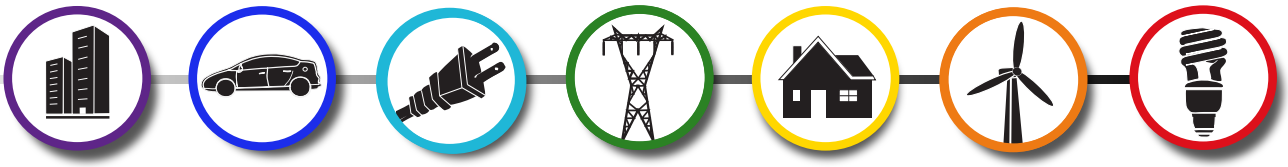
Paths to Smart Grid Interoperability

A Smart Grid Policy Center White Paper

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

Overview and Summary



May 2011

Authorship Team

Erik I. Gilbert, B.S. Eng., MBA

Daniel M. Violette, M.S., Ph.D.

Brad Rogers, M.S. Eng, MBA

ACKNOWLEDGMENTS

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 on the final page. The authors greatly appreciate the time and insights volunteered by the thought leaders.

Technical Reviewers

We would like to extend a special thanks to the technical reviewers – Ron Ambrosio, George Arnold, Steve Bossart, Steve Hauser, Terry Oliver, Rob Pratt, Steve Widergren, and Dave Wollman – who provided valuable insight and guidance for this white paper.

Additional Contributors

We would like to thank Katherine Hamilton and Lynn Sutcliffe for their valuable input on early drafts. Assistance in analysis and conducting the interviews was provided by Jonathan Poor and Forrest Small of Navigant's Smart Grid Practice. Many other industry stakeholders provided views and insights on the topics and issues presented.

Smart Grid Policy Center Trustees

Guido Bartels, IBM
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Rob Pratt, Pacific Northwest National Laboratory
Lynn Sutcliffe, EnergySolve
Michele Tihami, IBM
Lee Coogan, Executive Director, Smart Grid Policy Center

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

Prepared for:

Smart Grid Policy Center
1155 15th Street NW, Suite 500
Washington, D.C. 20005

Prepared by:

Navigant Consulting, Inc.
1375 Walnut Street, Suite 200
Boulder, CO 80302

This document, *Paths to Smart Grid Interoperability – Overview and Summary*, presents key points of the full white paper, with emphasis on its recommendations. The outline structure used here follows the white paper structure, so readers seeking more detail on a specific topic can easily locate it in the white paper.

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.

1 Introduction

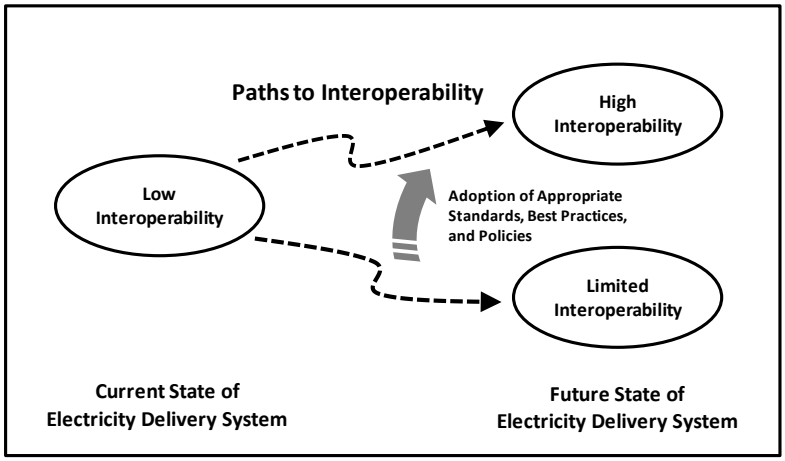
The *smart grid* promises many benefits for the nation. The benefits include a more reliable and stable supply of electricity, increased efficiency of the immense investment in electric infrastructure, increased capability to integrate renewable sources of electricity, reduced greenhouse gas emissions, 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.

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* across this diverse and changing environment.

Interoperability is a key lynchpin of smart grid success. The promised smart grid benefits cannot materialize without appropriate levels of interoperability.[1] 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.

The stakeholders involved in this effort will effectively determine the paths taken en route to an interoperable smart grid, as illustrated in Figure 1. A high-interoperability grid will deliver many of the promised benefits; a limited interoperability grid will deliver far fewer.

FIGURE 1. PATHS TO INTEROPERABILITY



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

[1] *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 transmission and distribution (T&D) system to the power source, enhancing the coordination of energy flows with real-time information and analysis.*

- 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 effect 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?

The 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[2] 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. 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.

The white paper is structured to provide clarity to this complex issue, as follows:

- A **problem statement** provides context and backdrop for the issues, arguments, and discussion in the white paper.
- **Six key issues in establishing smart grid standards** are developed and discussed to help explain some of the complexities involved.
- **Ten competing priorities** are described in detail to provide an understanding of the trade-offs that must be made in establishing smart grid standards.
- **Five recommendations** are presented to suggest a practical path forward.

A brief overview of each section, including a subsection outline, is provided below.

2 Problem Statement

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.[3] Unsuccessful outcomes will dampen investment, restrict synergies, limit the eventual benefits of the smart grid, and cause expensive redesign and reconstruction.

To explain these points, Section 2 of the white paper covers the following areas:

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[2] See the "List of Contributing Thought Leaders" presented on the final page.

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

2.1 What Is at Stake?

2.2 Why Is Interoperability So Hard?

2.3 What Are the Approaches to Establishing Standards?

2.3.1 Why Are Open Standards Key?

2.3.2 Standards Don't Always Yield Interoperability

2.3.3 Interoperability Testing Can Enhance Interoperation

2.4 How Is Standardization Being Addressed Today?

2.5 What Are the "Open" Paths to Interoperability?

For discussion purposes, the white paper looks at two types of standards development approaches – *Institutional Endorsement* which is more of a directed approach and *Market Toolkit* which allows market forces to have a larger role in the evolution of standards. The two constructs represent different views about how establishing interoperability standards should be approached. Each defines actionable directions that might be taken to further advance interoperability.

The backdrop and context provided in this section are useful for understanding the remaining sections of the white paper.

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:

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

3.2 Key Issue 2: Interoperability Must Accommodate Multiple Communications Layers

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

3.4 Key Issue 4: Stakeholder Interests Are Not Always Aligned

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

3.5.1 Security Issues

3.5.2 Privacy Issues

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

The discussion in this section establishes a basis for understanding the ten competing priorities to be addressed by interoperability approaches that should be considered for a given application area presented in Section 4.

4 Ten Competing Priorities in Establishing Smart Grid Standards

Each smart grid application area 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.[4] These priorities illustrate the key trade-offs in establishing smart grid standards.

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.

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

4.1.1 ***Competing Priority 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.

4.1.2 ***Competing Priority 2****: Backward Compatibility*– the ability of a new system or solution to integrate with legacy systems that are still operational.

4.1.3 ***Competing Priority 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.

4.1.4 ***Competing Priority 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.

4.1.5 ***Competing Priority 5****: Interoperability for Mobile Applications* – the ability of a solution to integrate, as needed, with systems in different geographical areas.

4.1.6 ***Competing Priority 6****: Bandwidth and Latency Requirements*– the necessity for certain solutions to send or receive specific information within a specified time limit.

4.2 Area II. Costs Resulting from Smart Grid Standards

4.2.1 ***Competing Priority 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.

4.2.2 ***Competing Priority 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.

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

[4] 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.

4.3.1 ***Competing Priority 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.

4.3.2 ***Competing Priority 10***: *Rate of Learning*– how quickly lessons can be learned from projects, deployments, and demonstrations of emerging technologies and solutions.

Section 4.4 provides context for the competing priorities by presenting 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 and allows for a far-ranging discussion addressing many of the competing priorities from Section 4 and drawing on the six key issues from Section 3.

5 A Practical Path Forward – Recommendations

This section presents recommendations to help develop a practical path forward and 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. The recommendations are summarized below.

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

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 as part of the National Institute of Standards and Technology (NIST) Smart Grid Interoperability Panel (SGIP) process 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.[5] The clarified architectural areas should be presented in a way that is useful to the smart grid technologists, standards development organizations, and implementers.

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

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.

[5] 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.

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 SGIP 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 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 Insitutional Endorsement

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 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 U.S. Department of Energy 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. 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. 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. 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.

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 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[6]

With the stakes so high, can we afford to wait 20 to 30 years for such change to take place?[7] Or will an additional policy, regulatory, or financial push be required to move the industry in the needed direction?[8]

Investments in the grid infrastructure will inevitably incorporate new technologies to create a smarter grid.. But will these technologies interoperate to achieve the promised benefits? 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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[6] Discussion with the authors, February 3, 2011.

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

[8] *"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.*

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