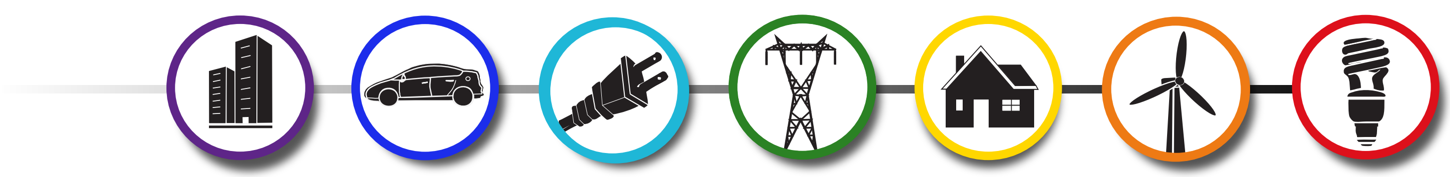
Paths to Smart Grid Interoperability

A Smart Grid Policy Center White Paper

The Smart Grid Policy Center is the research arm of the GridWise Alliance



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Thought Leader Interviewees

In-depth interviews from a range of industry thought leaders serve as a key source for the analysis presented in this white paper. The thought leaders interviewed are listed in Appendix A. The authors greatly appreciate the time and insights volunteered by the thought leaders.

Technical Reviewers

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White Paper Focus

Smart grid promises to transform the electricity industry, yielding benefits such as:

- A more reliable and stable supply of electricity
- Increased efficiency of the immense investment in electric infrastructure
- Increased capability to integrate renewable sources of electricity
- Reduced greenhouse gas emissions

However, smart grid is currently a vision that can be realized only if its diverse elements are able to work together as a system.

What do decision makers need to know to ensure that the current smart grid standards setting efforts lead to a highly interoperable grid that can ultimately transform the industry to deliver these benefits?

This white paper examines the issues to help decision makers put the interoperability standards setting effort on the path to the envisioned industry transformation and the realization of these benefits.

Contents

Focal Points ***(Illustrative Sidebar Discussions)***

1 Introduction

The *smart grid*[1] promises many benefits for the nation. The benefits include a more reliable and stable supply of electricity, increased efficiency of the immense investment in electric infrastructure, increased capability to integrate renewable sources of electricity, reduced greenhouse gas emissions, and more proactive and informed consumers. Overall, the smart grid can help provide a more flexible and affordable energy supply and a reduction in dependence on foreign fossil fuels.

Fundamentally, the smart grid leverages end-to-end communications and optimized operation through modern information technology to transform the traditional one-way power delivery system into a two-way power delivery system that can engage *customers*, and enable innovative services and business models. The new infrastructure spans the electric system from generation to end use and accommodates a diverse and evolving set of technologies, geographies, and new applications.

Realizing these promised benefits requires overcoming a number of challenges that extend beyond developing the needed technologies. The challenges include investment risk from uncertain future energy prices, a fragmented regulatory structure, questions about consumer reaction to new rate structures and technologies, the need for enhanced approaches for cost-benefit assessment, and the need for *interoperability*[2] across this diverse and changing environment.

The benefits of interoperability are broadly recognized and have been demonstrated in other industries,[3] and interoperability is a cornerstone for realizing future benefits from the smart grid. Interoperability cannot happen without *standards,*[4] which can reduce *integration costs*, enable new capabilities and *markets*, and promote innovation to develop new products and functions, some of which have not yet been envisioned.

> ***Interoperability** refers to the ability of diverse systems and organizations to work together (inter-operate). In the context of the electricity system, interoperability refers to the seamless, end-to-end connectivity of hardware and software from end-use devices through the T&D system to the power source, enhancing the coordination of energy flows with real-time information and analysis.*
>
> *A technical **standard** consists of specifications that establish the fitness of a product for a particular use or that define the function and performance of a device or system. It is usually a formal document that establishes uniform engineering or technical criteria, methods, processes, and practices.*

Interoperability is a key lynchpin of smart grid success. The promised smart grid benefits cannot materialize without appropriate levels of interoperability. Congress has recognized the importance of standards for achieving interoperability within the *Energy Independence and Security Act of 2007 (EISA),* which assigns the

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[1] The term "smart grid," as used here, refers to the utility power generation, transmission, distribution, and customer system enhanced through use of computer technology and two-way digital communications networking. The term is further defined in the glossary, and it is intentionally not capitalized in this document, as it refers to a wide range of concepts, technologies, and project types rather than a single, defined concept. In practice, many smart grids are already emerging, but this white paper refers to *the* smart grid (in the singular sense) as a general concept for the purposes of discussion.

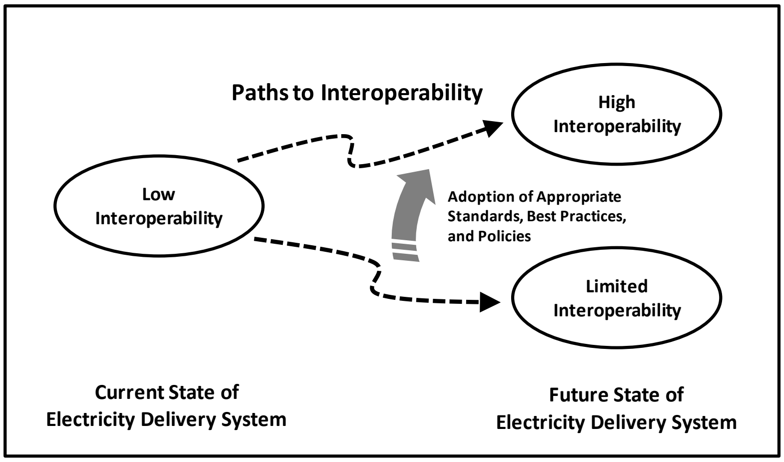
[2] "Introduction to Interoperability and Decision-Maker's Interoperability Checklist," V1.0,GridWise Architecture Council, Policy Team. Although "interoperability" and coordination among business context, procedures, objectives, and policies are critical to realizing the potential benefits of a smart grid, this white paper's primary focus is on the technical and informational aspects of interoperability.

[3] For example, interoperable protocols for monetary transactions are used widely in the financial services industry; call records and billing data are widely exchanged and reconciled to perform customer billing in the telecommunications industry; and the Internet delivers standard, interoperable communication across many industries and applications.

[4] The first time certain key terms appear in the white paper narrative, they are italicized to indicate that definitions are included in the glossary.

National Institute of Standards and Technology (NIST) the primary responsibility for developing the smart grid interoperability framework.[5] Once appropriate levels of interoperability are achieved, policymakers, investors, engineers, and other stakeholders can turn their attention to solving a broad set of challenges: improving the efficiency of power delivery, transitioning to cleaner energy sources, and enabling new markets that surround electricity delivery.

FIGURE 1. PATHS TO INTEROPERABILITY



The NIST-coordinated interoperability effort is structured to involve a broad set of stakeholders from across the industry,[6] and it is assessing the role of standards across the spectrum of smart grid interoperability areas. The stakeholders involved in this effort will effectively determine the paths taken en route to an interoperable smart grid, as illustrated in Figure 1.

Developing an interoperability roadmap and establishing standards for the national smart grid is a complex task, which raises important questions:

- **What are the key issues to consider in developing interoperability standards?**
- **How should competing priorities be considered while interoperability standards are being developed?**
- **Will interoperability standards development, selection, and adoption occur in the time frame required to affect the needed industry transformation, or will additional steps be necessary?**
- **What alternate approaches can be taken at this juncture to help ensure that we are on the path to high interoperability?**

This white paper examines these questions and related challenges that are needed to frame a discussion about the approach to interoperability that can help lead to an effective and sustainable smart grid. Industry thought leaders[7] were interviewed to provide insight into the issues surrounding interoperability. These individuals represent the spectrum of smart grid stakeholders, from regulators to technology experts, and were selected based on their experience and involvement with smart grid activities.

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

[6] The term industry is intended in the broadest sense and includes the whole electricity ecosystem.

[7] Appendix A contains a list of the interviewed thought leaders.

Less formal discussions were held with other stakeholders involved in smart grid interoperability efforts to help develop and synthesize concepts and details. This input, combined with additional background research, led to the development of the themes presented. The white paper draws out and explains issues, develops insights regarding their relative importance, and provides recommendations to help achieve high interoperability.

Two representative standards approaches – *Institutional Endorsement* and *Market Toolkit* – are described in Section 2.[8] These two approaches are used to help focus the interviews and discussions with the thought leaders. The two constructs represent different views about how establishing interoperability standards[9] should be approached. Each defines actionable directions that might be taken to further advance interoperability.

Quotes from the interviews and discussions emphasize particular points or perspectives throughout the white paper. Interviewees were assured confidentiality to enable candid responses. Comments are cited anonymously, and permission was obtained where appropriate. Each interviewee approached the standards issue with a different background, context, vocabulary, and point of view. This white paper synthesizes information from the interviews, identifies overarching issues, and develops common themes regarding the role of standards within the broader context of interoperability.

> *"Open standards ignite markets, they make things happen, they accelerate deployments and innovation. Open standards give customers comfort that they're protected and not locked in."*
>
> ***-Technical Executive, Vendor***

This white paper aims to present a balanced perspective on the relevant issues using the insights provided. Key issues of interoperability and competing priorities for establishing standards are used to illustrate the benefits of alternative approaches in specific areas of the smart grid.

The recent interoperability standards efforts have provided valuable momentum. Insights gained through the interviews indicate that industry influences and parochial interests are making these efforts more difficult and complex than they need to be. Some of these influences are discussed in the context of coordinating across a broad range of stakeholders.

The white paper is organized to frame the discussion and begin to address the questions presented here in Section 1. Section 2 presents the problem, introduces some of its complexities, and explains how the standards effort is being handled today. The Institutional Endorsement and Market Toolkit approaches are used to illustrate and draw contrast to points made in the remainder of the paper. Section 3 expands on the complexities presented in Section 2 as six key issues that facilitate understanding and further discussion of interoperability standards. Section 4 leverages this understanding and describes ten competing priorities – synthesized from thought leader interviews – that are important in establishing appropriate smart grid standards. An example dialogue at the end of the section illustrates the strengths and weaknesses of the two standards approaches in terms of the six key issues and ten competing priorities. The discussion contrasts the differences using debate points that might be made by advocates of each approach. Finally, Section 5 presents key insights and provides five recommendations to help illuminate the path forward.

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[8] The terms "Institutional Endorsement" and "Market Toolkit" are constructs used here to represent approaches to standards development developed for this white paper, and they are not necessarily used broadly in the industry.

[9] Interoperability standards are those standards that address the key boundary points within the electricity generation and delivery system to accommodate heterogeneity within the overall system.

2 Problem Statement

Section 2 Contents:

The level of interoperability achieved will largely enable the level of functionality and commensurate benefits delivered by the future smart grid. Architecting the appropriate approaches to establishing standards is essential to achieving high interoperability. Successful outcomes from standards development and standards selection can accelerate technology adoption by decreasing costs, reducing investment risk, and encouraging innovation.[10] Unsuccessful outcomes will dampen investment, restrict synergies, limit the eventual benefits of the smart grid, and cause expensive redesign and reconstruction.

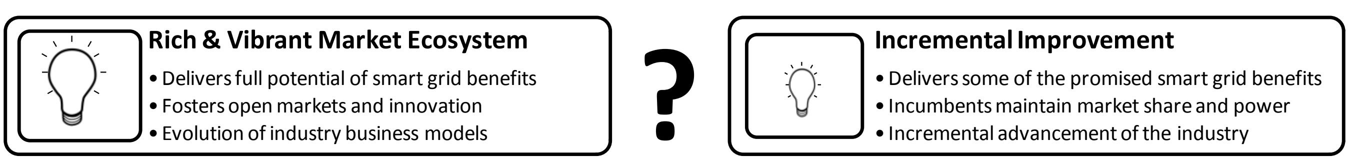
The importance of achieving interoperability is presented below with a description of what is at stake. The complexity of the issue is illustrated with six key issues related to establishing smart grid interoperability standards. A spectrum of possible approaches to standards is presented to explain the role of *open standards* in attaining interoperability. The spectrum is also used to help define the two aforementioned standards selection approaches, Institutional Endorsement and Market Toolkit, which are used in subsequent sections to examine possible paths forward.

2.1 What Is at Stake?

The smart grid development path and future *architecture* are not yet defined fully and are expected to evolve over time. The direction will be influenced by a number of uncertain economic, environmental, social, technology, policy, and regulatory dynamics. Different possible outcomes can yield vastly different benefits. The eventual outcome will be influenced by developing *appropriate standards* that can improve interoperability, allow for innovation, and provide for timely development of the smart grid.

The most desirable outcome is a transformed national power infrastructure supported by a rich, vibrant market ecosystem with significant private investment and broad entrepreneurial innovation. Less successful outcomes will deliver only incremental improvement over the current system, with a fraction of the promised benefits and limited private investment and innovation.

FIGURE 2. WHERE IS THE SMART GRID HEADING?



[10] Erich Gunther, "Interoperability – Why Should You Care?", EnerNex Corporation, p. 4.

Individual stakeholders and their organizations have an interest in the outcome and path taken. Decision makers need to educate themselves on interoperability and standards issues to be able to balance the costs, benefits, and investment risks, and – in many cases – to keep their organizations relevant in the changing marketplace. Decision makers should be able to ask the key questions of their staffs based on a solid understanding of the issues. The following stakeholder groups have specific reasons for involvement:

- **Utilities:** To reduce uncertainty and increase confidence that smart grid investments achieve the projected benefits for shareholders and ratepayers; to avoid being misled by vendors and technology suppliers; to understand the trade-offs made and risks taken by the organization in smart grid projects; and to explain these to their regulators and investors.
- **Consumers:** To ensure that the consumer perspective is present in making the necessary standards trade-offs, to provide for more choice and information to better manage energy consumption, and to ensure that prudent investment is being made to maintain cost-effective rates today and in the future.
- **Regulators:** To make decisions that balance the benefits and risks for different constituents, including ratepayers, utilities, and society as a whole.
- **Vendors:** To understand how the playing field is changing and what investments need to be made to capture new markets; to maintain market share by meeting interoperability standards with future products; and in some cases, simply to survive.

Stakeholders have different viewpoints on interoperability, and this is part of the challenge of developing the best path forward. Other key challenges are presented in the section below.

2.2 Why Is Interoperability So Hard?

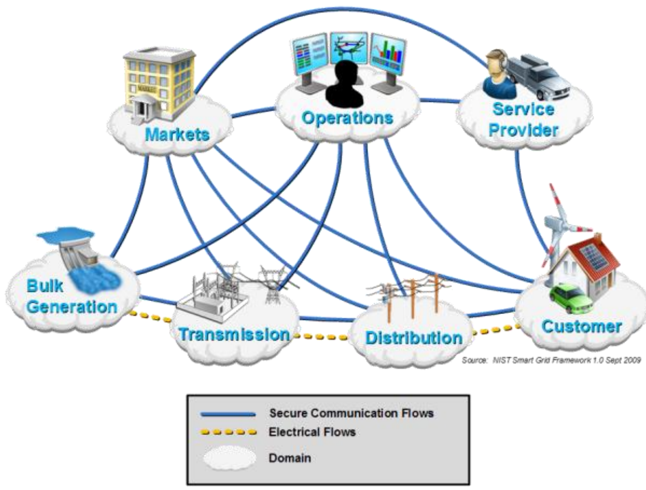
Smart grid interoperability presents a complex, multidimensional challenge. Issues, ideas, and challenges expressed in thought leader interviews and identified through subsequent synthesis lead to six key issues that help to explain why smart grid interoperability is hard. These six issues are introduced below and explored in greater depth in Section 3.

Key Issue 1: The Smart Grid Is a Complex System of Systems

The traditional electric grid has a complex set of *domains* and numerous *applications* to manage and support. These domains have been supplemented and described more formally as part of the recent smart grid standards effort.[11] The seven top-level domains – generation, transmission, distribution, and customers, as well as operations, markets, and service providers – are shown in Figure 3. Each domain has its own characteristics, participants, applications, constraints, and operational practices. In addition, each domain comprises multiple applications and infrastructural pieces, and there is considerable variation within domains across regions and utilities.

[11] "NIST Framework and Roadmap for Smart Grid Interoperability Standards Release 1.0," Office of the National Coordinator for Smart Grid Interoperability, NIST, September 2009.

FIGURE 3. NIST SMART GRID CONCEPTUAL MODEL OF APPLICATION DOMAINS[12]



Each domain must be supported or accommodated by the smart grid and by the overlay of new communications pathways, which are illustrated in Figure 3. The dotted line across the bottom illustrates the traditional flow of power, from central generation to consumption. The solid lines represent the communications and connectivity required to help deliver smart grid functionality among and between the domains. The high number of communication connections illustrates the complexity of overlaying new communications and distributed computing technology onto the traditional power infrastructure. The smart grid is often referred to as a "system of systems" to convey the complexity involved.

Key Issue 2: Interoperability Must Accommodate Multiple Communications Layers

A two-way communications infrastructure is essential to achieving interoperability in a system of systems. Communications systems are typically subdivided into *layers* of similar functions, each of which provides services to the layer above it and receives services from the layer below it. The full span of *protocols* across these layers is typically referred to as a *protocol stack*. The *Open Systems Interconnection 7-layer model* (OSI Model[13]) is a widely understood and accepted protocol stack model. The *GridWise Architecture Council* has developed a related interoperability framework tailored to the smart grid, and it is colloquially referred to as the "*GWAC Stack*."[14]

Digital applications that communicate with other applications require an appropriate set of protocol layers.[15] Each layer must be considered and accommodated within every communications path and often across multiple

[12] "Smart Grid Conceptual Model," version 1, Smart Grid Interoperability Panel, March 15, 2010. The document can be found at: http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/SGIPConceptualModelDevelopmentSGAC.

[13] The OSI, or Open Systems Interconnect model, was developed by the International Organization for Standardization, an international standards- setting body, in the early 1980s. This model is widely cited and referenced throughout many parts of the communications industry but is overly complicated for the discussion here. A good explanation of the model and some details of the history are provided at: http://en.wikipedia.org/wiki/Osi_7_layer_model.

[14] "GridWise Interoperability Context-Setting Framework," The GridWise Architecture Council, March 2008, p. 5. The GWAC Stack conceptually resembles the stack-architecture of communication services typically used for protocols, but it does not specify communications protocols and it extends the framework beyond technical and informational interoperability to include the higher organizational levels.

[15] The Internet Protocols (in particular the Transport and Network layers, typically TCP/IP, and their associated protocols and security services) are broadly considered to be appropriate for many smart grid applications areas; however, in certain application areas considerable discussion remains about whether the Internet Protocols are the best choice. In some cases, technical arguments suggest that significant modifications or adaptations would need to be made to Internet Protocols for them to meet application needs.

lower layer protocols. Communication layers represent another dimension of complexity, and appropriate standardization by layer is critical to achieving interoperability.[16]

Key Issue 3: Parts of the Smart Grid Will Evolve at Different Rates

Both the industry landscape and the architecture of the traditional power infrastructure are changing. The traditional, one-way, hierarchical power system that transmits energy from the point of generation to the consumer is giving way to a distributed network structure that enables the grid to accommodate renewable and distributed energy sources and vehicle charging. This transition will accelerate as the deadlines for policy objectives, such as increased renewable portfolio standards, draw near. Many utilities are in the midst of implementing smart grid projects. These utilities cannot wait for lengthy standards development efforts in some technology areas – they need to make smart grid technology decisions now. There is a timing priority with some technology decisions that need near-term resolution, while other technical and technology solutions will not be needed until later stages of the smart grid development path. It is important to recognize that the smart grid is not a single technology decision. Rather than being a single event, it is a series of decisions that will be made over time. This sequenced set of technology investment decisions will allow for learning across projects and over time that can enhance the overall efficiency of the investment process and reduce risk. The standard-setting process should create a platform that allows and encourages learning and innovation to be part of the migration towards a more complete smart grid.[17]

Traditional investment objectives in the industry will change with new policies, and new business models will emerge to seize new opportunities and meet new regulatory mandates. The industry dynamics and structure will likely look quite different in 20 or even 10 years. Regulators and investors need to understand and balance the risks in this changing landscape to appropriately address interoperability in their respective areas.

Key Issue 4: Stakeholder Interests Are Not Always Aligned

Stakeholders are spread across disparate geographies and regulatory jurisdictions, and they have varying commercial interests. Smart grid standards efforts inherit this complex set of interests. Stakeholder groups include consumers, utilities, regulators, vendors, investors, and society. Some of the *standards-setting organizations* (SSOs) present strong views on how interoperability should be approached and have become important stakeholders in the standards approach.

Stakeholders have different incentives for participation, different visions for interoperability standards, and even different perceptions of what the smart grid should be, making alignment difficult.

Key Issue 5: New Security and Privacy Challenges Are Created

Cyber security and customer privacy are overarching issues that cut across the dimensions of the smart grid architecture. Cyber security must address not only deliberate attacks launched by disgruntled employees, agents of industrial espionage, and terrorists, but also inadvertent compromises of the information infrastructure due to user errors, equipment failures, and natural disasters.

[16] The upper layers of the GWAC Stack Interoperability Framework focus on the organizational aspects of interoperability. Organizational interoperability is critical to the successful realization of smart grid benefits, but it is not the primary focus of this white paper. However, the complex issues that it presents must be addressed elsewhere.

[17] This could be accomplished, for example, by creating and facilitating a "market" for competing standards or by establishing and overseeing a process for updating standards (e.g., IPv4 to IPv6).

"If we are to truly modernize our electrical grid, we must have electricity producers, distributors and consumers all speaking the same language and all working together to make our grid more secure. Cyber security is an integral part of the grid."

-Steven Chu, U.S. Secretary of Energy[18]

The smart grid significantly expands the availability and granularity of consumption and grid system data, thereby creating new opportunities for general invasion of privacy. A more detailed picture can be obtained about activities within a given dwelling, building, or other property, and the time patterns associated with those activities make it possible to detect the presence of specific types of energy consumption or generation equipment. Granular energy data may even indicate the number of individuals in a dwelling unit, which could also reveal when the dwelling is empty or is occupied by more people than usual. These types of issues raise concerns about the privacy of this information and the need for clear privacy policies and approaches.[19]

Key Issue 6: Interoperability Standards Must Balance Certainty with Flexibility to Enable Innovation

Innovation is required to transform the industry into a rich and vibrant market ecosystem. Innovation is a concern for the interoperability standards effort because the structure and constraints established by standards can either enable or inhibit innovation. Standards that are overly prescriptive may result in the desired interoperability, but they can hinder the advancement of the grid to incorporate new technologies or business models. Standards that are overly flexible may not yield the desired levels of interoperability needed by a smart grid. An appropriate balance must be achieved to deliver high interoperability and leave room for innovation in the future.

In summary, interoperability efforts must overcome numerous constraints and complexities. Navigating these complexities will require flexibility and adaptability in the standards process. These six key issues are explored in greater depth in Section 3 to provide additional perspective about how each issue relates to standards and interoperability.

2.3 What Are the Approaches to Establishing Standards?

Approaches to establishing standards are numerous, and the types of standards extend well beyond interoperability standards. Approaches can be viewed along a spectrum of prescriptiveness. Four representative approaches are outlined below to illustrate this spectrum, and these range from more to less prescriptive, starting with standard by fiat (i.e., a government mandate) to entirely free market (i.e., a laissez-faire approach).

1. **Government Mandate** – Establishes a uniform standard for a given service or *application area*[20] through an enforceable rulemaking. This approach may or may not seek input from stakeholders.
2. **Institutional Endorsement** – Seeks to establish a uniform open standard for a given service or application area through a *consensus*[21] of experts and stakeholders.

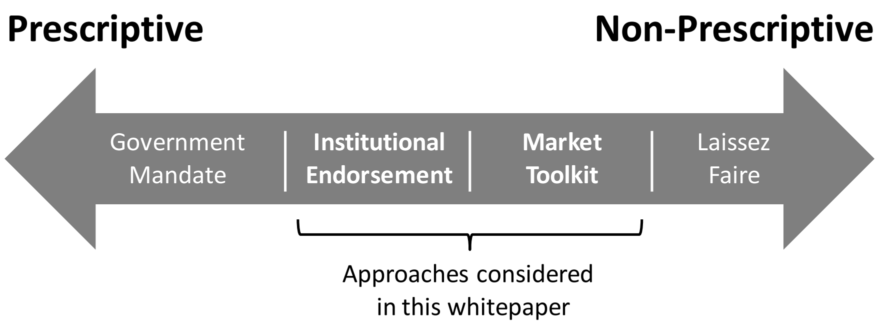
[18] Quote taken from the NIST Business and Public Affairs website article: "NIST Finalizes Initial Set of Smart Grid Cyber Security Guidelines." September 2, 2010.

[19] NISTIR 7628 Guidelines for Smart Grid Cyber Security, v1.0, Volume 2, August 2010.

[20] Application area is defined in the glossary and refers to a specific function or set of tasks in the smart grid that are typically discussed together as a single product or solution (e.g., the home area network application area).

3. **Market Toolkit** – Allows for multiple open standards for a given smart grid service or application area such that each standard meets a set of minimum requirements. The standards effort is more concerned with establishing requirements and ensuring quality of standards, rather than selecting or endorsing the best standard.
4. **Laissez-Faire –** Maintains a hands-off approach that can lead to solutions based on either open or proprietary standards.

FIGURE 4. SPECTRUM OF APPROACHES TO STANDARDS SELECTION



The Institutional Endorsement and Market Toolkit approaches are the two approaches considered in this white paper. These approaches, as defined in detail below, have similarities to those practiced in various SSOs and in standards selection processes. There is broad agreement that "open" standards are best suited to meet the needs of the smart grid,[22] and both of these approaches can produce open standards.

2.3.1 Why Are Open Standards Key?

Broadly accepted standards are critical to moving interoperability forward. Without some form of standardization, applications and systems are likely to remain largely isolated as integrating them continues to be unnecessarily costly.

Open[23] interoperability standards are widely considered to be the most effective way to stimulate innovation and investment. An open-standard interoperability approach has a number of

> ***Open Standard*** *refers to the fair development of a standard or its availability for use. Many definitions exist, but as used here, open standards possess the following general characteristics:*[23]
>
> *Availability: Open standards are available for all to read and implement.*
>
> *End-User Choice: Open standards create a fair, competitive market for implementations of the standard. They do not lock the customer in to a particular vendor or group.*
>
> *No Royalty: Open standards are free for all to implement, with no royalty or fee.*
>
> *Nondiscrimination: Open standards and the organizations that administer them do not favor one implementer over another.*

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[21]Consensus as used here is defined as general agreement, but not necessarily unanimity. Note that this definition is a subset of that provided by OMB Circular a-119, which provides a definition of "voluntary consensus standards" to clarify the definition from National Technology Transfer and Advancement Act of 1995. It includes additional elements such as a process for attempting to resolve objections by interested parties.

[22] "NIST Framework and Roadmap for Smart Grid Interoperability Standards Release 1.0," Office of the National Coordinator for Smart Grid Interoperability, NIST, September 2009.

[23] There are many definitions of "open." This white paper uses a definition intended to produce a more successful smart grid and is based on four of Bruce Perens' Six Principles of open standards; the two principles not mentioned above allow for extension of open standards and protect against subversion of the open standard. Read more at http://perens.com/OpenStandards/Definition.html.

expected benefits:[24]

- Reduced installation and integration cost
- Reduced cost to operate and upgrade
- Reduced capital cost for *information technology* (IT)
- Improved security management
- Reduced investment risk
- Increased variety in price points, features, and product choice
- Reduced likelihood of vendor or solution "lock-in" (future proofing)

These interoperability benefits cannot be achieved without open standards, which are essential to opening the path to the rich and vibrant smart grid ecosystem. However, "open" is used differently in various standards-setting contexts. The NIST/SGIP process interprets[25] "open" standards based on the definition employed by the American National Standards Institute (*ANSI)*: *"developed and maintained through a collaborative, consensus-driven process that is open to participation by all relevant and materially affected parties and not dominated or under the control of a single organization or group of organizations, and readily and reasonably available to all for Smart Grid applications."* [26]

This ANSI-based definition applies more to an *open process* used to define the standard, rather than the

FOCAL POINT: What's New and Different with Smart Grid Interoperability?

Electric utilities have many familiar elements – meters, transformers, capacitors, and so on – that now need to communicate and interoperate. New types of sensing and measurement devices are being added to familiar elements, generating significantly more data that requires new methods to process, store, and analyze. Entirely new elements, such as *phasor measurement units* (PMUs), *plug-in electric vehicles* (PEVs), and grid storage devices, are being introduced, and they require interoperation and coordination.

Many smart grid goals are similar to those that drove the development of the Internet: involving end users and customers in the development of new markets, unleashing entrepreneurial spirit to generate technical innovation, and motivating new investments. Who could have envisioned Facebook and Twitter, or even Google, 15 years ago when the Internet revolution was starting?

Industrial process control and manufacturing automation are other examples of significant advances that have been made during the past 30 years. These advances may have improved capital utilization by only a few percentage points but represent enormous returns due to the immense scale of capital involved (as is the case with the electric power industry).

Interoperability requirements and constraints in the electric power industry are different in important respects from those in previous revolutions. The electric system is funded by ratepayers based on regulatory decisions and approvals, so ratepayer capital, not only private investment capital, is at risk. Also, the regulatory decision-making process is often viewed as unpredictable by investors, significantly increasing the investment risk of private capital. Utilities operate under an "obligation to serve," which means downtime to upgrade entire portions of the infrastructure is essentially not allowed. And, as previously mentioned, the large number of application domains, jurisdictional complexities, and diversity of interoperability challenges makes smart grid interoperability unique.

[24] Erich Gunther, "Interoperability – Why Should You Care?", EnerNex Corporation, p. 4.

[25] "SGIPGB and SGIP Charter," v1.1, prepared for NIST by EnerNex Corporation, March 2010.

[26] "ANSI Essential Requirements: Due Process Requirements for American National Standards," Edition: January 2009.

standard itself.[27] In practice, other organizations in the electricity industry tend to use different definitions of "open" than the one used in this white paper. Some of these standards are referred to as "open proprietary" since access to them requires membership in specific groups or fees. Other *open proprietary standards* may be vendor based, which violates the "nondiscrimination" aspect of "open" used in the white paper.

2.3.2 Standards Don't Always Yield Interoperability

Broad agreement on a particular standard does not guarantee that it will be adopted. Some industry standards that are candidates for smart grid use have had substantial difficulty gaining traction in the market. In addition, if a standard is loosely written or allows too many options, implementations based on the standard might not interoperate without substantial additional integration work.

Common concerns include:[28, 29]

- Standards development efforts may take a long period of time (e.g., more than a decade) and represent heroic vendor efforts to compromise their own interests for the greater good.
- High levels of flexibility in the standard may make implementation difficult for utilities when significant expertise is required to make technical implementation decisions.
- Proprietary vendor solutions may currently be more cost efficient for utilities, delaying the adoption of "open" interoperability standards.

> *"I think everyone likes the idea of a homogenous standard; the problem is usually in how the industry comes together to accept the standard."*
>
> ***-Technical Executive, Vendor***

Standards-based implementations are sometimes assumed to be interoperable, and while standards may greatly facilitate interoperability, implementations do not always interoperate as envisioned.

> *"There are some very relevant standards that have so much flexibility that it defeats the purpose of standardization. The fact that multiple implementations have the rubber stamp of the same standard doesn't mean that the standard has resulted in multiple 'interoperable' implementations. Some standards that are widely used in the electricity industry, in fact, don't lead to interoperability in the sense that I use the term."*
>
> ***-Technical Executive, Vendor***

The benefits of interoperability depend on how broadly a standard is adopted, in addition to how well it is structured, to help ensure that implementations will interoperate without significant integration work. Standards certification and compliance testing can help ensure interoperable implementations but will not

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[27] ANSI's use of the terms "open" and "openness" to describe standards is meant "to characterize documents that have undergone [a] consensus-based, transparent process." ANSI permits "the payment of reasonable license fees and/or other reasonable and nondiscriminatory license terms may be required by the intellectual property rights holders." ANSI's definition also permits "the payment of a fee to obtain a copy of the standard."

[28] "Smart Grid Standards Assessment and Recommendations for Adoption and Development, Draft 0.83," prepared for the California Energy Commission, Gunther, et al., February 2009.

[29] Notably, ANSI C12, IEC 61850, and IEC 61968/61970 were mentioned in thought leader interviews.

ensure adoption. Smart grid implementers that specify standards requirements on equipment and systems procurements play an important role in broader adoption.

> *"It's just not as simple as NIST developing standards, sending them to FERC, and then we have interoperability. Actually achieving interoperability is much more complicated than this simple viewpoint – even if consensus on standards can be reached among the various stakeholders, the ultimate adoption of the standards may not progress as envisioned."*
>
> ***-Scientist, National Laboratory***

2.3.3 Interoperability Testing Can Enhance Interoperation

Interoperability of products or systems produced to a specific standard depends on the clarity of the standard, but discrepancies across implementations can still exist. This issue has long been recognized in communities interested in developing communications standards. A recent smart grid standards conformity landscape document elaborates: *"If they can communicate, it is still possible that they cannot perform any useful applications. These situations can arise because the implementations have conflicting interpretations of the specification or because they have chosen conflicting options within the standard."* [30]

One method to help ensure that standards-based implementations will interoperate is to use interoperability testing and certification. Interoperability testing requires implementations that are supposed to work together to actually be connected and tested, often overseen by a third-party test authority, to validate that they interoperate as they should according to the relevant standards. Certification can facilitate interoperability by validating that systems have been formally tested in a production scenario – as they will be finally implemented – to ensure that they intercommunicate. Certification can give customers and implementers confidence that the system will work as advertised. Implementation guidance, when published along with a technical interoperability standard, can also help implementers achieve the intended interoperation. Interoperability testing differs from standards conformance testing since conformance to a standard does not necessarily ensure interoperability with other conformance-tested systems.

2.4 How Is Standardization Being Addressed Today?

Smart grid interoperability standardization has been addressed by a number of efforts over the past decade or more – even before the term "smart grid" was applied. The Electric Power Research Institute (EPRI) initiated efforts in the late 1990s with its "Consortium for Electric Infrastructure to Support a Digital Society" (CEIDS) to address the future of electric power. This effort addressed systems interoperability, and evolved into the IntelliGrid[31] project. [32] The U.S. Department of Energy's national labs have been working for more than a decade on various aspects of smart grid development and interoperability. The MultiSpeak standard, developed by the National Rural Electric Cooperative Association (NRECA) and a group of industry vendors, is another significant

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[30] "Existing Conformity Assessment Program Landscape," Version 0.82, February 19, 2010, p. 9. Prepared for the National Institute of Standards and Technology by EnerNex Corporation.

[31] http://intelligrid.epri.com/

[32] Some of EPRI's efforts are described in the following article from 2001: "The Energy Web," Wired Magazine, Issue 9.07. 2001. http://www.wired.com/wired/archive/9.07/juice_pr.html

effort that dates back at least 10 years. MultiSpeak has been successfully implemented in a range of products and is used successfully by many cooperative utilities today. The U.S. Department of Energy's (DOE's) "Modern Grid Initiative" subsequently brought together many concepts that are now collectively called "smart grid."

The GridWise Architecture Council has played an important role in framing interoperability issues and challenges during the past five or more years with its "GridWise" vision[33] and related framework[34] and tools.[35] Many standards organizations have played important roles in defining standards that now come under the umbrella of smart grid, including: *ANSI, American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE), International Electrotechnical Commission (IEC), Institute of Electrical and Electronics Engineers (IEEE), Internet Engineering Task Force (IETF), North American Energy Standards Board (NAESB), and National Rural Electric Cooperative Association (NRECA)* with its MultiSpeak[36] initiative, and others.

In early 2009, NIST enhanced the resources assigned to coordinating the development of a national smart grid interoperability framework[37] across disparate activities and stakeholders. NIST has sought to bring focus and momentum to a range of smart-grid-related standards activities taking place across many standards organizations, vendors, and industry alliances and consortia. Previously these activities had limited coordination. NIST established a broad, cross-industry stakeholder community as a key part of this effort – the *Smart Grid Interoperability Panel* (SGIP). This effort aims to coordinate various smart-grid-related standards efforts and navigate the complexities described above to address interoperability issues that span the smart grid domains.

The SGIP effort uses "stakeholder consensus"[38] to establish *appropriate standards* for various smart grid areas, in addition to the activities discussed above. The SGIP has also created two standing committees, the Smart Grid Architecture Committee (SGAC)[39] and the Smart Grid Testing and Certification Committee (SGTCC),[40] recognizing the importance of these two particular issues. These efforts will help ensure that technologies and solutions being built to the standards actually meet the standards.

The SGIP does not seek to explicitly develop standards but rather to select appropriate standards for various application domains from the existing body of standards, as well as to identify gaps[41] and develop requirements where these gaps exist. The effort recognizes the broad set of standards already in existence and is working with many SSOs[42] to modify, update, or create new standards where necessary.

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[33] http://gridwise.pnl.gov/foundations/history.stm

[34] "GridWise Interoperability Context Setting Framework," The GridWise Architecture Council, March 2008.

[35] Such as the "Decision-Maker's Checklist" – "Introduction to Interoperability and Decision-Maker's Interoperability Checklist," v1.0, GridWise Architecture Council.

[36] http://www.multispeak.org/

[37] Resources for this expanded effort were provided at least in part by funding from the American Reinvestment and Recovery Act (ARRA) of 2009, which allowed NIST to give additional focus to the smart grid standardization responsibility assigned to the agency by the Energy Independence and Security Act of 2007 [EISA, Title XIII, Sec. 1305]

[38] "NIST Framework and Roadmap for Smart Grid Interoperability Standards Release 1.0," Office of the National Coordinator for Smart Grid Interoperability, NIST, September 2009, p. 44, discusses use of "stakeholder consensus." This document refers to OMB Circular a-119, which defines "voluntary consensus standards."

[39] http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/SmartGridArchitectureCommittee.

[40] http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/SmartGridTestingAndCertificationCommittee. The SGTCC details its plans for smart grid standards certification testing in its roadmap document, "Smart Grid Testing and Certification Committee (SGTCC): Testing and Certification Roadmap," March 31, 2010.

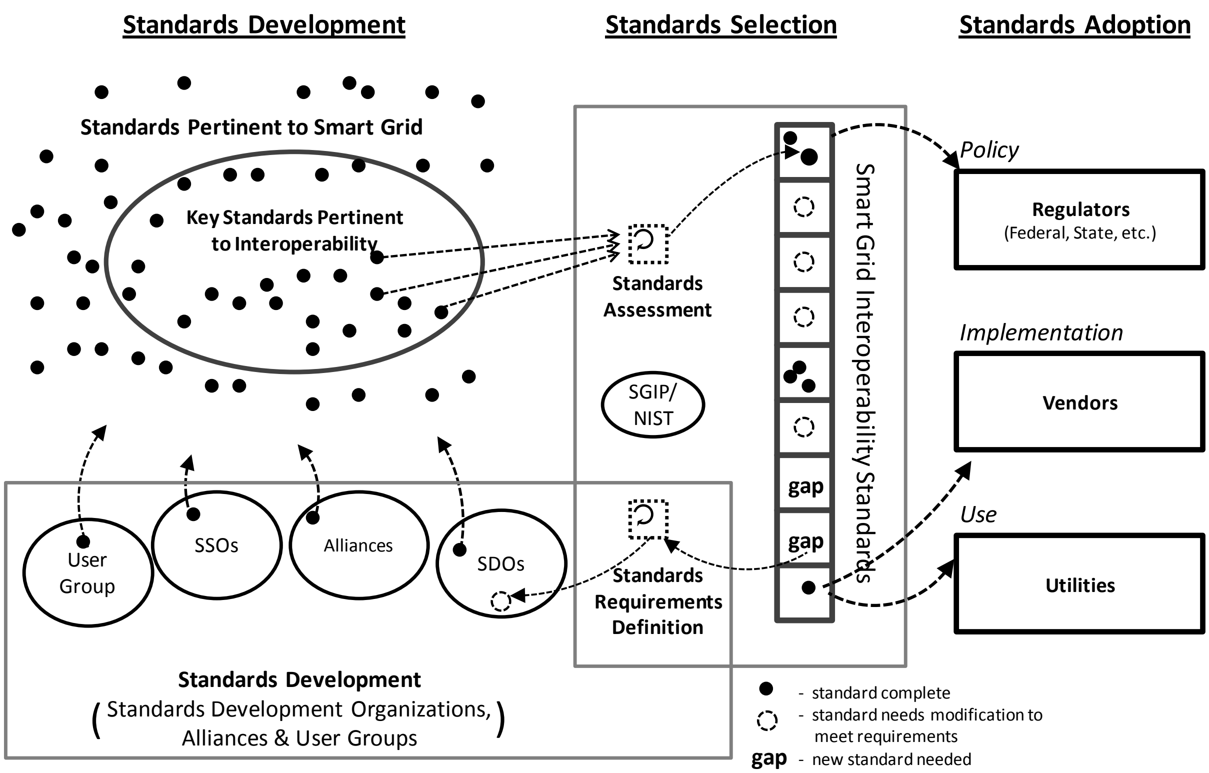
[41] Gaps include deficiencies in existing standards as well as the need for entirely new standards.

[42] "NIST Framework and Roadmap for Smart Grid Interoperability Standards Release 1.0," Office of the National Coordinator for Smart Grid Interoperability, NIST, September 2009, p. 45. Uses the term SSO (Standard Setting Organization) to refer to the "broader universe of organizations and

Interviewed thought leaders generally agreed that these efforts have provided much-needed focus and energy for smart grid interoperability standards efforts. Some discussions indicated that these efforts merit further examination to ensure they are producing valuable, useable output, and that some change may be necessary to develop the best path forward for interoperability.

These efforts, organizations, and dynamics, taken together, present a complex landscape within which interoperability must be achieved. Figure 5 illustrates a simplified "snapshot" of this process as it exists today. The NIST/SGIP process has taken on a central role in the past one and a half years, and thus is a key part of the discussion here. However, the decades of momentum and unique motivations of the various SSOs, as well as commercial interests of vendors, exert a powerful influence as well. These influences may not always align with the goals of the NIST/SGIP process, or the national interest in smart grid. For example, billions of dollars worth of legacy, proprietary solutions exist in the infrastructure today. Long-standing sales channels and vendor relationships will work to preserve business, even if it means slowing progress towards a richer smart grid ecosystem.

FIGURE 5. "SNAPSHOT" OF RELATIONSHIP BETWEEN STANDARDS DEVELOPMENT, SELECTION, AND ADOPTION[43]



groups – formal or informal – that develop standards, specifications, user requirements, guidelines, etc." "*Standards/Specification Setting Organization*" (SSO) and "*Standards Development Organizations*" (SDOs), user trade groups, alliances and other types of organizations can be included in this definition.

[43] For a complete list of standards organizations participating in the SGIP process, see: http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/SGIPMembersList (stakeholder categories 13 and 18).

Investment decisions are being made today by many utilities around the country, prompted significantly by American Recovery and Reinvestment Act of 2009 (ARRA) smart grid funding.[44] Industry, in many cases, must move forward using whatever specifications and standards currently exist, raising the stakes for timely standards development and selection processes. If this process does not move quickly enough, various

FOCAL POINT – Dr. George Arnold on Comparing the SGIP Effort to Early Standardization Efforts of Other Technologies

"It's useful to consider the development of some previous big infrastructures not unlike the smart grid. There's generally been sort of a "guiding hand" that has developed the overall framework. Then once that's established, a more decentralized process deals with the ongoing evolution.

Take the legacy telephone system, it was really developed and architected. The standards were picked or developed by AT&T, which at that time was a regulated monopoly. So in 1984, when AT&T was broken up and the industry that we have today appeared, there was a well-established framework that existed in the infrastructure. Then the ongoing evolution was handled by the standards organizations that were set up after the breakup – organizations like TIA and ATIS, for example.

Take the Internet, the driving force at its inception was DARPA, which is a government program, and a few individuals like Vint Cerf, who developed the early protocols. Their work became embedded in the initial infrastructure, and once it was well established, there was an ecosystem that continued the ongoing development. So there's this initial sort of guiding hand, and then it became an almost purely voluntary process with minimal government regulation.

Take the computer industry, there are a few key things that caused convergence to what we have today, which is a very rich set of interoperable standards and applications. One thing that began the convergence of the industry was Microsoft, through a de facto standard, and the other was the acceptance of the Internet and its protocols as the basic communications fabric to tie things together and the World Wide Web and the standards being done through W3C. Those things really caused the whole IT industry to move away from what had been a legacy of proprietary, closed systems, like in the days of DECnet and SNA, to what we have today. That transition wasn't really pushed by government, although there may have been a bit of a roll there, because the government did have a heavy hand in the development of the Internet. But there weren't any sort of standards that were adopted that caused things to move in this direction, but it did take a very long time.

The way that the EISA 2007 Act [Title XIII] has framed the smart grid, it essentially defined the role of NIST to be a guiding hand in getting the framework established, and the voluntary standards would continue to be developed and evolve through the processes that exist with the various SDOs and consortia. It also defines this role for the regulators to adopt standards coming out of the process, but it doesn't define what "adoption" means. So people in industry now are worried about the possibility that the regulators will pick up these standards that are developed through a collaborative consensus process mandate that particular standards be used.

So the legacy grid that we have today that has customized, proprietary systems, vendor-supplier relationships with the 3,200 electric utilities – most incumbent suppliers would like to perpetuate that. The question is whether this industry is going to naturally move towards the adoption of open, interoperable standards, or will there be a need for some government tool to either accelerate or encourage that transition? I think that the answer to that question is unknown."

[44] The ARRA smart grid funded projects require reporting of *build* and *impact* metrics that quantitatively measure project results. Learnings from funded projects will be collected and shared in the next three to five years to help direct future smart grid investment decisions.

regulatory bodies have tools that can make the process move faster, such as policy approaches and regulatory rulemaking that could essentially force adoption of specific standards.[45]

> *"If you have top-down control, like in the military, then you can make the case that a uniform set of standards probably could work because you can throw billions of dollars at it and say 'go off and do it.' This industry has some characteristics like the military control, but is also like the Wild West Internet; there are pieces of both. We have to come up with a blend between them, a blend that's reinforced by policy, by business models, and by standards."*
>
> ***-Technical Executive, Vendor***

Key questions for the overall nationwide direction include: Is the current process leading us toward a rich and vibrant smart grid ecosystem that can deliver the promised benefits? How can we tell if the process is moving in the right direction? Given this complex landscape, will existing market forces cause the proper standards to emerge in a time frame that is reasonable, or will some type of intervention be necessary?[46] A deeper examination of the approach to standards may illuminate a better path.

2.5 What are the "Open" Paths to Interoperability?

Two approaches to standards from the spectrum shown in Figure 4 were developed to illustrate alternative approaches to establishing standards. These descriptions can apply to either standards development or standards selection, and this distinction is noted where important.

The two approaches encapsulate the essential differences in the dominant approaches to open standards in use today, outside of government mandate.[47] They represent alternative directions on the path to interoperability, and they were used to frame the thought leader discussions. The approaches are:

- **Institutional Endorsement:** Seeks to develop a uniform, open standard for a given smart grid application area, eliminating the need for adapters, drivers, and *gateways* within the application area. Typically, the responsible SSO convenes the relevant stakeholders and experts to develop, through a consensus process, a standard that best fits the needs of an application area. This approach is similar to the one used by national and international standards organizations such as the IEC or ANSI.[48] In the case of standards selection, some form of consensus must be reached on the relevant SSOs, as well as details of the standard to be used. Where gaps are identified, one or more SSOs can be engaged to help bridge the gap based on

[45] Regulatory rulemaking by FERC or other organization with regulatory authority is a significant concern to the industry, which fears the negative side effects of such regulation. John Lucas, Transmission Policy and Services General Manager at Southern Company Services, Inc., in comments to FERC's Technical Conference on Smart Grid Interoperability Standards, January 31, 2011, writes: "…Southern believes the IEC and existing NIST/SGIP process should not yet be relied upon as establishing industry consensus for the Commission's [FERC's] adoption of standards." And Lucas goes on to cite a number of reasons why Southern Company holds this view.

[46] Some thought leaders have suggested that the authority over smart grid standards given to FERC in EISA 2007 provides a regulatory tool to "move the industry along more quickly" if interoperability progress proves to be slower than acceptable. Others have pointed to China, which is moving ahead with smart grid standardization and deployment at a rapid pace, as an example of how the smart grid process can be moved along more effectively using top-down mandate.

[47] These two constructs are slightly forced abstractions used to convey and illustrate the divergent choices, and they are not intended to be fully accurate descriptions of specific existing standards processes.

[48] Dr. George Arnold has pointed out that there is no requirement, policy, procedure or necessarily any objective on the part of the standards organizations mentioned (or others that may use similar processes) that requires them to develop only a single standard for any particular area. Dr. Arnold also pointed out that there are many instances of standards that allow for multiple options to address a particular area. While this may be true, the authors believe that the comparison is useful for purposes of discussion in the paper.

identified requirements. As the name suggests, the process results in the endorsement of the standard by the relevant institution(s).

- **Market Toolkit:** Allows for multiple open standards for a given smart grid service or application area. It would require a mechanism to declare which of the appropriate standards is being used on a particular implementation, and thus it makes clear where gateways or bridges are required to communicate to other standards implementations. This approach can be likened to that used by the Internet Engineering Task Force (IETF), which is inclined to let market forces, rather than explicit consensus, sort winners and losers. In the case of standards selection, the standards selection body acts as a registry for appropriate smart grid standards and for the applicable adapters, drivers, and gateways.[49] This approach calls for the standards selection body to define a set of characteristics or minimum requirements that must be met for a standard to be deemed appropriate.

Advocates of each approach have a vision of how they work ideally, but they often differ in their practical realities.

> *"The dynamic in a consensus-based approach is very different than that used in the more open market philosophy approach. For a consensus approach, you may be more gentlemanly, but you bring your stiletto in case you need it during negotiations. For a market approach, battle is more front and center, so you bring your sword and armor for everyone to see."*
>
> ***-Technical Executive, Utility***

Establishing smart grid interoperability standards is an important but complex effort. Open standards are widely considered to provide considerable advantages over other approaches in the standards-setting spectrum. Two defined approaches – Institutional Endorsement and Market Toolkit – represent viable but alternate approaches to establishing open standards for the smart grid moving forward. Understanding the benefits of the Institutional Endorsement and Market Toolkit approaches is facilitated by an expanded discussion of the six key issues. This expanded discussion is presented in Section 3.

[49] It is possible that items such as self-describing protocols (e.g., XML), open-source tests, and certification suites used for self-certification and other such tools could be used as part of such a toolkit, even though they are not necessarily interoperability standards by themselves, per se. The GridWise Architecture Council (GWAC) has addressed some of these issues in its document "GridWise Interoperability Context Setting Framework," GridWise Architecture Council, March 2008.

3 Six Key Issues in Establishing Smart Grid Standards

Six key issues should be considered when determining the approach to standards development for any particular smart grid application area. An understanding of the following issues can enrich the discussion of standards development approaches:

- KI 1. The Smart Grid Is a Complex System of Systems
- KI 2. Interoperability Must Accommodate Multiple Communications Layers
- KI 3. Parts of the Smart Grid Will Evolve at Different Rates
- KI 4. Stakeholder Interests Are Not Always Aligned
- KI 5. New Security and Privacy Challenges Are Created
- KI 6. Interoperability Standards Must Balance Certainty with Flexibility to Enable Innovation

The discussion below expands upon the brief previous discussion of these issues in Section 2.2. This more detailed discussion establishes a basis for understanding the ten competing priorities that should be considered for a given application area, which are presented in Section 4.

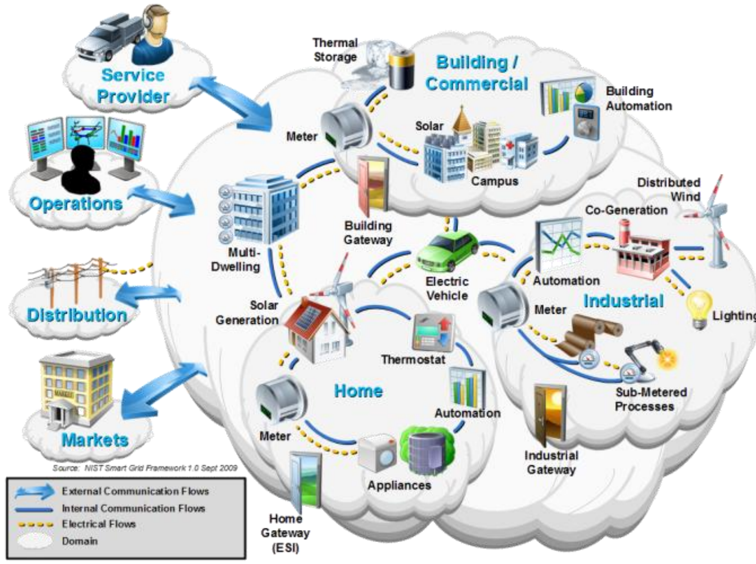
Section 3 Contents:

3.1 Key Issue 1: The Smart Grid Is a Complex System of Systems

Smart grid standards must consider both existing and emerging technologies and accommodate a mature industry structure with established boundaries and jurisdictions. The NIST Smart Grid Conceptual Model, introduced earlier, provides one set of considerations, but regulatory and other types of geographical differences are also important.

The NIST Smart Grid Conceptual Model shown in Figure 3 divides the industry into seven top-level domains that each have similar objectives and requirements across the industry: 1) Customer, 2) Distribution, 3) Transmission, 4) Bulk Generation, 5) Operations, 6) Markets, and 7) Service Providers. The Conceptual Model further divides the top-level domains into more granular application areas. As an example, the customer domain, shown in Figure 6, is divided into residential, commercial, and industrial customers and also recognizes important categories within each, such as multifamily housing, institutional, and campus settings. As the smart grid is built out, more information will allow utilities and other service providers to differentiate customers into dozens if not hundreds of different segments.

FIGURE 6. SMART GRID APPLICATIONS WITHIN THE CUSTOMER DOMAIN

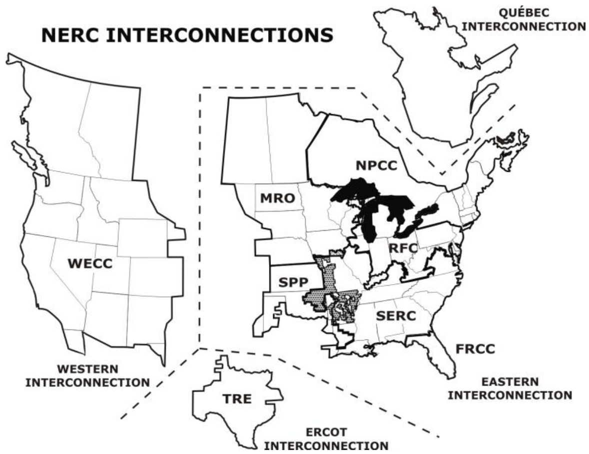


Standards efforts often must focus on interoperability within specific sub-domains, as the sub-domains may have markedly different requirements. For example, applications in the residential customer sub-domain exhibit a broad set of technical differences depending on residential construction type, size, availability of communication infrastructure, multifamily versus single family, and so on. Commercial customer requirements are in some cases similar to residential requirements, but generally have other characteristics as well, such as the need for three-phase metering, and different construction materials and building sizes. The differences between a customer's set of requirements and, say, transmission application requirements, are even greater.

> *"You have to consider that smart grid crosses a variety of domains that historically have not been highly integrated."*
>
> ***-Smart Grid Executive, Utility***

Other important boundaries impact standards requirements, and some of them are illustrated in Figure 7. Each *North American Electric Reliability Corporation* (NERC) region shown has regulatory responsibility within its boundaries. State lines present another type of regulatory boundary, and regulation can also exist at municipal or local levels, further complicating efforts. The patchwork regulatory system leads to market segmentation, and each regulatory jurisdiction may have different expectations regarding interoperability or the role of standards in mitigating financial risk to customers.

FIGURE 7. MAP OF THE NERC REGION BOUNDARIES[50]



> *"Regulators have to be part of this. It's fine to proceed down the standards path at the national level. But it can't impinge on the regulatory policies and cost recovery mechanisms that we decide at the state level."*
>
> ***- Regulatory Commissioner***

Some geographical areas may have abundant intermittent renewable resources that need to be integrated. Some areas have sparse population densities for which a wired communications infrastructure may be cost prohibitive. These segmentations and other new segments enabled by smart grid lead to a range of niche markets that may be difficult to address.

> *"The smart grid involves connecting protocols across industry, residences, commercial buildings, the distribution system, AMI, etc., all of which are fraught with their own political and technical complexities. The idea that we can somehow get a bunch of smart people in one room to seek out 'the one, true standard' seems on some level like we're kidding ourselves."*
>
> ***- Scientist, National Laboratory***

In some instances, a uniform consensus standard may not be practical or sufficient to cover the broad range of requirements. A market approach to standards may more naturally address such niches; however, multiple consensus standards also can potentially be selected to meet these varied needs in some circumstances.

3.2 Key Issue 2: Interoperability Must Accommodate Multiple Communications Layers

Standards are required at each level of the protocol stack[51,52] for a given application area, as briefly discussed in Section 2. This situation presents a decision for the approach to standards development, which can be

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[50] www.nerc.com

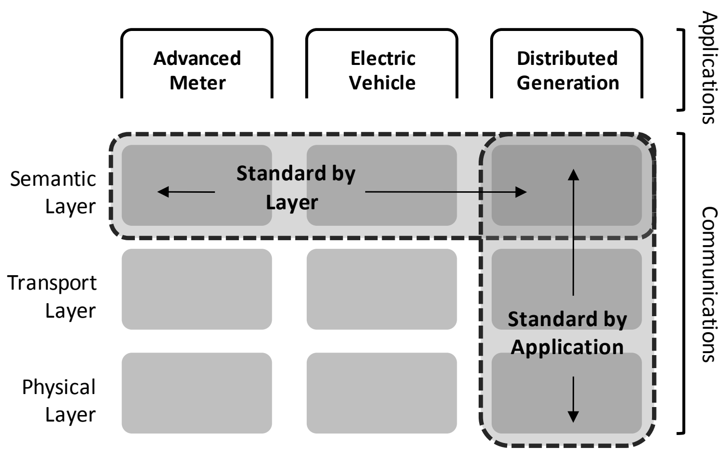
[51] http://en.wikipedia.org/wiki/Osi_model

[52] "GridWise Interoperability Context-Setting Framework," The GridWise Architecture Council, March 2008, p. 5.

developed either for a given smart grid application area across multiple layers of the protocol stack, or for a given layer of the protocol stack across multiple smart grid application areas.

> *"When we discuss architecture and standards, we need to consider the multiple layers of smart grid systems. Whether it's the transport layer or the application layer, each is fundamentally a little different than just 'communications' as it has been ubiquitously applied. As you move from the bottom layers of the protocol stack to the upper layers, different approaches to standards development may be warranted."*
>
> ***- Engineering Faculty, University***

FIGURE 8. CONCEPTUAL STANDARDS ARCHITECTURE BY PROTOCOL LAYER OR APPLICATION[53]



A standard developed for a particular application area can specify all layers of the protocol stack as part of its definition. However, if an implementation based on this standard is later required to communicate with another application area or meet new communications requirements, it may be necessary to build gateways, or update the entire standard to meet these new needs. Well-defined boundaries between the protocol layers can reduce the sensitivity of a particular application to new requirements or changes in lower protocol layers. Different standards can be used at different layers, independent of the types of applications using them. The notion of having a cleanly layered architecture is critical to make this approach work.

> *"Having very well-defined interfaces and layers has been proven time and time again to make the most sense from a design perspective."*
>
> ***Technical Executive, Vendor***

It is possible that different approaches to standards make sense at the different layers of the smart grid. For example, at the *physical layer*, there is a diversity of requirements across, and even within, some smart grid application areas, such that establishing a uniform standard is daunting if not impossible. Fortunately, multiple standards have been developed to meet some of these diverse requirements, and in effect, a Market Toolkit

[53] The simplified stack shown here can be mapped to the commonly used 7-layer OSI Protocol Stack. It can also be mapped to the lower layers of the "GWAC Stack"; however, it omits certain details for simplicity. For example, the syntactic layer is assumed to be part of the semantic layer for discussion in the paper. It also intentionally omits the upper layers of the GWAC Stack, namely Business Procedures, Business Objectives, and Economic/Regulatory Policy layers, which are important for interoperability, but aren't part of a protocol stack.

approach can be used in the selection process for the smart grid, so that several existing standards can be applied where appropriate.

Some of the thought leader discussions suggest that, as a general rule, the closer to the application level, the more a Market Toolkit seems to make sense, and the closer to the physical layer interconnection, the more an Institutional Endorsement approach seems to make sense. This view seems to provide more flexibility for creativity and adjustment at the application level as well as more stability, but may come at the expense of higher costs for the underlying communications hardware at the physical layer.[54]

The approach selected at a particular protocol layer for a specific smart grid application also depends on the specific application requirements, not solely on the layer. Application requirements such as very low *latency* (discussed in Section 4) may require a standard that specifies all protocol layers. In addition, there is a compelling argument for developing uniform *semantic layer* standards across multiple smart grid applications. Such a standard would provide greater certainty to parties investing in applications, and it would allow more resources to focus on innovative applications rather than on solving interoperability issues.

Developing a cleanly layered communications structure is an important consideration in establishing appropriate smart grid standards, regardless of the standards approach chosen.

3.3 Key Issue 3: Parts of the Smart Grid Will Evolve at Different Rates

Two time-related characteristics are important in transitioning the electricity infrastructure to the smart grid. The first is the *industry metabolism*. The metabolism indicates the general rate at which a business operates or decisions are made. Metabolism is influenced heavily by the rate of change required to meet customer needs and respond to competition – or in some cases, regulation. In the case of the electric power industry, customer requirements have changed only marginally for many decades, and much of the industry existed as a regulated monopoly business. Only recently, regulation has begun to impose changes to various smart grid domains to a greater or lesser degree, depending on the jurisdiction. These changes are clearly accelerating, and it seems likely that the industry metabolism will need to increase in response.

The second characteristic is the rate at which the technology is evolving. A mature technology, such as a transformer, is not evolving rapidly. Ten years from now, it is quite possible that transformer designs will be similar to the current state of the art. In-home displays, with expected lifetimes of two to four years, on the other hand, may look very different three years from now, and other devices may even subsume their functions.[55] The maturity of a technology along this technology evolution path is an important factor because standards written for immature technologies can impact innovation and the evolution of those technologies.

> *"On the transmission and distribution side there's a slow rate of turnover, and capital equipment could last 40 years. On the consumer side, the technology turns over much more frequently."*
>
> ***-Smart Grid Executive, Utility***

[54] Cost as used here indicates the expense of developing and manufacturing a hardware-based implementation across the scope of physical requirements for all applications, not necessarily the per-unit hardware cost borne by implementing a single physical layer within a single application.

[55] The functionality may be subsumed by another technology such as thermostats, smart phones, or other communicating devices that are becoming ubiquitous.

The metabolisms and expectations about the rate of technology evolution are very different in the traditional utility industry relative to the IT, computing, and communications industries. As these industries begin to merge to form the smart grid, a growing dissonance is evident among these respective cultures. The organizational and operational change necessary to take advantage of smart grid technologies and innovations requires executives and leaders to recognize and manage this dissonance. One option to help alleviate this issue is to establish a transition period between the time that standards are selected and the time that they will officially go into effect. Such a strategy has been applied to renewable energy standards, for example, where targets for renewable adoption are established for a future date, allowing utilities and vendors enough time to undertake the transition with less immediate pressure.

3.4 Key Issue 4: Stakeholder Interests Are Not Always Aligned

The challenge of developing and selecting appropriate interoperability standards is complex enough without having to worry about hidden agendas, or influences that may try to subvert the process for their own parochial interests. If all involved parties can be counted on to prioritize the end goal of a vibrant national smart grid ecosystem, then alignment on the path forward might be easier. However, as with any collaborative effort where the stakes are high, parties seek to influence the outcome to favor their desired ends. Sometimes the influence is not even a conscious effort but a result of seeing an issue through a narrowly focused lens.

> *"Unfortunately we've got very opinionated people not thinking about the physics of the grid, not thinking about the long-term implications to society, wanting their own special interest to be advantaged."*
>
> ***-Technical Executive, Utility***

Powerful companies or influential individuals can be expected to use their money and/or personal influence to bend the outcome in their favor within almost any stakeholder process. *Incumbent* technology providers can be expected to fight to preserve their incumbency, and their interest in standards tends toward a backwards focus on compatibility with existing product offerings, biasing efforts to move forward toward a new or different structure.

> *"I see a huge amount of commercial pressure to somehow find a way to bless standards that already exist rather than to define appropriate and interoperable communication standards."*
>
> ***-Technical Executive, Vendor***

Standards organizations, both SSOs and SDOs, are an important part of the stakeholder discussion. These organizations actively participate in the industry interoperability efforts, and they bring their own perspective and historical momentum to the process. Recognizing the difference between the standards development process and the standards selection process is important. The thought leader and stakeholder discussions revealed interesting insights and observations about the difference.

Observations related to the development processes of the standards organizations

Stakeholders working within various standards organizations provided the following observations:

- The consensus process used by some standards bodies seems to accommodate many stakeholder "wish lists," and in doing so, sometimes achieves little focus in the direction of interoperability.
- Relying strictly on "volunteers," as standards bodies often must do, can limit efforts to achieve the best outcome, and effectively is a way for organizations with commercial interest and significant resources to influence the process and outcome.
- Hypothetical arguments can dominate the discussion, especially in consensus-based standards bodies, where practical and implementation considerations sometimes receive less attention.
- Standards development efforts sometimes focus on short-term issues rather than on more substantive long-term issues, especially when "hot topics" dominate the discussion.

> *"One of the problems with the consensus approach is that the process can be dominated by the particular problem of the day, rather than striking the optimal balance of priorities."*
>
> ***-Engineering Faculty, University***

Observations specifically related to the NIST/SGIP process

Thought leaders generally agreed that industry interoperability efforts and overall coordination is heading in the right direction and lauded the efforts of the NIST leadership in gaining momentum and balancing interests in this complex process. The following concerns were expressed:[56]

- Utilities, as a stakeholder group, are not adequately represented given their importance as the technology consumers and implementers.[57]

> *"We are concerned that the vendors are influencing the standards efforts to drive the market in their favor versus advancing the greater cause of smart grid. We hope that just because it's a collaborative process, it'll all balance out…but there are certainly more vendors in the room than utility people."*
>
> ***-Smart Grid Executive, Utility***

- Some SSOs, which naturally bring their own historical perspective to issues, have sometimes been over-reaching in their attempts to become the most relevant standard body for the smart grid.

> *"A variety of standards bodies and incumbent vendors are turning the process into a land grab to become the organization most relevant to the smart grid."*
>
> ***-Technical Executive, Vendor***

- Some standards bodies do not recognize or acknowledge the limits of their areas of expertise and push for ownership of areas in which they have limited experience and capability.[58]

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[56] A number of thought leaders expressed the view that parts of the NIST process have been partially co-opted by influential parties. The thought leaders generally did not want to go on record with statements or specifics, but they wanted to express this opinion.

[57] There are no formal barriers in the NIST process impeding participation by utilities, but many utilities may have human resource or budget constraints that limit their involvement.

[58] The SGIP is attempting to manage this through the Priority Action Plan process by establishing requirements for the standards and selecting which standards bodies to engage in responding.

- New entrants to the electric power marketplace initially flooded into the SGIP process, hoping to use it as a way to enter into the smart grid arena, but often with very little understanding of the market or ability to add productively to the discussion.[59]

> *"[New vendors] will come in, see an opportunity and rather than taking the time to see what others have done – other than a patent search – they don't spend enough time educating their people on how similar problems have been solved in the past. It's someone who's been a plumber for years trying to be a carpenter, and it really doesn't work."*
>
> ***-Erich Gunther, Chief Technical Officer, EnerNex***[60]

- Some participants have strayed from the NIST/SGIP charter in some areas,[61] where they have started to develop standards rather than select standards and define requirements.
- Areas where gaps have been identified have been assigned to a relevant SSO. These areas thus are treated as Institutional Endorsement, by default.
- As a bright spot, various parties have put aside individual interests in certain instances and agreed to compromise for the goal of greater interoperability.[62]

These observations indicate dynamics that can work against the goal of interoperability, and they can move the industry away from the path of high interoperability. Stakeholders cannot be expected to place the greater good ahead of their own interests in every instance. Rather, the stakeholder process must consider the self-interest motive and provide for a balance of interests.

3.5 Key Issue 5: New Security and Privacy Challenges Are Created

Security of data and privacy are critical areas that have new connotations in the context of the smart grid. The term "cyber security" is used extensively in a smart grid context to describe issues related to reducing the risk of unauthorized information access and misuse of smart grid-enabled capabilities. The security of new types of data stemming from smart grid systems – energy activity of individual home appliances, personal behavior related to energy use, and energy conservation relative to that of neighbors – requires agreement on who owns the data, who can access it, and how can it be used. Security and privacy present complex issues that extend well beyond the brief consideration that can be given here, but they are introduced below to provide an overview of salient points.

[59] Others have pointed out that some of these newcomers bring critical knowledge needed for development of the smart grid: "photon / electron connection is critical", meaning that traditional IT and communications knowledge will be critical to the smart grid.

[60] Quote taken from *Smart Grid Today* article – *Gunther, Arnold put state of smart grid standards in perspective*, Feb. 24, 2011.

[61] The SGIP charter and bylaws have been set up to avoid this type of influence; however, as with any stakeholder process, some stakeholders find ways to exert influence outside the agreed organizational process. The SGIP charter and bylaws can be accessed at: http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/SGIPCharterAndBylaws

[62] One example is collaboration between the ZigBee Alliance and the Home Plug Alliance, which agreed to harmonize their disparate efforts toward a "Smart Energy Profile" for broad use in residential smart grid applications. It is also important to recognize that the SGIP is not a passively managed process, and that NIST and the SGIP Governing Board knowledgeably monitor SGIP process activities that could negatively impact the standards-setting process.

"Cyber security, privacy and consumer access to information are the issues that are at the top of what we're concerned about."

-Regulatory Commissioner

3.5.1 Security Issues

The integration of IT and telecommunications with the traditional electric delivery infrastructure can introduce new vulnerabilities that must be addressed.[63] Information security standards and methodologies have made tremendous progress in the past 10 to 15 years, but they require adaptation to meet the unique requirements of the electric power industry. Because security weaknesses can potentially be exploited to disrupt service over a wide portion of the grid, the costs of disruption can be high.

The NIST-coordinated interoperability effort includes a focus on cyber security and seeks to develop a strategy framework by which interoperability standards can be evaluated relative to security risk: "The primary goal is to develop an overall cyber-security strategy for the smart grid that includes a risk mitigation strategy to ensure interoperability of solutions across different domains/components of the infrastructure."[64]

This effort indicates several standards that are directly relevant to the smart grid in a number of areas – for example, *critical infrastructure protection* (CIP), *advanced meter infrastructure* (AMI), home automation network (HAN), and substation devices. Maintaining up-to-date security measures will require changes in management and operational practices, such as equipment that needs frequent software and firmware updates.

The indication that a particular standard is appropriate for smart grid use requires that it be filtered through this cyber-security strategy framework. This process has characteristics of the Market Toolkit approach in that a set of characteristics is used to determine whether a standard is appropriate. However, it also has characteristics of the Institutional Endorsement approach, in that the standards that have this set of characteristics also require consensus agreement of the relevant SGIP communities, due to the importance of this issue.

Another important dynamic that results from the intersection of IT and power delivery capabilities is that the application of standards is likely to cross traditional organizational boundaries in the electric power industry. This may cause strategic realignment of functions within the electric utility. For example, NERC critical infrastructure protection requirements (NERC CIP), which focus on protecting bulk power delivery, also have rules that may require reclassification of distribution assets as critical infrastructure. These requirements can come into play if elements are interconnected via certain communications protocol layers,[65] which smart grid projects will do in some cases. This may force IT skill sets into the traditional purview of the engineering organization within utilities.

[63] The DOE recently selected EPRI to lead a cyber-security collaborative that is intended ultimately to become the National Electric Sector Cyber Organization.

[64] From the NIST SGIP Twiki Web site: http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/CyberSecurityCTG

[65] E.g., protocol layer 3 (referred to as transport layer in this paper) and above protocol require special consideration within the NERC CIP classification rules.

3.5.2 Privacy Issues

The smart grid will allow new information to be gathered from consumers and businesses, and this information is potentially valuable. Just as Google gathers information on Internet search patterns and monetizes it via advertising, the behavior of energy users can be immensely valuable to utilities, third-party service providers, advertisers, and others who might monetize it.

> *"Privacy is absolutely a concern. Who owns and protects customer data? What happens when a customer wants a third party to get involved?"*
>
> ***- Regulatory Commissioner***

Consumer market research data suggests that privacy is a significant concern among large segments of the population. Fear of "big brother" using data for unknown purposes, selling it to a third party, or reaching into the living room to control a homeowner's thermostat are examples mentioned by interviewees. Concerns are accentuated by consumer backlash to AMI rollouts in several states.

Standards and safeguards must address these concerns, and public education may be required to help assuage fears.[66] Just as privacy standards and practices have addressed similar concerns in other industries, such as financial services, they must be dealt with effectively in the new domain of energy information. Key questions include:

- Who owns the data? Should the utility, customer, or someone else be responsible for the data?[67]
- Can the customer assign or sell the rights to use their data for specific purposes?
- What constitutes consent to use specific data and can the utility act on behalf of customers in this area?
- Will law enforcement or legal consultants be allowed access to electricity usage information?

The SGIP Cyber Security Working Group has issued "Guidelines for Smart Grid Cyber Security" as a three-volume series:

- Volume 1, Smart Grid Cyber Security Strategy, Architecture, and High-Level Requirements
- Volume 2, Privacy and the Smart Grid
- Volume 3, Supportive Analyses and References

These documents present an analytical framework that organizations can use to develop effective cyber-security strategies tailored to their particular combinations of smart grid-related characteristics, risks, and vulnerabilities.[68] Although NIST largely addressed the key elements in developing its guidelines, it did not address the risk of combined cyber-physical attacks as well as other key elements that surfaced during its development of the guidelines that need to be addressed in future guideline updates.[69]

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[66] The Information & Privacy Commission of Ontario has been a leader in the field of advocating and educating about smart grid privacy issues. Cavoukian, Ann, Information and Privacy Commissioner, "Privacy by Design: Achieving the Gold Standard in Data Protection for the Smart Grid," Ontario, Canada, June 2009.

[67] On September 29, 2010, California Governor Schwarzenegger signed into law new privacy protections for consumers' energy use data, which defines who is responsible for maintaining the data. CA Senate Bill 1476.

[68] NISTIR 7628, "Guidelines for Smart Grid Cyber Security," v1.0, Volume 1, August 2010.

[69] U.S. Government Accountability Office, "*Electricity Grid Modernization, Progress Being Made on Cyber Security Guidelines, but Key Challenges Remain to be Addressed*." GAO-11-117. January 2011.

The approach to privacy issues and their impact on smart grid interoperability are being addressed by SGIP working groups. Privacy is a significant societal issue, however, that may transcend a straightforward or prescriptive approach. A host of issues needs to be addressed by industry stakeholders, not only by the interoperability standards effort.

3.6 Key Issue 6: Interoperability Standards Must Balance Certainty with Flexibility to Enable Innovation

Realizing the full potential of the promised smart grid benefits requires more than interoperability; it requires innovation in many areas.

> *"In the smart grid space, we're not yet to the knee of the adoption curve. A lot of what we're talking about will totally be transformed by innovation and new approaches. We need standards to enable innovation, not lock us in."*
>
> ***- Engineering Faculty, University***

Measuring the level of innovation and advancement beyond an incremental improvement can be challenging. The *SEI Smart Grid Maturity Model* (SGMM) [70] provides a yardstick by which progress can be measured. The SGMM defines the ultimate level of maturity as "pioneering," which includes the following:

- Stakeholder strategies capitalize on the smart grid as a foundation for the introduction of new services and product offerings.
- Business activities provide sufficient financial resources to enable continued investment in smart grid sustainment and expansion.
- New business model opportunities emerge as a result of smart grid capabilities and are implemented.

The path to a rich and vibrant ecosystem can be diverted if standards are overly prescriptive, limiting innovation and allowing lock-in to specific solutions or market structures. A degree of flexibility is needed to allow companies to develop new technologies and create new business models.

> *"We see the market changing and the utility business model changing. Just as in the telecom industry 20 years ago, the companies that survived and thrived are the ones that embraced the change."*
>
> ***-Smart Grid Executive, Vendor***

Areas where innovation must occur require less overarching specification, but they are likely to require carefully specified interfaces. For example, the many promised benefits of the smart grid stem from applications and structures that leverage the semantic layer of the communications protocol stack. In application areas where the smart grid is expected to create new solutions,[71] consensus uniform standards at the semantic layer provide more certainty for application communication. This certainty allows more resources to focus on innovative applications to solve key smart grid challenges, rather than solving interoperability issues. On the other hand, if

[70] SEI Smart Grid Maturity Model, Version 1.1, Preview, Release 3, Carnegie Mellon University, June 2010.

[71] Plug-in electric vehicles or automatic demand response (auto DR) for commercial facilities are often envisioned as the "killer app" that will redefine the grid of the future.

an interface standard is over-specified, new solutions may lack flexibility and miss the opportunity to develop truly innovative approaches.

This perspective on innovation leads to the conclusion that a balance must be reached in standardization—that under-specification inhibits innovation by leaving too much uncertainty and diluting resources, and over-specification inhibits innovation by restricting a solution to a specific structure. For example, an implicit architectural assumption sometimes made by participants in the standards process is that the electricity meter will be the gateway for all energy-related information flowing in and out of a customer's site. Others, however, believe that this assumption is overly restrictive and that the "internet of things" will provide the dominant architecture for information flow, with energy devices along for the ride. The architects of the smart grid interoperability standards effort must understand the nuances of each domain, application, and communications layer and select the appropriate approach that enables high interoperability and allows for innovation.

FOCAL POINT – Home Area Network

Background: *Home Area Networks* (HANs) allow various digital devices throughout the home to communicate with each other and potentially with the utility or other outside parties. In the context of smart grid, HAN typically refers to the communication infrastructure among energy-consuming devices, a control system, a consumption feedback display, and a smart meter. The HAN can enable optimized energy consumption for residential customers and provide the ability to easily respond to utility signals with minimal customer intervention.

Analysis: The emerging market for HAN technologies is expected to grow rapidly, but the market characteristics are still undetermined. With the deployment of smart meters and variable pricing structures, HAN technologies, like smart appliances and in-home displays, are gaining traction. However, legacy appliances that are not digitally enabled possess lengthy equipment life cycles (10 to 15 years), which will reduce the immediate attractiveness of HAN technologies and slow their market penetration. Additionally, investment is still risky because of unsettled communication protocols and standards, although some efforts have proceeded using the available standards and specifications – for example Texas has initially decided on the use of *ZigBee Smart Energy Profile* (SEP) 1.0. A HAN can only operate if its devices function on a common set of communication protocols or if it uses a gateway to translate between different protocols. ZigBee is one leading standard protocol, but Homeplug, Z-Wave, and Wife are creating competition, and manufacturers fear investing too heavily in the wrong system. Until the uncertainty is reduced, manufacturers can either create costly products that are compatible with several standards, develop products around a single standard that may end up representing a fraction of the market, or postpone investment until winning standards begin to emerge. Although the potential is high for HAN technologies, the uncertainty makes investment decisions difficult. The uncertainty in HAN standards is increased by the presence of other types of HANs already present on customers' premises that provide wireless Internet connectivity and that connect end-use devices such as printers, televisions, and gaming consoles. It is not clear how these "other" HANs might compete with SEP for integration and control of end-use energy devices.

Lessons Learned for Standards Selection: The need for compatibility across a complex spectrum of utilities and appliance manufacturers implies strong benefits from having a uniform standard protocol that may be developed best through an Institutional Endorsement approach. The stability gained through the eventual adoption of a uniform standard in this market will eventually increase investment and kick-start adoption. With a goal of getting these new technologies into the field, a Market Toolkit approach has the potential to put solutions in the market more quickly, even if less cost effectively. A Market Toolkit approach might also provide more openness for learning and innovation in technology. A consensus standard developed today may be incompatible with future technologies, which sometimes evolve faster than a standard can be created and revised. Thus, there are trade-offs between standard selection approaches.

It is not clear whether the standards drive the markets, or the other way around.   Interoperability is a requisite to achieving a rich and vibrant market ecosystem, but it may be that the presence and growth of significant market opportunities will drive the needed standards development.

> *"There's this impression in Washington that if we can just get the standards right and in place, then the market will flourish. I tend to say standards follow the market, they don't make the market. And standards processes generally are so slow that if you wait for the standards process to run its full course, you've missed the opportunities."*
>
> ***-Scientist, National Laboratory***

Right now, the federal and state governments are driving the push toward interoperability standards. It may be that after proven business cases for certain types of smart grid investment emerge, private industry will drive the standards more than policy.

Understanding the six key issues described in this Section is necessary to design the appropriate approach to establishing interoperability standards. An overly general architecture that omits key dimensions such as communications layers, market segmentation, and rates of decision making may produce standards that are not defined tightly enough to solve key interoperability issues.   Lack of consideration for security, privacy, process integrity, and innovation is likely to limit adoption. Section 4 presents ten competing priorities in developing or selecting an interoperability standard.   For each priority, the strengths and weakness of the Institutional Endorsement and Market Toolkit approaches are examined based on the thought leader discussions and industry research to understand potential advantages of the each approach.

4 Ten Competing Priorities in Establishing Smart Grid Standards

One purpose of interoperability standards is to provide clarity to the marketplace, which helps accelerate the adoption of smart grid technologies and solutions. Appropriate standards promote this goal by lowering costs, reducing investment uncertainty, and increasing the achievable benefits. But what makes a standard, or set of standards, appropriate?

The standards selection process must determine appropriate standards for each smart grid application area. Each application area, however, has its own set of characteristics, drivers, requirements, and challenges. The process needs to account for these differences and select one or more standards that best meet the challenges presented in the specific area. Doing so requires balancing among a number of potentially competing priorities. Ten competing priorities were identified and synthesized from the thought leader interviews.[72] These priorities illustrate the key trade-offs in establishing smart grid standards. The standards selection process should balance among these priorities, just as is done by traditional processes for project management and product development.

The ten competing priorities shown below are grouped into the traditional development process priority areas – quality/performance, cost, and timing. The numbers assigned to the competing priorities are for identification purposes only and are **not** a reflection of relative importance among the priorities. The importance of each competing priority depends on the specific application area being addressed. Explicit identification and balancing of these priorities are important parts of the process for selecting the appropriate standards in the various areas.

Section 4 Contents:

[72] The ten competing priorities are not necessarily exhaustive of the priorities that may be considered but are rather the key priorities to consider based on thought leader interviews.

I: Quality and Performance

CP 1. Future interoperability and avoiding lock-in – the flexibility to adapt to new and changing requirements, technologies or systems that become available in the future without requiring "forklift upgrades" or incurring high integration costs.

CP 2. Backward compatibility – the ability of a new system or solution to integrate with legacy systems that are still operational.

CP 3. Interchangeability and plug-n-play – the ability to remove a component from the smart grid and replace with a like component that is higher functioning or has other advantages, with minimal cost and disruption.

CP 4. Interoperability with complementary products – the ability of a technology or solution to integrate with other technologies or solutions where the combination of the two (or more) provides added value.

CP 5. Interoperability for mobile applications – the ability of a solution to integrate, as needed, with systems in different geographical areas.

CP 6. Bandwidth and latency requirements – the necessity for certain solutions to send or receive specific information within a specified time limit.

II: Cost

CP 7. Integration and solution costs – the costs of getting a set of smart grid technologies connected to and working appropriately with the systems with which they must operate to deliver their desired functionality.

CP 8. Accommodating niche markets – markets in which varying requirements create a need for different solutions or different standards, even within the same application area, resulting in fragmentation into smaller niches.

III: Timing

CP 9. Speed of standards selection and adoption – how quickly standards can be established for a given smart grid application area and how quickly standards are adopted in the marketplace to achieve interoperability.

CP 10. Rate of learning – how quickly lessons can be learned from projects, deployments, and demonstrations of emerging technologies and solutions.

Each of the ten competing priorities is described in more detail below. Sections 4.1 through 4.3 present each competing priority, starting with a brief description followed by a discussion of the important points and related quotes from the thought leader interviews. Section 4.4 provides context for the competing priorities by presenting the arguments for and against the Institutional Endorsement and the Market Toolkit approaches. A mock dialogue between advocates of each approach leverages the point-counterpoint format of each standards approach. This allows a far-ranging discussion covering many of the competing priorities and drawing on the six key issues from Section 3.

4.1 Priority Area I. Quality and Performance of Standards in Meeting Smart Grid Objectives

This section contains a discussion on quality and performance of standards, which includes notions of whether the standard successfully meets the technical requirements for interoperability. In the context of smart grid standards, quality and performance have many dimensions, each of which can impact technology adoption differently.

4.1.1 Competing Priority 1: Future Interoperability and Avoiding Lock-in

Future interoperability provides flexibility to adapt to new and changing requirements, technologies or systems without incurring high integration costs. Problems involving complex systems, which typically require interoperation among components or subsystems, often have been addressed using proprietary solutions, which allowed the system vendors to "lock-in" their customers. In these cases, after the solution is in place, it becomes difficult and expensive to acquire components or subsystems from an alternate vendor whose components and systems can't interoperate with the in-place solution.

> *"When we look to purchase a new technology, we're looking at it in terms of not what its single purpose is today, but how that device might be repurposed for other uses in the future."*
>
> ***-Smart Grid Executive, Utility***

Lock-in makes customers dependent on the selected vendor for incremental or modular improvements. The introduction of *energy management systems* (EMSs) in utility control centers illustrates the lock-in issue. In the 1970s, most EMS solutions were proprietary. Vendors (e.g., Areva, Siemens, ABB, and GE) implemented different solution approaches, and the solutions used data formats specific to each vendor. This caused the exchanging and sharing of information—such as power system models—with neighboring utilities or the regional transmission organization to be difficult and expensive.

Solutions built on open interoperability standards offer a way to avoid lock-in by allowing subsystems or components from different vendors to work together as elements of the overall solution. For example, when consumers buy a USB-enabled external hard drive for their computers, the drive can simply plug into the computer and work. The EPRI and a number of utilities addressed interoperability across EMS solutions in the 1990s by working to divide control centers into standardized modules to promote increased competition and innovation in the EMS subsystems. This same notion of open standards has successfully driven interoperability efforts in other technology areas such as Internet communications.

However, even an open standard can lead to a lock-in phenomenon if the standard is established too early – while the market and/or technology is evolving and before key learnings are gained.

> *"We don't want to lock in to a standard when the various competing approaches have not yet shaken themselves out in any economic or technical sense.*
>
> ***- Scientist, National Laboratory***

Which standards selection approach might best avoid the negative consequences of lock-in and create flexibility for new and future smart grid applications?

4.1.2 Competing Priority 2: Backward Compatibility

Backward compatibility is the capability for newly installed components or subsystems to work well with in-place systems.[73] Lack of backward compatibility can create scenarios that require a change-out of entire systems rather than incremental upgrades, raising investment cost and risk.[74]

Today, grid system boundaries and layers are not cleanly separated, and communications between applications often are quite limited. The industry uses many fragmented, proprietary, and sometimes monolithic systems. Moving toward the envisioned smart grid with a modular, layered architecture initially requires significant investment in capabilities for backward compatibility. Standards must address the needs of the future, while working with legacy systems of the past. Thus, backward compatibility is a key hurdle in the initial smart grid transition to open standards-based interoperability.

> *"The real issue is how to make decisions that don't result in us needing to prematurely retire existing equipment before the end of its useful life –which can be 40 years. Utilities don't have the capital to go out and do that type of massive change out, and even if we did, our regulators would hang us out by our toes."*
>
> ***-Smart Grid Executive, Utility***

After the smart grid system-of-systems is appropriately separated along subsystem boundaries and layers using open standards, backwards compatibility becomes less problematic. Individual subsystems become much easier to replace or upgrade.[75] Each successive technology generation can move closer to high interoperability.

Much of the initial NIST/SGIP effort has focused on developing a list of existing interoperability standards with sufficient installed base and industry support to be used as smart grid standards moving forward. This approach helps ensure some level of backward compatibility, but to some degree leads to a "rear-view mirror" standards focus rather than a forward-looking focus toward clean subsystem boundaries and layers.

4.1.3 Competing Priority 3: Interchangeability and Plug-n-Play

Interchangeability is an aspect of interoperability that indicates the ease of adding or removing new components or subsystems – potentially from different vendors – within the existing infrastructure. The term "plug-n-play," which originated in the personal computer industry, represents one end of the interchangeability spectrum and indicates extreme ease of replacing components. A solution that offers plug-n-play components is

[73] For example, a newly installed distribution management system must work successfully with existing pole-top switches and transformers to be useful.

[74] For example, the AMR meter technology that delivered operational benefits to the utility has been overtaken by the AMI meter technology with two-way communication and additional capabilities. Utilities that implemented AMR are faced now with stranded asset investments if they choose to replace the AMR meters before they have reached the end of their useful lives.

[75] An example from another industry – a new generation PC can automatically connect with a legacy home Wi-Fi network and instantly provide access to the Internet. Upgrading an Internet router is relatively straightforward due to the open standards and separation of layers in the Internet communications architecture.

viewed as the ultimate state of interoperability because customers can purchase equipment without fear of lock-in and can plug in the new equipment at little or no cost and effort.[76]

Plug-n-play capability can be critical for some application areas; for example, consumer markets require plug-n-play or something very close. When a consumer brings a new product home from Best Buy, there is an expectation that it will be up and running in minutes – or at most, after briefly reviewing a simple product guide.

> *"At the consumer level, especially, everything has to be plug-n-play straight out of the box. If consumer products aren't proving to be interoperable, consumers will stop buying them."*
>
> ***-Technical Executive, Vendor***

Monolithic systems represent the extreme other end of the spectrum. In a monolithic system, none of the components or subsystems can be removed independently, so there is virtually no interchangeability. This type of system often results in the lock-in phenomenon discussed above.

Various levels of system integration can be required to "glue" new components or subsystems together, and the level of interchangeability largely determines how much time and effort is required. Systems integration can be labor intensive and complex, sometimes requiring the support of third-party systems integration specialists for days, weeks, months or more.

Considerable time and effort is required to develop standards, build products, and perform the certification and testing that is required to obtain plug-n-play capability. For some smart grid application areas, moving down the interchangeability spectrum to plug-n-play exceeds the requirements and may be overkill.[77]

There is a range of interoperability capabilities from completely custom integration to plug-n-play that can be targeted to accommodate the various smart grid application areas. Interoperability requirements can best be met with a standardization approach that targets the appropriate level of interchangeability merited for the specific smart grid application area.

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[76] An informative discussion relating plug-n-play capability with interoperability standards and integration costs can be found in "GridWise Interoperability Context-Setting Framework," The GridWise Architecture Council, March 2008, p. 10.

[77] For example, developing a standard to allow a new meter data management system (MDMS) to plug-n-play with the various other enterprise systems is extraordinarily expensive and time consuming, given the complexities involved and the differences between implementations across markets and utilities.

4.1.4 Competing Priority 4: Interoperability with Complementary Products

Complementary products or services are interdependent and add value to each other. In economic terms, the demand for a product is related to the availability, price, and attractiveness of its complementary products. This concept plays an important role in standards selection because interoperability increases the value derived from the use of complementary products and in some cases, may be needed to derive any value.

For example, a smart home appliance that has communication capability and built-in logic that allows it to react to electricity pricing is more valuable than a traditional appliance only when it is present in a home with the right HAN connectivity and logic interface (e.g., smart meter with AMI network, utility applications, and pricing programs). Making appliances interoperate with the utilities systems and programs requires various types of standards, from a wireless networking standard to a common semantic layer, and applications that can leverage this underlying communications.

FOCAL POINT – Betamax vs. VHS

Background: Videocassette recording (VCR) technology was introduced as a consumer product in the mid-1970s, and the widely known case of Betamax vs. VHS VCR formats illustrates the effects of complementary goods. At this time, there were two standards available to the consumer: Sony's Betamax and JVC's Video Home System (VHS). These products allowed consumers both to record television programming and to watch recorded videos on home entertainment systems. The two standards were not compatible with each other and varied in certain key parameters. In 1979, the VCR started to gain traction in the market, and the two standards coexisted without a clear winner until about 1984 – although VHS was substantially ahead in unit sales by 1982. After this five-year coexistence, Betamax began to fade from the market, and VHS became the dominant standard for VCR systems.

Analysis: Although Betamax had certain advantages compared to VHS, the availability of a particular complementary product – Hollywood movies – proved to be the dominant driver for the ultimate success of VHS. Betamax reached the shelves first in 1975, a year before VHS, giving Betamax a first-mover advantage. Further, Betamax was arguably a superior technology from a quality perspective. However, the limited recording duration of one hour, combined with Sony's brand protection practices, made the format relatively unattractive to movie producers. In contrast, VHS initially could record for two hours and was easily accessible to third-party investment, which made the format attractive to movie producers. By 1984, the attractiveness of the VHS VCR was largely driven by the availability of movies – a complementary product – in the VHS format.

Lessons Learned for Standards Selection: The Betamax vs. VHS case exemplifies a market-driven approach to standards selection (even though both standards are proprietary). The marketplace drove toward a single standard due to the high value derived from complementary products. From the perspective of an Institutional Endorsement advocate, this approach may have resulted in a sub-optimal outcome since the format that exhibited superior visual quality lost out. A consensus approach may have been able to integrate the visual quality of Betamax with the recording duration of VHS. Instead, the initial strategic decisions of Sony and JVC led to lock-in to an arguably "inferior" standard. However, from the perspective of a Market Toolkit advocate, the marketplace may have achieved a better result since adoption of VCR technology escalated rapidly and wasn't hampered by waiting for the development of consensus standards. The winning standard had the attributes most valued by the market – longer recording times and access to Hollywood movies – and other attributes, such as visual quality, were "good enough."

4.1.5 Competing Priority 5: Interoperability for Mobile Applications

Interoperability for mobile applications requires special consideration. Mobile applications need to connect and work with various systems, in different geographical areas and across regulatory boundaries, while potentially meeting other jurisdictional requirements. Stationary equipment, such as a thermostat or an advanced meter, on the other hand, may need only a single system interface over its entire useful life. The appropriate approach to standards development must consider these specialized requirements.

Electric vehicles represent critical applications for the smart grid, as do other mobile applications like emergency transformers. Although some aspects of the communication interface– the semantic layer and application above it – can be made software upgradeable, the physical interface for both communications and electrical power connection are cast in hardware and are difficult to change once selected and designed in. [78]

> *"We are less concerned with the time it takes to reach consensus on the standard, and more concerned with getting a good, single standard for the market."*
>
> ***-Smart Grid Executive, Vendor***

The challenges of mobile applications have been addressed in other industries such as mobile phones with roaming and retail financial transactions with global access to information, money, and credit. Mobile smart grid applications present the added complexity of requiring interoperability both for the electrical power interconnection and for communications, while meeting other application-specific requirements such as vehicle charging time.

4.1.6 Competing Priority 6: Bandwidth and Latency Requirements

Bandwidth and latency are characteristics of communication channels that require careful consideration for certain applications. Bandwidth refers to the capacity for information to be pushed through a communication channel, and latency refers to the time it takes the information to get from one point to another. Companies that build networks as part of their product or service offering spend considerable time designing networks to deliver the proper characteristics, including bandwidth and latency, to meet the requirements of the supported applications.

The wide range of smart grid application areas has an equally wide range of communications requirements – from rural, low-bandwidth meter reading to enterprise-level data analysis requiring high-bandwidth communications, to relay controls requiring very low latency. The approach to standardization can have an impact on how application requirements are met.

Some existing communication standards include definitions at the physical protocol layer, which must adhere to specific bandwidth and latency characteristics and constraints. For example, the various releases of the Wi-Fi, ZigBee, and Ethernet standards operate at specific bandwidths.[79] Other communications standards are largely

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[78] In the case of plug-in electric vehicles, the investment required to implement a standard power interface and charging profiles – designing it into a vehicle, building it into the manufacturing line, etc. – is considerable, but the cost of supporting multiple standards could be many times that of supporting a single standard; and the cost of changing to a new interface also is considerable.

[79] The actual bandwidth of a particular implementation varies based on a number of parameters, including distance, noise on the channel, upper layer protocol overhead, and other factors.

bandwidth independent; these standards tend to focus on the transport layer[80] and above. The TCP/IP suite of protocols fits this category and is essentially bandwidth independent.[81] When different standards are used for one portion of the transport or semantic communications versus another, gateway functionality – often implemented in a separate device – must be used to translate between the two. Gateway devices are created to translate between two or more protocols, and they are typically needed to complete communication between implementations based on different standards. The gateway device is likely to introduce latency into the communication, and it also may constrain the bandwidth on the channel.

The changing nature of the market is also important, in that the current characteristics of a particular application may change. This may be the case, for example, with the utility communications channel into the home. Whereas lower-bandwidth meter reading data was recently thought to be sufficient by many in the industry, new applications that require greater bandwidth for this channel are envisioned.

4.2 Priority Area II. Costs Resulting from Smart Grid Standards

The standards approach can have a significant impact on the cost of a smart grid application. A standard requiring a high level of interchangeability can make hardware and software solutions more expensive to deliver and certify but may reduce integration costs. This section discusses these trade-offs and cost impacts.

4.2.1 Competing Priority 7: Integration and Solution Costs

Life-cycle costs are an important consideration in the cost-benefit calculus for smart grid applications. Life-cycle costs often span several basic cost categories, including technology acquisition (e.g., equipment capital costs), integration, operations, and maintenance costs. Integration costs are particularly relevant to the topic of standards selection. The approach to standards can directly impact the targeted level of interchangeability, which can determine the relative cost of integrating a particular technology, component, or subsystem into an existing system.

> *"Driving toward a common standard will minimize the overall system cost. If we can't get to an industry standard, either the utilities, the aggregators, or the telecoms will have to weave through the standards mess; and in the end, it's the consumers who will pay for it."*
>
> ***-Smart Grid Executive, Vendor***

Components and subsystems that are highly interchangeable result in lower integration costs. A plug-n-play component can be plugged into the smart grid and used immediately with virtually no integration costs, whereas a subsystem with very low interchangeability requires considerable time and effort for integration. In some cases, integration costs can be the dominant portion of overall life-cycle cost, overshadowing the original technology acquisition costs. Gateways can be purchased or built to lower the integration costs, but these can

[80] Transport layer, as defined in Section 3, includes the various aspects of the protocol required to take the proper semantic information from one application to another, or from one part of a distributed application to another part of the application. The standard is thus independent of the physical characteristics of the communication channel and the semantics used in the application.

[81] Note that for certain channel characteristics, the transport protocol presents constraints. This is true, for example, with the TCP/IP suite of protocols, when large amounts of packet header information make it cumbersome and inefficient to use it directly for some low-bandwidth applications, such as those used in some telemetry applications. The same is true for more complex semantic layer protocols.

come with their own development, operations, and maintenance costs and may not be highly interchangeable themselves.

> *"Vendors supporting multiple standards result in higher production costs than if we had all agreed to some minimum, basic requirements. If your system doesn't natively understand the devices that connect to it, there's extra work to figure out what it means in your system, and that's an impedance issue and a cost of integration. Still, you have to weigh that extra cost against the flexibility of having multiple options available."*
>
> ***- Technical Executive, Vendor***

Standards that are overly prescriptive, or those that are developed from a biased perspective or incomplete understanding of requirements, can unwittingly drive up product and solution costs. For example, a standard that specifies capabilities that require sophisticated processing in a consumer-targeted device can drive up product costs for individual devices, increasing solution costs for systems that use these devices. Cost increases may apply across millions of consumers. If an alternate approach can meet the same set of requirements by utilizing simpler processing, the products may cost less and the economics of the overall solution may be dramatically improved.

The approach to establishing appropriate standards must balance these various cost considerations from the perspective of individual customers and for the industry as a whole. The goal of complete interchangeability in some cases can simply move the costs from integration activities into the cost of the technology or product itself. For example, a standard that requires plug-n-play capability for MDMS products would lead to expensive MDMS products. Such a product would, in theory, reduce integration costs, but it’s not clear that this approach would lead to overall lower life-cycle costs.

4.2.2 Competing Priority 8: Accommodating Niche Markets

Niche markets present an interesting challenge to standardization. These markets, by definition, have diverse requirements, and larger markets with diverse requirements may naturally segment into niches. The AMI market presents an interesting example of a large market that has many niches, such as residential, commercial, and industrial customers as well as sub-segmentation within each of these niches. The smart grid adds a communication dimension that historically has not been a key consideration for electric power applications.

A market niche can merit specific standards if it is large or important enough. Characteristics of the niche must be defined carefully enough so that appropriate standards can be developed to serve it.

For example, standards for the various niches of the AMI market must traverse a diversity of characteristics – geographical areas, topographies, climates, population densities, building architectures, and construction materials. Diversity in physical characteristics, for example, may warrant separating the physical layer standards from the transport layer standards. This allows a range of standards-based physical layer communications solutions to meet the diversity.

"As regulators, we won't specify that utilities have to standardize communications on WiMAX as opposed to power line carrier, for example, because we can foresee situations where each would be appropriate."

-Regulatory Commissioner

Examination of the requirements may indicate far less variation across the niches at a different protocol layer. If the requirements at the semantic layer, for example, exhibit far less diversity, the niches may amount to a single large market at this layer and may need to be treated as such. Once the appropriate architecture of application areas, communications, and markets is recognized, standards efforts can be targeted to aggregate standards efforts where possible and divide them where niche markets remain.[82]

4.3 Priority Area III. Timing of Standards in Meeting Smart Grid Objectives

The time characteristics of the chosen standards selection approach can impact the eventual adoption of standards in the marketplace. Some thought leaders believe that timing may be the most important factor in the ultimate success of the smart grid – and that in many application areas the industry cannot afford to wait for consensus to be reached. Others believe that it is important to take the time now to develop the appropriate standards that can lead to a state of high interoperability in the long run. These timing-related priorities are discussed in the sections below.

4.3.1 Competing Priority 9: Speed of Standards Selection and Adoption

The time required to define or select an open standard for a particular application area can impact the development of the market. A standard that takes a long time to develop can slow development of the market or provide opportunity for proprietary solutions to gain traction.

Smart grid projects are moving forward, in some cases, on time lines for which the availability of suitable open standards is not the primary driver. Vendors identify these projects as opportunities to sell legacy solutions that can meet the project time line. If suitable open standards are not available, proprietary implementations can meet immediate needs, even though they introduce the same problems that have been previously discussed – high integration costs, inflexibility, and lock-in.

Other smart grid efforts are on hold, waiting for suitable open standards to emerge. Waiting may be driven by a philosophy of only using solutions based on open standards or reducing the uncertainties surrounding the project costs and benefits, which make proceeding too financially risky. In either case, the market is stalled due to lack of an open standard.

"Consensus standards efforts can freeze the marketplace. The technologies and markets that could have been advancing and everything that could have been learned…it's all stopped dead in its tracks waiting for the release of a new standard."

-Technical Executive, Vendor

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[82] Note that the importance of semantic layer consistency across many smart grid applications is recognized in the SGIG process, and efforts are underway to "harmonize" many of the different semantic layer standards that exist.

A slow standards process can also result in a standard that is less relevant than initially envisioned because new standards or new technologies have passed it by. This wastes the time of participating individuals and organizations, misuses the resources available to develop or select standards, and ultimately slows progress toward high interoperability. Even if speed is not the top priority for some smart grid standards areas, most stakeholders can agree that it is better to realize the promised benefits of the smart grid sooner rather than later.

> *"These multi-year consensus standards efforts often take so long that they are barely relevant by the time the standard is published. By then, too many companies have created proprietary standards because they had a business to run and couldn't wait."*
>
> ***-Technical Executive, Vendor***

Even the timely release of a standard does not guarantee its adoption. Low adoption may result from the perception that a standard won't improve interoperability. A host of other factors can influence adoption, such as the influence of important organizations that might favor or disfavor its adoption or disappointing results of early trials leveraging the standard.

FOCAL POINT – BACnet

Background: Building automation allows building control systems (e.g., HVAC, lighting, security, and fire and life safety) to operate with limited human input. In the early decades of building automation systems (BAS), building owners had two options to avoid lock-in to a single manufacturer. They could either pay to purchase, implement, and support software packages that translated between different manufacturing languages (known as gateways) or use several disparate systems. As a result of this dilemma, a group from ASHRAE, the Standard Protocol Commission 135P, met in June 1987 to begin developing a standard communication protocol, later called BACnet (Building Automation and Control Networks). It took almost a decade, but after eight and a half years of work, BACnet was released as an open standard. More than 20 years later, open systems like BACnet are growing in the marketplace but are still more commonly used as translators between existing proprietary systems rather than as complete BAS solutions.

Analysis: BACnet offers translation between proprietary systems in a marketplace riddled with incompatible technologies, thus avoiding pair-wise gateways between these systems. This allows customers to select the best products from across the industry and provides a common interface for new products. BACnet has slowly gained ground as more than just a translation gateway, because it offers high performance and scalability in addition to other benefits. On the other hand, it has taken almost two and a half decades to reach this point. Technology advancements during that period (such as IP and Wi-Fi) threaten BACnet's broad applicability and acceptance. It has taken many years, for example, to partially address a commercial lighting function within BACnet. ASHRAE is working to achieve BACnet compatibility with emerging technology standards, but it is not clear BACnet will ever achieve the role and market penetration as originally envisioned.

Lessons Learned for Standards Selection: BACnet's development exemplifies a consensus path standards approach that has taken a very long time. It has been hailed as a success of technical effectiveness and criticized for its inability to replace proprietary protocols in the marketplace. Although buildings controlled using solely "native" BACnet systems operate well and provide a testament to its high performance, BACnet has gained market penetration primarily as a translator between proprietary systems. Finally, BACnet was initially developed prior to the widespread emergence of Internet protocols, and thus illustrates a scenario in which consensus standards can lock-in an industry to an inferior technology even if it avoids lock-in to a proprietary system. In the end, the lengthy time frame of BACnet development and adoption is not an aspect of the standard that the smart grid interoperability efforts can afford to emulate.

4.3.2 Competing Priority 10: Rate of Learning

Some smart grid applications rely on emerging technologies or novel integration practices, and some will require technologies that have not yet been envisioned. Experience and learning for these new applications may change the way that the problem is approached and the way a standardized solution is developed or selected. Residential energy management systems,[83] for example, have entered the market primarily as pilots and demonstration projects with the anticipation of learning how these customers will interact with the systems and how residential devices can best be integrated into a single system.

Stakeholders involved in standardization efforts may not have sufficient knowledge or expertise to develop appropriate standards until lessons can be learned from systems deployed at scale in the field. Standardization efforts must recognize this and leave flexibility in areas where key learnings have not emerged, while providing more prescriptive guidance in areas that are well understood. This requires the various involved parties to agree on the areas where uncertainty remains high or where substantial learning is still expected. These areas can include applications or protocol layers that are changing or evolving rapidly, where there are a diverse set of requirements that have unclear prioritization, or where the path to balancing priorities is not evident.

> *"If we want the market to really evolve, we need to start deploying now. There are too many lessons to be learned before we standardize everything, and we're not going to learn them until we get the equipment out in the field."*
>
> ***-Smart Grid Executive, Vendor***

4.4 Institutional Endorsement and Market Toolkit Positions on the Competing Priorities

This section illustrates the positions that might be taken and a resulting dialogue that could ensue discussing these positions. This is accomplished by constructing a mock dialogue between an advocate of the Institutional Endorsement approach and an advocate of the Market Toolkit approach. This exercise is intended to develop context and help illustrate how the ten competing priorities, along with the six key issues presented in Section 3, can be used to examine advantages and disadvantages of each approach, and then to support possible findings about which approach should be used for a specific application area.

Section 4.5.1 below contains a table illustrating general positions that might be taken by each advocate. These positions aren't specific to a particular application area, but rather, they apply generally across the smart grid. Section 4.5.2 presents the mock dialogue between these advocates as they attempt to sort out which approach should be used for standards in a specific application area. The HAN application area is used in the dialogue for illustrative purposes.

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[83] This is also true to a large degree for commercial energy management systems and to a degree for industrial energy management, although the latter has received more facility-by-facility focus given the large amount of potential energy savings for these facilities.

4.4.1 Illustration of Respective Positions

Table 1 below uses the ten competing priorities to illustrate positions that would likely be taken by advocates of the Market Toolkit and Institutional Endorsement approaches. The positions are not meant to be exhaustive of the potential arguments that could be made, nor do they apply equally to every smart grid application area. Rather, they are intended to illustrate some of the more interesting points.

TABLE 1. EXAMPLE POSITIONS THAT CAN BE TAKEN BY ADVOCATES OF THE INSTITUTIONAL ENDORSEMENT AND MARKET TOOLKIT APPROACHES

Institutional Endorsement Advocate Position	Market Toolkit Advocate Position
CP1. Future Interoperability and Avoiding Lock-in	
The Institutional Endorsement approach can balance short and long-term requirements and tradeoffs to avoid future lock-in to proprietary vendor solutions. This is done by leveraging the knowledge and experience of technical and industry experts who can best make the tradeoffs needed.	The Market Toolkit approach provides a venue for standards to compete. Competition will ensure that standards remain relevant into the future and will prevent lock-in to a single standard. Even if a single standard emerges as the winner, we can have confidence that the winning standard is vetted and robust, which can be more important than safeguarding against investment in a losing standard.
The Market Toolkit approach will fragment the market with multiple standards, which can lock-in customers and vendors to losing standards without a path forward once a "winning" standard emerges.	The Institutional Endorsement approach ties vendors and customers into a single standard. Once everyone uses the same standard, there will be less incentive for standards organization to update and improve the standard.
CP2. Backward Compatibility	
The Institutional Endorsement approach can achieve an appropriate balance between backward compatibility and future interoperability. For example, the IEEE 802.11 standard for wireless computer networking was developed by consensus and has been largely successful in maintaining backward compatibility while advancing the standard as technology and markets have evolved.	The Market Toolkit approach is best suited to address backward compatibility since customers should be able to choose a standard to best accommodate their legacy systems. Although the IEEE 802.11 standard may have addressed backward compatibility well, it did not need to address a disparate range of legacy systems already in place prior to the release of the first version.
The Market Toolkit approach overplays the importance of backward compatibility since vendors are lending the most support to standards that accommodate their own legacy technology. This approach won't push the vendor community in the direction needed to move the industry forward.	There are too many different non-standard legacy systems in the field for a uniform approach to standards to adequately address backward compatibility across the range of applications and solutions.
CP3. Interchangeability and Plug-n-Play	
The Institutional Endorsement approach will deliver the right level of interchangeability for a given application area and will avoid creating a complex set of customer decisions that would result from multiple standards.	Plug-n-play interchangeability sounds nice in concept, but it is not simple to achieve and is only needed in a small set of application areas. Systems that are fully interchangeable can be very expensive to design.
Certain applications, such as home area network devices, require plug-n-play levels of interchangeability, which can only be achieved by a single standard.	In a static environment, full interchangeability would be easier to attain. However, in an evolving smart grid environment, plug-n-play often isn't feasible and would be very expensive to maintain as the grid elements evolve. In addition, it's not really needed for most smart grid application areas.
The gateways and adapters that would be required to implement a Market Toolkit approach are expensive and often difficult to install and operate The alternative to these is custom software that is expensive to integrate and maintain.	The Institutional Endorsement approach may not yield true plug-n-play in many applications. Many consensus standards are complex and have been known to produce implementations that are not readily interoperable. Uniform adoption of consensus standards does not directly equate to easy interoperability.

Institutional Endorsement Advocate Position	Market Toolkit Advocate Position
CP4. Interoperability with Complementary Products	
Building products that interoperate with multiple standard protocols makes them more expensive. This extra expense will not only reduce the adoption of that product, but of its complementary products as well, inhibiting the overall adoption of smart grid technologies.	Multiple standards won't slow the adoption of systems with complementary products. By the time a uniform consensus standard has been developed, solutions based on multiple standards will already be available using the Market Toolkit approach.
Vendors incur more risk if they must choose to implement one out of several standards, which slows investment. A uniform standards approach will eliminate this expense and increase adoption.	Translating gateways can be easily be incorporated into products and systems at a relatively low cost if there is a market need.
CP5. Interoperability for Mobile Applications	
For mobile applications, having a single standard is essential. Electric vehicles, for example, will need to interface with equipment in a variety of locations and geographies, even the slightest degree of customization or retrofit would not be practical for most customers. Mobile applications require national-level interoperability for physical, electrical, and communications interfaces.	Mobility is only an issue for a few specific applications. Even in these cases, it isn't clear that a simple gateway or adapter couldn't solve the problem of integrating across multiple standards.
In a Market Toolkit approach, there's too much risk that products won't work across geographies. For example, potential customers for electric vehicles will be greatly dissuaded from purchasing the vehicle if they can't be assured that they can refuel in many or most places. Vendors and customers would rather wait for a consensus standard then face the uncertainty of having multiple standards out in the market .	Uniform standards would benefit mobile applications at the lower layers of the protocol stack (e.g., physical, transport, semantic), but application level logic such as charging schemes may not need uniform standards.
CP6. Bandwidth and Latency Requirements	
A single standard should exist for applications that have strict latency requirements, such as Phasor Measurement Unit (PMU) systems or relay control devices. Gateways needed to translate between multiple standards that would be required for the Market Toolkit approach would not be able to meet these latency requirements.	The majority of smart grid applications will not be affected by low latency requirements. In many cases, today's low cost processing power can deliver high bandwidth gateway functionality that meet the requirements of many latency-sensitive applications.
CP7. Integration and Solution Costs	
Integrating components of differing standards into a common system raises the costs of integration. These costs may be built into the devices or in the design of gateways and adapters. The Institutional Endorsement approach will reduce integration costs and produced more economies of scale.	A Market Toolkit approach will incur lower solution costs since customers can choose among multiple standards to meet their needs, allowing competition to drive costs downward.
A Market Toolkit approach does not guarantee a single standard, and could potentially take a long time (or never) arrive at one.	A Market Toolkit approach will help find the most cost effective solution in the long run. Competition among standards based implementations will lead to focus on cost effectiveness, which in a Institutional Endorsement approach, isn't necessarily a top priority.

Institutional Endorsement Advocate Position	Market Toolkit Advocate Position
CP8. Accommodating Niche Markets	
Niche markets with highly different requirements could be served by the Institutional Endorsement approach if a single standard is chosen for each niche. The approach will depend on how the markets are defined and how the standards architecture addresses these markets.	The Market Toolkit approach can provide customers with enough selection to meet the needs of very diverse markets. This will allow niches to select the standards that best suit their needs.
Niche markets with similar characteristics may be served by uniform standards with options or slight modifications, providing economies of scale for manufacturers and the industry as a whole.	The Institutional Endorsement approach is a one-size-fits all mentality that may work sometimes, but for many markets and applications, it isn't realistic.
CP9. Speed of Standards Selection and Adoption	
Adoption of smart grid technologies will occur more quickly with a uniform standards than with multiple standards. Even if it takes longer to arrive at a consensus, once a consensus standard is released the customer decision is simplified, costs will be lower, and there is less risk with each purchase.	The Market Toolkit will deliver standards to the market without wasting time to academically hash out which one is best through a laborious consensus process. Markets that are already waiting for standards don't have the time for a Institutional Endorsement approach.
The Market Toolkit approach may put standards in the market more quickly, but the market may take longer to grow and mature with multiple standards. In some areas, the market may never arrive at a single standard.	The Institutional Endorsement approach has taken decades in some cases. It would be a waste of time to develop or select a standard, just to have it be irrelevant by the time it is released.
CP10. Rate of Learning	
The Institutional Endorsement approach can incorporate learning for a controlled evolution of standards. The experts that know the most about the technology and markets need to be involved, and are in the best position to develop the standards.	Even “experts” may not have enough knowledge and experience to select a uniform standard for many new technologies and emerging markets. The best way to accelerate learning is to use a Market Toolkit approach and put equipment in the field quickly.
In the Market Toolkit approach, the market could converge and lock-in a single standard before sufficient learning has taken place.	The market can reveal the most appropriate standard when we don't know enough to select a standard by consensus.

4.4.2 Example Dialogue Focused on the Home Area Network

The following dialogue illustrates specific points that might be made by individuals or organizations adhering to a Market Toolkit position versus an Institutional Endorsement position. The example dialogue focuses on the customer domain, and in particular the home area network. Focus on a single application area allows the dialogue to include more detail, such as specific types of products and technologies, and to provide a rich elaboration of the points that are made in Table 1**.**

The dialogue is organized according to the ten competing priorities. The Institutional Endorsement advocate is labeled "**IE**" and the Market Toolkit advocate is labeled "**MT**". The home area network was chosen for the illustration due to the interesting range of competing arguments on both sides, as well as its current importance as a key element of customer engagement in the future of the smart grid. Similar dialogues can be constructed for other smart grid domains or technology areas, and the hope is that this example illustrates the usefulness of such dialogue to smart grid standards stakeholders.

The dialog is not meant to be entirely comprehensive,[84] but rather it serves as an example to illustrate the positions of the Institutional Endorsement and Market Toolkit approaches in the context of a smart grid application. This section focuses on the competing priorities, but not in the order CP1 through CP10 as previously presented. Instead, the dialog is organized with a focus on developing a natural flow in the dialog. The dialog on the HAN application area starts with CP3—Interchangeability— and moves through the different competing priorities.

[84] The complete set of issues could produce numerous pages of point-counterpoint dialog.

EXAMPLE DIALOGUE:

CP3. Interchangeability and Plug-n-Play (IE=Institutional Endorsement advocate and MT = Market Toolkit advocate)

IE: A plug-n-play level of interchangeability is necessary for networked consumer devices that are used in a HAN. Consumers won't tolerate devices or appliances that take a lot of time or installation effort, and so they demand plug-n-play for HAN devices.

MT: Plug-n-play sounds nice in concept, but it is not simple to achieve; look at how long it took Microsoft Windows to achieve plug-n-play for peripherals. Also, it's not necessarily needed. Appliances, thermostats, and other devices are commonly installed by professionals rather than consumers anyway.

IE: But lack of plug-n-play limits the appeal of these devices and appliances. The Institutional Endorsement approach helps deliver a common plug-n-play capability for interconnected HAN devices across the industry, so any HAN device you buy works on one common standard. This reduces complexity for consumers and creates a single market for these devices.

MT: A single market is not needed for success of HAN-connected devices. What is needed is for all HAN-connected devices in a single home to work together seamlessly. If there are several standards that achieve this, consumers will simply choose the one that they prefer. They still get plug-n-play.

IE: Yes, but this approach creates a confusing set of choices for customers. They have to ensure that their HAN equipment works together, and they'll have to decide which option among potentially confusing options is right for their needs.

MT: Reducing customer confusion about the choices is a simple matter of labeling and branding the products so they are easy to identify. This works well with cell phones today.

CP7. Integration and Solution Costs (IE=Institutional Endorsement and MT=Market Toolkit)

IE: Perhaps, but gateways and adapters are likely to be needed for interchangeability in a Market Toolkit approach, and these add expense and complexity, which just won't be acceptable in a consumer market.

MT: Gateway devices are needed only if a consumer chooses multiple different standards for their HAN-attached devices.

IE: Or, they are needed if a consumer wishes to move his or her devices to a new home that uses a different HAN standard. Also, device and appliance manufacturers have to support the multiple standards, driving up costs for their products and slowing the market.

MT: Translating gateways can be incorporated into HAN products and systems at a relatively low cost if needed, just as cell phones have multiple radios for compatibility with different wireless standards.

IE: Manufacturers of these HAN products disagree. And if vendors and customers are forced to "bet" on one out of several HAN standards, there is a risk that the initial bet by a vendor on a selected standard might eventually lose the standards battle. This business risk slows investment and potentially freezes the market. A uniform standard eliminates this risk and increases the rate of adoption.

MT: It is true that the costs may be higher initially for HAN technologies that are required to adhere to multiple standards, but in the long run, market forces will select a standard that is cost-effective and meets the market needs, just as cell phone standards are converging on the next-generation technology called Long-Term Evolution (LTE).

CP9. Speed of Standards Setting and Adoption (IE=Institutional Endorsement and MT=Market Toolkit)

IE: The Market Toolkit approach assumes that a winner will emerge and not leave the market fragmented with multiple standards for the long run.

MT: The Market Toolkit approach can pick winners quickly, especially when the underlying technologies are evolving fairly rapidly, as is the case with HAN devices and appliances. And multiple standards can actually accelerate the adoption of HAN systems and devices by providing more product choices sooner.

IE: Look at the situation with a lack of a uniform standard for DC power supplies for home electronics. Most people have a drawer full of power supplies from old cell phones, computers, and other electronics they bought over the years. None of these are interchangeable or useful any more.

MT: Yes, but historically it has taken so long to develop most uniform standards with all the negotiation needed to develop a consensus, that the point may be moot. Consensus standards have taken ten years to develop in some cases. The market for these technologies is moving ahead quickly, following closely on the heels of the broad deployment of AMI. By the time a standard can be agreed on, either customers have already chosen from what's available on the market (i.e., proprietary or Market Toolkit standards), or the market will have been frozen for years, waiting on a consensus standard to emerge.

CP4. Interoperability with Complementary Products (IE=Institutional Endorsement and MT=Market Toolkit)

IE: With the Market Toolkit approach, even if multiple standards do converge over time, the extra expense to initially support multiple standards reduces the adoption of the product in question and also of its complementary products as well. This includes things like refrigerators, dryers, and home appliances as well as thermostats and in-home displays, and these all need to be compatible with the utility's meter.

CP2. Backward Compatibility (IE=Institutional Endorsement and MT=Market Toolkit)

MT: The Market Toolkit approach is best suited to quickly evolving technologies and applications to accommodate the new capabilities of these home appliances and maintain backward compatibility with the meter.

IE: The consensus approach has been used to successfully maintain backward compatibility and meet evolving needs. Look at the IEEE 802.11 standard – Wi-Fi – as an example. This consensus standard serves as the basis for most wireless local area networks in the U.S. This standard has evolved over time to maintain backward compatibility and improve performance and capabilities over successive versions.

MT: IEEE 802.11 is an example of a standard that applies to new technology. Many smart grid applications will be new, but many will have to interoperate with substantial legacy systems. This is likely to include millions of smart meters that are deployed.

IE: The Institutional Endorsement approach can do the best job of balancing backward compatibility with future needs and direction. This works because it leverages a team of experts from diverse areas to make the right trade-offs to converge on the answer and direction.

MT: The Institutional Endorsement approach weights backward compatibility more heavily than needed. If there's only one standard, that standard has to be compatible with the bulk of legacy equipment. The Market Toolkit approach, on the other hand, provides a choice of standards that gives customers looking to move forward the opportunity to do so.

CP10. Rate of Learning (IE=Institutional Endorsement and MT=Market Toolkit)

IE: Since HAN technologies are relatively new, there are not a lot of legacy equipment and systems to worry about. The team of experts used in the Institutional Endorsement approach can monitor and update the standard as the market evolves to meet the changing needs.

MT: Even "experts" may not have enough knowledge and experience to select really good HAN standards by consensus. We need to put equipment in the field quickly to learn about these emerging HAN technologies and markets, and let the standards evolve as the learning occurs.

IE: The Institutional Endorsement approach can incorporate learning and create a controlled evolution of HAN standards.

MT: We don't know how things will or should play out. The Institutional Endorsement approach assumes we do. The Market Toolkit approach is flexible enough to meet diverse needs and changes as the market develops.

IE: Granted, there is a lot of uncertainty about how this market will evolve. It will be difficult for a consensus approach to address the broad market unless the requirements and future architecture can be defined fairly well in advance.

CP8. Accommodating Niche Markets (IE=Institutional Endorsement and MT=Market Toolkit)

MT: Yes, and the Institutional Endorsement approach is not likely to be able to meet the diversity of requirements across all residential customers in the country. For example, take a case where certain wireless technologies can have problems, say, in an apartment complex or large commercial site? Different standards may be required to support these different niches. This is likely to be especially true at the physical layer of the protocol stack, where widely varying requirements such as distance and local interference merit different technologies.

CP1. Future Interoperability and Avoiding Lock-In (IE=Institutional Endorsement and MT=Market Toolkit)

IE: Yes, this may be true at the lower protocol layers, but in the Market Toolkit approach, the market could fragment at the higher protocol layers as well, reducing interoperability and locking in customers to one of many standards.

MT: But at the lower layers, a uniform standard would lock-in the industry to a solution that won't meet the diversity of needs.

Dialogue Concluding Remarks (IE=Institutional Endorsement and MT=Market Toolkit)

IE: It seems that each approach has advantages at different layers of the protocol stack.

MT: Agreed. But, it seems that in many areas, it's hard to draw a clear conclusion about which approach is superior.

IE: True, but, in some of the areas – at least in the case of the HAN – one approach appears to have advantages over the other. For example, the high rate of learning and uncertainty in some markets may be better addressed by the Market Toolkit approach.

MT: Yes, and it does seem more likely that a uniform standard at the semantic protocol layer may be a superior approach.

IE: And the niche nature of market requirements at the lower protocol layers may be better addressed by a Market Toolkit approach.

MT: But clear architectural guidelines are needed to ensure this clean separation between protocol layers.

4.5 Section 4 – Summary

Section 4 focuses on developing and illustrating competing priorities in the development of standards. Ten competing priorities are identified spanning three overarching areas – quality/performance, cost, and timing. Each of these areas is discussed above in Sections 4.1 though 4.3. The final section presents a table of arguments that can be advanced for the two standards constructs – an Institutional Endorsement approach and a Market Toolkit approach. An example dialog between advocates of each approach illustrates the arguments that could be made for one smart grid application area, in this case, the home area network. Although the dialog focuses on the HAN application area, each smart grid application area will have its own unique requirements, nuances, and priorities that lead to relative strengths and weaknesses for each standards approach. Explicit identification and balancing of these competing priorities can help determine which standards approach is appropriate for each application area.

5 A Practical Path Forward – Recommendations

This section presents recommendations related to the development of a practical path forward to inform the approach to establishing smart grid interoperability standards. The recommendations are based on the synthesis of thought leader interviews, stakeholder discussions, and additional information presented in the white paper. Five recommendations are intended to complement current interoperability standards efforts by providing more clarity on important issues, helping define issues that are complex, and addressing priorities in establishing interoperability standards. These recommendations form an approach to help the standardization efforts move the industry—and in particular utilities, who will be implementing the smart grid—along the path to high interoperability.

Section 5 Contents:

5.1 Recommendation No. 1: Establish Forward-Looking Architectural Clarity

Further development of the standards effort can benefit from additional clarity and detail in the overall smart grid architecture. The initial NIST "Framework and Roadmap"[85] presents a list of smart grid standards and gaps for standards development along with a high-level conceptual model with stated plans for more detail later in the process. Current and next steps by industry participants require more detailed architectural direction to provide an appropriate guide and platform for standards development.

The current Priority Action Plan (PAP) efforts – created to help fill some of the identified gaps in standards– are structured along varying dimensions without explicit architectural guidelines relative to a future smart grid. Some PAPs are focused on specific technology areas, and others are focused on application areas.[86] In the absence of a target architecture, PAP participants are somewhat free to envision end-states that they believe are the most useful.

> *"Listing the standards isn't really adequate. You need to define the architecture and boundaries within which we can establish interoperability standards. Before setting a standard, we need to identify the problem that needs to be solved within the overall architecture."*
>
> ***-Technical Executive, Vendor***

The Smart Grid Conceptual Model[87] provides a view of the future smart grid by domain and sub-domain application area. This model illustrates, at a high level, how to break down the smart grid system of systems

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[85] NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0.

[86] For example, PAP2 (wireless) is technology specific, PAP6 (semantic model) is layer specific, and PAP 8 (distribution grid management) is application specific.

[87] "Smart Grid Conceptual Model," version 1, Smart Grid Interoperability Panel, March 15, 2010. The document can be found at: http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/SGIPConceptualModelDevelopmentSGAC.

into more manageable pieces. The "GWAC stack"[88] provides a key reference for layered communications in the smart grid. These two references, together, provide an indication of how the smart grid standardization effort might be architecturally organized. These documents alone do not provide enough architectural structure to effectively guide standards development activities at the detailed level that would be more useful.[89]

In addition, the use of a consensus-focused process to fill gaps tends to result in standards that favor inclusion of multiple elements and options stemming from the multiple stakeholder views and may not provide decisiveness and clarity that can better facilitate interoperability.

The goal of achieving interoperable solutions and implementations is made more difficult without such clarity and decisiveness. The effort of clarifying the overall smart grid architecture can potentially result in a set of "architectural areas," each of which focuses on a specific smart grid application, protocol layer, or combination of these, with well-defined interfaces to other architectural areas. In this way, the standards efforts may be more narrowly focused on these discrete areas to provide focus and guidance.

A smart grid *foundational architecture* might be explored as another concept for architectural clarity. A foundational architecture defines a minimal set of technologies and capabilities required to enable the future smart grid. Just as a computer operating system has basic capabilities and services to run useful applications, so a foundational architecture has the basic capabilities and services needed to build a broad set of smart grid applications in the future.[90] Such a foundational architecture, if successfully defined, gives policymakers, investors, and other stakeholders the confidence to build today with enough certainty of future benefits to justify the up-front investment.

Insight: A clarified and more detailed architecture for the future smart grid is needed more urgently than currently recognized. Without architectural clarity, standards developed and selected by a consensus process tend to be underspecified (i.e., allow for multiple elements and options that may not lead to interoperable implementations) and tend to be backward looking with a focus on blessing existing standards.

Recommendation: The Conceptual Architecture being defined by the Smart Grid Architecture Committee should extend the protocol layers across smart grid domains and application areas. An effort should be made to "carve up" the complex system of systems into explicit *architectural areas* that provide definition for the expected functions at each layer in each application area and specifications for the interfaces. A simplified protocol layer model—such as the one suggested in this document—may be suitable for this activity with physical, transport, and semantic layers represented.[91] The clarified architectural areas should be presented in a way that is useful to the smart grid technologists, standards development organizations, and implementers.

[88] "GridWise Interoperability Context-Setting Framework," The GridWise Architecture Council, March 2008, p. 5.

[89] For example, defining the interfaces between applications and application areas and elaborating the potential standards used at the various layers of the protocol stack across these interfaces.

[90] The notion that advanced meter infrastructure is this foundational architecture, which has been promulgated by vendors and some other stakeholders, should be scrutinized as part of this process and not simply accepted at face value.

[91] The layers should be cleanly separated wherever possible, with exceptions made for certain application areas in which a vertical application approach may be needed to handle specific requirements (e.g., electric vehicles may be one such area). A graded approach to the level of clarity defined for the various architectural areas can provide flexibility to handle the levels of certainty seen across these areas.

5.2 Recommendation No. 2: Focus on Semantic Layer Standards for Application Interoperability

Innovation that truly leads to enhanced grid functionality happens most often at the application level, not in the midst of the communications protocol layers. The protocol layers below the application are required to support the application functionality and provide the foundation for new and innovative smart grid applications. Internet applications that are redefining our lives – such as Google, Wikipedia, and Facebook – were built on the foundation of Internet communications, which did not exist 20 years ago.

Facilitating creativity in applications by technology vendors and solution providers requires a sufficient semantic layer upon which to build. Also, importantly, certainty at the semantic layer allows engineering teams working on smart grid to spend their creative energy on the application, rather than on building gateways and interfaces to the underlying protocol layers that may exist across the marketplace.

> *"The interfaces should be standardized. Inside the black box you can have some freedom - that's where innovation can continue to live. Standards are necessary but we have to leave room for innovation as well."*
>
> ***-Technical Executive, Utility***

Smart grid innovation requires pragmatic and expedient solutions to semantic layer interoperability. A semantic layer solution across a broad set of smart grid application areas can be selected through an Institutional Endorsement process. This does not imply that a single semantic layer must be implemented across the entire smart grid. It is important to recognize that for any application, the development of different semantic layer interfaces takes resource and creative energy away from the real end goal, which is the application.

Insight: Applications, not the underlying communications protocols, can transform the electric power industry. The protocol layers beneath the application are only the means to achieve this end, not the end itself.

Recommendation: Focus on semantic layer standards and decouple these standards from underlying protocol layers whenever feasible. The sooner standards can be completed and selected at the semantic layer for specific application areas, and to the degree that it makes sense across application areas, the sooner innovation at the smart grid application layer can receive focus and attention. In general, this effort lends itself to selection by Institutional Endorsement for a particular application area. Multiple standards for the semantic layer require the focus and support of resources that can otherwise be focused on the application. Semantic layer "harmonization" is currently receiving priority in the standards process. This recommendation is an acknowledgement and recognition of the importance of this harmonization effort.

5.3 Recommendation No. 3: Update and Communicate Priorities Across and Within Architectural Areas

The initial list of smart grid standards[92] was produced using a set of policy priorities defined at the overall smart grid level (e.g., "wide area situational awareness," "energy storage"), not at an architectural level for individual application areas. These overall priorities originate from *Federal Energy Regulatory Commission* (FERC) policy statement,[93] and don't necessarily align with other policy priorities (e.g. those of individual states) or with the commercial realities of the marketplace (e.g., application areas that technology providers and investors perceive to be profitable).

Additional prioritization at two levels will help address disparate priorities and provide guidance:

- Prioritization of efforts across the various smart grid architectural areas, after these are clarified (as called for in Recommendation No. 1 above)
- Prioritization within each architectural area, taking into account the ten competing priorities described in Section 4 of this white paper)

<u>Prioritization Across Smart Grid Architectural Areas</u>

Seventy-five standards and numerous gaps are identified in the Framework and Roadmap for Smart Grid Interoperability Standards. Working across these efforts and areas requires focus and prioritization to eliminate overlap and inconsistencies and ensure that efforts don't become diffuse and ineffective.

"Anytime you've got 80 standards under development, there's no way you can cover all the bases."

-Smart Grid Executive, Utility

The prioritization process should explicitly recognize the commercial interests that are already implicit in the process. The process can harness these interests to help prioritize the areas that would receive significant focus from these commercial interests and channel that energy to improve the effectiveness and overall interoperability outcome. Prioritization can focus energy on near-term priorities, while explicitly targeting other areas for mid- or long-term treatment.

Marketplace "turbulence,"[94] investment uncertainties, levels of knowledge, and rapid learning in some application areas[95] are considerations for prioritization and timing decisions. Standardization efforts for areas agreed to have significant turbulence or uncertainties can be scheduled for future focus – perhaps targeted one or more years into the future – to allow time for the marketplace and technology direction to become clearer.

Prioritization across architectural areas should be informed not only by the interests described above but also by technical and architectural considerations. The six key issues presented in Section 3 can be used to inform this cross-smart grid prioritization. This approach can consider the foundational architecture concept discussed in Recommendation No. 1 above to help determine which areas might be included as part of the foundational

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[92] NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0, p. 8.

[93] Federal Energy Regulatory Commission, Smart Grid Policy, 128 FERC S.61,060, [Docket No. PL09-4-000], July 16, 2009.

[94] The term "turbulence" is used here to indicate that the marketplace is evolving rapidly and changing such that marketplace outcomes or equilibriums are unclear. Thus, winning products, solutions, and companies are not yet determined and widely varying market outcomes are possible.

[95] Examples include distributed and renewable integration into the grid and consumer response to dynamic pricing programs.

smart grid and which are additions that can leverage the foundation to deliver benefits as the smart grid evolves.

Prioritization Within Smart Grid Architectural Areas

The broad policy priorities mentioned above provide limited guidance at the detailed level needed to make trade-offs required in standards development efforts. Prioritization can be facilitated by recommendation No. 1 above, which calls for greater architectural clarity to the various smart grid domains, sub-domains, application areas, and protocol layers across the smart grid, by defining discrete architectural areas that can be the focal points for prioritization activities.

The process moving forward should identify priorities within these architectural areas. The ten competing priorities presented in Section 4 can be used to develop clarity within each area. This can provide focus on the most important aspects in each area and help accelerate standardization efforts. The process used to identify and fill gaps should recognize the strengths and weaknesses of participating SDOs and SSOs and help channel the efforts of these bodies into appropriate and specific architectural areas in which they can be most productive. Clear communications detailing the updated priorities and rationale will be important to align stakeholders.

Insight: The broad policy priorities used for the standardization effort lack the specificity that is useful for effectively guiding the details of the standards process. Commercial and architectural priorities, along with the state of marketplace learning and market turbulence, should also be considered in prioritization decisions. Architectural clarity, called for in recommendation No. 1 above, will facilitate prioritization by clarifying the architectural areas that can be considered during prioritization efforts.

Recommendation: Undertake an updated prioritization process that incorporates commercial, market, and architectural considerations in addition to the policy priorities that are already under consideration. This update of priorities across architectural areas should take into account the six key issues presented in Section 3 to help make detailed trade-off decisions. The update of priorities within architectural areas should focus on the areas viewed as having near-term significance. The ten competing priorities developed in Section 4 can be used to examine the trade-offs within each architectural area. Communicate the trade-off decisions and priorities broadly and explicitly to stakeholders to provide detailed guidance about the ongoing standards decision processes.

5.4 Recommendation No. 4: Leverage the Market Toolkit Approach and Apply a "No Regrets" Approach to Institutional Endorsement

Smart grid standards selection tended toward laissez-faire prior to the smart grid standardization efforts of the past few years. Limited coordination existed between standards bodies that were addressing domains, sub-domains, and application areas.[96] Recent efforts have introduced more structure and focus and have heavily

[96] Many SSOs have completed extensive work on smart grid relevant standards (e.g., IEEE 1547, IEC 61850), which were developed primarily with a consensus approach. These efforts did not focus on coordination across the full range of interrelated smart grid application areas, and thus selection of a standard for a particular area was left largely to the customer.

leveraged the existing standards and development processes of various SSOs and SDOs.[97] These efforts have identified a variety of standards as suitable for the smart grid. This identification process, along with the threat of potential regulatory rulemaking on these standards, has led to considerable concern that these standards could become a regulatory requirement, rather than voluntary.[98] Thus, the effective result seems to be that the pendulum may have swung towards the more prescriptive Institutional Endorsement approach.

Smart grid interoperability would benefit from more emphasis on a Market Toolkit approach that could allow more speed, flexibility, and innovation in the appropriate areas. A balance between these two approaches – a blended approach – is appropriate.

> *"Without core design and consensus in some cases, you break things; and without entrepreneurial effort, you won't move ahead. They both are needed".*
>
> ***-Technical Executive, Utility***

The Institutional Endorsement approach may be able to produce some near-term "win-win" standards by applying a "no regrets" decision process. This process helps focus decision making on areas where the decisions are less likely to have negative consequences in the future. In these areas there is more likely a broad agreement on the direction and maturity of the marketplace, the efficacy of the technology, and the regulatory outcomes. Seeking out areas where standards decisions have limited downside risks can provide a focus for near-term action.

*A **no regrets** approach is a decision technique that advocates making decisions only to the extent justified by the strong likelihood that those decisions will not have substantial negative consequences in the future. A no regrets approach brings focus to the potential consequences of proceeding under false assumptions, such as creating a standard based on architectural assumptions that may prove to be false. Implementing a no regrets approach for smart grid standards essentially means proceeding with decisions where confidence is high and consequences are low and waiting to make decisions where confidence is low and consequences are high.*

The no regrets decision process can help determine architectural areas where an Institutional Endorsement approach is more appropriate, and can help avoid over-defining standards in areas that are evolving or where significant uncertainties or diverse marketplace needs exist. These areas tend to lend themselves to a Market Toolkit approach.[99] The marketplace will lead to the development of various standards that move the area forward until the dust settles and the picture clears. A blended approach reduces the likelihood that near-term decisions will have unintended, costly outcomes.[100]

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[97] NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0, p. 9, states that "NIST believes that interoperability standards should be open." It goes on to say, "This means that the standards should be developed and maintained through a collaborative, consensus driven process…"

[98] As mentioned previously, regulatory rulemaking by FERC or other organization with regulatory authority is a significant concern to the industry, which fears the negative side effects of such regulation. Due at least in part to these concerns, Dr. George Arnold, National Coordinator for Smart Grid Interoperability at NIST, has suggested that FERC may not want to adopt use of the initial standards that NIST has endorsed for FERC review: "I recommend that the Commission consider taking a different approach that focuses on the question of whether regulatory adoption is needed to ensure use of the standards by industry to achieve smart grid interoperability." Opening Remarks to FERC Technical Conference on Smart Grid Interoperability Standards, January 31, 2011.

[99] A Market Toolkit approach seems to be the obvious choice, for example, in residential customer applications at the physical layer (as we have defined it here), where a wide range of technologies may be needed to address the diversity of requirements. The same may be true, but is slightly less clear, at the network layer where IP is predominant in most worldwide communications, but special considerations for low-bandwidth and wireless connectivity in the home may favor other technologies. However, at the semantic layer, there are considerable advantages to a single consensus standard.

"It can't be one size fits all in approaching interoperability standards. There are some pieces that are so critical and so expensive that consensus on a single standard must be reached. But for other pieces, it would be better to let the market sort it out."

-Smart Grid Executive, Utility

The current process of filling smart grid standards gaps may have mixed standards development with standards selection[101] in some instances.[102] Maintaining a clean separation between the development process and the selection process can clarify the process of filling the standards gaps. Also, it can help determine which approach can be best applied to the various architectural areas. In addition, clean separation is important to maintaining overall process clarity.

Insight: The recent efforts to establish standards may result in an Institutional Endorsement approach, even if unintentionally. Some interoperability efforts would benefit from a more market-based approach. Architectural clarity combined with explicit prioritization, discussed above, provides the groundwork for choosing the appropriate approach in each architectural area.

Recommendation: Adopt a blended approach to selecting smart grid standards, where either an Institutional Endorsement or a Market Toolkit approach is chosen based on an assessment of priorities for each architectural area. Leverage "no regrets" decision making to help decide which approach is appropriate in a particular architectural area. This will likely lead to Institutional Endorsement being used when there is a clear and obvious reason to pursue a single standard, and a Market Toolkit approach being used in areas that must adapt and evolve and where considerable uncertainties exist. The goal is to leverage "the right tools for the right job" in this way. This recommendation represents a "bend" in the current direction, towards a more blended approach.

5.5 Recommendation No. 5: Refine Elements of the Process to Better Address Stakeholder Issues

The recent industry efforts are providing forward momentum in addressing interoperability and needed standards. This momentum includes considerable stakeholder energy that might be leveraged to accelerate and improve the efficiency of the standards process. To do so requires careful management and balance of stakeholder interests. (See Section 3.4 for a discussion of stakeholder interests.)

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[100] In the case of phasor measurement unit projects, for example, the requirement for low-latency communication may indicate that a single consensus approach is beneficial for the portion of the application requiring low latency. But inter-area communication for wide-area situational awareness may simply leverage an array of existing standards, and thus the Market Toolkit approach is preferable.

[101] Section 2.4 describes the difference between standards selection and standards development, and illustrates how these activities are related in the current NIST/SGIP process (see Figure 5). The glossary provides definitions.

[102] Thought leader interviews indicated that the SGIP PAP process, designed to expedite efforts to fill standards gaps, has sometimes taken on the characteristics of standards development, whereas selection and requirements definition is the stated charter of the SGIP effort.

Balancing stakeholder interests poses challenges in any process that can affect who wins and who loses. These challenges can be exacerbated when there is a sense of urgency. Smart grid standards require a level of urgency and speed that is not typical of the traditional consensus-based standards development used by many SDOs. Thought leaders indicated that a number of stakeholder-related interests and issues have the potential to negatively impact or slow interoperability efforts. These issues include:

- **Volunteer Model:** Many standards efforts described here, including both development and selection processes, rely on volunteer resources to perform the needed work. Typically, these volunteers have "day jobs," and are only able to perform their volunteer duties during a small portion of their working hours, making standards progress slow.[103]
- **Under-represented Stakeholders:** An imbalance of stakeholder perspectives can bias the process, in part, by the weight of overall opinions and the work vested stakeholders may contribute to the process. One concern expressed is that the process may suffer from the under-representation of utilities. [104]
- **Narrow Stakeholder Perspectives:** Narrow perspectives can have impacts such as:
    - A standards selection process encumbered by efforts on the part of standards organizations to promulgate their views and historical directions
    - Incumbent vendor intentions to preserve market share
    - Distractions caused by the introduction of new and sometimes uninformed perspectives from new entrant vendors

  Some of these efforts may be the result of "true believers" who are entrenched in their positions to an extent that they may not fully consider alternative approaches.[105]

- **Overly Expansive Standards:** Consensus processes can result in standards that don't lend themselves easily to interoperability.[106]

Some of these competing and conflicting interests are due, in part, to the nature of the consensus process and the effective Institutional Endorsement that is occurring. A bend toward a Market Toolkit approach presents an opportunity to reduce some of the stakeholder challenges and leverage existing energy to help make the standards process more effective.

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[103] The volunteer funding mechanisms used in many standards bodies may be especially problematic for utilities, which sometimes cannot spare the technical resources to participate. Volunteer funding mechanisms used in general standards development and selection processes can also lead to problems when commercial interests allocate significant "volunteer" resources to focus on certain areas but leave other important areas unattended.

[104] Several interview discussions indicated that utilities, as a stakeholder group, are not adequately represented given their importance as the technology consumers and smart grid implementers.

[105] Thought leader interviews indicated that commercial and other vested interests – including the SDOs – can overly influence the process when allowed. Any collaborative effort with high stakes has parties seeking to influence the outcome, and this can lead to entrenched positions when stakeholders are unwilling to compromise. As mentioned above, these situations often arise from "true believers," who are entrenched in their positions. Incumbents act to preserve their incumbency and protect near-term business, and new entrants bring new and sometimes uninformed perspectives to the process while seeking to gain market share. These factors combined with the need for backwards compatibility sometimes result in more of a "rear-view mirror" focus than a forward-looking focus on the desired future state.

[106] Standards resulting from a consensus of entrenched stakeholder groups tend to include many provisions that do not necessarily benefit the quality of the standard but are needed to achieve a consensus among stakeholders. Expansive "kitchen sink" standards sometimes result since options and provisions must be added to appease the various stakeholders. The result can be a loosely defined standard with so many options that creating interoperable implementations becomes difficult. Implementations based on such standards are unlikely to interoperate without significant additional integration work.

Insight: The effectiveness of the consensus process relies on achieving a balance of stakeholder perspectives and on explicit specification of the goals, priorities, and rules directing the effort. This process can become a bottleneck given the range of standards areas that must be addressed in the next few years, and it has difficulties accommodating uncertainties. More active use of a market-based approach, such as the Market Toolkit, can help alleviate some stakeholder issues that arise in the consensus-centered process, and it can more naturally help resolve uncertainties in appropriate application areas.

Recommendation: Create a formal feedback mechanism based on the real-world smart grid projects that are now being implemented to specifically inform the standards process. This effort can leverage the lessons from many smart grid projects funded recently by the DOE Investment Grant and Regional Demonstration programs. This approach can help increase utility input, since many of the projects are being executed by utilities, and it would provide real-world data input, which can reduce the influence of narrow stakeholder perspectives.

Separate the prioritization activities – including timing – from the selection or development of standards. Separation can help free the prioritization and timing decisions from the considerations and influences of stakeholders that favor particular technologies, standards, or approaches. Then the standards selection and development processes can be guided by prioritization and timing decisions that have already been made.

6 Final Comments

Thought leaders that span stakeholder groups provided input to the paper, including technology leaders, business leaders, regulators, and experts with deep experience in standards-setting activities. Several themes cut across the discussions. A view that was repeatedly articulated is the need for a more defined architecture to “get in front of” the standardization process. This is a step that would allow the process to be more effective, and it was judged as an urgent and critical need by some. Just as a house built without a solid blueprint is likely to be deficient, the smart grid without a clear architecture is likely to take longer, encounter problems, and turn out less structurally sound than it otherwise could be.

The discussions acknowledged the complexity of the interoperability standards efforts, and there was agreement that these efforts have gained significant momentum in the past few years. There was also a common view that the standards-setting process should adapt and evolve as experiences are gained. This will keep the industry on an expedient path to high interoperability while encouraging innovation in smart grid applications.

Thought leaders confirmed that there is no “silver bullet.” No single or simple answer can make a dramatic improvement in the process. The insights drawn from thought leaders suggest that the best way to improve interoperability is by leveraging a more market-based approach to establishing standards, given the complexities and uncertainties involved.

A range of market-based directions may be viable. Defining and introducing market-based approaches to standards selection, possibly using some of the constructs of the Market Toolkit approach, should be an integral part of the overall consideration of standards. This would represent a “bend” in the current direction of establishing standards. This bend is not intended to slow momentum or hold up the standards process but to accelerate the process, make it more efficient, and put us on a straighter path towards a rich and vibrant smart grid ecosystem.

Appropriately blending the consensus focused, Institutional Endorsement process with the market-based process may best achieve the goal of interoperability. For example, recommendation No. 2 indicates that Institutional Endorsement may be the most useful approach to semantic layer standards, as it can help limit the number of implementation options required for application development.

A fair amount of learning is needed in many smart grid areas, and the best way to learn is to allow different types of solutions. Some solutions may not prove fully successful, but the knowledge gained from the experience can outweigh the costs of failed experiments. The community must accept that the path to interoperability may look messy from the outside, just as it did in the development of today’s Internet and mobile phone systems.

A smarter grid will come about. New technologies throughout the grid will be adopted, and new communications, computing, and sensing technologies will be applied to improve the grid. Technology evolution will continue, grid investments will be made, and the result will be a more advanced grid structure.

"We never set out to build a 'dumb' grid. We have always been looking at more advanced technologies with each investment."

-Technical Executive, Vendor

Decision makers, whether they realize it or not, are making decisions about the smart grid every time they consider a grid investment. Some regulators, for example, have not allowed full rate recovery on enhanced grid devices that have new communications and other smart capabilities, instead only allowing recovery on the portion of costs related to the more traditional functionality of these devices.

A key question that remains unanswered is whether this smarter grid will deliver on the great promise of high interoperability that enables a rich, dynamic ecosystem of energy-related solutions and businesses. The task moving forward involves making the grid investments more efficient and effective, accelerating progress, and producing this vibrant and rich environment of innovation and learning that enables the grid to realize its envisioned potential. Will the interoperability efforts that have been undertaken to date deliver on the promise of smart grid?

"Consider the development of some previous big infrastructures not unlike the smart grid. There's generally been sort of a "guiding hand" that has developed the overall framework. Then, once that's established, a more decentralized process deals with the ongoing evolution."

-Dr. George Arnold, National Coordinator for Smart Grid Interoperability, NIST[107]

The government funding that has helped create the positive momentum in the past few years won't last indefinitely. Will the NIST/SGIP effort set the smart grid on the path to high interoperability as DARPA initially did for Internet?[108]

"One can't expect government to fund at such a high level forever. The NIST funding everything associated with SGIP has to end at some point, or at least change. Heck, with all the budget controversies these days, it could be sooner rather than later."

-Erich Gunther, Chief Technology Officer, EnerNex[109]

With the stakes so high, can we afford to wait 20 to 30 years for such change to take place?[110] Or will an additional policy, regulatory, or financial push be required to move the industry in the needed direction?[111]

These pressing questions must be answered soon. The insights and discussion provided in this paper should help inform a broad range of decision makers so they can move the industry in the necessary direction to achieve the envisioned promise of the smart grid.

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[107] Discussion with the authors, February 3, 2011.

[108] Dr. George Arnold discusses the "guiding hand" concept in a Focal Point on page 20.

[109] Quote taken from *Smart Grid Today* article – *Arnold, Gunther report on progress of smart grid standards efforts*, Feb. 23, 2011.

[110] Note that the Internet revolution that has produced Google and Facebook, among others, has been ongoing for 30 years.

[111] *"I see* more people interested because of fear of regulation – 'By gosh, we better look at this because someone's going to mandate us to implement A, B, or C standard' – rather than saying, 'We have a complicated problem to solve, and these standards are our tools for doing that quickly, efficiently and cleanly, so we'll do that.'" Erich Gunther, Chief Technology Officer, EnerNex, taken from *Smart Grid Today* article. *"Gunther, Arnold put state of smart grid standards in perspective" , Feb. 24, 2011.*

Appendix A – List of Contributing Thought Leaders

In-depth interviews from a range of industry thought leaders serve as a key source for the analysis presented in this white paper. The authors greatly appreciate the time and insights volunteered by the thought leaders. The organizations identified are those where the thought leaders worked at the time of their interview(s).

Name	Formal Title	Organization
George Arnold	National Coordinator for Smart Grid Interoperability	National Institute of Standards & Technology
Tom Bailek	Chief Engineer, Technology Development and Innovation	San Diego Gas & Electric
Fred Baker	Fellow	Cisco
Tony Bamonti	Vice President, Business Development	Tendril
Daryl Belock	Director, Vertical Marketing and R&D Collaboration	Thermo Fisher Scientific
Steve Bossart	Director, Integrated Electric Power Systems	National Energy Technology Lab
Jay Britton	Principal Architect Areva T&D	Areva
Cameron Brooks	Senior Director, Market Development & Policy Strategy	Tendril
Paul Centolella	Commissioner	PUC Ohio
Britta Gross	Director, Global Energy Systems & Infrastructure Commercialization	General Motors
Dave Hardin	Chief Technology Officer, Invensys Process Systems	Invensys
Becky Harrison	General Manager, Smart Grid Program	Progress Energy
Steve Hauser	Vice President, Grid Integration	National Renewable Energy Lab
Brent Hodges	Director, Smart Energy Partnerships	Reliant Energy
Wayne Longcore	Director, Enterprise Architecture & Standards	Consumers Energy
Rick Morgan	Commissioner	PSC District of Columbia
Scott Neumann	Chief Technology Officer	Utility Integration Solutions
Terry Oliver	Chief Technology Innovation Officer	Bonneville Power Administration
Rob Pratt	Program Manager	Pacific Northwest National Lab
Wade Troxell	Associate Professor	Colorado State University
Raj Vaswani	Chief Technology Officer	Silver Spring Networks
Andy Wheeler	Chief Technology Officer	Adura

Appendix B – Glossary of Terms

Advanced Meter Infrastructure (AMI): Systems that automatically measure and record electricity consumption and that provide the ability to interact with metering or consumptive devices. AMI typically includes digitally enabled meters, two-way communications infrastructure, and a meter data management system.

American National Standards Institute (ANSI): A standards organization that facilitates the development of American National Standards (ANS) by accrediting the procedures of standards-developing organizations (SDOs). These groups work cooperatively to develop voluntary national consensus standards. Accreditation by ANSI signifies that the procedures used by the standards body in connection with the development of American National Standards meet the Institute's essential requirements for openness, balance, consensus, and due process. ANSI has served in its capacity as administrator and coordinator of the United States private-sector voluntary standardization system for more than 90 years.

ANSI is a standards organization which promotes an "open," collaborative, balanced, and consensus-based process to developing and approving standards.

Application: The functionality of the smart grid, often provided by computer software, that helps a grid user or operator perform specific related tasks. Application, as used here, is contrasted with system software, middleware, or communications software, which manage and integrate various needed functions, but typically don't perform useful tasks *directly* for the user or operator.

Application Area: A related set of smart grid tasks that perform useful function directly useable by some group of smart grid stakeholders. For example, the *demand response* application area, the *wide area situational awareness* application area, or home area network (HAN) application area.

Appropriate Standards: A conceptual term referring to the ability of a standard to strike a balance between the specific issues, priorities, stakeholders' interests, time lines, and complexities to achieve its intended purpose.

American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE): An international organization with a mission to advance heating, ventilation, air conditioning, and refrigeration to serve humanity and promote a sustainable world through research, standards development, publishing, and continuing education. ASHRAE is responsible for the initial development of the BACnet protocol standard for building automation.

Architecture: A formal description and representation of a system, organized in a way that supports reasoning about the structure of the system, which comprises system components and the relationships between components and provides plans from which systems can be developed.

Architectural Area: A grouping of elements or functions in the smart grid that are specifically defined through the effort of clarifying the overall architecture (see recommendation No. 1 in Section 5.1) to lend themselves to standardization with a uniform standard or limited, related set of standards. This is distinct from an "application area" in that an architectural area may represent a specific protocol layer or layers without reference to any specific smart grid application (e.g., TCP/IP used as a transport layer standard).

Backward Compatibility: The ability of newly installed technology to work well with in-place technologies. Lack of backward compatibility can create scenarios that require a change-out of entire systems rather than incremental upgrades, raising investment cost and risk.

Building Automation and Control Networks (BACnet): A standard managed and promulgated by ASHRAE that was designed to allow communication of building automation and control systems such as HVAC systems, lighting systems, and fire detection systems.

Critical Infrastructure Protection (CIP): Standards created and maintained by the North American Electric Reliability Corporation (NERC) that cover physical and cyber security for the bulk power system.

Communications Bandwidth: The capacity of a system or communications channel to transfer information. Communications bandwidth is typically measured in bits per second (b/s) or megabits per second (Mb/s).

Complementary Goods: Products whose uses are interdependent and which add value to each other. In economic terms, the demand for a product is positively related with the price and attractiveness of its complementary products.

Consensus: General agreement, but not necessarily unanimity, including a process for attempting to resolve objections by interested parties. This definition is based on Circular a-119 which is tied to the National Technology Transfer and Advancement Act of 1995.

Consumer: An individual that participates in the marketplace by purchasing goods and services, such as electricity. As used in this document the term refers to residential customers of electricity and other products, but does not refer to commercial and industrial organizations or institutions that purchase electricity (see "customer" below).

Customer: Any market participant that purchases electricity. This term as used here is consistent with its use in the NIST Conceptual Model (see Figure 3 in the document body), and includes residential, commercial, industrial, and institutional purchasers of electricity.

De Facto Standard: A standard that gains broad use or user adoption, often achieving a dominant position, through market forces (such as early entrance to the market) and user acceptance.

De Jure Standard: A standard created through a formal standards-making process with legal authority for standards setting in a particular application area.

Domain: A high-level grouping defined by the NIST Conceptual Model that comprises organizations, buildings, individuals, systems, devices or other actors that have similar objectives and that rely on—or participate in—similar types of applications. Top-level domains include: generation, transmission, distribution, customers, operations, markets, and service providers. Actors in the same domain tend to have similar practices and objectives. Communications within the same domain generally have similar characteristics, constraints, and requirements.

Electric Power Research Institute (EPRI): An independent, nonprofit company performing research, development, and demonstration in the electricity sector to address industry challenges such as reliability, efficiency, health, safety, and the environment. EPRI's IntelliGrid initiative aims to create the technical foundation for a smart power grid that links electricity with communications and computer control to achieve gains in reliability, capacity, and customer services.

Energy Independence and Security Act (EISA) of 2007: An act of Congress concerning the energy policy of the United States that is intended to move the United States toward greater energy independence and security, to increase the production of clean renewable fuels, to protect consumers, to increase the efficiency of products, buildings, and vehicles, to promote research on and deploy greenhouse gas capture and storage options, and to improve the energy performance of the federal government, and for other purposes.

EISA 2007 establishes NIST as the responsible entity for coordinating the development of protocols and model standards to achieve interoperability of smart grid devices and systems with input and cooperation from other federal and state agencies and interested private-sector entities.

Energy Management System (EMS): A system of computer-aided tools used by operators of electric utility grids to monitor, control, and optimize the performance of the generation, transmission, or distribution system. EMS can also refer to the automated system used to manage building energy consumption including HVAC systems and lighting.

Federal Energy Regulatory Commission (FERC): An independent federal agency that regulates the interstate transmission of electricity, natural gas, and oil. FERC has many responsibilities including regulating the transmission and wholesale sales of electricity in interstate commerce and protecting the reliability of the high-voltage interstate transmission system through mandatory reliability standards. The Energy Independence and Security Act of 2007 gives FERC authority to institute a rulemaking proceeding to adopt standards and protocols to ensure smart grid functionality and interoperability in interstate transmission of electric power and in regional and wholesale electricity markets at any time after NIST's work has led to sufficient consensus.

Foundational Architecture (for smart grid): The definition and structure of a minimal set of grid technologies and capabilities required to enable the future capabilities and benefits promised by the smart grid.

Gateway: A device or piece of software functionality that translates between two or more communication protocols or applications. For example, a gateway may be needed to translate between a demand response signal and the protocol used by a building Energy Management System to allow the EMS to understand what response is being requested.

GridWise Architecture Council (GWAC): A team of industry leaders who are shaping the guiding principles and architecture of a highly intelligent and interactive electric system—one ripe with decision-making information exchange and market-based opportunities. This architecture will provide guidelines for interaction between participants and interoperability between technologies and systems. GWAC is neither a design team, nor a standards-making body. Its role is to help identify areas for standardization that allow significant levels of interoperation between system components.

GWAC Stack: A communications protocol stack tailored for smart grid interoperability, developed by the GridWise Architecture Council.

Home Area Network (HAN): A communication network, typically within a single residence that provides communication between devices that control, monitor or consume energy (e.g., smart home appliances, programmable communicating thermostats, and smart meters).

International Electrotechnical Commission (IEC): A standards organization that prepares and publishes international standards for all electrical, electronic, and related technologies.

Institute of Electrical and Electronics Engineers (IEEE): A professional association dedicated to advancing technological innovation related to electricity. IEEE includes a standards association that develops electricity-related standards for a wide range of industries. IEEE employs a consensus-based process.

Institutional Endorsement: An approach to establishing standards that seeks to develop a uniform, open standard for a given smart grid service or application within a specific domain. Typically, the responsible standards-setting body convenes a team of experts to achieve consensus on the problem and prescribed solution. Then the team facilitates design of smart grid technologies and systems. This approach is similar to the one used by national and international standards organizations such as the International Electrotechnical Commission (IEC) or the American National Standards Institute (ANSI).

Internet Engineering Task Force (IETF): A technical standards-setting organization responsible for developing and maintaining the Internet's core standards, including the DNS protocol and its security extensions and the current and next-generation versions of the Internet Protocol. The core standards the IETF develops define, on a basic level, how the Internet operates and what functions it is capable of performing. It is a voluntary standards body, whose participants include network operators, academics, and representatives of government and industry, among others. The mission of the IETF is to is to make the Internet work better by producing high-quality, relevant technical documents that influence the way people design, use, and manage the Internet.

The IETF is a standards organization which uses a process that can be described as “rapid fire, testing & refinement, where multiple standards can be developed and the market determines who wins. This process has similarities to the *Market Toolkit* approach described in this white paper.

Incumbent: A company that holds substantial market share in its industry.

Industry Metabolism: The rate at which the existing stock of assets turn over and new technologies are adopted.

Integration Cost: The costs of connecting a set of smart grid technologies to, and working appropriately with, the systems with which they must interoperate to deliver their desired functionality.

Interchangeability: The characteristic describing the ease of integration of new equipment or systems, potentially from different vendors, into the existing infrastructure.

Interoperability: The ability of diverse systems and organizations to work together (interoperate). The term is used in a technical systems engineering sense, or in a broad sense, taking into account social, political, and organizational factors that impact system-to-system performance.

Information Technology (IT): The design, development, application, implementation, support, study or management of computer-based information systems, particularly software applications and digital or computer hardware.

Latency: The time delay in a communications system.

Layers: Divisions of a communications protocol stack that group similar functions. Each layer generally provides services to the layer above it and receives services from the layer below it.

Market: A structure that allows buyers and sellers to exchange products and services. Vendors that sell similar products or services are said to be in competition and divide the capitalization of the market for similar products or services into market share.

Market Toolkit: An approach to establishing standards that allows for multiple open standards for a given smart grid service or application within a specific domain. The approach calls for the responsible standards-setting body to define a set of characteristics or requirements that must be met, at minimum, for a standard to be appropriate. It also requires a mechanism to declare which of the appropriate standards is to be used at a particular point or for a particular service or application in the smart grid. This approach is similar to the one used by the Internet Engineering Task Force (IETF), which is inclined to let market forces sort winners and losers.

Mobile Applications and Mobility: The degree to which an application needs to be able to function properly in different locations and geographies.

National Institute of Standards and Technology (NIST): A non-regulatory agency of the U.S. Department of Commerce, NIST promotes U.S. innovation and industrial competiveness by advancing measurement science, standards, and technology. As one of its many functions, NIST coordinates the U.S. government's use of standards, including coordinating the development of a framework for smart grid interoperability and security standards as called out in the Energy Independence and Security Act of 2007.

National Rural Electric Cooperative Association (NRECA): The national service organization dedicated to representing the national interests of cooperative electric utilities and the consumers they serve. NRECA's MultiSpeak specification is an industry-wide software standard that facilitates interoperability of diverse business and automation applications used in electric utilities.

North American Electric Reliability Corporation (NERC): A nonprofit organization formed by the electric utility industry to promote the reliability and adequacy of bulk electric power transmission in North America.

North American Energy Standards Board (NAESB): An organization the serves as an industry forum for the development and promotion of standards that will lead to a seamless marketplace for wholesale and retail natural gas and electricity, as recognized by its customers, business community, participants, and regulatory entities.

Open Process: A process by which standards are developed and maintained through a collaborative, consensus-driven process that is open to participation by all relevant and materially affected parties and not dominated or under the control of a single organization or group of organizations, and readily and reasonably available to all for Smart Grid applications. The process for approval of standards is intended to verify that the principles of openness and due process have been followed and that a consensus of all interested stakeholder groups has been reached. One of the hallmarks of this process is that consensus must be reached by representatives from materially affected and interested parties. Other characteristics include:

- Standards are required to undergo public reviews when any member of the public may submit comments.
- Comments from the consensus body and public review commenters must be responded to in good faith.
- An appeals process is required.

The definition of open process used in this white paper is that employed by the American National Standards Institute (ANSI).

Open Proprietary Standard: A standard that claims to be "open" but does not exhibit the full range of characteristics of an open standard. Often open proprietary standards are developed by an "open" consensus process, but violate the "no royalty" clause required of an open standard. Another variant of the term refers to vendor-owned proprietary standards that are made publically available to facilitate integration, but that violate the "nondiscrimination" clause required of an open standard.

Open Standard: A quality of a standard referring to its development or availability for use. Generally, open standards posses the following characteristics:

- Availability: Open Standards are available for all to read and implement.
- Maximize End-User Choice: Open Standards create a fair, competitive market for implementations of the standard. They do not lock the customer in to a particular vendor or group.
- No Royalty: Open Standards are free for all to *implement*, with no royalty or fee.

- Nondiscrimination: Open Standards and the organizations that administer them do not favor one implementer over another.

The definition of open standard used in this white paper is based on four of Bruce Perens' Six Principles of open standards. [Source: http://perens.com/OpenStandards/Definition.html]

Open Systems Interconnection (OSI) Model: A general communications protocol stack model that serves as a useful reference point for many Internet protocols. The OSI model is divided into seven layers – physical, data link, network, transport, session, presentation, and application.

Physical Layer: The protocol of a communication system that delivers information from one device to an adjacent device. As used in this paper, the physical layer is one of three, simplified protocol layers (the others being the transport layer and the semantic layer), and it encompasses roughly the physical and data-link layers of the OSI Protocol Stack model. A metaphor for this layer is the road system upon which a mail delivery system can operate.

Plug-in Electric Vehicle (PEV): A transportation vehicle that utilizes an electric motor for propulsion and rechargeable batteries for energy storage. Batteries may be charged via a plug connecting to an electric grid.

Plug-n-Play: The highest level of interchangeability (*see definition for interchangeability)* in which a new component or technology can simply plug in and replace an older one with virtually no integration cost or effort

Phasor Measurement Unit (PMU): A device that measures voltage and current many times per second at a given location on an electricity grid to determine the state or health of the system. PMUs are also commonly referred to as synchrophasors and are considered one of the most important measuring devices in the future of power systems.

Priority Action Plan (PAP): A plan created within the NIST-coordinated SGIP interoperability effort to address high- priority issues, such as gaps where standards (or extensions to standards) are needed for the smart grid, or areas where inconsistencies in overlapping standards must be addressed.

Proprietary Protocol: A communications protocol that is typically owned by a single organization whose use is restricted as a means for profitability.

Protocol (Communications): A description of digital message formats and the rules for exchanging and interpreting those messages between computing and telecommunications systems.

Protocol Stack: The span of layers of similar communication functions, each of which provides services to the layer above it and receives services from the layer below it.

Semantic Layer: The protocol layer of a communication system that enables automatic and meaningful interpretation of information delivered to a device or application as intended by the system or application from which it originated. As used in this paper, the semantic layer is one of three, simplified protocol layers (the others being the physical layer and the transport layer), and it encompasses roughly the presentation and application layers of the OSI Protocol Stack model. A metaphor for this layer is a dictionary that allows for interpretation of written text.

Smart Energy Profile (SEP): A ZigBee Alliance defined "application profile" targeted at home energy management. SEP defines communication between home energy devices—such as programmable communicating thermostats, in-home displays, appliances, smart meters or other gateway devices, and local or remote applications like a utility demand response application. SEP is a semantic layer protocol in the definitions used in this document.

Smart Grid: A term for the enhancement of the traditional electricity infrastructure that uses computer technology and two-way digital communications networking to improve and expand the capabilities of the grid with the intent to increase energy efficiency, improve power reliability, reduce electricity rates, reduce environmental impacts, and advance the security of the grid.

Smart Grid Executive: A high-ranking corporate officer or administrator in charge of part or all of the management of smart grid-related activities at an electric utility or a vendor. Examples of titles that fall within the Smart Grid Executive classification include: Vice President of Business Development, Smart Grid General Manager, and Director of Global Energy Systems.

Smart Grid Interoperability Panel (SGIP): An organization initiated by NIST to provide an open process for stakeholders to participate in providing input and cooperating with NIST in the ongoing coordination, acceleration, and harmonization of standards development for the smart grid. The SGIP identifies, prioritizes and addresses new and emerging requirements for smart grid standards. The SGIP does not write standards, but serves as a forum to coordinate the development of standards by other organizations.

Smart Grid Maturity Model (SGMM): A management tool under the stewardship of the Software Engineering Institute at Carnegie Mellon University that provides a framework for understanding the current state of smart grid deployment and capability within an electric utility and provides a context for establishing future strategies and work plans as they pertain to smart grid implementations. It is comprised of eight model domains that each contains six defined levels of maturity.

Smart Grid Policy Center (SGPC): A nonprofit corporation that conducts and fosters research in the application of smart technologies to electric power grids, including specifically the United States electric power grid; conduct policy research on such energy issues as reliability, efficiency, security, and climate change; create avenues for dialogue and cooperation between the private and public sectors on issues relating to the deployment of smart electric power grid technologies. The Smart Grid Policy Center has applied to the U.S. Internal Revenue Service for tax-exempt status as a charitable, educational organization under Section 501 (c)(3) of the Internal Revenue Code.

Standard (Technical): Specifications that establish the fitness of a product for a particular use or that define the function and performance of a device or system. It is usually a formal document that establishes uniform engineering or technical criteria, methods, processes, and practices. Standards can be prescriptive to different degrees; they can specify a specific technology design, set protocols for communication, or require interconnection capability by specifying a connection interface be made public. Standards are key facilitators of compatibility and interoperability. They define specifications for languages, communication protocols, data formats, linkages within and across systems, interfaces between software applications and between hardware devices, and much more.

Standards Development Organizations (SDO): Organizations that are established with the purpose of developing and maintaining standards. SDOs are typically organized around an industry or a discipline, and have well-defined processes for standards development as well as legal authority within certain jurisdictions to set standards.

Standards Development: The process by which a standard is created.

Standards Selection: The process by which one standard is chosen or endorsed over other standards for a given need or application.

Standards-Setting Organization (SSO): Organizations – sometimes formed by industry consortia – whose primary activities are developing, coordinating, or maintaining standards that address a broad range of industry interests outside the standards development organization. Often, SSOs are created to establish standards for a general area, such as the IETF, whose focus is on Internet-related protocols and standards.

Technical Executive: A high-ranking corporate officer or administrator in charge of part or all of the management of technology- or engineering-related activities at an electric utility or a vendor. Examples of titles that fall within the Technical Executive classification include: Chief Technology Officer, Principal System Architect, and Chief Engineer.

Transport Layer: The protocol of a communication system that allows delivery of information accurately, reliably, and end to end, from the originating application to the intended recipient application. As used in this paper, the transport layer is one of three, simplified protocol layers (the others being the physical layer and the semantic layer), and it encompasses roughly the network, transport and session Layers of the OSI Protocol Stack model. A metaphor for this layer is the U.S. mail system which, given an appropriately formatted street address, takes care of getting an envelope from its origin to its destination.

Voluntary Consensus Standard: A standard developed or adopted by voluntary consensus standards bodies (defined below), both domestic and international. These standards include provisions requiring that owners of relevant intellectual property have agreed to make that intellectual property available on a non-discriminatory, royalty-free or reasonable royalty basis to all interested parties.

Voluntary consensus standards bodies are domestic or international organizations that plan, develop, establish, or coordinate voluntary consensus standards using agreed-upon procedures. A voluntary consensus standards body is defined by the following attributes: openness, balance of interest, due process, an appeals process, and consensus.

Voluntary consensus standard is a term defined by OMB Circular a-119, which helps clarify language in the National Technology Transfer and Advancement Act of 1995.

ZigBee: A leading standard protocol for home area network (HAN) technologies that is based on low-power radio frequency technologies. ZigBee protocols are developed by an industry consortium called the ZigBee Alliance.