of outage events and corrective actions.
SCADA	Operations	Distribution SCADA database is updated via remote monitoring and operator inputs. Required scope, speed, and accuracy of real-time measurements are provided, supervisory and closed-loop control is supported.
Field Devices	Distribution	Field equipment with local intelligence for monitoring and control of automated devices in distribution which communicates with SCADA, as well as distributed intelligence capabilities for automatic operations in a localized distribution area based on local information and on data exchange between members of the group.
Workforce Tool	Distribution	Manual operations of field devices, repair and construction work, patrolling facilities, recording changes in facility parameters, connectivity, in mobile computers, transferring data to the operator, and corresponding database administrators
Meter	Customer	Unless otherwise qualified, a device of the utility used in measuring watts, vars, var-hours, volt-amperes, or volt-ampere-hours.
Energy Services Interface (ESI)	Customer	Provides cyber security and, often, coordination functions that enable secure interactions between relevant Home Area Network Devices and the Utility. Permits applications such as remote load control, monitoring and control of distributed generation, in-home display of customer usage, reading of non-energy meters, and integration with building management systems. Provides auditing/logging functions that record transactions to and from Home Area Networking Devices. Can also act as a gateway.
Customer EMS	Customer	Customer Energy Management System can receive pricing and other signals for managing customer devices, including appliances, DER, electric storage, and PEVs.

Actor	Domains	Description
Customer appliances, DER, PEV, and Electric Storage	Customer	Equipment and systems at the customer site that could participate in demand response and other programs
Sub-Meter	Customer	A meter that measures a sub load, such as a plug-in electric vehicle.
Electric Vehicle	Customer	Plug-in Electric Vehicle. Plugs into an Energy Portal (see actor definition below) at a premise to charge vehicle. A PEV is also an EV (Electric Vehicle) that relies only on electric propulsion. A PEV is also a PHEV (Plug-In-Hybrid Vehicle) that also includes an alternative source of propulsion power.

4.7.4 Requirements Drivers

The Advanced Metering Infrastructure (AMI) is characterized by interactions between the actors that must traverse between the Customer Domain and the Operations Domain, although these same Actors may interact over other infrastructures. Information is exchanged between devices of varied complexity, ownership, and access rights.

4.7.5 Communications Diagram

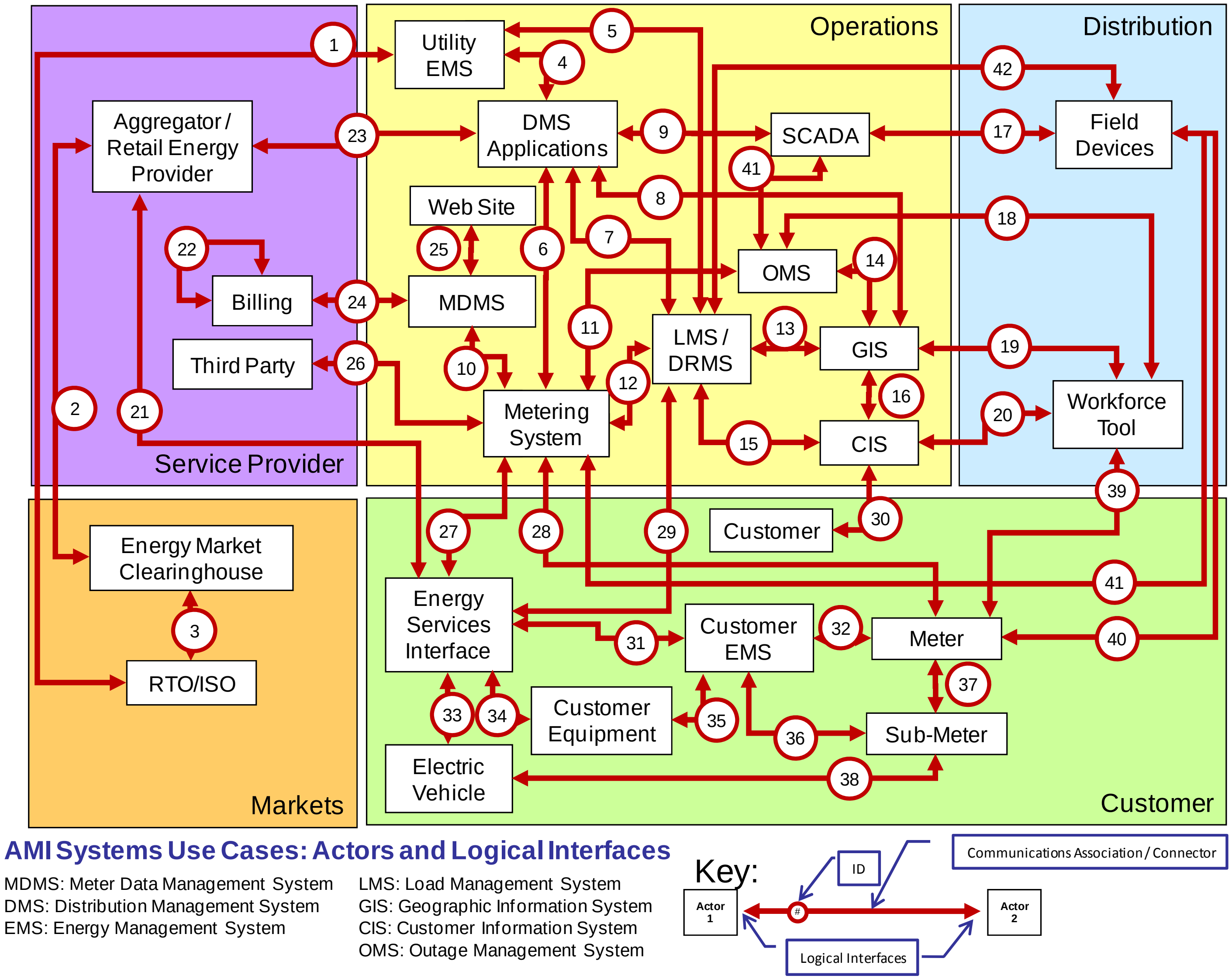

Figure 19 – AMI Systems Applications Summary Communications Diagram

4.8 Distribution Grid Management

4.8.1 Description

The existing distribution power systems consist of hundreds of distribution feeders, thousands of distribution transformers supplying millions of customers and contain a large number of locally and remotely controllable devices. Even now, they present large and complex objects to control. With significant penetration of AMI, Demand Response, Distributed Energy Resources, and PEVs, the distribution systems become active participant in the overall power system operations and can become capable energy market participants.

In order to maximally utilize the potentials of the advanced distribution operation applications and their integration with customer and transmission systems operations, a large amount of information should be exchanged between the field IEDs, transmission SCADA/EMS, Distribution SCADA/DMS, and customer systems (AMI, DER, DR, PEV, and Electric Storage). A large amount of input data comes from corporate databases and models.

Most of the DMS Advanced Applications are integrated in a system based on a common DMS database, which, in turns is integrated with corporate databases, Utility SCADA/EMS and interfaced with AMI and other customer EMS, including DER systems.

Close functional integration with Transmission/Generation Operations via corresponding EMS will significantly enhance the efficiency and reliability of both distribution and transmission grids and will provide a comprehensive Wide-Area Situational Awareness.

The use cases listed below describe the functions of Automated Distribution Operations that are architecturally significant for the interoperability in Smart Grid environment. The list includes the real-time applications

4.8.2 Use Cases

4.8.2.1 Monitoring Distribution Operations with DR, DER, PEV, and ES

The objectives of this function are to monitor in the near-real time and in close look-ahead time the behavior of distribution operations under normal and abnormal operating conditions, analyze the operations, and provide the operator and other applications with the results of the analysis in a concise manner. The scope of the function includes monitoring the operations of distribution and immediate transmission systems including all elements connected to the distribution primaries and loads connected to the distribution secondaries, comprising conventional loads, loads with demand response (DR), distributed energy resources (DER), plug-in electric vehicles (PEV), and electric storage devices (ES).

4.8.2.2 Service Restoration

The objectives of this use case are to demonstrate that the distribution Service Restoration Functions a) take into account the near-real time behavior of the DR, DER, ES, and PEV as loads and as Electric Storage and utilizes these technologies for improvement of reliability, and b) have the needed input information for the close look-ahead Contingency Analysis reflecting the utilization of the DR, DER, ES, and PEV as loads and as Electric Storage to account for the effect on current operations.

4.8.2.3 VVWC with DR, DER, PEV, and ES

The following objectives, which could be selected by the distribution operator for different times of the day, are supported by the application: Minimize kWh consumption at voltages beyond given voltage quality limits (i.e., ensure standard voltages at customer terminals); Minimize feeder segment(s) overload; Reduce load while respecting given voltage tolerance (normal and emergency); Conserve energy via voltage reduction; Reduce or eliminate overload in transmission lines; Reduce or eliminate voltage violations on transmission lines; Provide reactive power support for transmission/distribution bus; Provide spinning reserve support; Minimize cost of energy based on the financial impact of coordinated volt/var/watt control, taking into account the real-time energy prices and real-time commercial requirements; Reduce technical losses; Provide compatible combinations of above objectives.

4.8.2.4 Coordination of Emergency and Restorative Actions in Distribution

The objectives of this use case are to demonstrate that the advanced DMS application are capable of a) providing the WACS with updated in near real-time information about the ownership and available load shedding, load management, and load swapping means in case of a wide-area emergency situation. b) coordinating the controllable load management means (VVWC, DR, DER, ES, and PEV, to reduce the impact of intrusive load shedding under emergency conditions, and c) coordinate the restoration of services after the emergency situation is mitigated .

4.8.2.5 Impact of PEV as Load and Electric Storage on Distribution Operations

The objectives of this use case are to demonstrate that the distribution monitoring and controlling functions a) take into account the near-real time behavior of the PEV as loads and as Electric Storage and b) have the needed input information for the close look-ahead monitoring and controlling DMS functions reflecting the behavior of the PEV as loads and as Electric Storage.

4.8.3 Actors

The following table is a summary of the key Actors and which domains they participate in.

Table 13 – Actors in Distribution Grid Management

Actor	Domains	Description
Energy Market Clearinghouse	Market	Wide-area energy market operation system providing high-level market signals for operations.
Distribution Operator	Operations	Person in charge of distribution operations during the shift

Actor	Domains	Description
Distribution SCADA	Operations	Distribution SCADA database is updated via remote monitoring and operator inputs. Required scope, speed, and accuracy of real-time measurements are provided, supervisory and closed-loop control is supported.
DMS functions: DOMA, VVWS, FLIR, MFR, OMS, WMS, etc	Operations	Calculation and analysis of power flow/state estimation results with the inclusion of distribution automation capabilities, demand response signaling, distributed energy resources, electric storage, PEVs, and load management
Load Management System	Operations	Controlling DR, DER, PEV and ES charging/discharging; processing and storing data on load management programs, contracts, relevant historic information, creating behavioral models, collecting, processing, and storing customer-specific power quality and reliability characteristics, etc.
Distribution Field Crews, Mobile Computing	Operations	Manual operations of field devices, repair and construction work, patrolling facilities, recording changes in facility parameters, connectivity, in mobile computers, transferring data to the operator, and corresponding database administrators
Transmission SCADA/EMS	Operations	Transmission and generation management system providing DA with transmission/generation-related objectives, constraints, and input data. EMS system contains the transmission power system model, and can provide the transmission connectivity information for facilities in the vicinity of the distribution power system facilities and with outputs from other EMS applications.
ISO/RTO	Operations	Wide-area power system control center providing high-level load management and other signals for distribution companies.
Distribution Engineering	Operations	Planning distribution systems, operations, arranging data gathering, design of constructions, selection and placement of equipment, etc.
Distribution Field RTUs, IEDs, and Distributed Intelligence Capabilities	Distribution	Field equipment with local intelligence for monitoring and control of automated devices in distribution which communicates with SCADA, as well as distributed intelligence capabilities for automatic operations in a localized distribution area based on local information and on data exchange between members of the group.

Actor	Domains	Description
Metering, Billing, Utility Back Office	Distribution	The systems used for collecting metering information, validating it, settling bills across accounting entities, and issuing bills to customers.
Geographic Information System AM/FM	Distribution	Repository of distribution system assets, their relationships (connectivity), ownerships, and activities. AM/FM system contains the geographical information of the distribution power system circuit connectivity, as well as the parameters describing the power system facilities. Conceptually, the AM/FM/GIS database can contain transmission connectivity and facility data and relevant to distribution operations customer-related data.
Customer Information System (CIS)	Distribution	Repository of customer information related to distribution company services. CIS contains load data for customers that are estimated for each nodal location on a feeder, based on billing data and time-of-day and day-of week load shapes for different load categories.
AMI Headend	Distribution	Interface to the Advanced Metering Infrastructure
Aggregator/Energy Services Company	Service Provider	A person or company combining two or more customers into a single purchasing unit to negotiate the purchase of electricity from retail electric providers, or the sale to these entities. Aggregators may not sell or take title to electricity. Retail electric providers are not aggregators.
3rd Party, External Systems (e.g. Weather)	Service Provider	Public information systems outside the utility, provides the utility with information on weather and major event relevant to utility operations.
Meter/HAN Gateway	Customer	The gateway to the meter and the home area network at the customer site
Customer EMS	Customer	Customer Energy Management System can receive pricing and other signals for managing customer devices, including appliances, DER, electric storage, and PEVs.
Customer appliances, DER, PEV, and Electric Storage	Customer	Equipment and systems at the customer site that could participate in demand response and other programs

4.8.4 Requirements Drivers

The distribution power systems comprise a multitude of information sources. These information sources reside inside and outside the customer premises, along the primary distribution feeders, at the transmission-to-distribution substations, in SCADA/EMS databases, in asset management, work management, outage management, and customer information system databases.

New management systems will need to be developed with significant penetration of AMI, demand response, PEV, electric storage, and distributed generation. These management systems will analyze the behavior of the above mention technologies on a node-by-node basis, and will process the data according to the standard object models providing the distribution operation applications with updated node-specific input data.

A portion of the application results will be used directly in the distribution domain for situational awareness of the distribution system (monitoring) and for close-loop and advisory control of the distribution operations. Another portion of the application output will go directly to the customers, e.g., load management, reliability price signals, etc. Another portion of the application results will be provided to the transmission domain for use in its operational decision making processes.

There will be information exchange with other domains, like market/aggregator and external systems. On the other hand, distribution operation applications will need information support from the customer domain directly, e.g., for outage detection and fault location, critical power quality distortions, significant changes of DER operations, etc. The distribution operation applications will also need input from the transmission domain, like operational limits, real-time prices, load management requests, and so forth. Common interfaces and data encodings that enable communication between these actors will need to implement, for example, location data and requests for geospatial processing services such as “lies within a specified area” and “along corridor.” Interaction with emergency management systems, which already use such information will be improved by common interfaces and encodings.

With so many sources of information, the interoperability issue becomes critical to the implementation of the Smart Grid concept in power distribution systems.

4.8.5 Communications Diagram

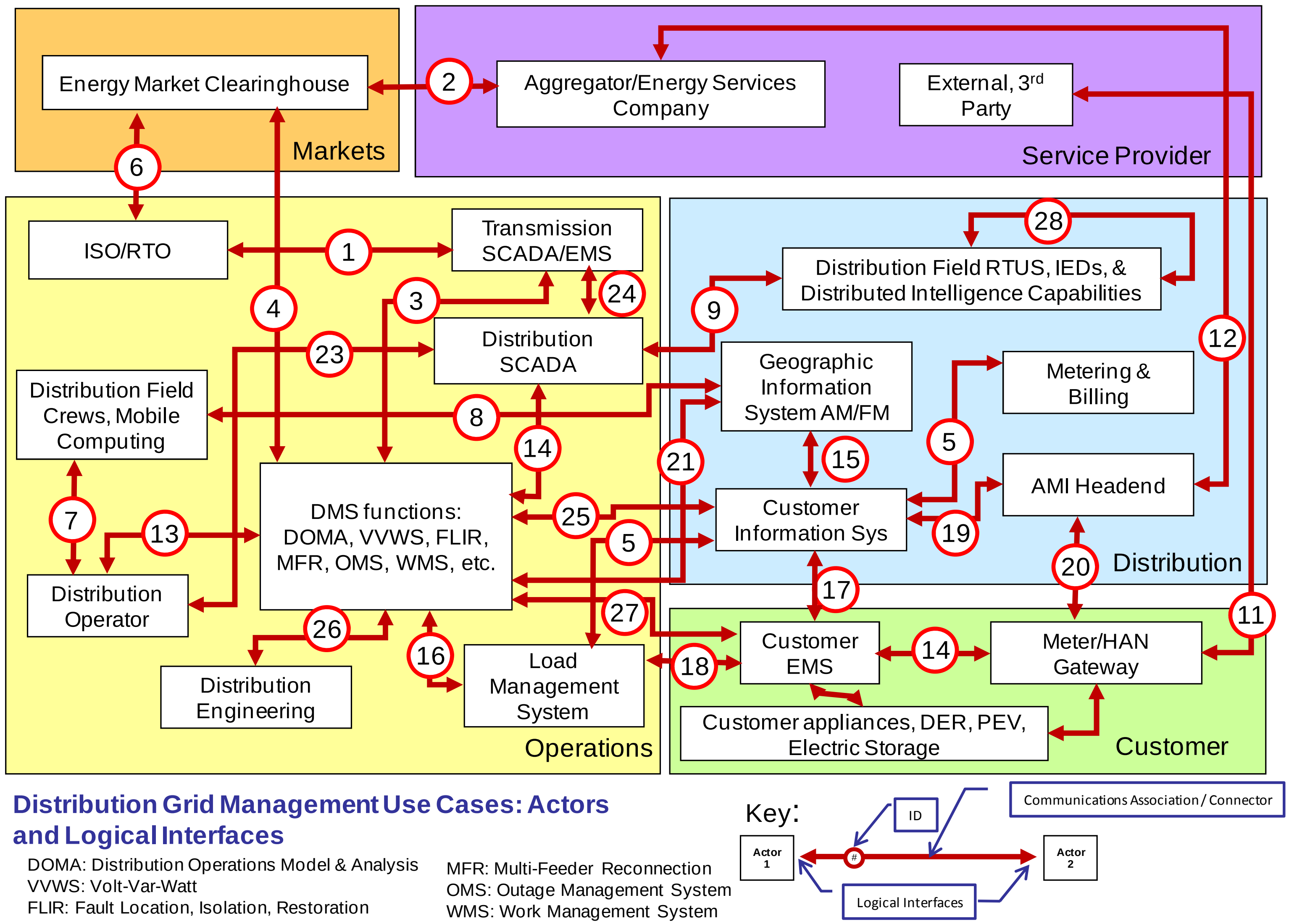

Figure 20 – Distribution Grid Management Applications Summary Communications Diagram

4.9 Requirements Analysis

The process described herein seeks to meet the following requirements of the NIST Interim Roadmap:

- Select a set of standards and requirements targeted for the Smart Grid.
- Identify gaps in those standards to allow the definition of needed enhancements.
- Identify boundaries between standards to allow harmonization efforts to be defined and pursued.
- While perfect objectivity is a goal, never an achievement, devise an objective process around which consensus can be gathered.

The Interim Roadmap was developed using a time concentrated sequence of analysis and writing steps interspersed with inputs from the NIST DEWGs and other stakeholders through a series of two workshops.

The first document draft and first workshop exposed initial thinking and experiences surrounding the exposition of a set of Smart Grid standards.

The second draft and workshop went to the next level and analyzed a series of Use Cases as a means to derive standard enumerating profiles for the Domains introduced in section 9 Appendix A: Standards Profiles by Domain.

The figure that follows, Figure 21 – Interim Roadmap Analysis Process, illustrates the steps in the second workshop and the requirements analysis of the results which follow. As shown, the second draft followed by workshop II performs the collection of Use Cases and Standards prospected to be used for Smart Grid Release 1. These Use Cases are analyzed to identify their Actors, Information exchanges, and unique requirements. This results in the description of an initial set of Domain Profiles that can be further analyzed in the requirements analysis which is done next.

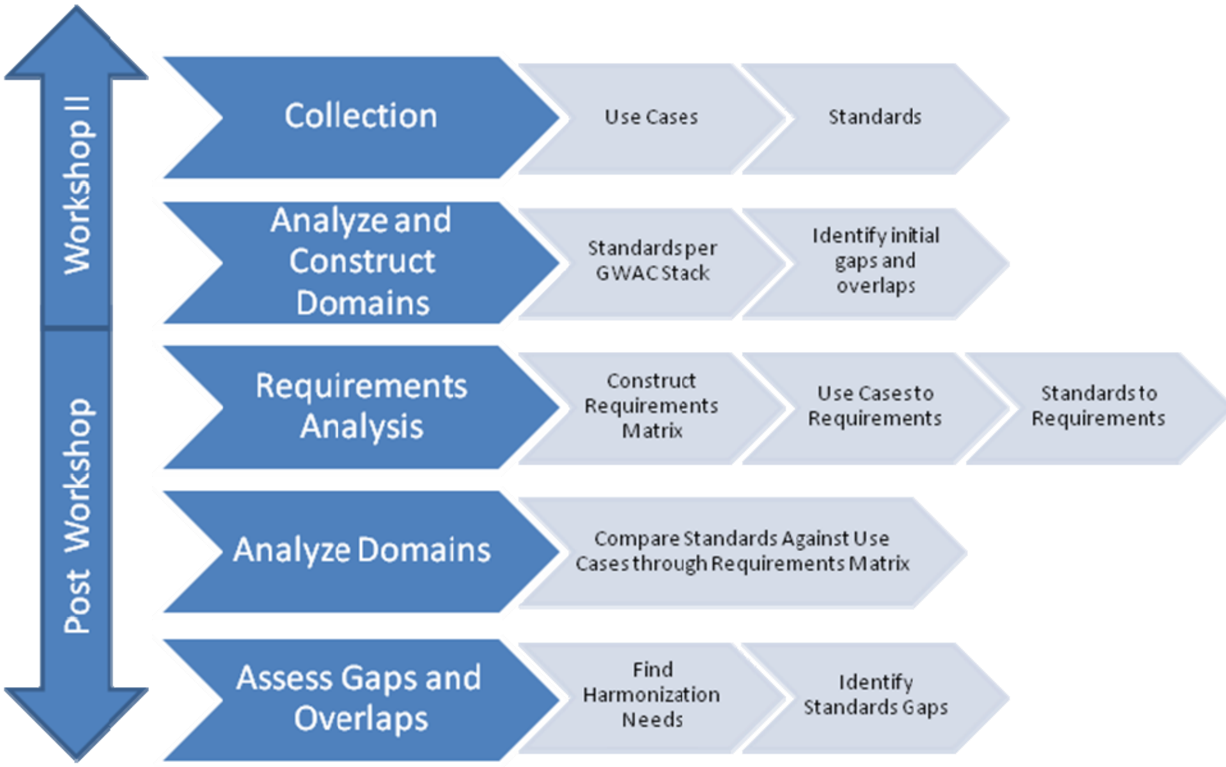

Figure 21 – Interim Roadmap Analysis Process

The classic systems engineering analysis process recognizes that the appropriate elements of a selection process such as this are to:

1) Identify Use Cases that impact the interfaces where standards are needed, and that illustrate how the results will be utilized
2) Derive Requirements that satisfy the Use Cases
3) Select Standards that afford the capabilities to satisfy the Requirements

This classic waterfall approach to system's engineering is appropriate to our goals. However, in the Smart Grid Standards selection process there are on the order of 1000 existing Use Cases; with thousands of identified Requirements and hundreds of potentially appropriate Standards for selection. So to great extent, we focus on harvesting the existing knowledge and coordinating its analysis to achieve our results.

The present requirements analysis process, therefore, begins with a collection activity to organize the most relevant requirements in each category. It further correlates the Use Cases with Requirements and the Requirements with the Standards. This way, the set of Requirements can be considered building blocks with reflect the Use Cases and drive the Standards. Finally, these sets are correlated in an assessment function which identifies "goodness of fit" of the Standards to the Use Cases via the Requirements, resulting in the Domain Profiles presented in section 9 Appendix A: Standards Profiles by Domain.

The following figure illustrates this arrangement:

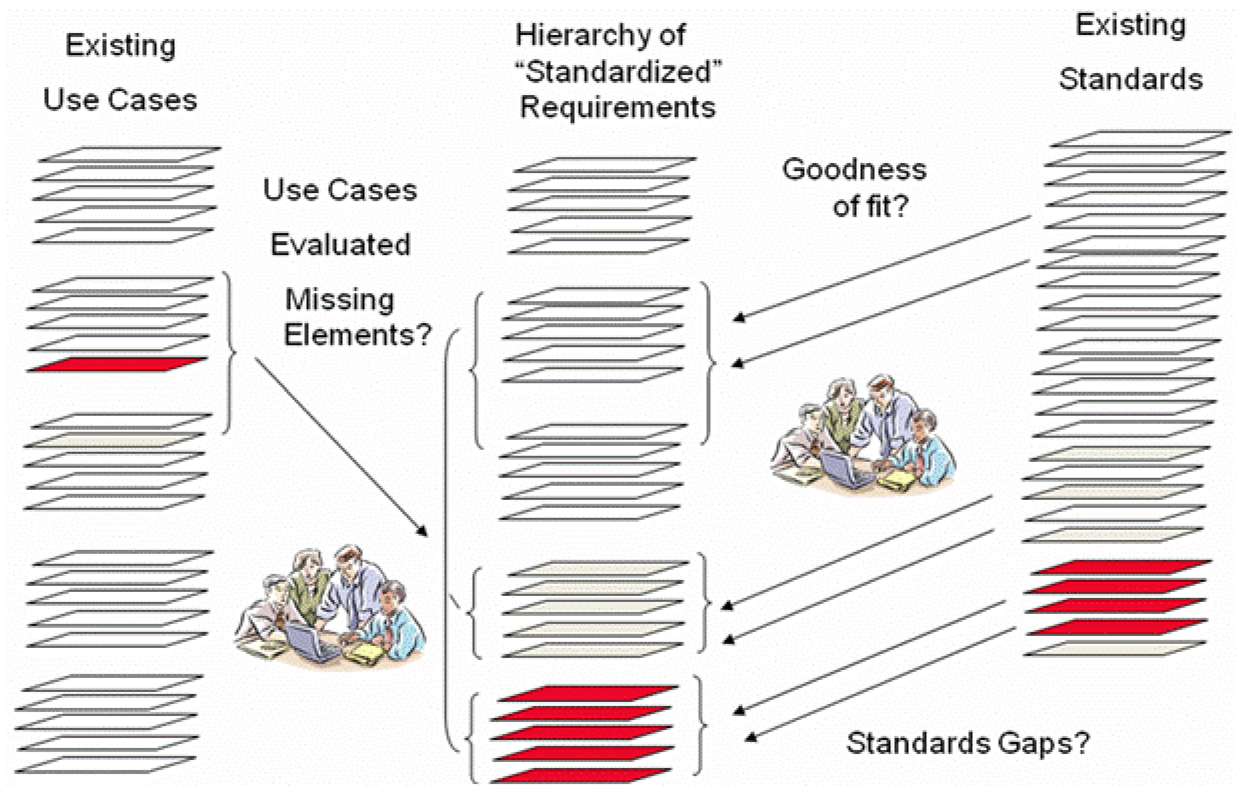

Figure 22 – Relating Use Cases, Requirements, and Standards

The Hierarchy of "Standardized" Requirements is used to collate Requirements from a variety of relevant sources and organize them according to type of Requirement. This effort is proposed to develop a master list of requirements from the stakeholders.

The requirements in this hierarchy include those from recommended practices, systems, software and communications engineering as well as from utility Use Cases and Requirements documents. This master collection of requirements once completed can be used as a set of metrics against which to evaluate either standards or the use cases.

Note that some Requirements are very high level. And some are very detailed.

A standards based definition of a requirement is from IEEE STD 610.12:

Requirement: (1) A condition or capability needed by a user to solve a problem or achieve an objective. (2) A condition or capability that must be met or possessed by a system or system component to satisfy a contract, standard, specification, or other formally imposed documents.

Note that to be a good requirement, it must address one and only one thing, and the statement that the Requirements makes must be testable in a straightforward manner.

In order to accommodate Requirements from varied sources, an organizational means is required. Each organization that has produced documents containing explicit Requirements has chosen a specific level of abstraction at which to relate its needs. For example, one organization may say that "it is a requirement to use open source implementations". Another relevant requirement might be "the meter must be able to store 1 minute load profile". Both kinds (and many more for that matter) of Requirements are relevant to the Smart Grid. How then to arrange these sets of somewhat orthogonal, and, somewhat overlapping Requirements? There is a need to recognize both the differing nature of the Requirements, as well as, their level of specificity.

The resulting organization is a tree structure. The branches are the outline heading levels, for example 1.1.2.1.1 Price Requirements. The Requirements, themselves, represent the leaves of the tree. The Branches and the leaves represent either recommended practices or the Requirements or should have attribution to the origin of the standard.

Once the requirements have been collected and arranged, they can be utilized to evaluate the Domain Profiles ability to satisfy the Use Cases.

Here is the step by step cookbook process to achieve the goal:

1) Collection of Requirements
2) Preliminary analysis (What is missing)
3) Complete initial collection (Fill gaps discovered)
4) Complete analysis
5) Refine Domains to optimize contents
6) Assess remaining Requirements mismatches
7) Describe the gaps in the Standards

5 Cyber Security Considerations for the Smart Grid

The energy sector is one of the national critical infrastructures that now will increase dependency upon the information and telecommunications infrastructures. This Smart Grid will have many complex cyber security requirements. This section includes the deliverables identified in Section 3.3 of this document, including a requirements matrix, list of vulnerability classes, and potential impacts.

5.1 Smart Grid Cyber Security Strategy

The overall cyber security strategy for the Smart Grid must examine both domain-specific and common requirements when developing a mitigation strategy to ensure interoperability of solutions across different parts of the infrastructure.

Implementation of a cyber security strategy will require the development of an overall cyber security risk management framework for the Smart Grid. This framework will be based on existing risk management approaches developed by both the private and public sectors. This risk management framework will establish the processes for combining impact, vulnerability, and threat information to produce an assessment of risk to the Smart Grid. Risk is the potential for an unwanted outcome resulting from an incident, event, or occurrence, as determined by its likelihood and the associated impacts. Because the Smart Grid includes systems and components from the IT, telecommunications and energy sectors, the risk management framework will be applied on an asset, system, and network basis, as applicable. The goal is to ensure that a comprehensive assessment of the systems and components of the Smart Grid is completed.

The following initial list of documents will be used in developing the risk management approach for the Smart Grid (Additional documents may be used as this task continues):

- National Institute of Standards and Technology (NIST) Special Publication (SP), 800-39, *DRAFT Managing Risk from Information Systems: An Organizational Perspective*, April 2008;
- Federal Information Processing Standard (FIPS) 200, *Minimum Security Requirements for Federal Information and Information Systems*, March 2006;
- FIPS 199, *Standards for Security Categorization of Federal Information and Information Systems*, February 2004;
- North American Electric Reliability Corporation (NERC), *Security Guidelines for the Electricity Sector: Vulnerability and Risk Assessment*, 2002;
- *National Infrastructure Protection Plan*, 2009;
- The IT, telecommunications, and energy sectors sector specific plans (SSPs), published in 2007 and updated annually;
- ANSI/ISA-99, *Manufacturing and Control Systems Security*, *Part 1: Concepts, Models and Terminology*, 2007 and *Part 2: Establishing a Manufacturing and Control Systems Security Program*, 2009; and

- The *Advanced Metering Infrastructure (AMI) System Security Requirements*, 2008.

In a typical risk management process, assets, systems and networks are identified; risks are assessed (including vulnerabilities, impacts and threats); cyber security requirements are specified and cyber security controls are selected, implemented, assessed for effectiveness, authorized[15], and then monitored over the lifecycle of the system In contrast, the final product of this effort will be a set of recommended cyber security requirements that will be allocated to interfaces of the Smart Grid[16]. These requirements will be selected based on a risk assessment and will apply to the Smart Grid as a whole. The requirements will not be allocated to specific systems, components, or functions. In specifying the cyber security requirements, any gaps will be identified.

The tasks for this Smart Grid phase include:

(1) Selection of use cases with cyber security considerations[17];

(2) Performance of a risk assessment of the Smart Grid, including assessing vulnerabilities, threats and impacts;

(3) Development of a security architecture linked to the Smart Grid conceptual architecture; and

(4) Identification of cyber security requirements and risk mitigation measures to provide adequate protection[18].

The tasks listed above can be performed in parallel, with significant interactions among the groups addressing the tasks. Each task is further detailed below.

(1) Select use cases with cyber security considerations:

The set of use cases will provide a common framework for performing the risk assessment, developing the security architecture, and specification of the cyber security requirements.

(2) Perform a risk assessment:

The risk assessment, including identifying vulnerabilities, impacts and threats will be done from a high-level architectural and functional perspective. The output from these components will be used in the selection of cyber security requirements and the

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[15] Security authorization is the step where the designated official accepts the risk to the mission.

[16] The full risk management process should be applied to legacy systems and when Smart Grid owners and operators implement new systems or augment/modify existing systems.

[17] A use case is a method of documenting applications and processes for purposes of defining requirements.

[18] The cyber security requirements will not be allocated to specific domains, mission/business functions, and interfaces of the conceptual Smart Grid architecture.

identification of requirements gaps. Because the impact of a security compromise may vary across the domains and interfaces of the Smart Grid, different baselines of security requirements will be considered. For example, in the federal government, FIPS 199 identifies three impact levels: low, moderate and high. The impact is based on the potential impact of the security breach of confidentiality, integrity, and availability. FIPS 200 establishes the minimum security requirements for federal information and information systems. These minimum requirements are further defined by a set of baseline security controls in SP 800-53 that are based on the impact levels in FIPS 199.

Both top-down and bottom-up approaches will be used. The top-down approach will focus on the use cases and the overall Smart Grid functionality. The bottom-up approach will focus on well-understood problems that need to be addressed.

Also, interdependencies among Smart Grid domains/systems should be considered when evaluating the impacts of a cyber or physical security incident. An incident in one infrastructure can cascade to failures in other domains/systems.

(3) Develop a security architecture linked to the Smart Grid conceptual architecture:

The Smart Grid conceptual architecture will provide a common view that will be used to develop the Smart Grid security architecture. The Smart Grid security architecture will overlay this conceptual architecture and security requirements defined in the Smart Grid security architecture will be allocated to specific domains, mission/business functions and/or interfaces included in the Smart Grid conceptual architecture. The objective is to ensure that cyber security is addressed as a critical cross-cutting requirement of the Smart Grid.

(4) Specification of cyber security requirements:

There are many requirements documents that may be applicable to the Smart Grid. Currently, only the NERC Critical Infrastructure Protection (CIP) documents are mandatory for a specific domain of the Smart Grid. The following documents have been identified by members of the Smart Grid Cyber Security Coordination Task Group (CSCTG) as having security requirements relevant to one or more aspects of the smart grid.

The following standards are directly Relevant to Smart Grid:

- NERC CIP 002, 003-009
- IEEE 1686-2007, *IEEE Standard for Substation Intelligent Electronic Devices (IEDs) Cyber Security Capabilities*
- AMI System Security Requirements, 2008
- *UtilityAMI Home Area Network System Requirements Specification*, 2008
- IEC 62351 1-8, Power System Control and Associated Communications - Data and Communication Security

The following documents are applicable to control systems and close corollary:

- ANSI/ISA-99, Manufacturing and Control Systems Security, Part 1: Concepts, Models and Terminology and Part 2: Establishing a Manufacturing and Control Systems Security Program
- NIST SP 800-53, Recommended Security Controls for Federal Information Systems, Dec. 2007
- NIST SP 800-82, DRAFT Guide to Industrial Control Systems (ICS) Security, Sept. 2008
- DHS Procurement Language for Control Systems
- ISA SP100, Wireless Standards

5.2 Other Cyber Security Issues

Cyber Security for the Smart Grid is being aggressively pursued by the Cyber Security Coordination Task Group. Rather than replicate the status of this ongoing activity here, the reader is directed to this project's TWIKI pages. To follow this activity and review all related documents, use the following Web link:

http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/CyberSecurityCTG

6 Prioritized Actions

This section presents near-term actions that NIST can take to develop the smart grid interoperability framework. Sections 6.1and 6.2 identify the highest priority standards-related issues that are limiting the wide-spread deployment of the smart grid and recommends specific actions for NIST to take to address these issues. These issues were identified at the May 19-20 workshop or by the Project Team. Additional actions are listed in section Appendix C: Requirements, Standards Gaps, and Discussion Issues for the Action Plan.

Section 6.3 defines the steps needed to further develop the roadmap for creating the smart grid interoperability framework.

In the recommended actions in this section standards development organizations are identified for engagement in the solutions. These were identified by the Interim Roadmap team as likely candidate SDOs that could codify solutions to the problems posed by the actions primarily through the harmonization and enhancement of existing standards. Additionally, it should be expected that active participation by all interested stakeholders would accompany these activities as they are pursued. Significantly it is recognized that active users groups often can play an accelerating role in advancing standards to fruition.

6.1 Cross-cutting and Overarching Issues

This section presents recommended actions for NIST to take to address cross-cutting and overarching issues identified at the May 19-20 workshop or by the Project Team.

Interactions between actors drive the recommendation and selection of standards. A specific actor may interoperate in several ways depending on the nature of the interaction and the domain of the partner. Common semantic and information models at an appropriate level of detail will improve the quality and cost of interoperation. To support cross-domain integration scenarios, shallow interfaces carry the key information.

The design of the actor interfaces is not determined by the actor’s domain – for example, as in the next section, you should be able to exchange a price that is universally understood regardless of the domain.

6.1.1 Common Pricing Model Standard

The need for a common pricing model crosses all domains that use price. Price is more than a simple number; it carries market context, and information such as quantity, units, time for use, and characteristics including source type and potentially carbon characteristics. A common and interoperable pricing model is a key to Demand-Response systems, Dynamic Pricing in all its forms, and energy markets and trading including forward markets.

The complexity of tariff structures and content means that to fully understand a price one needs to fully understand thousands of pages of tariffs for each jurisdiction. Driving toward simplified tariffs or (at minimum) machine-readable descriptions of tariffs would lead to more efficient markets. For example, the machine-readable tags for end user license agreements have simplified licensing decisions; a similar markup language for tariffs would allow better decisions in markets without implicit knowledge beyond price. The NAESB work on “eTariffs” is a first step in addressing this important area of interoperability.

Key Actions:

(1) **Develop and standardize a pricing model –** NIST should work with IEEE, IEC, OASIS, ASHRAE, NAESB and other relevant SDOs to develop an approach for developing a common pricing model to traverse the entire value chain. The model must include price, currency, delivery time, and product definition.

6.1.2 Common Time Synchronization and Management

The Smart Grid will be a platform for a dynamic marketplace with many participants. Common time synchronization at a fine resolution is a key to common scheduling and reaction to and post mortem analysis of contingencies.

For interactions with buildings and markets, lower resolution, synchronization with fine-grained time signals, and semantic compatibility with calendar models as described in the following section is important. Appropriate time zone representation based on ISO 8601 should be included.

Consideration must be given to data validity in ensuring that time references obtained are correct and not tampered with.

Key Action:

(1) **Develop or adopt application or role based synchronization guidelines –**NIST should organize a meeting between standards groups IETF, NASPI, IEC TC57 and IEEE PSRC and other stakeholders with the objective of developing processes for aligning applications and guidelines around IEEE 1588, Network Time Protocol and IRIG-B and other time requirements. Ensure processes will be applicable to devices, groups of devices, regions and combinations of regions. Ensure efforts include common scheduling, non-technical data sources (weather, markets), operational issues, recovery from loss of synchronization, and post mortem analysis.

6.1.3 Common Semantic Model

A common semantic model for application level communications is necessary in several areas of the Smart Grid. Key areas, for example, are the integration of utility Transmission and Distribution field operations with Information Technology and Back Office Systems and ultimately with Customer Premise Systems.

Several applications require integration and harmonization across these operating domains. In addition convergence on common semantics for communications with Consumers including but not limited to price and control signals exchanged with consumer equipment would minimize the complexity of adding services to the Smart Grid.

Several organizations are working independently on consumer communications semantics for a variety of applications. These activities need to be brought together under specific focused work in concert with SDO and Consortia activities. The structure of this task should maintain mutual respect for the domain knowledge in each of the activities and seek to diplomatically bring the work together and develop contributions to the appropriate SDOs and consortia.

Key Actions:

(1) **Develop a Common Semantic Model –** NIST should work with IEC TC57, NEMA, ASHRAE SPC 135, and OASIS to devise a common semantic model (using, for example, XML Schema and XML). The objective will be to unify the models of CIM (IEC61970, IEC61968, MultiSpeak) and IEC 61850 including correspondences with ANSI C12.19 and ASHRAE 135 to form a common representation of information models constructed by these standards efforts for the Smart Grid.

Sections 6.1.3.1 and 6.1.3.2 discuss but two of a number of important cross-domain information models that should be developed.

6.1.3.1 Common Meteorological and Geospatial Models

Weather has a major influence on electricity demand and, in the case of renewable energy resources such as wind and solar, may also influence supply. A common mechanism for communicating current and predicted weather would help in managing electricity supply and demand in real time as well as for planning purposes. Most forward forward-looking energy markets are based on assumptions about weather. Detailed knowledge of local weather and micro-climates is used by service providers and building operators to influence their operational decisions. IEC 61850 has a weather model included, but that standard is primarily used for substation communication and is not used across all Smart Grid domains.

Digital Weather Markup Language (DWML)[19] is an existing specification developed by the National Oceanic and Atmospheric Administration (NOAA). NOAA offers SOAP access to its National Digital Forecast Database (NFDS); one can submit a longitude and latitude and receive in reply a DWML forecast. There are no plans to develop DWML as a standard at this time.

A common weather information model should include a format for observations as well as for forecasts. This model could be used when querying local weather stations and even personal weather systems. A standard weather information model would encourage the development of software markets that analyze weather and micro-climates to inform energy market decisions.

Such a standard might reference UnitsML[20] (for internationalization) as well as time interval (section 6.1.3.2). NOAA might be encouraged to formulate the DWML specification into a standard; such a standard would is also of interest to the Emergency Response community.

Many aspects of smart grid information exchanges require the specification of the physical location of assets, events, and other objects. This is best accomplished using well defined geospatial information models. One example is the work of the Open Geospatial Consortium, Inc (OGC) - an international industry consortium participating in a consensus process to develop

[19] http://www.nws.noaa.gov/xml/

[20] http://unitsml.nist.gov/

publicly available interface standards. The OpenGIS® Standards provide the tools and information models necessary empower technology developers to make complex spatial information and services accessible and useful with all kinds of applications.

Key Actions:

(1) **Develop or adopt generic models for weather, pricing, Geographic Information Systems (GIS), and scheduling, using the Common Semantic Model –** NIST should work with IEC TC57, NEMA, ASHRAE SPC 135, Open Geospatial Consortium, and OASIS to assemble and existing approaches to the representation of meteorological and geospatial information. The resulting common information would be represented in the common semantic model and then forwarded back to the individual standards bodies for harmonization

6.1.3.2 Common Scheduling Mechanism

The Smart Grid will be a dynamic marketplace with many participants. Synchronized activities are dependent upon shared schedules. Scheduling activities, prices, maintenance, etc. will help level the playing field across the participants and support a dynamic, competitive, and efficient environment.

ICALENDAR (IETF RFC 2445) [19] is a calendar exchange specification for time intervals. It is used for appointment and meeting invitations in personal calendars. This same functionality is needed for price communication and pricing, market bidding, weather predictions, building management, and other decisions.

A web services standard, or WS-Calendar, could provide calendar functions to the Smart Grid. Development of the WS-Calendar standard could be quick since the requirements are well understood. WS-Calendar should be developed outside the Smart Grid effort as its anticipated uses extend into many business interactions. Development in a larger e-commerce sphere will lead to wider adoption and more benefit.

Key Actions:

(1) **Communicate with Smart Grid stakeholders on scheduling standard –** NIST shall communicate with Smart Grid stakeholders to determine if existing scheduling specifications may be used or whether new standards need to be created.

(2.a) **If existing specifications may be used, than Create a scheduling standard –** NIST to communicate with specification owner and coordinate activities necessary to make it a Smart Grid standard. SDO shall convert specification into a Smart Grid standard.

(2.b) **On the other hand, if new standards are needed, identify a SDO to create a new Smart Grid scheduling model –** NIST communicate with IEEE, IEC, UCA, OASIS, OpenADR to identify and select scheduling model SDO. NIST shall choose a SDO based on meeting results. SDO shall develop requirements for scheduling standard. Chosen SDO develop common scheduling model that meets Smart Grid requirements.

6.1.4 Application of Internet-Based Networking Technology

The IP network or the Internet consists of a set of protocols to transport data messages using IP packets, as well as a set of protocols to manage and control the network, such as routing, mapping of IP addresses, device management, etc. This protocol suite enables distributed network architecture and allows distributed applications to run over the network. Internet Protocol standards will have applicability in many parts of the Smart Grid although not necessarily all.

The workshop process as well as other industry activities has clearly illustrated that specific protocols within the Internet Protocol Suite are fundamental to networking in general and smart grid application networking infrastructure specifically. Protocols within the Internet Protocol Suite such as IPv4, IPv6, TCP, UDP, TLS/SSL, IPSec and others are being implemented now in utility specific networks and will likely continue to do so.

These suites of protocols are combined into what are often known as networking “stacks” or “profiles”. These profiles provide the networking infrastructure for a given set of applications. There are many protocols and supporting documents, known as Requests for Comment (RFCs) that would comprise a given networking profile. For several of the advanced networks required for the smart grid it is important to understand the capabilities of any given profile as well as its ability to meet the application requirements. For interoperable networks it is important to reach agreement on the composition of networking profiles for any given application or set of applications.

What is missing is a comprehensive mapping of smart grid application requirements to the capabilities of protocols and technologies in the Internet Protocol Suite by experts well versed in the applications and the protocols. Such an analysis would permit selected Internet protocol Suite subsets to be identified as important for various applications in the various domains of the NIST Conceptual Model of a Smart Grid.

Key Actions:

(1) **Educate the Smart Grid Community on the Internet Protocol Suite.** NIST should sponsor workshops to educate a wide smart grid stakeholder audience on what the Internet Protocol Suite is - its constituent protocols and technologies, their capabilities, and how their attributes should be compared to smart grid application non-functional requirements to facilitate appropriate protocol selection.

(2) **Perform a rigorous mapping of common smart grid application requirements against Internet Protocol Suite protocols**. NIST should convene a meeting of representatives from the IETF, IEEE, and selected industry groups to organize a cross industry group to perform this analysis. The analysis should be segmented by Conceptual Model Domain and sub-domains to address domain specific requirements in addition to cross domain networking requirements. The analysis should identify those protocols that are clearly applicable in specific application contexts (e.g. use of IPV4, IPv6, and TCP in enterprise applications) in addition to identifying any existing gaps.

(3) **Develop recommended Internet Protocol Suite Network Profiles for Smart Grid domains**. NIST should direct or encourage the group doing the requirements analysis to

create a standards level body within the IETF, IEEE, or other SDO to develop smart grid domain specific application profiles based on that analysis.

6.1.5 Communications Interference in Unlicensed Radio Spectrums

The Smart Grid provides mission-critical capabilities to the US economy and infrastructure. Communications is a key aspect of ensuring interoperability and increased efficiencies. Yet wireless Smart Grid device manufacturers and system integrators struggle with communication interference issues with other devices in unlicensed radio spectrums. Usage is not uniform across states further complicating the interoperability of networks.

At the workshops, a recurring theme emerged desiring licensed spectrum for Smart Grid communications (for example the 700MHz D block). This would alleviate many communication issues currently experienced in the industry and provide a private communication highway for the mission-critical inter-operations of the Smart Grid.

Additionally, during the plenary, a representative of the FCC indicated sensitivity to the potential requirements of the Smart Grid in this area. This opportunity should be pursued.

Key Actions:

(1) **Determine the need for dedicated spectrum –** NIST should commission a group of experts to study the issue of communications interference in unlicensed radio spectrums for smart grid applications and develop business and technical requirements on the optimal requirements for wireless spectrum usage for Smart Grid communications. The objective is to produce the necessary arguments to identify the preferred usage of spectrum throughout North America.

6.2 Priority Functionality Issues

This section presents recommended actions for NIST to take to address issues associated with the 6 applications assessed in this Interim Roadmap.

6.2.1 Demand Response

There are 3 key gaps or issues within Demand Response (other than the pricing model, which was discussed in 6.1.1). The first gap is in standardizing the DR signals to DER devices. The second gap is the need for robust DER discovery and interaction. The third gap is in provision of information to consumers about their energy consumption.

There are competing standards and specifications that include OpenADR, NAESB, and others. Although the purpose fo these standards is aligned, the different semantics in the OpenADR and NAESB terms used for DR can confuse the public and the practitioner, and thereby reduce participation. Just as a common standard for communicating to both load control and supply control devices will help accelerate DR implementations at the utilities and DER device manufacturing with products, common terminology will accelerate acceptance. A common standard should unify semantics as well as technology.

Market information is currently not available to the customer domain. Without this information, customers cannot participate in the wholesale or retail markets. In order to include customers in the electricity marketplace, they need to understand when opportunities present themselves to bid into the marketplace and how much electricity is needed. Once a bid is made, the contractual obligation to commit the accepted amount of electricity for the set period of time needs to also be communicated in a standard way.

Customers and/or their energy management systems would like or require energy usage information in order to help make decisions, such as what parameters to set for demand response, whether to change demand response (DR) plans, or whether to take specific actions now in anticipation of future DR events. Other informational interactions include curtailment and energy market operations; the best solution allows for easy interaction between these services. Energy sales and purchases, dynamic bids and acceptances, including the non-price attributes of that energy, are the basic transaction of transactional energy; a common shared understanding of each transaction proximate to the operating decisions that influence energy use is essential to collaborative energy on the smart grid.

As DER devices become pervasive and consumers can buy them at retail stores, the complexity of provisioning and tracking all the DER devices must be automated. The DERs may be provisioned at the premise energy management system (EMS) and allow the EMS to aggregate and report total premise DER baseline capabilities. Or the DERs may announce themselves to the service provider or utility or perhaps even the ISO. Both of these approaches use device discovery and profiles. Regardless, these reporting and management issues need to be resolved and an automated mechanism for announcing, configuring, and removing devices must be standardized or we limit opportunities for wide-spread adoption of DER and limit the amount of efficiency we can create in the system. Measurement and verification of demand reduction is of growing importance, with many issues such as what is the baseline, or is the device actually off.

Key Actions:

(1) **Develop or adopt standard DR signals –** NIST shall organize a meeting with IEC TC57, OASIS, NAESB, and AMI-ENT to specify a process for developing a common semantic model for standard DR signals. The effort shall ensure DR signal standards support load control, supply control, and environmental DERs.

(2) **Develop market signal standards** – NIST shall organize a meeting with policy makers, market operators/ISOs, and standards committees to develop common syntax and semantics for communicating market opportunities through the value chain and all the way to the customer. The effort shall develop policies that protect customers, but allow them to participate in the market. This is not an immediate need, but is something that requires a lot of thought and situational analysis.

(3) **Develop DER discovery and profiling standards –** NIST shall coordinate a meeting with IEC TC57, OASIS, NAESB, and AMI-ENT for developing standard mechanisms for DER device discovery and profiling, persistence checks, and registry updates. The effort shall develop standard mechanisms for DER device discovery and profiling, persistence checks, and registry updates.

(4) **Develop a common semantic model of customer energy information –** NIST shall coordinate with OASIS and NEMA to devise a standard. First, develop a summary of information needs for various means of customer information access about metering and

billing. Then, develop composite information model that can be easily transformed without loss for transport via web services, CIM, IEC61850, and ANSI C12.19/22.

6.2.2 Wide Area Situational Awareness

The most critical elements of wide area situational awareness can be related to time. The events captured in different places of the power system need to have a common time base. Action for Time Synchronization and Management are shown in section 6.1.2.

At the enterprise application level, situational awareness is often tied to market conditions, weather, system configuration, outage awareness, neighbor system configuration, and many other factors. In order to properly account for these, at a minimum the timely exchange of system model data must be achieved. There are several standards that address this problem, but much more work is needed on model development, harmonization, exchange, etc.

A third topic is the requirement to have topology of the power network available in the different systems that require it in real time. Information captured needs to be associated with the current topology and with the place within the power network that information was acquired. Some mechanisms are in place today, but additional investigations are required on harmonization and extensions of these mechanisms.

As it becomes increasingly critical for transmission and distribution operations to have clear and accurate information about the status and situations of each other, they need to be able to exchange their respective T&D power system models including the merging of relevant databases for interconnected power systems.

Key actions:

(1) **Develop application or role based synchronization guidelines** –NIST should organize a meeting between NASPI, IEC TC57 WG10 and IEEE PSRC with the objective of dealing with applications and guidelines around IEEE 1588, Network Time Protocol and IRIG-B as applied to power systems. Ensure efforts are applicable to devices, groups of devices, regions and combinations of regions. Ensure efforts include recovery from loss of synchronization.

(2) **Develop map of IEC 61850 objects to DNP3 –** IEC TC57 and DNP3 Users Group need to create mapping to provide for support of DNP3 protocols with the objectives of minimizing impact of existing installed asset base.

(3) **Develop and extend IEC 61970 Abstract Service for access to data from WASA** related applications. The development of WASA applications is largely a matter of real time analysis of data stored in existing applications and devices. However, IEC TC 57 WG 13 and 14 work to date largely addresses business process automation, but do not address synchronous data access to heterogeneous data from applications critical to Wide Area Situational Awareness. IEC TC 57 WG 13 should work to apply the abstract service defined in IEC 61970 to specific applications and thus provide a common data access mechanisms based on the CIM.

(4) **Extend CIM and 61850 to support distribution and transmission device function –** NIST shall work with IEC TC57 to extend the IEC 61970/61968 standards to encompass distribution and transmission device functions.

6.2.3 Electric Storage

Electric Storage is a new and emerging technology that has been identified by FERC as a functionality of smart grid. Due to the infancy of this technology there are few standards that exist to capture how it should be utilized on the Smart Grid. For example, to-date there exist no guidance or standards to address large or small mobile storage such as PHEVs. Electric Storage is treated as a distributed energy resource in some standards, but there may be distinctions between electric storage and connected generation.

The IEEE 1547 is an interconnection standard for interconnecting distributed energy resources (DER) with the electric power system. This standard defines DER as a small-scale electric generator located next to and connected to the load being served either with or without an electric grid interconnection. The standard does specify a distinction between electric storage devices within the DER portfolio. Also, there is no standardization for functioning during islanding.

FERC Order 719 currently prohibits generation of power within islanding. Distribution systems are beyond the purview of FERC and regulation does not exist for authorizing the application and dispatch of storage. ISOs and regulatory bodies today have a tendency to treat storage as a generation device and struggle with seeing transmission or distribution entities owning storage.

Key actions:

(1) **Develop storage device electrical interconnection guidelines**. NIST should issue a request to IEEE SCC 21 that the IEEE 1547 working group recruit domain experts in energy storage devices and update or augment the 1547 standards series as appropriate to accommodate energy storage system specific requirements. Coordination with UL and SAE may be required for electric vehicle based storage systems.

(2) **Develop storage device specific common information model**. NIST should issue a request to IEC TC 57 WG17 to recruit domain experts in energy storage devices and update or augment the 61850-7-420 standard as appropriate to accommodate energy storage system specific requirements.

6.2.4 Electric Transportation

There are three principle gaps in the area of Electric Transportation and the Smart Grid. We focus on vehicles such as Plug-In Electric [Hybrid] automobiles, trucks, and buses.

Models for settlement of energy costs and payments are developing slowly, with significant technical and policy/regulatory barriers. Proposals range from complex schemes for billing back to the driver’s (or the owner’s) home utility, simple charging as with current gasoline stations, to mixtures of prepaid and billed services as with cellular phones. When charging stations are ubiquitous, these issues will become even more important.

Similarly, mobile loads stress the distribution infrastructure. Similar approaches to those used for non-mobile loads point to two related gaps: a common model for Demand-Response signals (grid safety, and pricing for demand shaping), and a common model for price, energy characteristics, and time for use. There are alternatives, including very specific demand control mechanisms, but the benefits of applying economic demand shaping appear to be much greater, particularly given the growth of Demand-Response use in other customer areas.

We recognize that electric transportation will have a dual role as both a load to be managed and as a potential power source. Additionally, the impact of the PEVs on the planning and the management distribution system and its impact on system protection should be considered.

Key actions:

(1) **Develop and standardize common object models –** SAE is developing the requirements as well as providing the definitions for data exchanges of PEVs, chargers, metering equipment, registration equipment, and other PEV-related equipment. However, they need to pass these data requirements and definitions to a standards organization for mapping into actual object models. NIST shall communicate with SAE, IEEE, IEC, UCA, OASIS, and NAESB to identify and select SDO for pricing model (see Section 6.1.1), DR signal standards (see Section 6.2.1), and scheduling standard (see Section 6.1.3.2).

6.2.5 Advanced Metering Infrastructure

The principle gap in this area is the substantial overlap without uniformity between metering models in use including ANSI C12.19, IEC 61850, IEC 61968, SEP 1, SEP2, COSEM/DLMS. Current protocols support primarily unidirectional relationships between the AMI head end and the meter. Other applications both within and external to customer premises seek to interact with the “meter” in near real-time on an as needed basis.

The primary goal of standards activities, should therefore, be the coercion of at least a subset of these models into cleanly nested complexity levels with common semantics for each shared subset.

The next highest priority is determining how to infuse a common set of cross-cutting requirements into these standards to facilitate exchange of confidential and authentic information across standards. Currently each AMI standard has its own distinct set of cyber security protocols and capabilities making sharing of information exceedingly complex and limited by the least common denominator.

A common theme raised with regard to ANSI C12.22 mixes the roles of various communications layers for functionality beyond what is traditionally the application layer. Extremely detailed knowledge of the standard is required to recognize where the boundaries exist for the application layer and, perhaps, where it replicates the functions of lower layer functionalities. Most commonly cited are the availability of segmentation and message routing capabilities. As is the common case in open SDO standards processes, there is often a need for implementation agreements done in a user forum that can constrain some of the flexibilities that the standard expresses and what users need.

In order to manage change in a dynamically growing Smart Grid, it is essential to be able to upgrade firmware in the field (meters, etc…) without "rolling a truck". Remote image download capability, common practice today in many embedded computing devices, will permit the characteristics of the meter to be substantially altered on an as needed basis. Due to the fiduciary responsibilities inherent in revenue meters, such an image replacement must be protected by the highest degree of cyber security afforded by the C12.22 standard.

Finally, while ANSI C12.19 is an extremely flexible revenue metering model, it leaves so large a set of degrees of freedom available that a consumer of this information needs to be fairly complex to resolve simple meter information such a total KWH. ANSI C12.19 2008 has a mechanism by which table choices can be described, termed Exchange Data Language (EDL). This can be used to constrain oft utilized information into a well known form.

Key Actions:

(1) **Translate ANSI C12.19 into the form of the common semantic model (See section 6.1.3) --** NIST should work with NEMA to take on this task. The objective is to allow the lossless translation from the common form to the various syntactic representations prevalent in each Domain. Details will include the representation of the Decade/Table/Element model, as well as, the table-independent representation of key measurements of a revenue meter.

(2) **Extend ANSIC12.19 and ANSI C12.22 to support common cyber security requirements –** NIST should complete a common set of cyber security requirements through its Cyber Security Task Group. When complete NIST should engage NEMA in a normalization activity to capture results into ANSI C12.22 and C12.19 so that they have the capabilities to satisfy the requirements.

(3) **Define a conformance classification for ANSI C12.22 to constrain its scope –** NIST should work with NEMA to define, in their conformance testing standard C12.23, a set of conformance classifications that permit the varied capabilities of C12.22 to be selected and specified. Then work with UCAIug to define an implementation agreement to select subsets of ANSI C12.22 for use when integrating with other Smart Grid standard protocols.

(4) **Design one or more standard meter profiles using ANSI C12.19 Exchange Data Language –** NIST should work with NEMA to utilize EDL to represent one or more meter profiles with distinct information locations and formats to simplify client access to commonly shared information.

(5) **Design a meter image replacement enhancement to ANSI C12**.22 to manage change **–** NIST should work with NEMA to standardize a method to use C12.22 to download replacement images (meter programming) to facilitate version upgrades as the Smart Grid matures. Image replacement should use the highest degree of security available for ANSI C12.22 and ANSI C12.19 metering.

6.2.6 Distribution Grid Management Initiatives

The key gaps or issues within DGM are primarily around standards harmonization (IEC 61968 and MultiSpeak®) and standards extensions (IEC 61968, MultiSpeak, IEC 61850, and IEEE 1547). Also, the implication of integrating information from individual customers, widespread sensors, and large numbers of PEVs with the real time operation of the grid needs study and modeling.

There is a clear need for developing a common semantic representation for distribution assets, equipment, interfaces, and characteristics. This would include building a semantic bridge between the two most widely implemented standard data models in DGM -- MultiSpeak and IEC 61968 CIM. Working Group 14 of IEC TC57 has already developed a roadmap for development of the IEC 61968 CIM to support distribution smart grid applications. This includes implementing a CIM profile for MultiSpeak. Accelerating this development will permit interoperability between a wide variety of smart grid applications that require access to common data and information and will also provide interoperability between MultiSpeak- and CIM-compliant applications. Such interoperation will make it easier for electric utilities to leverage investment in enterprise applications.

Applications that perform an automated verification of the different settings of the components of a power system will be essential in the future to prevent system failures due to mis-configurations that may create blackouts. Therefore it is essential to extend models of configuration and control to facilitate direct assessments of configuration.

For actual device level communications and interfaces, DNP3 is typically used now and it is expected that this will continue for some time. In the short term, standardized approaches for network management, cyber security, and managing point lists using DNP3 are needed. This would essentially apply some of the important principles of IEC 61850 to DNP3 applications. In the longer term, migration to IEC 61850 for distribution management applications will require a number of important extensions and developments.

Key Actions:

(1) **Accelerate the work of developing the Common Information Model (CIM)** for distribution applications, including integration of a CIM profile for MultiSpeak interoperability. Use the IEC TC57 WG 14 roadmap as a starting point for this effort.

(2) **Develop neutral hosted vendor interoperability testing to demonstrate interoperability based on the CIM profiles.** Ensure that requirements developed by groups such as UCAIug AMI-ENT are included. Ensure that profiles account for capabilities inherent in both.

(3) **Amend and extend IEC 61968, IEC 61850, and IEEE 1547 –** NIST should bring together IEC TC57 WG14, WG10, IEEE SCC21 and OASIS architects to develop the framework for the amendment and extension of these standards to account for device profiles and discovery. Ensure that web services methods are harmonized among the candidate standards. Ensure that the standards are scalable for systems such as AMI and HAN.

(4) **Develop processes to model PEV impact on the grid operations along with impacts of other widespread distributed resource impacts (local storage, high penetration PV, demand response as a distribution resource, etc.) –** NIST to work with DOE to explore the business and technical impact of these widely distributed resources (including aspects of PEV as highly portable demand/storage) on the grid with the objective of mitigating severe contingencies due to the widespread adoption and use of these technologies. Ensure that work includes transactional elements (settlement when charging/discharging away from "home").

6.2.7 Cyber Security Strategy

The key actions are to complete the tasks identified in Section 5 of this document.

6.3 Further 2009 Roadmap Activities

This section summarizes actions to be taken beyond the initiation of the tasks listed in sections 6.1 and 6.2. These tasks are of more general and greater scope then the specific actions enumerated already in this report. They are necessary to complete the picture guiding the roadmap to completion and for achieving an active maintainable and evolving Smart Grid.

6.3.1 Completion of the NIST Standards Evaluation Process

This section identifies additional recommended work to conduct a more complete standards evaluation process. The work builds from the Interim Roadmap project including the input received from both workshops. These are in recognition that some key areas were not covered to the depth necessary to cover the full landscape of standards that could be applied to the Smart Grid.

To understand the full landscape of the Smart Grid applications landscape a selected set of additional priority use cases based on priority areas not selected for the workshops should be developed as part of the standards evaluation process.

In turn, through a more complete process, all the use cases can become fully developed for moving to the designs and implementations of equipment.

These raw materials should be imported into the NIST IKB to enable a growing ontology and applications database to be used for further analysis, elaboration, and application development.

Key Action:

(1) **Additional Smart Grid Application Use Cases –** NIST should convene the DEWGS to summarize a list of use cases and assemble them according to the process devised for the Interim Roadmap. Identify and implement additional architecturally significant use cases within critical application areas not covered in the Interim Roadmap

(2) **Bring all Roadmap Use Cases to common basis of completion –** NIST should facilitate completion of the body of Roadmap Use Cases. This includes the completion of the narratives, lists of actors, information objects, a diagram, and the allocation of standards and requirements to GWAC Stack layers.

(3) **Import the results into the NIST IKB**. – NIST should task the managers of the IKB to perform the import.

6.3.1.1 Requirements Analysis

The workshops and initial team analysis uncovered some of the significant requirements but the work needs to be continued to get to the details necessary to reveal key requirements. Critical areas include not only refining the applications requirements but developing full sets of cyber security and management requirements.

Section 4.9 Requirements Analysis identifies the suggested process for performing a detailed analysis of the Use Cases and the standards.

Key Action:

(1) **Requirements Analysis –** NIST should authorize a project to execute this task. Implement the requirements analysis process of section 4.9. The objective of this task is to analyze Use Cases and Requirements so that they can quantitatively analyze the fit of proposed domain profiles to the Use Cases.

(2) **GAPS/Overlaps Resolution Process –** NIST should authorize a project to perform this task. The objective of this task is to evaluate the adequacy of the candidate standards domain profiles and optimize them to select specific standards for specific GWAC layers. Use the requirements analysis to perform an evaluation of the standards and recommended practices proposed for the Smart Grid. Additionally, this analysis is used to elucidate the remaining gaps and overlaps not discovered by the “inspection process” of the workshops and Interim Roadmap analysis.

6.3.2 Architecture Framework Development and NIST IKB

Architecture development processes can develop the mechanisms to effectively integrate the development of standards and recommended practices across the greater Smart Grid industry. Architecture development by definition covers the top four categories of the GridWise Architecture Council (GWAC) Stack, the use cases for specific applications, and virtually all of the cross cutting issues in the GWAC documents. In addition Architecture development includes the development of methods, tools and strategies by which the greater Smart Grid industry can converge on not only business, policy and governance topics but can also assist in the resolution of many of the technical issues that have resulted from narrowly focused but well intended bodies of work.

The industry can benefit from a systematic approach to integrating key policies from regulators and key stakeholders. In addition forms of governance and policy management should be developed to effectively establish a National infrastructure in critical areas such as management and cyber security.

This roadmap has served as an initial form of industry baseline for standards. This baseline has shown that the industry has substantial good work but much of it remains largely fragmented. This is where Architecture development concepts are useful. Baseline development itself is one of several architecture related technical activities.

The following are recommendations for evaluating and adopting a more formal and structured approach to industry architecture.

Key Action:

(1) **Define scoping tasks to substantiate the need for Interoperability Architecture for the Smart Grid** - NIST working with key stakeholders establishes a project to evaluate and, pending a positive result, define an architectural framework for Smart Grid at about the level of FEA or DODAF for their respective communities. Then, integrate work from established SDO and technical organizations that have been working on Architecture development processes. Develop cooperative relationships between Federal and State Agencies as well as Stakeholder communities.

(2) **Interoperability Architecture Process Adoption** - The Smart Grid requires a systematic approach to the integration of technical standards and recommended practices. Pending the successful determination of task (1), above, NIST should oversee the development of an Interoperability Architecture to guide the work described in this interim roadmap. NIST should rely on existing work including: The Open Group Architecture Framework Version 9, IEEE 1479, ISO 10746, and other published work on interoperability.

6.3.3 Policy and Regulatory

We must understand the affect of policy and regulatory choices on technology choices.

For example, a regulatory decision that merely permits resale of electricity can enable a new (or extended) business for charging Plug-in Electric Vehicles that follows the model for gasoline sale with customers paying cash or using credit/debit cards to pay for charging, while using Automated Demand Response and grid safety signals to ensure the continued reliability of the electricity distribution infrastructure.

A further set of regulations and policy changes would be needed to support identity-based charge-back for energy use and supply to the "home" utility, but requires augmentation of the users' expectations – and a great deal of additional complexity to allow identification, billing, clearing, and related issues.

Policy makers and regulators should carefully consider the complexity and costs of the induced technology changes, and whether changes are critical to Smart Grid evolution. For example, a generative approach might take the minimal changes and allow the development of unregulated business models, while a more complex chargeback scheme may require deep and rigid technologies—just because we can execute a technological solution does not necessarily mean that we should.

(1) **Development of Architecture Governance and Policy Integration Processes**. This task should also include consistent approaches to energy industry business models where they are critical to the development of Smart Grid components and equipment such as revenue meters, and consumer owned equipment.

(2) **Consideration of changes in regulation to enable new business models and complex technologies**. Minor differences in regulation may require major investment in technology to satisfy requirements. The standard cost-benefit analyses made by

regulators need to address broader economic and stakeholder issues.

7 Definitions

7.1 Terms

Note that it is impossible to write a document of broad scope such as this without encroaching on definitions understood to have accepted but different meanings in more than one constituent audience. Therefore, for the purposes of considered understanding, the definitions in this section represent the intended meanings of the authors when used within this document.

Availability	"Ensuring timely and reliable access to and use of information…" [44 U.S.C., SEC. 3542] A loss of availability is the disruption of access to or use of information or an information system.
Architecture	The Federal Enterprise Architecture Framework defines architectures as "*the structure of components, their interrelationships, and the principles and guidelines governing their design and evolution over time.*"[12].
Capability	The ability of a standard to satisfy a Requirement
Cyber Infrastructure	Includes electronic information and communications systems and services and the information contained in these systems and services. Information and communications systems and services are composed of all hardware and software that process, store, and communicate information, or any combination of all of these elements. Processing includes the creation, access, modification, and destruction of information. Storage includes paper, magnetic, electronic, and all other media types. Communications include sharing and distribution of information. For example: computer systems; control systems (e.g., SCADA); networks, such as the Internet; and cyber services (e.g., managed security services) are part of cyber infrastructure.
Cyber security	The prevention of damage to, unauthorized use of, exploitation of, and, if needed, the restoration of electronic information and communications systems and services (and the information contained therein) to ensure confidentiality, integrity, and availability.
Confidentiality	"Preserving authorized restrictions on information access and disclosure, including means for protecting personal privacy and proprietary information…" [44 U.S.C., Sec. 3542] A loss of confidentiality is the unauthorized disclosure of information.
Customer	The consumer of energy or services

Domain	A relatively cohesive set of actors and applications connected by associations.
Gateway	In a communications network, a network node equipped for interfacing with another network that uses different protocols. (188) Note 1: A gateway may contain devices such as protocol translators, impedance matching devices, rate converters, fault isolators, or signal translators as necessary to provide system interoperability. It also requires that mutually acceptable administrative procedures be established between the two networks. Note 2: A protocol translation/mapping gateway interconnects networks with different network protocol technologies by performing the required protocol conversions. [Federal Standard 1037C]
Integrity	"Guarding against improper information modification or destruction, and includes ensuring information non-repudiation and authenticity…" [44 U.S.C., Sec. 3542] A loss of integrity is the unauthorized modification or destruction of information.
Interface	The place at which two systems meet and act on or communicate with each other.
Requirement	(1) A condition or capability needed by a user to solve a problem or achieve an objective. (2) A condition or capability that must be met or possessed by a system or system component to satisfy a contract, standard, specification, or other formally imposed documents.
Standards	A technical specification, usually produced by a Standards Development Organization (SDO).
System	a regularly interacting or interdependent group of items forming a unified whole; a group of devices or artificial objects or an organization forming a network especially for distributing something or serving a common purpose.

7.2 ACRONYMS

ACSE	Association Control Service Element
AES	Advanced Encryption Standard
AMI	Advanced Metering Infrastructure
AMR	Automated Meter Reading
ANSI	American National Standards Institute
API	Application Program Interface

7 6BDefinitions

ASD	NII DoD CIO - Assistant Secretary of Defense - Networks & Information Integration - CIO Office
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BAS	Building Automation System
CA	Contingency Analysis
CEIDS	Consortium for Electric Infrastructure to Support a Digital Society
CM	Configuration Management
CIM	Common Information Model
CIGRE	International Council On Large Electric Systems
CIP	Critical Infrastructure Protection
CIS	Customer Information System
CPP	Critical Peak Pricing
CSCTG	Smart Grid Cyber Security Coordination Task Group
CSRC	Computer Security Resource Center
DA	Distribution Automation
DDNS	Dynamic Domain Name System
DER	Distributed Energy Resources
DES	Data Encryption Standard
DEWG	Domain Expert Working Group
DGM	Distribution Grid Management
DHCP	Dynamic Host Configuration Protocol
DHS	Department of Homeland Security
DLC	Direct Load Control
DMS	Distribution Management System
DNS	Domain Name System
DOD	Department of Defense
DOE	Department of Energy
DP	Dynamic Pricing
DR	Demand Response

DWML	Digital Weather Markup Language
ECWG	Electronic Commerce Working Group
EDL	Exchange Data Language
EISA	Energy Independence and Security Act
EMCS	Utility/Energy Management and Control Systems
EMS	Energy Management System
EPRI	Electric Power Research Institute
ES	Energy Storage
ESI	Energy Services Interface
ESP	Energy Service Provider
EUMD	End Use Measurement Device
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FBI	Federal Bureau of Investigation
FCC	Federal Communications Commission
FERC	Federal Energy Regulatory Commission
FIPS	Federal Information Processing Standards
FTP	File Transfer Protocol
GHG	Greenhouse Gases
GID	Generic Interface Definition
GIS	Geographic Information System
GOOSE	Generic Object-Oriented Substation Event
GSA	General Services Administration
GWAC	GridWise Architecture Council
HTTP	Hyper Text Transfer Protocol
HVAC	Heating Ventilating and Air Conditioning
IATFF	Information Assurance Technical Framework Forum
ICS	Industrial Control Systems

IEC	International Electrotechnical Commission
IECSA	Integrated Energy and Communications System Architecture
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronic Engineers
IETF	Internet Engineering Task Force
IHD	In-Home Display
IRM	Interface Reference Model
IOSS	Interagency OPSEC Support Staff
IP	Internet Protocol
ISO	International Organization for Standardization, Independent Systems Operator
IT	Information Technology
KPI	Key Point of Interoperability
LAN	Local Area Network
LMS	Load Management System
LTC	Load Tap Changer
MDMS	Meter Data Management System
MGI	Modern Grid Initiative
MIB	Management Information Base
MIME	Multipurpose Internet Mail Extensions
MFR	Multi-level Feeder Reconfiguration
MMS	Manufacturing Messaging Specification
NAESB	North American Energy Standards Board
NARUC	National Association of Regulatory Utility Commissioners
NEMA	National Electrical Manufacturers Association
NERC	North American Electric Reliability Corporation
NIAP	National Information Assurance Partnership
NIPP	National Infrastructure Protection Plan
NIETP	National IA Education and Training Program

7 6BDefinitions

NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NSA	National Security Agency
NSM	Network and System Management
OASIS	Organization for the Advancement of Structured Information Standards
OGC	Open Geospatial Consortium
OID	Object Identifier
OMG	Object Management Group
OMS	Outage Management System
OpenSG	Open Smart Grid
OSI	Open Systems Interconnection
OWASP	Open Web Application Security Project
PEV	Plug-in Electric Vehicles
PMU	Phasor Measurement Unit
QOS	Quality Of Service
RAS	Remedial Automation Schemes
RBAC	Role Based Access Control
RFC	Request For Comments, Remote Feedback Controller
RSA	Rivest, Shamir, Adelman
RTO	Regional Transmission Operator
RTP	Real-Time Pricing
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SCL	Substation Configuration Language
SCP	Secure Copy Protocol
SDO	Standards Development Organization
SOA	Services Oriented Architecture
SHA	Secure Hash Algorithm

SNMP	Simple Network Management Protocol
SNTP	Simple Network Time Protocol
SP	Special Publication
SOA	Service-Oriented Architecture
SSH	Secure Shell
SSP	Sector Specific Plan
TCP	Transport Control Protocol
TFTP	Trivial File Transfer Protocol
TOGAF	The Open Group Architecture Framework
TOU	Time-of-Use
UCA	Utility Communications Architecture
UCAIug	UCA International Users Group
UID	Universal Identifier
UML	Unified Modeling Language
VAR	Volt Amps Reactive
VVWC	Voltage, Var, and Watt Control
WAMS	Wide-Area Measurement System
WAN	Wide Area Network
WASA	Wide Area Situational Awareness
XML	Extensible Markup Language

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9 Appendix A: Standards Profiles by Domain

This section organizes subsets of standards and specifications into Domain Profiles. As described in the conceptual model, presented in section 3.2, information must flow across interfaces between Actors. These Actors may be within the same Domain or may be in separate domains; therefore, these interfaces may be intra-Domain or inter-Domain. Many of the same standards and specifications are used across many different interfaces, and, conversely, many interfaces must support different standards and specifications for engineering design reasons. Given this many-to-many relationship, the interfaces with similar requirements are combined, and the key standards and specifications are organized by Domain and categorized into hierarchical layers by the GWAC stack.

The word “standard” is used for all in this section, regardless of whether it was developed by a Standards Developing Organization (although as stated below, the SDO process is preferred as a means of testing a specification with broad stakeholder input). Any further description occurs in a particular listing (*e.g.*, “specification”, “requirements”, “agreement”, etc.).

For a summary of the standards referenced in this section, see section 10 Appendix B: Alphabetical Standards List.

Selection for inclusion in the Interim Roadmap was based upon the following non-exclusive criteria:

(1) Standard was supported by an Standards Developing Organization (SDO) or via an emergent SDO process

(2) Standard is also supported by a users community

(3) Standard is directly relevant to the Use Cases analyzed for the Smart Grid

(4) Consideration was given to those standards with a viable installed base and vendor community

In the tables which follow, each conceptual model domain is represented by a table of standards and specifications that represent the union of results from the analyses performed for this Interim Roadmap. As discussed in section 4.9 Requirements Analysis, these tables will be further refined as standards gaps are filled and harmonization across standards are realized.

As can be seen in the tables, there are many standards that were identified for each GWAC layer. Each of the GWAC layers represents one or more interfaces at which one or more standards can be applied. These fall into three categories:

(1) Upper layers 4-8: These layers represent application-specific information that binds closely to the function of the Actor, as opposed to where the Actor is located. For this reason, they are largely Domain-independent. Complementary standards should be retained, and overlapping standards should be either harmonized or chosen amongst.

(2) Layer 3 and the cross-cutting issues: These represent highly domain-specific standards. An optimized process should result in the combining and harmonization of

standards to minimize the options for these interfaces so that devices and applications for that domain can have a minimum of complexity.

(3) Layers 1&2: These represent media and lower layers of communications interfaces. Although communications infrastructures should be as homogeneous as possible, engineering designs and constraints must dictate local decisions. As long as these interfaces can carry the semantics of the upper layers with the required qualities of service, the specific choice of these layers can be transparent to the Actors. Thus these interfaces can be optimized for the actual physical locations in which they are deployed.

When the tables below are viewed, the functional and performance requirements can be used to select the best sets of standards and specifications to meet those requirements.

The analysis process discussed in sections 4.9 and 6.3.1 will lead to valuing some standards over others and the harmonization of other standards to minimize the need for adaptors at interfaces. As the Smart Grid evolves, the construction of concise, non-duplicative profiles will simplify the design and need for those adaptors. Naturally, adaptors will still be necessary to allow the legacy technologies to interact in the Smart Grid. In essence this permits adaptors to be constructed to translate from the limited number of domain profile standards to the other domain profile standards, thus predominantly simplifying the many-to-many translation task to a one-to-many basis.

Finally, it can be recognized that for any Actor to communicate with any other Actor, all mismatches between standards at each GWAC interface must be resolved by adaptor devices – bridges, routers, or gateways. By decoupling the need for these adaptors from the nature of the Actors, themselves, efficiencies and simplifications can be achieved in the marketplace by devising such adaptors that can represent many Actors on either side of the Domain boundary rather than duplicated in each device itself.

9.1.1 Operations

Table 14 – Standards Profile for Operations Domain

GWAC Stack Layer	Operations
8. Policy	*IEC 61968, Measurement&Verification (NAESB WEQ015), Access to usage data, FERC Rulings, CIP Reliability Standards, FERC 888
7. Business Objectives	FERC 888
6. Business Procedures	Measurement&Verification (NAESB WEQ015), DNP3, FixML, OpenADR, CIP -004-1 Reliability Standards, NAESB (OASIS)
5. Business Context	*ICCP (IEC 60870-6/TASE 2), MultiSpeak
4. Semantic Understanding	IEC 61968, IEC 61970, ICCP (IEC 60870-6/TASE 2), MultiSpeak, DNP3, IEC 61850, ZigBee, ASHRAE 135-2008, ISO/IEC 14908-1 etc, EMIX (OASIS), OpenADR, NAESB OASIS, DNP3
3. Syntactic Interoperability	XML/SOAP, Web Services, message queueing, ZigBee, ASHRAE 135-2008, ISO/IEC 14908-1 etc, DNP3, FixML, WS-Calendar (OASIS), OpenADR (OASIS Energy Interop), oBIX, ZigBee HomePlug Smart Energy Profile, OpenHAN, Smart Energy Profile, OpenADR, ANSI C12.22, ANSI C12.19, IEC 60870-6 (ICCP), IEC 61850, FTP, IEC 60870-6 TASE.2, IEEE C37.111-1999, IEEE 37.118, NASPI

2. Network Interoperability	UDP, IPSec, DSCP, MPLS, VPN, Ethernet (IEEE 802.3), IEEE 802.1 and 802.2, TCP/IP, UDP/IP, ZigBee, HomePlug, ASHRAE 135-2008, BACnet Web Services, ISO/IEC 14908-1 etc, LAN, WAN, WLAN, TCP/IP, Metropolitan Area Network (MAN) – IEEE 802.11x MAC, TCP & IPv4, IPv6 Addressing, Distributed Network Protocol (DNP3), IEEE 1379-2000 Data Link Layer, NIST 140-2
1. Basic Connectivity	ZigBee, IEEE 802.15.4, IEEE 802.11, IEEE 803, ASHRAE 135-2008, ANSI/CEA 852, ANSI/CEA 709 Series, GSM, CDMA, GPRS, DSL, LAN, WAN, WLAN, TCP/IP, GPRS, 3GPP/LTE, WiMAX, IEEE 802.20, IEEE 802.16d, WiMAX, IEEE 802.3, IEEE 1379-2000 PHY Layer, IEEE 1588
Shared Meaning of Content	ICCP (IEC 60870-6/TASE 2), MultiSpeak
Resource Identification	ICCP (IEC 60870-6/TASE 2), MultiSpeak
Time Synch & Sequencing	NTP
Security and Privacy	IPSec, SSL, TLS, AES128 for example, Access Control, Authentication, Data and Messaging Integrity, Non-repudiation, Confidentiality, Privacy, IEC 61968, IEC 61970, NIST 800-53
Logging & Auditing	SNMP v3, SysLog
Transaction State Management	
System Preservation	
Quality of Service	DSCP
Discovery & Configuration	
System Evolution & Scalability	
Network Management [non-GWAC Stack]	
Electromechanical [non-GWAC Stack]	

9.1.2 Markets

Table 15 – Standards Profile for Markets Domain

GWAC Stack Layer	
8. Policy	AMI-SEC
7. Business Objectives	
6. Business Procedures	DNP3, FixML
5. Business Context	
4. Semantic Understanding	MultiSpeak, IEC 61970, NAESB OASIS, IEC 61970
3. Syntactic Interoperability	XML, WSDL, DNP3, FixML, Web services
2. Network Interoperability	TCP/IP, SSL, ZigBee, ANSI C12.24
1. Basic Connectivity	TCP/IP
Shared Meaning of Content	
Resource Identification	

Time Synch & Sequencing	
Security and Privacy	Access Control, Authentication, Data and Messaging Integrity, Non-repudiation, Confidentiality, Privacy
Logging & Auditing	
Transaction State Management	
System Preservation	
Quality of Service	
Discovery & Configuration	
System Evolution & Scalability	
Network Management [non-GWAC Stack]	
Electromechanical [non-GWAC Stack]	

9.1.3 Service Provider

Table 16 – Standards Profile for Service Provider Domain

GWAC Stack Layer	
8. Policy	Access to usage data
7. Business Objectives	
6. Business Procedures	
5. Business Context	
4. Semantic Understanding	OpenADR/OASIS Energy Interop, ZigBee SEPs, IEC 61968, IEC 61970, Encryption and Security, OpenADR, IEC 61850
3. Syntactic Interoperability	ASHRAE 135-2008, XML, Web services, OpenADR, J2293 or similar (see PEV), ANSI C12.22, ANSI C12.19
2. Network Interoperability	ANSI C12.19, ANSI C12.22, ZigBee, HomePlug, WAN, GPRS, LAN, OpenAMI, TCP/IP
1. Basic Connectivity	DSL, T1, etc, Ethernet IEEE 802.x, Internet, WAN, GPRS, 3GPP/LTE, WiMAX, TCP/IP
Shared Meaning of Content	
Resource Identification	
Time Synch & Sequencing	
Security and Privacy	
Logging & Auditing	
Transaction State Management	
System Preservation	

Quality of Service	
Discovery & Configuration	
System Evolution & Scalability	
Network Management [non-GWAC Stack]	
Electromechanical [non-GWAC Stack]	

9.1.4 Bulk Generation

Table 17 – Standards Profile for Bulk Generation Domain

GWAC Stack Layer	
8. Policy	NERC Reliability
7. Business Objectives	FERC, States
6. Business Procedures	
5. Business Context	
4. Semantic Understanding	IEC 60870-6 / TASE.2 , IEC 61968, IEC 61850-7-420
3. Syntactic Interoperability	IEC 60870-6 TASE.2, IEEE C37.111-1999, IEEE 37.118, IEC 61850, NASPI, ASN.1
2. Network Interoperability	TCP/IP
1. Basic Connectivity	IEEE 802.3
Shared Meaning of Content	
Resource Identification	
Time Synch & Sequencing	
Security and Privacy	IEC 61968, IEC 61970, NIST 800-53
Logging & Auditing	
Transaction State Management	
System Preservation	
Quality of Service	
Discovery & Configuration	
System Evolution & Scalability	
Network Management [non-GWAC Stack]	

Electromechanical [non-GWAC Stack]	

9.1.5 Distribution

Table 18 – Standards Profile for Distribution Domain

GWAC Stack Layer	
8. Policy	NERC Reliability
7. Business Objectives	
6. Business Procedures	
5. Business Context	IEC 61968-9, MultiSpeak
4. Semantic Understanding	DNP3, IEC 61850-7-3, IEC 61850-7-4, IEC 61968-9, MultiSpeak, IEC 61970, GIS Standards, SNMP, IEC 62351-7, ANSI C37.118
3. Syntactic Interoperability	DNP3, IEC 61850-7-2, W3C XML, W3C XSD, W3C SOAP, MultiSpeak, W3C EXI, W3C WSDL, ANSI C12.22, IEC 60870-6, ICCP, IEC 61968, MultiSpeak v4, IEC 62351, VPN, IEEE 1686-2007, NERC-CIP (Tx), IEC 60870-6 TASE.2, IEEE C37.111-1999, IEEE 37.118, NASPI
2. Network Interoperability	IP Suite, TCP/IP
1. Basic Connectivity	IEEE 802.*, GPRS, EVDO, 1xRTT, POTS, IEEE P1901, IEEE 802.16
Shared Meaning of Content	
Resource Identification	
Time Synch & Sequencing	
Security and Privacy	IEC 62351-4, IPSec, SSL, TLS, AMI-SEC, WS-Security, TLS, IEC 61968, IEC 61970, NIST 800-53
Logging & Auditing	
Transaction State Management	
System Preservation	
Quality of Service	DSCP
Discovery & Configuration	
System Evolution & Scalability	
Network Management [non-GWAC Stack]	
Electromechanical [non-GWAC Stack]	

9.1.6 Transmission

Table 19 – Standards Profile for Transmission Domain

GWAC Stack Layer	
8. Policy	NERC PRC
7. Business Objectives	Reliability
6. Business Procedures	
5. Business Context	
4. Semantic Understanding	IEC 60870-6 / TASE.2, IEEE C37.118 , DNP3, IEC 61850, IEC 61968, IEC 61970, MultiSpeak V4, IEEE C37.118, IEEE C37.232, IEEE 1588, IEC 61970-452, -453, -456, ANSI C12.19
3. Syntactic Interoperability	DNP3, IEC 61850, XML, WSDL, ICCP, IEEE C37.111-1999, IEEE 1159.3, IEC 61970-552, IEC 61850, IEC 60870-6 TASE.2, IEEE 37.118, NASPI, ASN.1
2. Network Interoperability	TCP/IP, ICCP: IEC 60870-6, IEC 61850, DNP3, W3C
1. Basic Connectivity	IEC 61850, IEEE 802.3
Shared Meaning of Content	
Resource Identification	IEEE C37.2
Time Synch & Sequencing	IEEE 1588
Security and Privacy	IEEE 1686, IEC 62351, NERC CIP, IEC 61968, IEC 61970, NIST 800-53
Logging & Auditing	
Transaction State Management	
System Preservation	
Quality of Service	
Discovery & Configuration	
System Evolution & Scalability	
Network Management [non-GWAC Stack]	
Electromechanical [non-GWAC Stack]	

9.1.7 Customer

Table 20 – Standards Profile for Customer Domain

GWAC Stack Layer	CustomersHome
8. Policy	AMI-SEC, Open HAN, UL Safety Standards, ANSI C12
7. Business Objectives	ANSI C12.19, ANSI C12.1, ANSI C12.20
6. Business Procedures	Measurement &Verification (NAESB WEQ015), Web stuff-Discovery, Web

	Services
5. Business Context	OpenADR/OASIS Energy Interop, OpenHAN
4. Semantic Understanding	ANSI C12.19, IEC 61968, SEP 2.0, ANSI C12.22, ANSI C12.21, ANSI C12 , Measurement &Verification (NAESB WEQ015), ISO/IEC 18012, ASHRAE 135-2008, ISO/IEC 14908-1, oBIX, IEC 60929 DALI, ZigBee SEPv2 (in prep), XML, OpenADR, OASIS Energy Interop, OpenHAN, Web services, ISO/IEC 24752 (Universal Remote Console UI), ICCP, DLMS/COSEM, IEC 61850, ISO/IEC 14908-1 etc, OpenHAN, IEC 61968-9
3. Syntactic Interoperability	ZigBee SEP 2, ANSI C12.22, IEC 61850, HTTP, XML, JAVA, ANSI C12.19, W3C EXI, ZigBee Smart Energy Profile (in prep), ANSI C12.21, ANSI C12, Measurement&Verif (NAESB WEQ015), ISO/IEC 18012, ASHRAE 135-2008, ISO/IEC 14908-1, oBIX, IEC 60929 DALI, OpenADR, OASIS Energy Interop, OpenHAN, UDP, IEC 61968 XML, Web Services, DLMS/COSEM, ASHRAE 135-2008, ISO/IEC 14908-1,
2. Network Interoperability	IETF approved IPV6 or 6LoWPAN, Gateway Stds ISO/IEC 15045, SOAP, HTTP, ZigBee SEP, HOMEPLUG, ISO/IEC 14908-1 etc, ASHRAE 135-2008, ANSI C12.19, C12.22, ISO/IEC 15067-3 (EMC), ISO/IEC 18012, OpenAMI, OpenHAN, TCP/IP, WAN, LAN, WLAN, GPRS, ISO/IEC 14908-1 etc, ZigBee
1. Basic Connectivity	IEEE 802.15.4, IEEE 802.11, 802.16e or any other standardized PHY (eg: cdma, gsm), SAE J-series, IEEE P1901, ANSI C12.18, POTS, GPRS, EVDO, 1xRTT, GSM, C12.22-2008, IEEE 802.15.4 , IEEE 802.3, GSM/GPRS/EDGE/HSDPA, CDMA/EVDO, SMS, IEEE 802.x, IEEE P1901, RDS, ISO/IEC 14908-1 etc, NIC to Meter, ZigBee, IETF 6LOWPAN, LAN, WLAN, Internet, WAN, GPRS, 3GPP/LTE, WiMAX, IEEE P1901, IEEE P2030, HPAV/HPGP, SAE J2836/3, SAE J2847/3, ZigBee/HomePlug
Shared Meaning of Content	ANSI C12.19 Document/XML forms/Tables, ZigBee Smart Energy Profile, , IEEE 802.x, IEEE P1901, RDS, ISO/IEC 14908-1, NIC to Meter, XML Schema, IEC 61968, IEC 61970 Part 3
Resource Identification	ISO Registered Object IDs per NAEDRA and sub-registrars, ZigBee Resource IDs, Provisioning of meters, association with customer accts, PKI
Time Synch & Sequencing	ANSI C12.19, Zigbee SEP 2, GPS, C12.19-2008, ZigBee, NTP, 802.11, 802.15, GPS
Security and Privacy	Zigbee SEP 2, AES128, ECC , IP-SEC, TLS, WS-Security, ANSI C12.22, IEEE 802.1x, EAP, FIPS 197, RADIUS,ANSI C12.19-2008, NIST 800-53, NIST 800-82, ISO 27000 Series, IEEE 802.11x WiFi, Common Criteria
Logging & Auditing	ANSI C12.19-2008, NIST 800-53, NIST 800-82, ISO 27000 Series
Transaction State Management	C12.19-2008, C12.22-2008, AMI-SEC, SOAP/XML
System Preservation	ISO 27000 Series, NIST 800-53
Quality of Service	C12.19-2008
Discovery & Configuration	Zigbee SEP 2,C12.19-2008, C12.22-2008
System Evolution & Scalability	C12.19-2008, C12.22-2008
Network Management [non-GWAC Stack]	

Electromechanical [non-GWAC Stack]	C12.22-2008

GWAC Stack Layer	CustomersCommercial
8. Policy	AMI-SEC, ANSI C12
7. Business Objectives	
6. Business Procedures	Measurement &Verification (NAESB WEQ015), Web stuff-Discovery, web services
5. Business Context	
4. Semantic Understanding	ASHRAE 135-2008, MultiSpeak v4, IEC 61968, LonWorks, XML, oBIX, ANSI C12, Measurement &Verification (NAESB WEQ015), ISO/IEC 18012, ISO/IEC 14908-1, oBIX, IEC 60929 DALI, ZigBee SEPv2 (in prep), XML Schema, OpenADR, OASIS Energy Interop, ICCP, Web Services, ANSI C12.19, DLMS/COSEM, IEC 61850, ANSI C12.18
3. Syntactic Interoperability	ASHRAE 135-2008, XML, WSDL, SOAP, Web services, ICCP, IEC 61850, IEC 61968, DNP3, ModBus, ANSI C12, Measurement&Verif(NAESB WEQ015), ISO/IEC 18012, ISO/IEC 14908-1, oBIX, IEC 60929 DALI, ZigBee SEPv2 (in prep), XML Schema, OpenADR/OASIS Energy Interop, XML, DLMS/COSEM, ANSI C12.22, IEC 61849
2. Network Interoperability	ASHRAE 135-2008, TCP/IP, SSL, ZigBee, ANSI C12.22, Gateway Stds, ISO/IEC 15045, HTTP, OpenHAN, WAN, LAN, WLAN, GPRS, ISO/IEC 14908-1
1. Basic Connectivity	ASHRAE 135-2008, IEEE 802.x, LAN, WLAN, Internet, WAN, GPRS, 3GPP/LTE, WiMAX, IEEE P1901, IEEE P2030, HPAV/HPGP, SAE J2836/3, SAE J2847/3, IEEE 802.15.4, IEEE 802.16, ZigBee/HomePlug
Shared Meaning of Content	
Resource Identification	Provisioning of meters, association with customer accts
Time Synch & Sequencing	ASHRAE 135-2008
Security and Privacy	ASHRAE 135-2008, Access Control, Authentication, Data and Messaging Integrity, Non-repudiation, Confidentiality, Privacy
Logging & Auditing	ASHRAE 135-2008
Transaction State Management	ASHRAE 135-2008
System Preservation	
Quality of Service	
Discovery & Configuration	
System Evolution & Scalability	ASHRAE 135-2008
Network Management [non-GWAC Stack]	
Electromechanical [non-GWAC Stack]	

GWAC Stack Layer	CustomersIndustrial
8. Policy	AMI-SEC, ANSI C12
7. Business Objectives	
6. Business Procedures	Measurement &Verification (NAESB WEQ015), Web stuff-Discovery, web services
5. Business Context	
4. Semantic Understanding	ASHRAE 135-2008, MultiSpeak v4, IEC 61968, LonWorks, XML, oBIX, ANSI C12, Measurement &Verification (NAESB WEQ015), ISO/IEC 18012, ISO/IEC 14908-1, oBIX, IEC 60929 DALI, ZigBee SEPv2, OpenADR, OASIS Energy Interop, ICCP, Web Services, ANSI C12.19, DLMS/COSEM, IEC 61850, ANSI C12.18
3. Syntactic Interoperability	ASHRAE 135-2008, XML, WSDL, Web services, ICCP, IEC 61850, IEC 61968, DNP3, ModBus, ANSI C12, Measurement &Verification (NAESB WEQ015), ISO/IEC 18012, ISO/IEC 14908-1, oBIX, IEC 60929 DALI, ZigBee SEPv2, SOAP, OpenADR, OASIS Energy Interop, DLMS/COSEM, ANSI C12.22, IEC 61849
2. Network Interoperability	ASHRAE 135-2008, TCP/IP, SSL, ZigBee, ANSI C12.22, Gateway Stds, ISO/IEC 15045, HTTP, OpenHAN, WAN, LAN, WLAN, GPRS, ISO/IEC 14908-1
1. Basic Connectivity	ASHRAE 135-2008, IEEE 802.x, LAN, WLAN, Internet, WAN, GPRS, 3GPP/LTE, WiMAX, IEEE P1901, IEEE P2030, HPAV/HPGP, SAE J2836/3, SAE J2847/3, IEEE 802.15.4, IEEE 802.16, ZigBee/HomePlug
Shared Meaning of Content	
Resource Identification	Provisioning of meters, association with customer accts
Time Synch & Sequencing	ASHRAE 135-2008
Security and Privacy	ASHRAE 135-2008, Access Control, Authentication, Data and Messaging Integrity, Non-repudiation, Confidentiality, Privacy
Logging & Auditing	ASHRAE 135-2008
Transaction State Management	ASHRAE 135-2008
System Preservation	
Quality of Service	
Discovery & Configuration	
System Evolution & Scalability	ASHRAE 135-2008
Network Management [non-GWAC Stack]	
Electromechanical [non-GWAC Stack]	

GWAC Stack Layer	CustomersPEV
8. Policy	ANSI C12, FCC Frequency Stds
7. Business Objectives	
6. Business Procedures	Measurement &Verification (NAESB WEQ015), Web stuff-Discovery, web services

5. Business Context	
4. Semantic Understanding	ANSI C12, Measurement &Verification (NAESB WEQ015), ISO/IEC 18012, ASHRAE 135-2008, ISO/IEC 14908-1, oBIX, IEC 60929 DALI, ZigBee SEPv2, OpenADR, OASIS Energy Interop, ICCP, XML, Web Services, Financial transaction models, SAE J2836, SAE J2847
3. Syntactic Interoperability	ANSI C12, Measurement &Verification (NAESB WEQ015), ISO/IEC 18012, ASHRAE 135-2008, oBIX, IEC 60929 DALI, ZigBee SEPv2, OpenADR, OASIS Energy Interop, Web Services, XML, OpenHAN, SAE J2293, SAE J2836, ISO/IEC 14908-1 etc
2. Network Interoperability	Gateway Stds ISO/IEC 15045, SOAP, HTTP, Web services, TCP/IP, Internet, WiFi, Cellular, P1901, HomePlug, ZigBee, ISO/IEC 14908-1
1. Basic Connectivity	IEEE 802.x, SAE J1772-Power Delivery, SAE 2836, IEEE P1901, HomePlug, PLC, Wireless Communication
Shared Meaning of Content	
Resource Identification	Provisioning of meters, association with customer accts
Time Synch & Sequencing	
Security and Privacy	Access Control, Authentication, Data and Messaging Integrity, Non-repudiation, Confidentiality, Privacy, Existing standards for financial transactions, TCP/IP security suite
Logging & Auditing	
Transaction State Management	
System Preservation	
Quality of Service	
Discovery & Configuration	HomePlug
System Evolution & Scalability	
Network Management [non-GWAC Stack]	
Electromechanical [non-GWAC Stack]	IEEE 1547, SAE J1772-Power Delivery

10 Appendix B: Alphabetical Standards List

The information provided is a guide to standards listed elsewhere in this document. This listing contains information available and collated at "press" time on these standards. An appropriate activity for further work would be to more fully quantify this information so it may be used in the requirements analysis (see section 4.9 Requirements Analysis). These standards were all referenced in workshop 2 Use Case analysis by the participants.

For each standard listed in this section, find summarized:

Application	A brief description of the application area for the standard
Actors	List of typical actors using the standards
Interfaces	GWAC Stack interfaces where the standard applies
Maturity	A brief description of the maturity of the standard
Category	Nature of the organization responsible for the creation and maintenance of the standard and the organization name

10.1 ANSI C12.1

Application: Performance and safety type tests for revenue meters

Actors: Revenue meter, Utility personnel

Interfaces:

Maturity: About 100 years old and continually under revision

Category: SDO – ANSI (NEMA) Accredited Standards Committee

10.2 ANSI C12.18/IEEE P1701/MC1218

Application: protocol and optical interface for measurement devices

Actors: End devices

Interfaces: handheld computer, computer, end device

Maturity: Revision 2.0 published in 2006

Category: SDO – ANSI / IEEE / MC - American National Standard designated standard developed by ANSI (NEMA) Accredited Standards Committee (will be IEEE 1701 and MC1218)

10.3 ANSI C12.19-2008/IEEE 1377-200x/MC1219-200x

Application: End Devices, including revenue metering applications for electricity, water, and natural gas, MDMS, home appliances, load control devices, sensors; the information model

Actors: End Device (including Meters, Gateways), Metering System devices, Meter Data Management System, Enterprise, Handheld Interrogator, Testing Apparatus

Interfaces: Multiple media – optical, wired, wireless, any-available; requires companion protocol for messaging and services (*e.g.*, ANSI C12.18, ANSI C12.21, ANSI C12.22) plus an underlying transport protocol (*e.g.*, TCP/IP, TCP/UDP, WiFi)

Maturity: Version 2.0 (2008) published March 2009, has certification and testing, industry-wide implementations.

Category: SDO – ANSI (NEMA) / IEEE / MC – American National Standard designated standard developed by ANSI Accredited Standards Committee, IEEE Standard, Measurement Canada Standard

10.4 ANSI C12.20

Application: Revenue metering accuracy specification and type tests

Actors: Revenue meters

Interfaces: Revenue meter, certification personnel, billing systems

Maturity: Many revisions, under ballot for next revision.

Category: SDO – ANSI (NEMA) Accredited Standards Committee

10.5 ANSI C12.21/IEEE P1702/MC1221

Application: Transport of measurement device data over telephone networks

Actors: Measurement devices

Interfaces: Measurement devices, utility communications network

Maturity: Version 2.0 published in 2006

Category: SDO – ANSI (NEMA) / IEEE / MC – American National Standard designated standard developed by ANSI Accredited Standards Committee (will be IEEE 1702 and MC1222)

10.6 ANSI C12.22-2008/IEEE P1703/MC1222

Application: End Device Tables communications over any network

Actors: End Device (including Meters), Advanced Metering Infrastructure (AMI), Head End, AMI Collector, Handheld Interrogator

Interfaces: Multiple media – optical, wired, and wireless

Maturity: Version 1.0 published March 2009, has certification and testing companion standard in development (ANSI C12.23).

Category: SDO – ANSI (NEMA) / IEEE / MC– American National Standard designated standard developed by ANSI Accredited Standards Committee (will be IEEE 1703 and MC1222)

10.7 ANSI C12.24

Application: VA calculation algorithm catalog

Actors: Measurement devices, sensors, MDMS, enterprise applications

Interfaces: Multiple

Maturity: In development

Category: SDO – ANSI (NEMA)

10.8 ANSI/CEA 709/IEC 14908 LonWorks

Application: Building Automation, HAN, AMI

Actors: Building EMS, building infrastructure devices, meters

Interfaces: Serial, Ethernet, IP – wired and wireless, Power line communication

Maturity: Has users group, has certification and testing

Category: SDO – Consumer Electronics Association (CEA) and International Standard (ISO/IEC). Also adopted by IFSF (Gasoline station standards), IEEE Passenger Rail standards, CECED Home Appliance standards

10.9 ANSI/CEA 852-2002

Application: Tunneling Component Network Protocols over Internet Protocol Channels

Actors:

Interfaces:

Maturity: 2002

Category: SDO – Consumer Electronics Association

10.10 ASN.1 (Abstract Syntax Notation)

Application: Used to serialize data; used in (e.g.) X.400

Actors:

Interfaces: Information exchange

Maturity: 1984, revised 1995 and 2002

Category: SDO—ISO/IEC/ITU-T

10.11 BACnet ANSI ASHRAE 135-2008/ISO 16484-5

Application: building automation

Actors: Building EMS, building infrastructure devices

Interfaces: Serial, Ethernet, IP – wired and wireless

Maturity: Has users group, has certification and testing

Category: SDO – National (ASHRAE/ANSI) and International Standard (ISO)

10.12 DHS Cyber Security Procurement Language for Control Systems

The National Cyber Security Division of the Department of Homeland Security (DHS) developed this document to provide guidance to procuring control systems products and services - it is not intended as policy or standard. Since it speaks to control systems, its methodology can be used with those aspects of Smart Grid systems.

Application: Guidance on procuring cyber security technologies for control systems

Actors: Control systems

Interfaces: Interfaces requiring security

Maturity: Methodology is mature; detailed security technologies require on-going updates

Category: Security

10.13 DLMS/COSEM (IEC 62056-X) Electricity metering - Data exchange for meter reading, tariff and load control.

Device Language Message Specification/Companion Specification for Energy Metering

Application: Meters

Actors: meters and head end

Interfaces: protocol

Maturity: Deployed.

Category: UA/SDO

10.14 DNP3

Application: Substation and feeder device automation

Actors: Protective relays, metering devices, cap bank controllers, switches, SCADA Master, applications

Interfaces: Serial, Ethernet, IP over TCP or UDP,

Maturity: Has security built in, has users group, has certification and testing

Category: De facto, Open, Industry Standard

10.15 EMIX (OASIS)

Application: Exchange of price, characteristics, time, and related information for markets

Actors: Market makers, market participants, quote streams, premises automation, and devices

Interfaces: Information carried by (e.g.) Demand Response and Dynamic Price communication

Maturity: Under development.

Category: Open, International SDO

10.16 FERC 888 Promoting Wholesale Competition Through Open Access Non-discriminatory Transmission Services by Public Utilities; Recovery of Stranded Costs by Public Utilities and Transmitting Utilities

Application: Regulatory Documentation for Wholesale Competition

Actors: Various across the Smart Grid

Interfaces: Various across the Smart Grid

Maturity: Issued for several years by Federal Energy Regulatory Commission

Category: Regulator

10.17 FIXML Financial Information eXchange Markup Language

Application: Data exchange for markets

Actors:

Interfaces:

Maturity: 1992. Used in financial markets including NASDAQ.

Category: Consortium maintains public domain specifications

10.18 Geospatial Information Systems

See "Open Geospatial Consortium"

10.19 GPS

Application: Global Positioning System

Actors:

Interfaces: Geospatial location, time

Maturity: Deployed

Category: Gov

10.20 HomePlug AV

Application: Entertainment Networking Content Distribution

Actors: Consumer Electronic Equipment

Interfaces: Powerline Communications with Consumer Electronics

Maturity: HomePlug AV released 2005

Category: Consortia

10.21 HomePlug Green Phy

Application: Control and Management of Residential Equipment

Actors: Whole-house control products: Energy Management, lighting, appliances, climate control, security and other devices.

Interfaces: Residential Equipment through Power Line Physical Media Communications

Maturity: Ongoing activity

Category: Consortia

10.22 IEC 60870-6 / TASE.2

Application: Inter-Control Center Communications

Actors: SCADA, EMS

Interfaces: Ethernet and IP based communications, MMS

Maturity: Implemented

Category: SDO - IEC

10.23 IEC 60929 AC-supplied electronic ballasts for tubular fluorescent lamps – performance requirements

Appendix E is known as DALI.

Application: Information to and from lighting ballasts for Energy Management Systems

Actors: Energy Management Systems, devices

Interfaces:

Maturity: Implemented

Category: SDO - IEC

10.24 IEC 61850

Application: Substation Automation and Protection, Distribution Automation, Distributed Energy Resources, Hydro Generation, SCADA to field devices

Actors: Protective relays, SCADA Master, DER, PQ Meters, fault recorders, applications

Interfaces: Ethernet and IP based communications, with on-going work for network architecture to address environments with different network constraints

Maturity: Parts into third round of update, has users group, has certification and testing

Category: SDO - IEC

10.25 IEC 61968 Common Information Model (CIM)

Application: Enterprise information representation, including transmission, distribution, back office metering

Actors: Databases, software applications

Interfaces: Application to application information exchange

Maturity: Parts in second revision, parts in first revision, parts under development, has users group, however, no certification, interoperability has not been standardized, and significant testing is required.

Category: SDO - IEC

10.26 IEC 61970 Common Information Model / Generic Interface Definition (GID)

Application: Back Office Information Systems Integration

Actors: Workstations and Desktop Systems in Control Centers

Interfaces: Workstations and Desktop Systems in Control Centers

Maturity: Has users group; however, no certification, interoperability has not been standardized, and significant testing is required

Category: SDO - IEC

10.27 IEC 62351 Parts 1-8

Application: Security for protocols, network and system management, role-based access control

Actors: Field devices, SCADA, networks

Interfaces: Field networks

Maturity: New standard, being implemented by field protocols, NSM being mapped to protocols

Category: SDO –IEC

10.28 IEC PAS 62559

Application: Requirements development method for all applications

Actors: Many

Interfaces: Many

Maturity: Pre-standard, wide acceptance by early smart grid and AMI implementing organizations

Category: SDO - International Publicly Available Specification (IEC)

10.29 IEEE C37.2

Application: Protective circuit device modeling numbering scheme

Actors: various switchgear

Interfaces: Semantic

Maturity: Mature standard

Category: SDO - IEEE

10.30 IEEE C37.111-1999

Application: Applications using Transient Data from Power System Monitoring

Actors: Power System Relays, Power Quality Monitoring Field and Workstation equipment

Interfaces: Power System Relays and Field Equipment with Transient and PQ monitoring Capabilities

Maturity: Mature IEEE Standard (COMTRADE), Work items in progress

Category: SDO - IEEE

10.31 IEEE C37.118

Application: Phasor Measurement Unit communications

Actors: Phasor Measurement Unit (PMU), Phasor Data Concentrator (PDC), Applications

Interfaces: Ethernet, IP, and serial based communications

Maturity: Published version 2.0 in 1005 (was IEEE Std 1344-1995), no certification or testing

Category: SDO - IEEE

10.32 IEEE C37.232

Application: Naming Time Sequence Data Files

Actors: Substation Equipment requiring Time Sequence Data

Interfaces: Substation Equipment communications

Maturity: Released as IEEE Standard

Category: SDO - IEEE

10.33 IEEE 802 Family

This includes 802.1, 802.2, 802.3, 802.11 and subparts, 802.15.4, 802.15.4g, 802.16 and subparts, 802.20.

- 802.1 Standard for Local and Metropolitan Area Networks (MAC/PHY layers)
- Station and Media Access Control Connectivity Discovery
- 802.2 No reference material found
- 802.3 Carrier Sense Multiple Access with Collision Detection Physical Layer
- 802.11 Wireless LAN Medium Access Control and Physical Layer (MAC/PHY). Subparts are different network speeds and MAC/PHY characteristics. Commonly called WiFi. IEEE 802.11b data rate is 11Mbps, IEEE 802.11g data rate is 54Mbps, IEEE 802.11i specifies security
- 802.15.1 Wireless Personal Area Networks (WPAN). Base for Bluetooth
- 802.15.4 Wireless Personal Area Networks (WPANs). Base for ZigBee and others
- 802.16 Fixed Broadband Wireless access systems. Base for WiMAX
- 802.20 No reference material found

Application: Networking

Actors: Hardware devices, network interfaces

Interfaces: Hardware

Maturity: Mature, deployed, certification. Newer/later numbers are somewhat less mature

Category: SDO - IEEE

10.34 IEEE 803

Application: Recommended Practice for Unique Identification in Power Plants

Actors:

Interfaces:

Maturity: Withdrawn/archived. Originally 1983.

Category: SDO - IEEE

10.35 IEEE 1159.3

Application: Communications with Distributed Energy Resources

Actors: Distributed Energy Resources and Master Station Controls

Interfaces: Various for DER equipment

Maturity: Issued as IEEE Standard

Category: SDO - IEEE

10.36 IEEE 1379-2000

Application: Substation Automation

Actors: Intelligent Electronic Devices (IEDs) and remote terminal units (RTUs) in electric utility substations

Interfaces: IED and RTU communications

Maturity: Available as IEEE Standard

Category: SDO - IEEE

10.37 IEEE 1547

Application: Physical and Electrical Interconnections between utility and distributed generation (DG); subparts for test procedures (1547.1), interconnection (1547.2) and monitoring, information exchange and control (1547.3)

Actors: Customers, vendors, utilities

Interfaces: Point of Common Coupling (PCC)

Maturity: Reaffirmed in 2008, Implementations by utilities, vendors, and their customers

Category: SDO – IEEE

10.38 IEEE 1588

Application: Time Management and Clock Synchronization

Actors: Various across the Smart Grid, equipment needing consistent time management

Interfaces: Various across the Smart Grid

Maturity: IEEE 1588-2008 Now Available from IEEE SA, additional work in progress

Category: SDO - IEEE

10.39 IEEE 1686-2007

Application: The IEEE 1686-2007 is a standard that defines the functions and features to be provided in substation intelligent electronic devices (IEDs) to accommodate critical infrastructure protection programs. The standard covers IED security capabilities including the access, operation, configuration, firmware revision, and data retrieval.

Actors:

Interfaces:

Maturity: Does not support strong authentication, required by FERC 706 to be included in future revision of CIP 002-009. (See NIST SP 800-63)[added by Stanley A. Klein during comment period]

Category: SDO – IEEE

10.40 IEEE P1901

Application: Smart Grid Physical Communications Broadband over Powerline (MAC/PHY)

Actors: Various across the Smart Grid

Interfaces: Potentially applicable across the Smart Grid

Maturity: P1901 Approved as Baseline standard December 2008

Category: SDO-IEEE

10.41 IEEE P2030

Application: Smart Grid Infrastructure

Actors: Various across the Smart Grid

Interfaces: Potentially applicable to across the Smart Grid

Maturity: First meeting June 2007. States will build on prior IEEE work

Category: SDO-IEEE

10.42 IETF Standards

See "Networking Profiles Standards and Protocols."

10.43 Internet-Based Management Standards (DMTF, CIM, WBEM, ANSI INCITS 438-2008, IPDR)

Application: Data Communications Networking, Routing, Addressing, Multihoming, Faults, Configuration, Accounting, Performance, Security and other management

Actors: Routers, Intermediate and Edge Devices

Interfaces: Routers, Intermediate and Edge Devices

Maturity: Broadly deployed. Support in NICs for secure distributed management.

Category: SDO – National Standard ANSI INCITS 438-2008. DMTF Server Management listed in DOE/EPA Energy Star for Servers

10.44 Internet-Based Management Standards (SNMP vX)

Application: Data Communications Networking, Routing, Addressing, Multihoming, Fault, Configuration, Accounting, Performance, Security and other management

Actors: Routers, Intermediate and Edge Devices

Interfaces: Routers, Intermediate and Edge Devices

Maturity: SNMPv1 mature and in widespread use, SNMP v3 added security features and released in 2003 as Standard.

Category: SDO – Internet Engineering Task Force (IETF)

10.45 ISA SP99

Application: Cyber security mitigation for industrial and bulk power generation stations. International Society of Automation (ISA) Special Publication (SP) 99 is a standard that explains the process for establishing an industrial automation and control systems security program through risk analysis, establishing awareness and countermeasures, and monitoring and improving an organization's cyber security management system. Smart Grid contains many control systems that require cyber security management.

Actors: Industrial automation systems

Interfaces: Affects various interfaces in an industrial automation system

Maturity: Published and in use

Category: SDO – ISA

10.46 ISA SP100

Application: Wireless communication standard intended to provide reliable and secure operation for non-critical monitoring, alerting, and control applications specifically focused to meet the needs of industrial users.

Actors: Industrial meters and edge devices

Interfaces: ISA100.11a provides extensions to the 802.15.4 MAC layer and defines network layer through application layer functions and services.

Maturity: ISA 100.11A is in final draft form, being balloted for approval. Projected completion: June 2009.

Category: SDO – ISA

10.47 ISO27000

Application: Security Management Infrastructure

Actors: Various across IT environments, could be applied to field systems

Interfaces: Potentially applicable to many Smart Grid systems

Maturity: 27000 series standards are in their infancy, identified related standards in British and other SDOs

Category: SDO- International Standard ISO

10.48 ISO/IEC DIS 14908 Open Data Communication in Building Automation, Controls and Building Management (LonWorks)

Application: Building Automation, HAN, AMI

Actors: Building EMS, building infrastructure devices, meters

Interfaces: Serial, Ethernet, IP – wired and wireless, Power line communication

Maturity: Has users group, has certification and testing

Category: SDO – National (ANSI) and International Standard (ISO/IEC). Also adopted by IFSF (Gasoline station standards), IEEE Passenger Rail standards, CECED Home Appliance standards

10.49 ISO/IEC 15045 Home Electronic Systems Gateway

Application: The Residential Gateway (RG) is a device of the Home Electronic System (HES) that connects home network domains to network domains outside the house. It supports communications among devices within the premises, and among systems, service providers, operators, and users outside the premises.

Actors: Residential Gateway, HAN devices, non -premise systems

Interfaces: Interfaces between the RG and other devices and systems

Maturity: Published 2004

Category: HAN Gateways – SDO – ISO/IEC

10.50 ISO/IEC TR 15067-3 Home Electronic Systems (HES) application model -- Part 3: Model of an energy management system for HES

Application: Home Electronic Systems (HES) application model -- Part 3: Model of an energy management system for HES

Actors: Energy management system, HAN devices

Interfaces: HAN

Maturity: Published 2000

Category: HAN – SDO – ISO/IEC

10.51 ISO/IEC 18012 home electronic systems - guidelines for product interoperability

Application: Specifies requirements for product interoperability in the area of home and building automation systems, with sufficient detail needed to design interoperable Home Electronic System products.

Actors: HAN devices

Interfaces: HAN

Maturity: Published 2004

Category: HAN – SDO – ISO/IEC

10.52 ISO/IEC 24752 user interface – universal remote control

Application: Facilitates operation of information and electronic products through remote and alternative interfaces and intelligent agents. The series of standards, ISO/IEC 24752: 1-5, defines a framework of components that combine to enable remote user interfaces and remote control of network-accessible electronic devices and services through a universal remote console (URC)

Actors: User interface devices

Interfaces: Language and template for user interfaces

Maturity: Published in 2008

Category: User Interface – SDO – ISO/IEC

10.53 MultiSpeak v4.0

Application: Integration for utilities, vendors, and service providers. Supports enterprise integration including the transmission, distribution, metering, demand response, and procurement domains.

Actors: Transmission and distribution components, meters, software applications, and service providers.

Interfaces: Common semantics, message structure and business process support for application to application information exchange and inter-application exchange of control signals

Maturity: Three previous versions. Version 4.0 has been issued, but development of future builds of Version 4.0 is on-going. Has user group. Has extensive training for adopters and integrators. Has had robust certification testing program since 2001

Category: Consortium—National Rural Electric Cooperative Association

10.54 NAESB OASIS (Open Access Same-Time Information Systems)

Application: Utility business practices

Actors: Utility and market operators

Interfaces: Business process

Maturity: Mature, has certification

Category: SDO—North American Energy Standards Board

10.55 NAESB WEQ 015 Business Practices for Wholesale Electricity Demand Response Programs

Application: Utility business practices for Demand Response

Actors: Utility and market operators

Interfaces: Business process

Maturity: Released

Category: SDO—North American Energy Standards Board

10.56 Networking Profiles Standards and Protocols

Recent workshops and prior work by the power industry has needed to adopt open standards for networking profiles. The Internet Protocols and standards in widespread use are supported by a significant number of documents. There is no single document that defines a networking profile for the use of the Internet Protocol. In addition the power industry will need a variety of different profiles to meet different requirements.

NIST Special Publication 500-267[16] provides an example of profiles that several Internet Protocols and their capabilities satisfying the requirements of Smart Grid applications.

10.57 Network Standards

This list represents the collections of communications networking standards: 1xRTT, 3GPPP/LTE, CDMA, DLS, EDGE, EvDO, GPRS, GSM, HSDPA, POTS, RDS, SMS.

10.58 NERC CIP 002-009

The National Electric Reliability Corporation (NERC) Critical Infrastructure Protection (CIP) is a series of standards are directly relevant to the bulk power system critical cyber assets. CIP-002 states the means by which a critical cyber asset is identified. The remaining standards identify security management controls, personnel and training, electronic security perimeters, physical security of cyber assets, systems security management, incident handling and recovery planning.

10.59 NIST FIPS 140-2

Application: U.S. government computer security standard used to accredit cryptographic modules.

Actors: All actors requiring security

Interfaces: Interfaces requiring security

Maturity: Security levels are used extensively

Category: Security –Gov NIST/ITL, IETF

10.60 NIST FIPS 197 AES

Application: Cryptographic standard: Advanced Encryption Standard (AES)

Actors: Actors using AES encryption

Interfaces: Interfaces using AES encryption

Maturity: Used widely

Category: Security –Gov NIST/ITL, IETF

10.61 NIST SP 800-53

Application: NIST Special Publication 800-53 is a standard developed as a foundational level of security controls required for federal information systems. The standard provides a method for tailoring security controls to an organization. Appendix I of the document provides guidance for tailoring to industrial control systems (ICS).

Actors: Federal information systems

Interfaces: Interfaces between federal information systems

Maturity: Widely used by federal information systems

Category: Security –Gov NIST/ITL not a standard

10.62 NIST SP 800-82

Application: NIST Special Publication 800-82 Guide to Industrial Control Systems (ICS) Security is a draft standard covers security guidance for Supervisory Control and Data

Acquisition (SCADA) systems, distributed control systems and other control system configurations. The standard defines ICS characteristics, potential threats and vulnerabilities to these types of systems, developing an ICS security program, network architecture and security controls.

Actors: Actors in distributed control environments

Interfaces: Interfaces in distributed control environments

Maturity: Just released

Category: Security – Gov NIST/ITL not a standard

10.63 oBIX

Application: Building automation, access control

Actors: Building EMS

Interfaces: Web services to embedded systems

Maturity: International deployment, but early adoption. Open source clients and servers available; identified roadmap to include scheduling component.

Category: Open specification, OASIS (SDO-International), next stage is OASIS Standard

10.64 OGC Standards

See “Open Geospatial Consortium Standards.”

10.65 Open Automated Demand Response (OpenADR)

Application: Demand response

Actors: Utility/ISO operations, DRAS server (a system introduced under OpenADR to communicate supply-side DR signals), customer EMS/device

Interfaces: Utility/ISO to aggregation server (using SOAP), aggregation server to customer EMS/device (using SOAP or REST), various configuration/management interfaces

Maturity: V1.0 specification published in 2009 as a CEC report, used in some California DR programs with commercial and industrial customers. OpenADR encourages customer choice and enhances grid reliability through pricing-based information. OpenADR is the basis for the developing Energy Interoperability TC.

Category: Open specification, contributed to OASIS (SDO – International) and UCAIug (Industry Consortia Requirements and User Group) for further development. Under development in OASIS.

10.66 Open Geospatial Consortium Standards

Application: Geospatial and location based services, Geographical Information System (GIS) standards.

Actors: Spatial coordinates (three dimensional)

Interfaces: Various

Maturity: Wide international deployment, integrated with many technologies including building information systems, emergency management systems, sensor webs and transducer control, and location databases

Category: Open specification, Open Geospatial Consortium, International Consensus Standards

10.67 OSI (Open Systems Interconnect) Networking Profiles

Application: Data Communications Networking, Routing, Addressing, Multihoming, Mobility and other networking services supporting functions

Actors: Routers, Intermediate and Edge Devices at layers 3 through 7 of OSI BRM

Interfaces: Routers, Intermediate and Edge Devices

Maturity: Developed but little market share, technical issues remaining

Category: SDO – International Organization for Standardization (OSI CLNP/TP4)

10.68 OSI-Based Management Standards (CMIP/CMIS)

Application: Application: Data Communications Networking, Routing, Addressing, Multihoming, Fault, Configuration, Accounting, Performance, Security and other management

Actors: Routers, Intermediate and Edge Devices

Interfaces: Routers, Intermediate and Edge Devices

Maturity: In widespread use in telecommunications infrastructure, mature technology

Category: SDO – International Organization for Standardization (OSI)

10.69 RFC 3261 SIP: Session Initiation Protocol

Application: Session Initiation Protocol (SIP) is an application-layer control (signaling) protocol for creating, modifying, and terminating sessions with one or more participants.

Actors: cross-cutting

Interfaces: syntax, semantic

Maturity: IETF Internet standards track protocol

Category: SDO - IETF

10.70 SAE J1772 Electrical Connector between PEV and EVSE

Application: Electrical connector between Plug-in Electric Vehicles (PEVs) and Electric Vehicle Supply Equipment (EVSE)

Actors: PEVs, EVSEs

Interfaces: Interface between PEV and EVSE

Maturity: Under development

Category: PEVs – SDO - SAE

10.71 SAE J2293 Communications between PEVs and EVSE for DC Energy

Application: Communications between PEVs and EVSE for DC energy flow

Actors: PEV, EVSE

Interfaces: Interface between PEV and EVSE

Maturity: Re-issued for DC energy flow interactions – superseded for other communications

Category: PEVs - SDO - SAE

10.72 SAE J2836/1-3 Use Cases for PEV Interactions

Application: J2836/1: Use Cases for Communication between Plug-in Vehicles and the Utility Grid. J2836/2: Use Cases for Communication between Plug-in Vehicles and the Supply Equipment (EVSE). J2836/3: Use Cases for Communication between Plug-in Vehicles and the Utility Grid for Reverse Power Flow

Actors: PEV, EVSE, Utility Grid

Interfaces: PEV to EVSE to Utility

Maturity: Under development

Category: PEV - SDO - SAE

10.73 SAE J2847/1-3 Communications for PEV Interactions

Application: J2847/1 Communication between Plug-in Vehicles and the Utility Grid. J2847/2 Communication between Plug-in Vehicles and the Supply Equipment (EVSE). J2847/3 Communication between Plug-in Vehicles and the Utility Grid for Reverse Power Flow

Actors: PEV, EVSE, Utility Grid

Interfaces: PEV to EVSE to Utility

Maturity: Under development

Category: PEV - SDO – SAE

10.74 UCAIug AMI-SEC System Security Requirements

Application: The AMI Security (AMI-SEC) System Security Requirements (SSR) are a set of high-level requirements ratified by the utility user community in the AMI-SEC Task Force of the UCA International Users Group (UCAIug) and developed by ASAP (AMI Security Acceleration Project). These requirements are directly relevant to Smart Grid AMI and other applications. Utilities use these requirements to procure equipment. Vendors use the SSR in Smart Grid product development.

Actors: cross-cutting

Interfaces: Security

Maturity: published reference

Category: De facto, Open, Industry Consortia Requirements Specification (UCAIug)

10.75 UCAIug OpenHAN System Requirements Specification

Application: Home Area Network device communication, measurement, and control

Actors: Energy Service Interface, HAN Devices

Interfaces: Technology and GridWise Architecture Council (GWAC) layers 1-3 independent

Maturity: First version, no certification or testing

Category: De facto, Open, Industry Consortia Requirements Specification (UCAIug)

10.76 W3C EXI (Efficient XML Interchange)

Application: Tokenized/compressed transmission for XML

Actors: Any

Interfaces: Format

Maturity: Second Public Working Draft.

Category: Open, SDO – W3C

10.77 W3C Simple Object Access Protocol (SOAP)

Application: XML protocol for information exchange

Actors: Any

Interfaces:

Maturity: Standard. (W3C Recommendation). Version 1.2, User groups

Category: Open, SDO – W3C

10.78 W3C WSDL Web Service Definition Language

Application: Definition for Web services interactions

Actors: Any

Interfaces:

Maturity: Standard (W3C Recommendation), Version 2.0, User groups

Category: Open, SDO – W3C

10.79 W3C XML eXtensible Markup Language

Application: Self-describing language for expressing and exchanging information

Actors: Any

Interfaces:

Maturity: Standard (W3C Recommendation), Version 1.0 (4^{th} Edition), and Version 1.1 (2^{nd} Edition), User groups

Category: Open, SDO – W3C

10.80 W3C XSD (XML Schema Definition)

Application: Description of XML artifacts, used in WSDL (q.v.) and Web Services as well as other XML applications.

Actors: All

Interfaces:

Maturity: Standard (W3C Recommendation), Implemented, Version 1.0. Version 1.1 in progress.

Category: Open, SDO – W3C

10.81 WS-Calendar (OASIS)

Application: XML serialization of IETF iCalendar for use in calendars, buildings, pricing, markets, and other environments

Actors: Any

Interfaces:

Maturity: Under development (Calendar Consortium, IETF)

Category: Open, SDO - International

10.82 WS-Security

Application: Toolkit for building secure, distributed applications. Broadly used in eCommerce and eBusiness applications. Fine-grained security. Part of extended suite using SAML, XACML, and other fine-grained security standards.

Actors: Any

Interfaces:

Maturity: Standard (OASIS), Version 1.1 (Feb 2006), Version 1.0 (March 2004), Implemented, User group

Category: Open, International SDO (OASIS)

10.83 ZigBee/HomePlug Smart Energy Profile 2.0

Application: Home Area Network (HAN) Device Communications and Information Model

Actors: Meter / HAN Gateway, HAN Device

Interfaces: Multiple media – wireless and Power Line Carrier (PLC)

Maturity: Version 1.0 published by ZigBee Alliance, has users group, has certification and testing

Category: De facto, Open, Industry Consortia Specification

10.84 Internet-Based Management Standards (COPS)

Application: Data Communications Networking, Routing, Addressing, Multihoming, Fault, Configuration, Accounting, Performance, Security and other management

Actors: Routers, Intermediate and Edge Devices

Interfaces: Routers, Intermediate and Edge Devices

Maturity: COPS mature and in widespread use in utility, telecommunications and cable industries

Category: SDO – Internet Engineering Task Force (IETF)

***** Additional Standards Mentioned During Comment Period**

10.85 HD_PLC

Application: Networking and Smart Grid broadband physical communications over powerlines

Actors: telecom and power utility equipment, consumer electronics, meter, HAN gateway, whole-house control products (energy management, appliances, climate control, etc.), PEVs, and various others across the Smart Grid

Interfaces: Potentially applicable across the Smart, including Residential Equipment operating over power lines.

Maturity: Released 2006.

Category: Consortia

10.86 FERC 706

Application: Acceptance and desired/mandated changes to CIP 002-009

Actors: Various across the Smart Grid (bulk power)

Interfaces: Various across the Smart Grid (bulk power)

Maturity: Formally accepted CIP 002-009 under Energy Policy Act of 2005. Changes in process at NERC. First group of changes (Version 2 of CIP 002-009) approved in May 2009 by NERC Board

Category: Regulator

10.87 FERC 889 Open Access Same Time

Information System and Standards of Conduct Application: Issued at same time as FERC 888. Defines information systems for open transmission access. Also defines prohibited information flows (Standards of Conduct) among system operators and market participants.

Actors: Various across the Smart Grid

Interfaces: Various across the Smart Grid

Maturity: Issued for several years by Federal Energy Regulatory Commission

Category: Regulator

10.88 IEC 61400-25

Application: Applies 61850 to wind power

Actors: Wind turbines, other wind power and wind farm devices

Interfaces: Adds communications mappings beyond those currently in IEC-61850, including a mapping to W3C Web Services (SOAP)

Maturity: Basic functionality adopted. Some volumes (e.g., condition monitoring) still being developed. Has users group.

Category: SDO – IEC

10.89 IEEE PC37.238

Application: Companion standard (profile) for applying IEEE 1588 in electric power systems

Actors:

Interfaces: Interfaces between time standard systems and field equipment

Maturity: In development

Category: SDO-IEEE

10.90 IEEE PC37.239 Common Format for Event Data Exchange (COMFEDE)

Application: XML Schema for event data. Intended to be compatible with IEC61850 and to define format for event data

Actors:

Interfaces: Equipment detecting events, equipment/systems handling and analyzing event data

Maturity: In development

Category: SDO-IEEE

10.91 NIST SP 800-63 Electronic Authentication Guideline

Application: Provides useful information on strong authentication.

Actors: Various

Interfaces: Various

Maturity: Written as Federal Guideline. Unsuitable for citation in standard, such as IEEE 1696-2007. Requires revision to become suitable for citation to support compliance with FERC 706.

Category: NIST Guideline

10.92 WS-Addressing

Application: Supports message IDs, endpoint references, and stateful interactions

Actors: Various

Interfaces: Various

Maturity: Maturity: Standard (W3C Recommendation), Implemented, Version 1.0.

Category: Open, Industry Consortium

10.93 Z-Wave

Application: Z-wave is a short-range, wireless communications technology that is the accepted standard for wireless home control and automation.

Actors: Meter, HAN Gateway, HAN devices

Interfaces: Wireless

Maturity: Developed and maintained by the Z-Wave Alliance, some manufacturers are developing products with a Z-wave interface, has been deployed in some customer homes

Category: Proprietary, Industry Consortia Specification

10.94 DOCSIS Cable Modem

Application: Communications to Customer Premises

Actors: Customer Premise Cable Modems, Cable Head End

Interfaces: Between customer premise cable modems and the cable

Maturity: Devices in the MarketPlace, Testing and Certification in Place

Category: De facto, Open, Industry Consortia Specification

10.95 ITU-T G.hn

Application: Networking and Smart Grid broadband physical communications over powerlines, coaxial cables, phone lines and CAT-5 (MAC/PHY)

Actors: Telecom and power utility equipment, consumer electronics, meter, HAN gateway, whole-house control products (energy management, appliances, climate control, etc.), PEVs, and various others across the Smart Grid

Interfaces: Potentially applicable across the Smart Grid on multiple wiring types, including: Powerline, coaxial, telephone wire.

Maturity: Physical Layer (G.9960) received consent on Dec 2008. Data Link Layer expected to receive consent in Oct 2009

Category: SDO - ITU-T

10.96 IEC 61400-25-1 through 61400-25-5

Application: Wind power communications

Actors: Intelligent Electronic Devices (IEDs) and remote terminal units (RTUs) in electric utility

Interfaces: Multiple media – wireless and Power Line Carrier (PLC) and wired Ethernet

Maturity: Version 1.0 published 2006-2008

Category: SDO - IEC

10.97 IEC 61499

Application: IEC 61850 interchange

Actors: Any

Interfaces: Various
Maturity: Version 1.0 published 2005
Category: SDO - IEC

11 Appendix C: Requirements, Standards Gaps, and Discussion Issues for the Action Plan

The following tables of requirements and standards gaps were derived primarily from the results of the Smart Grid Workshop #2, with clarifications, edits, and a few additions from the Project Team. These tables form the basis for the NIST Action Plan described in Section 6 and provides the detailed actions that NIST should promote. In addition to the specific requirements and standards gaps, some issues were identified that need further discussion before concrete actions on standards can be taken.

The complete results from the Workshop #2 are shown in the Gaps Assessment Spreadsheet in a separate annex to this document.

11.1 Action Items Related to Demand Response and Markets

11.1.1 Requirements and Standards Gaps Related to Demand Response and Markets

The following requirements and related gaps in standards were identified, where the activities can be commenced (or have already commenced) relatively quickly, after brief discussions with the organizations identified.

Requirements	Standards	Gaps	Who	GWAC Layer	Domains	Actors/ Interface
Common Model for Price As PEVs move from area to area, a common interoperable model for price and energy characteristics and time for dynamic pricing across areas, markets, providing a consistent integration model.	NAESB, EMIX, OpenADR, IEC 61850-7-420, SEP 2, others	Common interoperable price formats, characteristics, time, and units are needed to abstract away the complexities of markets to actionable information for the PEV.	SAE, IEC, NEMA, NAESB, OASIS, ZigBee	Semantic Syntactic	Customer Operations Services Markets	PEV Customer EMS Commerc'l Industrial Generation

Requirements	Standards	Gaps	Who	GWAC Layer	Domains	Actors/ Interface
Provide energy usage information to Customer EMS: Customers and/or their energy management systems would like or require energy usage information in order to help make decisions, such as what parameters to set for demand response, whether to change DR plans, or whether to take specific actions now in anticipation of future DR events.	OpenHAN Smart Energy Profile ANSI C12.19	Open access protocol needed for timely access to metering information by the premises management system	OpenHAN, ZigBee/HomePlug Alliance, NEMA	Object Modeling Messaging	Customer	Meter, Customer EMS
Extend IEC 61850-7-420 standard for additional DER: In order for DR signals to interact appropriately with all types of DER devices, additional types of DER equipment need to be modeled. These models will need to take into account how the DER could be used for demand response and/or load management, which DER information can be simple extensions to existing DER models, and which need new development.	IEC 61850-7-420, EnergyInterop, Smart Energy Profile	Currently IEC 61850-7-420 for DER covers wind (actually IEC 62400-25), photovoltaic systems, fuel cells, diesel generators, batteries, and combined heat and power (CHP). These models need to be extended to include updates or new models of DER devices.	IEC TC57 WG17, NEMA, OASIS, ZigBee, Policy	Policy Semantic Syntactic Interoperability	Operations Service Provider Customer	Transmission EMS Distribution DMS Aggregators DER
Extend IEC 61968 and MultiSpeak standards for DER: IEC 61968 needs DER models, but should be harmonized with the existing DER object models in IEC 61850-7-420, as well as all on-going DER 61850 development. IEC 61850-7-420 has architectural issues to be addressed.	IEC 61968-xx, eBusiness, others TBD	IEC 61968 needs DER models to carry the IEC 61850-7-420 models of DER and PEV to integrate with the enterprise. Address issues in IEC 61850-7-420,	IEC TC57 WG14	Semantic Syntactic interoperability Network	Operations DER	Distribution DMS

11.1.2 Discussion Issues Related to Demand Response and Markets

The following table lists the topics that need to be discussed and resolved before the appropriate standards can be developed or extended, usually to ensure that standards which were already developed are used (rather than re-inventing the wheel) or that the most appropriate standard is selected to extend.

Domain	Discussion Issues	Standards Potentially involved	Who
Customer	**Make available pricing and market information**: Market information must be delivered across all domains: Generation, market, DER, T&D, customer, etc. (Wholesale and retail real-time pricing available to everyone.) IEC 61970, IEC 61968, and IEC 61850-7-420 need updates for handling prices. OpenADR needs to be vetted as if it becomes a standard, Smart Energy Profile provides communications at the Customer site.	FERC's OASIS, IEC CIM for Markets, IEC 61850-7-420, OpenADR, Smart Energy Profile, MultiSpeak	FERC/PUC IEC TC57 WG13, WG14, WG16, WG17 SAE, OASIS
Customer	**Consumer registration of out-of-the-box appliances**;: open up and authenticate on someone's smart home network; how to authenticate – how will this happen in future	IEC 61850-7-420, OpenADR, Smart Energy Profile	IEC TC57, NEMA, OASIS, SG Users Group

11.2 Action Items for Wide Area Situational Awareness

11.2.1 Requirements and Standards Gaps Related to Wide Area Situational Awareness

The following requirements and related gaps in standards were identified, where the activities can be commenced (or have already commenced) relatively quickly, after brief discussions with the organizations identified.

Requirements	Standards	Gaps	Who	GWAC Layer	Domains	Actors/ Interface
Extend IEC 61850 standard from substation to control center: Since the data in the substation uses the IEC 61850 information model, this data should be reported to the control center using the same information model. This will also simplify the harmonization efforts between the models of data collected from the field and the CIM.	IEC 61850	IEC 61850 models all the equipment and functions in the substation. If those models could be brought back to the control center, then this same powerful information model would be used for SCADA and other applications, thus minimizing translations and expensive and data maintenance activities that sometimes lead to insecure and/or unsafe situations.	IEC TC57 WG10 & WG19, MultiSpeak Initiative	Object Modeling Messaging	Operations	Substations , SCADA systems, EMS, DMS

Requirements	Standards	Gaps	Who	GWAC Layer	Domains	Actors/ Interface
Extend IEC 61850 standard between substations: Some protective relaying and certain other functions require communications between substations, but still rely on legacy, or proprietary protocols. Since IEC 61850 is used within substations, the same protocol should be used between substations.	IEC 61850	IEC 61850 needs to be expanded to handling substation-to-substation protective relaying and other information exchanges.	IEC TC57 WG10	Messaging Networkin g	Operations Transmission Distribution	Protective relays
Extend IEC 61970 standards for sharing CIM data: The IEC 61970 CIM power system needs to be extended to include 3 phase network modeling. The IEC 61970 abstract services need to be updated to use web service technology. Also, while the abstract services are defined generically, IEC 61970 does not sufficiently specify how these services should be used to access data from applications involved with WASA.	IEC 61970	Existing IEC 61970 abstract service definitions should be defined using web service technology such as IEC 62541 to enable model driven access to CIM data.	IEC TC57 WG13	Messaging	Transmission	EMS
Extend the time synchronization standard: Time synchronization to millisecond based on GPS clock is needed by Phasor Measurement Units (PMUs) for accurate timestamping. Specifically IEEE 1588, Network Time Protocol (NTP), and IRIG-B need to ensure they can handle this time synchronization, and mappings to IEC 61850 and DNP3 need to ensure they can transport the results.	IEEE 1588, Network Time Protocol, IRIG-B	Timestamps at the accuracy required for PMU's are not specifically covered in the time protocols.	NASPI-PSTT IEC TC57 WG10, IEEE PSRC H7	Time Synch & Sequencing	Operations	Field sensors
Develop calibration rules for PMUs: Standard rules for calibration & update of measurement devices, common tolerances, depending on application	No Standards Exist	Standard Needed for PMU, Real Time Rating System	NASPI/NERC/ NIST IEEE/IEC TC95	Business Objectives	Operations	Field sensors

Requirements	Standards	Gaps	Who	GWAC Layer	Domains	Actors/ Interface
Map IEC 61850 objects to DNP3 for legacy interfaces: For transition between using DNP3 and IEC 61850, the IEC 61850 object models need to be mapped to DNP3 and vice versa.	DNP3 - Application Layer	IEC 61850 object models need to be mapped to DNP objects	IEC TC57 WG03	Object Modeling	Operations	T&D SCADA Field Equipment
Exchanging both transmission and distribution power system models: As it becomes increasingly critical for transmission and distribution operations to have clear and accurate information about the status and situations of each other, they need to be able to exchange their respective T&D power system models including the merging of relevant databases for interconnected power systems.	IEC 61970 & IEC 61968-11 IEC61850, MultiSpeak	Standards for both transmission (IEC 61970 552-4) and distribution (IEC 61968 - 13) model exchange have been defined. Previous EPRI sponsored Interoperability tests have tested the exchange of transmission and distribution system network modeling data using the CIM XML format. These efforts should be expanded to include exchange of three phase network models using CIM XML and also include a wider set of applications including but not limited to EMS, DMS, and GIS	IEC TC57 WG13 & WG14, IEEE/ NASPI/ NERC/ FERC, MultiSpeak Initiative	Object Modeling Messaging	Operations	Cross-utility T&D EMS & DMS
Broad discussion on functional integration of EMS, DMS, & MOS: As transmission operations and distribution operations become increasingly intermeshed with electricity markets, both to set prices and to respond to prices, there needs to be functional integration of EMS and DMS functions and market operations systems (MOS) and corresponding information exchange. At the same time, rules and regulations for these information exchanges between unbundled entities need to be established and monitored.	IEC 61970, IEC 61968, IEC61850, DNP3, ANSI C37.1, ANSI C37.118, ANSI C12.19-12.22, IEC 60870-6 (ICCP), MultiSpeak	There is a lack of coordination or understanding on to achieve functional integration of EMS, DMS, and MOS systems.	IEC TC57 WG13 & WG14 & WG16, NEMA, MultiSpeak Initiative	Policy Object Modeling Messaging	Operations Market	T&D EMS & DMS Market Operations

Requirements	Standards	Gaps	Who	GWAC Layer	Domains	Actors/ Interface
Integration of the relay settings and other field component management functions: Applications that perform an automated verification of the different settings of the components of a power system will be essential in the future to prevent system failures due to miss configurations that may create blackouts.	IEC 61850	One of the required pieces to enable such applications is the standardization of relay settings and other field component management functions. One first step in that direction is the work currently done within IEEE PSRC, H5a working group.	IEEE PSRC, IEC TC57		Operations	Protective relays
Object models of bulk generation plants: Due to the fact that IEC 61850 is today and for the foreseeable future the communications protocol for integration of power system equipment, object models of power plants will need to be developed**.**	IEC 61850	Bulk generation plants are not modeled in IEC 61850. Workshops with power plant domain experts from utilities involved in Smart Grid development projects and IEC 61850 modeling experts can be used in order to determine and document the functional and modeling requirements.	IEC TC57, bulk generation experts		Operations	Bulk generation, energy manageme nt systems

11.2.2 Discussion Issues for Wide Area Situational Awareness

The following table identifies the issues that require further discussion before any specific work on the relevant standards can be undertaken. Often this discussion involves the identification and agreement on exactly which of the existing standards should be extended to cover the issue, while other discussions reflect resolving issues in on-going standards activities.

Domain	Discussion Issues	Standards Potentially involved	Who
Operations	**Discuss cross-utility handling of major events:** Major events, like the blackout of August 2003, could have been avoided if adequate event information had been provided to the right place within the appropriate time frame. If (and when) a major event does occur, there is an additional need to have a mechanism or system to support the restoration of communication systems across utilities, to federal and state agencies, and to first responder organizations.	NASPInet, ANSI C37.118 IEC 62351-7, MultiSpeak	NAESB, IEC

Domain	Discussion Issues	Standards Potentially involved	Who
All Domains	**Systems and Network Management Infrastructure Development for the Smart Grid** The Smart Grid represents a System of Systems/Networks of Networks that must be able to operate across traditional industry boundaries such as States, Service Territories, and Consumers. Development of an open systems based infrastructure that can effectively manage the envisioned networks of systems is a significant challenge that has not been resolved. The Architecture of the networks is intimately connected with its management infrastructure and this issue needs to be investigated systematically. The experts from the fields of networking, systems management, cyber security, and communications technology need to investigate Smart Grid requirements emerging from the NIST Roadmap and Workshops and industry projects as a starting place to examine the issues surrounding Management infrastructure. The topic is multidisciplinary and will take in depth work to fully understand the plausible Smart Grid build out and the scenarios for network scaling and growth. The management functions include but are not limited to Fault, Configuration, Accounting, Performance, Security, and Applications. The topic overlaps significantly with Security issues but it includes many functions that are not directly security.	OSI Management Standards: CMIP, CMIS Internet Based Management Standards: SNMP Vx Data Management and Directory Services Standards Distributed Desktop Management Task Force Standards: Common Information Model Applications Management Standards Related IEC and IEEE Management Standards associated with key networking and end device communications Other	ISO/OSI, IETF, ITU, IEEE, IEC and Associated Working Groups: UCA International Users Group Other
Operations Customer	**Detailed architecture to be used for T&D operations, down to the customer:** A high level architecture was identified in this NIST roadmap document, but it needs to be extended to the actual transmission and distribution operations, including the interactions with customers who are participating in demand response, own DER units, operate PEVs, and may have electric storage facilities..What additional standards need to be developed or extended in order for systems and tools to process and aggregate data from across the grid to make it actionable? What information exchanges are needed to coordinate across all levels of the energy system, behavioral models and data sharing (i.e. between transmission, distribution, consumer, system planning, etc. including commercial data, i.e. AMI data)	Although applications should not be standardized, the input/output can be provided by many standards. However, there are both too few and too many standards to chose from. Which should be used for which functions?	IEEE/ NASPI/ NERC/ FERC UCA SG Users Group, IEEE 2030, IEC TC57 WGs, NEMA

Domain	Discussion Issues	Standards Potentially involved	Who
Operations	**Development of a common weather information model:** A common weather information model needs to be developed that includes a format for observations as well as for forecasts. This model could be used when querying local weather stations and even personal weather systems. The Digital Weather Markup Language (DWML) is an existing specification developed by the National Oceanic and Atmospheric Administration (NOAA). IEC 61850 has models for retrieving weather data from field equipment.	DWML, IEC 61850	NOAA, IEC
Operations Customer	**Clarification of standards to be used for data management.** What additional standards need to be developed or extended for supporting efficient data management, farming, analysis and reporting? Hierarchical aggregation of data; down and up the hierarchy. User-specific object models	Applications should not be standardized, but input/output can be provided by IEC 61850 and CIM	IEEE/ NASPI/ NERC/ FERC UCA SG Users Group, IEEE 2030, IEC TC57 WGs
Operations	**Transmission transfer capacity (TTC) information to Distribution Operations and C&I Customers.** What additional standards need to be developed or extended in order for Transmission Transfer capacity to be available to T&D operation (and major customers) in real time? There is a need to know impact of distribution activities on the capacity issues and deliver this knowledge to transmission.	Guide in Process: CIGRE WG B2.36 Applications should not be standardized, but input/output could be provided by IEC 61850 and CIM	CIGRE/IEEE UCA SG Users Group, IEEE 2030, IEC TC57 WGs
Operations	**What should the continuing role of DNP be:** DNP does not support CIM or network management functions. Should it?	DNP3	DNP Users Group
Operations	**Discussions are needed on the integration of COMTRADE and PQDIF**	COMTRADE	IEC TC57
Operations	**Harmonize IEC 61850 with IEEE C37.118**	IEC 61850 IEEE C37.118	Joint work IEC TC57 WG100 and IEEE PSRC

11.3 Action Items Related to Electric Storage

11.3.1 Requirements and Standards Gaps Related to Electric Storage

The following requirements and related gaps in standards were identified, where the activities can be started (or have already started) relatively quickly, after focused discussions among the organizations identified.

Requirements	Standards	Gaps	Who	GWAC Layer/XC	Domains	Actors/ Interface
Extend IEEE 1547 standard for Electric Storage if necessary: IEEE SCC21 needs to review whether any changes are needed in the IEEE 1547 standards for static and mobile electric storage, including both small and large electric storage facilities. In particular, the management of storage in islands needs to be studied.	IEEE 1547	Need to extend the IEEE 1547 standards as necessary to include the electrical interconnection of electric storage	IEEE Standards Coordinating Committee 21 (SCC21)	Semantic Understanding; Syntactic Interoperability	Operations Service Provider Customer	Transmission EMS Distribution DMS Aggregators DER

11.3.2 Discussion Issues Related to Electric Storage

The following table lists the topics that need to be discussed and resolved to guide standards work, primarily to ensure that standards which are appropriate and already developed are used (rather than re-inventing the wheel) or to select

Domain	Discussion Issues	Standards Potentially involved	Who
Operations Customer	**What standards and models are needed for distribution management system (DMS) to send appropriate signals to electric storage?** Distribution management systems must be able to influence charging profiles and discharging incentives of electric storage, either through price signals or through direct control signals to energy service interfaces, to help manage the distribution system, especially during reconfiguration, unusual loading conditions, and emergencies.	IEC 61850, ANSI C12.19, BACnet, OpenADR, ANSI C12.22, DLMS/COSEM, Smart Energy Profile, etc.	IEC TC57 WG17, NEMA, ZigBee/HomePlug Alliance, BACnet

11.4 Action Items Related to Electric Transportation

11.4.1 Requirements and Standards Gaps Related to Electric Transportation

The following requirements and related gaps in standards were identified, where the activities can be started (or have already started) relatively quickly, after focused discussions among the organizations identified.

Requirements	Standards	Gaps	Who	GWAC Layer/XC	Domains	Actors/ Interface
Common Model for Price+: As PEVs move from area to area, a common interoperable model for price and energy characteristics and time for dynamic pricing across areas, markets, providing a consistent integration model.	NAESB, EMIX, OpenADR, IEC 61850-7-420, others	Common interoperable price formats, characteristics, time, and units are needed to abstract away the complexities of markets to actionable information for the PEV.	SAE, IEC, NEMA, NAESB, OASIS	Semantic Syntactic	Customer Operations Services Markets	PEV Customer EMS Commerc'l Industrial Generation
Common Model for DR Signals: As PEVs move from area to area, a common model for signaling DR events in addition to price is needed. This model should address signaling to other curtailment & generation resources. Must be able to influence charge profiles and discharge incentives.	IEC 61850-7-420, OpenADR Smart Energy Profile, SAE J2836, Price+	Common model for DR signals, including grid safety, environmental, and price is needed to broaden markets and decrease customization. Premises Management Systems are important partners in collaboration.	SAE, IEC, NEMA, ZigBee/Home Plug Alliance, OASIS, NAESB	Semantic Syntactic	Customer Operations Services Markets	PEV Customer EMS Commerc'l Industrial Generation Operations
Mobile Generation/Load Accounting: Determine how costs and payments for PEV are settled.	SAE J2847, OpenADR, SEP Advice of Charge (Cell phone)	Mobility introduces billing model issues; similarity to gasoline purchase may be useful.	SAE, ANSI, Policy, IEC TC57, NEMA	Policy, business objectives	Distribution Customer Markets Policy	PEV

Requirements	Standards	Gaps	Who	GWAC Layer/XC	Domains	Actors/ Interface
Extend IEC 61850-7-420 standard for additional DER, including PEV, Storage, and Renewables: Need to extend IEC 61850-7-420 for more Distributed Energy Resource (DER) equipment. Currently IEC 61850-7-420 for DER covers wind (actually IEC 62400-25), photovoltaic systems, fuel cells, diesel generators, batteries, and combined heat and power (CHP). Needs extension to PEV, additional storage devices, microturbines, gas turbines, etc., including operations and for dynamic and flexible protection systems.	IEC 61850-7-420, OpenADR, Smart Energy Profile	Need to extend IEC 61850 for more Distributed Energy Resource (DER) equipment such as Storage and PEVs, and to cover additional functions, such as dynamic protection settings, load shedding, etc.	IEC TC57 WG17, NEMA, OASIS, ZigBee, Policy	Policy Semantic Syntactic Interoperab ility	Operations Service Provider Customer	Transmission EMS Distribution DMS Aggregators DER
Extend IEC 61968 and MultiSpeak standards for DER: IEC 61968 needs DER and PEV models, but should be harmonized with the existing DER object models in IEC 61850-7-420, as well as all on-going DER 61850 development. IEC 61850-7-420 has architectural issues to be addressed.	IEC 61968-xx, eBusiness, MultiSpeak, others TBD	IEC 61968 needs DER models to carry the IEC 61850-7-420 models of DER and PEV to integrate with the enterprise. Address issues in IEC 61850-7-420,	IEC TC57 WG14, NEMA, MultiSpeak Initiative, others TBD	Semantic Syntactic interoperab ility Network	Operations DER	Distribution DMS

11.4.2 Discussion Issues Related to Electric Transportation

The following table lists the topics that need to be discussed and resolved to guide standards work, primarily to ensure that standards which are appropriate and already developed are used (rather than re-inventing the wheel) or to select to extend.

Domain	Discussion Issues	Standards Potentially involved	Who
Operations Customer	**What standards and models are needed for DMS to send appropriate signals to PEVs and other DR devices?** Distribution management systems must be able to influence charging profiles and discharging incentives (through price signals or direct control signals to energy service interfaces) to help manage the distribution system, especially during reconfiguration, unusual loading conditions, etc.	IEC 61850, ANSI C12.19, BACnet, OpenADR, ANSI C12.22, DLMS/COSEM, Smart Energy Profile, EMIX, SAE J2836 etc.	IEC TC57 WG17, ZigBee/HomePlug Alliance, NEMA, LONWorks, BACnet, SAE IEC TC13, OASIS

Domain	Discussion Issues	Standards Potentially involved	Who
Customer Operations	**Which standards should be used for information models of PEV?** A decision needs to be made on which information modeling standards should be used to model PEVs, and in which domains. Then they could be tasked to develop those models. In all cases, need harmonization across domains for PEVs	IEC 61850, IEC 61968, Smart Energy Profile, OpenADR, ANSI C12.19, eBusiness integration	SAE, IEC TC57 WG17, IEC TC57 WG14, , NEMA OpenADR
Market	**If regulations change, there is a need to develop new Use Cases** and the standards that would be derived from them if reselling stored retail power were permitted by regulators	SAE J 2836 ™, markets	SAE, SEP, OpenADR, NEMA, IEC TC57, Policy, EMIX, NAESB
Distribution	**PEV accounting and settlements:** Currently regulations do not permit electricity to be resold. This means that all the accounting and settlement issues must be handled by utilities (or energy service providers) without the middleman reseller as is the normal market method. This puts the burden on the utility or ESP to manage the complex accounting and settlement processes usually handled by credit card companies or other retail accounting providers. However, if regulations were to change to allow the unbundling of electricity so that stored electricity could be resold, then the accounting model would change dramatically, since normal retail methods could be used. Models for the settlement of PEV charging and discharging pricing, costs, and cross-utility payments are developing slowly, with significant technical and policy/regulatory unknowns. Proposals range from complex schemes for billing back to the driver's (or the owner's) home utility, simple charging as with current gasoline stations, to mixtures of prepaid and billed services as with cellular phones. When charging stations are ubiquitous, these issues will become even more important.	SAE J 2847, others	SAE, IEC, OASIS, ZigBee Alliance, NEMA
Customer	**PEV charging/discharging constraints and regulations.** May need some type of weights and standards seal for charging/discharging *(issue needs clarification)*	SAE J 1772 ™	SAE, PUC/Policy
Distribution	**Submetering for PEV.** May need submetering standard for non-utilities, so need policies, regulations, and testing as well as understanding whether existing standards for metering and retrieving metered data are adequate	ANSI C12.19	SAE, NEMA, OpenADR, Service Providers
Customer	**Role of government and emergency responders with PEV:** There is a missing actor, or even domain – the government agencies (state or federal); as they'll be playing active role with respect to PEVs; emergency, disaster response; charge rates, giving first-responders with priority. Elevating ability to charge PEVs. Government access in bidirectional way – getting information from, or sending information down	SAE J 1772, IEC 61968	SAE, FEMA, Emergency First Responders

Domain	Discussion Issues	Standards Potentially involved	Who
	through the system		

11.5 Action Items Related to AMI Systems

11.5.1 Requirements and Standards Gaps Related to AMI Systems

The following requirements and related gaps in standards were identified, where the activities can be commenced (or have already commenced) relatively quickly, after brief discussions with the organizations identified.

Requirements	Standards	Gaps	Who	GWAC Layer	Domains	Actors/ Interface
Interoperability of ANSI C12.19: ANSI C12.19 has too much flexibility, so that implementations of different meters are often not interoperable. Some standard meter profiles need to be developed to constrain that flexibility for common types of meters and metering requirements.	ANSI C12.19-2008 Exchange Data Language	One or more standard meter profiles need to be defined using the ANSI C12.19 Exchange Data Language.	NEMA	Object Modeling	Customer	Meter
ANSI C12.22 not meeting future requirements: ANSI C12.22 is viewed as mixing the roles of various communications layers for functionality beyond what is traditionally the application layer. Extremely detailed knowledge of the standard is required to recognize where the boundaries exist for the application layer and, perhaps, where it replicates the functions of lower layer functionalities.	ANSI C12.22	A conformance classification for ANSI C12.22 needs to be defined to constrain its scope	NEMA	Messaging	Operations Customer	Metering, DER, Customer EMS, PEV, etc.

Requirements	Standards	Gaps	Who	GWAC Layer	Domains	Actors/ Interface
IEC 61968 Testing: Interoperability testing, along with conformance testing, is the best method for confirming that a standard is performing correctly and actually doing what it is supposed to do. These tests can also feed back to the standards group on issues where the standards are unclear, missing, or incorrect.	IEC 61968-9	Interoperability testing for IEC 61968-9 needs to be performed (this is expected to take place in late 2009).	IEC TC57 WG14, NEMA	Testing	Cross-cutting	Actors needed for testing

11.5.2 Discussion Issues for AMI Systems

The following table lists the topics that need to be discussed and resolved before the appropriate standards can be developed or extended, usually to ensure that standards which were already developed are used (rather than re-inventing the wheel) or that the most appropriate standard is selected to extend.

Domain	Discussion Issues	Standards Potentially involved	Who
Customer	**Should the Internet Protocol (IPv4 or IPv6) be mandated for all protocols:** Assuming that the issue is whether or not IPv4/v6 (rather than whether the Internet Protocol Suite of hundreds of protocols) should be specified for all protocols, what are the requirements? For instance, should ZigBee and all AMI and HAN protocols be required to use IPv4/v6? Can certain protocols get exemptions for specific justifiable reasons? What about IPv4 versus IPv6? What about IPsec?	ANSI C12.22, ZigBee, HAN, Smart Energy Profile, MultiSpeak	ZigBee/HomePlug Alliance, NEMA, SAE, MultiSpeak Initiative
Customer	**Coordination and Future-proofing AMI Systems:** Since AMI systems are going to become widespread, they will inevitably want to be used for more than meter reading or other purely metering functions. They could be used for monitoring DER at the customer site, for DA monitoring and possibly control, for access by third parties to gateways into the customer HAN, etc. The AMI systems should be able to handle, at a minimum, the IEC 61850 object models mapped to an “appropriate” protocol (possibly IEC 61850-lite when it is developed). Need to ensure AMI communications systems use open standards capable of interfacing to DER and distribution automation equipment. ANSI C12.22 is being revised, Europe uses DLMS/COSEM, and AMI vendors are developing their systems over a wide range of media, from PLC, to BPL, to ZigBee meshed radios, to UtiliNet radios, to GPRS, etc.	Smart Energy Profile, ANSI C12.22-2008, DLMS/COSEM	ZigBee/HomePlug Alliance, NEMA, SAE, IEC TC57 WG14, IEC TC57 WG17, IEC TC13

Domain	Discussion Issues	Standards Potentially involved	Who
Customer	**Concerns about unlicensed spectrum in AMI systems:** Use of unlicensed spectrum leaves utilities competing with other industries for bandwidth. There is risk of non-utility applications emerging that would greatly increase the utilization of unlicensed spectrum. This could result in reduction of performance of utility systems with little warning or recourse. Does the "critical infrastructure" aspect of utility systems justify the allocation of dedicated spectrum with bandwidth comparable to the unlicensed ISM bands?	AMI meshed radio systems, ZigBee, Smart Energy Profile, ANSI C12.22-2008	FCC, NEMA, ZigBee, SAE
Customer	**Should ANSI C12.19 be expanded for DER?** ANSI C12.19 may have extension requirements for distributed resource information, forecasts, etc. But should ANSI C12.19 be extended for non-metering devices or should IEC 61850-7-420 objects be used?	ANSI C12.19, IEC 61850-7-420	NEMA, IEC TC57
Service Provider	**Discussion on which standards third party energy providers should use.** What additional standards need to be developed or extended in order to transfer data across various energy providers?	No specific standard exists: CIM and/or IEC 61850 could be used	UCA SG Users Group, IEEE 2030, IEC TC57 WGs, NEMA
Customer Market	**Which standards should be used or extended with pricing models?** Ability to include real time pricing information and other pricing models in both information model standards and information transfer standards	OpenADR, IEC 61850-7-420	OASIS IEC TC57 WG17, NEMA
Customer	**Should standard physical and mac layers be defined for AMI systems?** This would include standards for the common AMI approaches: wireless mesh, wireless star (point to point), and long range power line carrier. Do the benefits of vendor interoperability outweigh the risk of stifling creativity?	IEEE 802.15.TG4g Other IEEE standards	IEEE, ITU
Customer	**Should an open standard be developed for routing and connectivity in wireless AMI networks?** Notionally, such a standard would be built upon open standard phy/macs and would be a necessary part of allowing devices from multiple vendors interoperate and exchange data as part of a single network.	ANSI C12, IEEE, ZigBee	NEMA, IEEE, ZigBee Alliance

11.6 Action Items Related to Distribution Management

11.6.1 Requirements and Standards Gaps Related to Distribution Management

The following requirements and related gaps in standards were identified, where the activities can be commenced (or have already commenced) relatively quickly, after brief discussions with the organizations identified.

Requirements	Standards	Gaps	Who	GWAC Layer/XC	Domains	Actors/ Interface
ICCP legacy transition: ICCP standard may need information models for interaction with aggregators of distributed resources and even distributed resources directly	IEC 60870-6 (ICCP), IEC 61850-7-420	Decision by IEC TC57 needs to be made on whether ICCP or IEC 61850-7-420 should be used for DER information exchanges with Service Providers	IEC TC57 WG19, NEMA	Semantic Syntactic Network	Operations Service Provider	DER units & plants Service Providers
Extend IEC 61850-6 standard: The System Configuration Language (SCL) that is used for configuring the communication networks and systems for substations is not yet capable of configuring DER or distribution automation networks and systems.	IEC 61850 WS-DD WS-DP	IEC 61850-6 SCL needs expansion to distribution automation and DER, possibly in coordination with WS-DD/WS-DP	IEC TC57 WG10 & WG17, OASIS	Discovery and configuratio n	Operations	DA equipment
Extend IEC 61850 standard for Distribution Automation: IEC 61850 has been selected by the IEC for all field communications with power system equipment. It currently has models for substation equipment, large hydro power plants, and many types of DER. However, it does not yet have object models for distribution automation equipment	IEC 61850-7-xxx	Object models for Distribution Automation equipment need to be added.	IEC TC57 WG17	Semantic	Distribution Operations	Distribution DMS Distribution equipment

Requirements	Standards	Gaps	Who	GWAC Layer/XC	Domains	Actors/ Interface
Harmonize IEC 61968 and MultiSpeak: MultiSpeak and IEC 61968 overlap in many areas, but not in all areas. MultiSpeak already has a wide base of implementations, primarily with small utilities, while IEC 61968 is designed for larger utilities, but has not yet become a standard nor been implemented anywhere. MultiSpeak is working closely with the IEC 61968 effort on the overlapping areas, but further harmonization is necessary. As the IEC 61968 CIM profiles become available as standards, it will be important to minimize any conflicts with MultiSpeak and to develop mappings between the existing MultiSpeak interfaces and the new IEC 61968 interfaces so that products and software developed to be compatible with the different standards can interoperate.	IEC 61968, MultiSpeak	The gaps and overlaps between MultiSpeak and the IEC 61968 standards under development need to be minimized and harmonized.	IEC TC57 WG14, NRECA MultiSpea k	Semantic	Distribution	DMS, AMI Headend, OMS, Distribution computer systems, etc
Revise and update IEC 61968 standard: The IEC 61968 CIM for distribution is currently not usable except for the very latest part (Part 9), since the messaging schemes and the CIM model for the earlier parts were not well enough defined to allow vendors to implement them. However, if these older parts are revised, then interoperability of the messages may be achieved. These revisions are in the IEC TC57 WG14 roadmap, but will need significant effort to be achieved.	IEC 61968	Some of the earlier parts of the IEC 61968 standards are not implementable and do not yet specify the types of interoperable messaging schemes being developed. The roadmap is expected to take a long time to achieve and could benefit from significant support.	IEC TC57 WG14	Semantic Syntactic Network	Distribution	DMS, AMI Headend, OMS, Distribution computer systems, etc

Requirements	Standards	Gaps	Who	GWAC Layer/XC	Domains	Actors/ Interface
Extend IEEE 1547 standard: Voltage support specifications (electrical interconnections) for distributed resources need to be defined for scenarios where such voltage support is needed or permitted.	IEEE 1547	The IEEE 1547 standard currently states that "The DER shall not actively regulate the voltage at the PCC." However, for islanded systems or for Area-EPS operations-approved actions, voltage support should be permitted, and specifications for these situations should be developed..	IEEE 1547, IEEE P2030	Policy, Business objective	Operations	DER units & plants Distribution power system
Map IEC 61850 object models to AMI system protocols: If IEC 61850 object models are going to be used to exchange information with equipment (such as DERs) at customer sites, then these models need to be mapped to AMI communications protocols	IEC 61850, ANSI C12.22, DLMS/COSEM, Smart Energy Profile	IEC 61850 objects need to be mapped to AMI communications such as ANSI C12.22. This may or may not be the same solution as IEC 61850-lite.	IEC TC57, NEMA, IEC TC13	Semantic Syntactic Network	Customer Service Provider Operations	DER, DA equipment, PEV
MultiSpeak and IEC 61968 Interoperability Testing: Once a mapping between MultiSpeak V4 and IEC61968, Part 9 has been finalized (planned for late 2009), then it will be critical to test for interoperability between appropriate profiles of the two standards.	IEC 61968, MultiSpeak	Perform interoperability testing on harmonized profiles between MultiSpeak and IEC 61968.	IEC TC57 WG14, NRECA MultiSpeak	Interop Testing	Cross-cutting	Actors needed for testing

11.6.2 Discussion Issues for Distribution Operations and Management

The following table lists the topics that need to be discussed and resolved before the appropriate standards can be developed or extended, usually to ensure that standards which were already developed are used (rather than re-inventing the wheel) or that the most appropriate standard is selected to extend.

Domain	Discussion Issues	Standards Potentially involved	Who
Operations Customer	**Develop IEC 61850-lite as efficient, compact protocol:** Since many communications systems still have limited bandwidth, such as those used in rural environments and/or to wide-spread distribution automation devices, one or	IEC 61850, Smart Energy Profile, C12.22, and other compact profiles	IEC TC57 ZigBee/HomePlug Alliance, NEMA,

Domain	Discussion Issues	Standards Potentially involved	Who
	more efficient, compact communication protocol profiles need to be specified for IEC 61850 and other object models to be mapped to. Therefore, there is a need to develop "IEC 61850-lite" profile to which these object models can be mapped. In addition, some inexpensive devices (e.g. sensors, collectors, or "software agents") may not want or need to implement the full IEC 61850 capabilities, in order to minimize compute constraints or development costs.		telecom providers
Distribution	**What GIS standards should be specified, developed, or extended?** The status of GIS standards not clear.	GIS standards, IEC 61968, MultiSpeak	
Distribution	**What standards should be developed or extended for Work Order management?** Could include IEC61334, IEC61968, or MultiSpeak	IEC 61968, MultiSpeak	
Operations Customer	**What standards should be used or need extensions to provide distribution operations with information about customer behavior and response to prices?** This information must be available to distribution management systems for development of accurate models that can be used to manage voltage, component loading, etc.	IEC 61850, ANSI C12.19, BACnet, OpenADR, ANSI C12.22, DLMS/COSEM, Smart Energy Profile, SAE etc.	IEC TC57 WG17, ZigBee/HomePlug Alliance, NEMA, BACnet, SAE,
Operations	**Transmission operations access to DER information.** What additional standards need to be developed or extended in order to use distribution resources in the bulk electric system infrastructure for contingency analysis, mitigation and control (incl. Restoration)?	CIM, IEC61850, DNP3, 37.1, 37.118, ANSI C12.19, 12.21, 12.22, ICCP (IEC 60870-6), IEC 61850-7-420	UCA SG Users Group, IEEE 2030, IEC TC57 WGs
Operations	**Distribution operations access to bulk generation information.** What additional standards need to be developed or extended in order for bulk generation to be available to T&D operation (and major customers) in real time. Need to know impact of distribution activities on the capacity issues and deliver this knowledge to transmission.	CIM, IEC61850, DNP3, 37.1, 37.118, ANSI C12.19, 12.21, 12.22, ICCP (IEC 60870-6), IEC 61850-7-420, MultiSpeak	NERC/FERC UCA SG Users Group, IEEE 2030, IEC TC57 WGs, NEMA, MultiSpeak Initiative
Operations Customer	**Discussions needed on modeling loads, given DER and mobile PEV.** Need to develop behavioral models to plan for diversity and allocation of loads. The aggregated model will be used in T&D. Base load profiles may be required to define benefits for demand response and alternate load profiles associated with PEV charging. This requires accurate definition of customer loads as a function of parameters. The information is needed from AMI systems and must be provided to system models and model management systems.	Load models themselves should not be standardized, but the information exchanges could involve IEC 61850, ANSI C12.19, BACnet, OpenADR, ANSI C12.22, DLMS/COSEM, Smart Energy Profile, SAE Jxxxx etc.	IEEE/ NASPI/ NERC/ FERC, UCA SG Users Group, IEEE 2030, IEC TC57, NEMA, ZigBee/HomePlug Alliance, BACnet,

Domain	Discussion Issues	Standards Potentially involved	Who
			SAE