GRIDWISE Architecture Council

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GRIDWISE ARCHITECTURE COUNCIL
POLICY TEAM

INTRODUCTION TO INTEROPERABILITY AND DECISION-MAKER'S INTEROPERABILITY CHECKLIST VERSION 1.6

INTRODUCTION TO INTEROPERABILITY

Historically, progress occurs when many entities communicate, share information, and together create something that no one individual could do alone. Moving beyond people to machines and systems, *interoperability* is the capability of systems or devices to provide and receive services and information between each other, and to use the services and information exchanged to operate effectively together in predictable ways without significant user intervention. Systems composed of advanced devices and applications require an interchange process that utilizes well-defined interfaces for the transfer of information between components and to simplify the integration process.[1] ***When people talk about the "modernized" or "smart" grid, interoperability is a necessary foundation of that concept.*** Within the electricity system, interoperability enables the seamless, end-to-end connectivity of hardware and software from the customers' equipment and systems to the power sources. This includes traditional power generation transmitted through the Transmission and Distribution system's coordination of energy flows supported by real-time flows of information and analysis.

As illustrated in telecommunications[2] and banking domains, interoperability is a necessary platform for innovation of services and technologies that create new value for users. Consider telecommunications as an interoperable system. In the past, there was the black rotary phone and one telephone company. Today 96%[3] of American adults have a cell phone and use such devices to take pictures, listen to music, handle text messaging and e-mail, watch or post videos, surf the Web, play games, map locations and monitor traffic, and even talk on the phone. Data traffic dwarfs voice traffic over the world's telecommunications systems, and 90%[4] of adult Americans use the Internet. All this happened not because some early visionaries preached "convergence," but because the telephone companies needed common information protocols and architectures to exchange information more effectively across the phone network.

Interoperability has important economic consequences.[5] Systems with high interoperability have lower equipment costs and lower transactions costs, higher productivity through automation, more conversion of data and information into insight, greater competition between equipment suppliers, and more innovation of both technology and applications. Those systems grow faster, use resources more efficiently, and create more value for their users. Such systems consistently prove that interoperability and standards enhance users' choices, because those requirements create a framework within which vendors and competitors can innovate – as long as the finished products perform the needed functions and exchange data with other, related products.

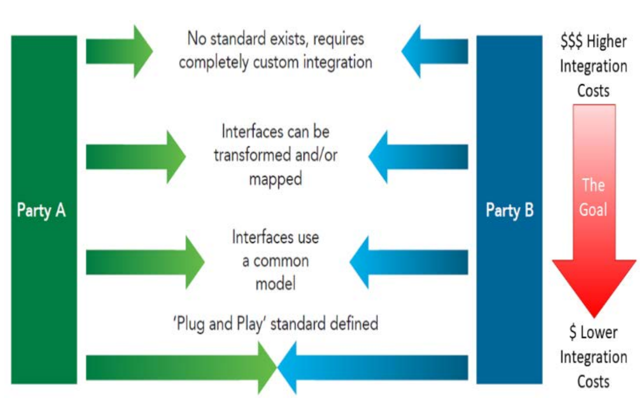

Figure 1- Distance to Integrate

Once interoperability is established and implemented, users can choose between features (e.g., a high resolution camera or voice control in a cell phone) and vendors rather than proprietary technologies (e.g., Android™ v. iOS®, PlayStation® v. Xbox®, cable v. satellite v. broadcast TV), because they know the devices will communicate and work together in predictable ways. Such devices can often be updated and upgraded (as through remote reprogramming of firmware or adding software to increase functionality or modify instructions) without becoming obsolete.

There are three categories of interoperability.[6] ***Technical interoperability*** covers the physical and communications connections between and among devices or systems (e.g., power plugs and USB ports***).*** ***Informational interoperability*** covers the content, semantics and format for data or instructions flows (such as the accepted meanings of human or computer languages and common symbols). ***Organizational interoperability*** covers the relationships between organizations and individuals and their parts of the system, including business relationships (such as contracts, ownership, and market structures) and legal relationships (e.g., regulatory structures and requirements, and protection of physical and intellectual property). There are also cross-cutting issues which are relevant across more than one interoperability category. All of these categories and issues must be addressed to achieve effective interoperability in any system.

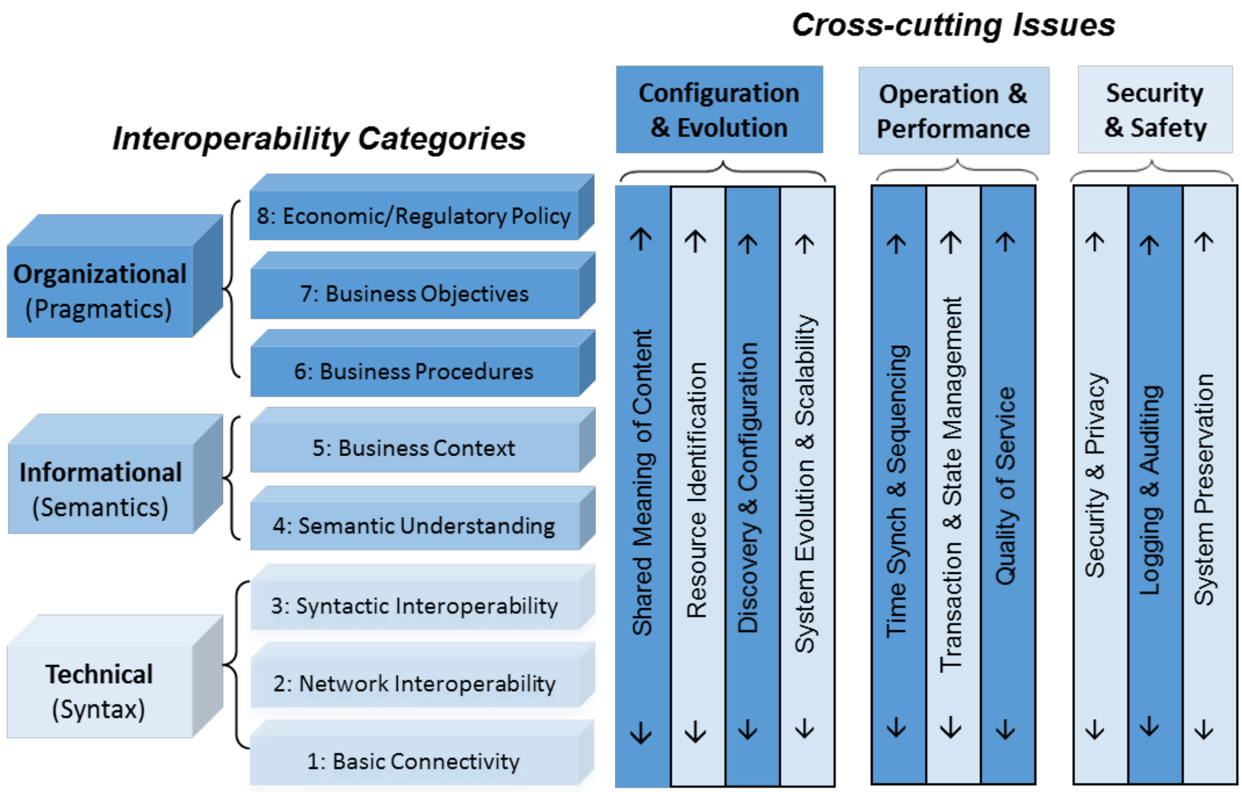

Figure 2- GWAC Interoperability Context-Setting Framework, aka GWAC Stack[7]

Interoperability between communicating grid equipment and systems will enable innovation and new services that leverage today's electric system and add value while driving down the costs of electricity use in the decades ahead.

Interoperability and the Electric System

What can interoperability do for the electric system? Advanced communication and information technology can interconnect the whole power system, better integrating the parties in the network and improving energy flows. These richer information connections will produce a more efficient, resilient and reliable grid, and more robust competitive markets, enabled in part by better interaction and collaboration between power users and power suppliers.

Interoperability will improve grid reliability and resilience by collecting more useful information and transferring it to operators and equipment to improve and protect grid operations. Interoperability and higher quality data flows between transmission and generation devices -- complemented by improved monitoring, communications and control systems and power management devices -- can provide timely, automatic, and seamless ways to operate the grid to deliver more energy more efficiently and effectively under normal and adverse conditions. This will reduce the need for emergency actions like involuntary load shedding and lower the risk of blackouts.

Within the power system, achieving and maximizing the benefits of interoperability from the end user to the power plant to the grid operator's control room will require collecting and using information in different ways, expanding interconnectivity (the flow of information and instructions between participants and their devices), and more automation (building more capability for electronic analysis, operations and control between DER and the transmission and distribution systems). The greatest impact from interoperability will occur when these communications and automation flow bi-directionally between the grid, energy users, their buildings, and equipment including local generation and energy storage, enabling automatic interaction between energy end use systems or equipment and the electric grid.

Interoperability with the consumer's energy-using buildings and equipment facilitated by making real-time electricity prices accessible to users will improve market operations by letting users or their assets/equipment react to electricity prices determined by supply and demand and current grid conditions, reducing energy use or increasing production when prices are highest or shifting energy use to when prices are lowest. This will lower consumers' electricity costs and improve service reliability and quality, while lowering costs and risks to wholesale power purchasers. It will also enable easier integration of renewable resources such as distributed generation and storage while simplifying potential transformations such as those possible from the widespread use of electric vehicles.

Over time, ***interoperability and integration will lower grid capital costs*** by using information to leverage and optimize capital investments. Utilities and grid operators will be able to use the information provided from advanced metering, smart inverters, and other DER, customer and aggregator data management systems, demand response, and transmission and distribution automation to better size a new distribution or transmission line, more precisely manage customer loads during peak load times to protect heavily loaded distribution or transmission transformers, identify and develop opportunities for non-wires alternatives, displace costly reliability-must-run generation for voltage support, identify high risk conditions, and prevent a grid failure – all exploiting information and information technology to use conventional grid assets more effectively. Grid operational and capital costs will fall as smart devices, that are part of the Internet of Things (IoT), leverage information technology and advanced electronics in order to perform the same tasks at lower costs and higher speeds than electromechanical devices, and they will be less costly and more easily integrated when they are all designed to be interoperable.

But interoperability doesn't just happen, it takes work.[8] Underlying every interoperable system is hard work by many people over many years to converge around a common vision of the value of an interoperable system, develop common principles and architecture for the bones of the system and some early applications goals, agree to common information protocols and device identification -- and eventually, converge around the detailed standards (and associated testing and certification) that express and implement all of these things.

Recent estimates of total investment requirements necessary for grid modernization range from a low of about $350 billion to a high of about $500 billion.[9] As this investment continues, we can build interoperability principles and capabilities into those investments and hasten the improvements in reliability, costs, innovation and value that interoperability can deliver. If we do not, more resources will be wasted, more assets stranded, and reliability threatened by our failure to move ahead with a focus on interoperability in this modernization effort.

THE GRIDWISE ARCHITECTURE COUNCIL

The GridWise Architecture Council (GWAC)[10] is dedicated to the development and implementation of interoperability principles and standards for the modernization of the electric power network. The GWAC is a group of cross-industry experts formed by the U.S. Department of Energy, representing organizations across the sector including utilities, regulatory and policy making entities, B2B (business to business electronic communications), utility software, demand response, building automation, information technology, academia, and more across the electricity value chain. The 13 GWAC members are volunteers and receive staff support from the Pacific Northwest National Laboratory.

Unlike other grid modernization proponents, the GWAC focuses extensively on interoperability principles and architectural frameworks to facilitate smart grid investments.[11] One of the GWAC's roles is to help key stakeholders understand these principles and to provide resources that facilitate development of an interoperable, modern, smart, electric power network that enables end-users and their energy facilities to become collaborators with suppliers in the grid's reliable, affordable operation.

DECISION-MAKER'S INTEROPERABILITY CHECKLIST

The Decision-Maker's Interoperability Checklist is a tool to help regulatory and utility decision-makers evaluate options such as capital asset investments or new information technology opportunities to determine whether they have the characteristics and attributes that contribute to interoperability – i.e., facilitate and enhance the transactions and bidirectional flows of energy, information and money across the electric grid, including electricity use, delivery and production. Decision-makers can use the checklist to review electricity-related policy or asset investment proposals, including the purchase of new distribution and transmission equipment, the specification of advanced meters, the design of a new demand response or distributed generation program, grid automation and SCADA (Supervisory Control and Data Acquisition system), the adoption of new energy end-use devices, system software, or the adoption of new market protocols.

In every question on the checklist, an answer of Yes means that the project advances interoperability along the dimension outlined in that question; an answer of No or I Don't Know means that it may be possible to improve the proposal by modifying it to better address that interoperability criterion.

This checklist is a starting point for interoperability, not an endpoint. Regulators and utility managers are encouraged to learn more about interoperability and to scrutinize investment proposals more deeply after reviewing them against the points below. Several references are offered at the end of this paper, and the GWAC is continuing its work to articulate the technical details of the interoperability framework. Additional references on interoperability and grid modernization are also available from companion organizations such as the EPRI Intelligrid[12], the NIST Smart Grid Framework[13], and DOE's Grid Modernization Initiative.[14]

Given the state of Smart Grid standards and interoperability, it may be prudent for decision-makers to ask further questions aimed at understanding the reality of the asserted conformance to standards and interoperability. The Supplemental Interoperability Checklist includes a good starting point for further questions about the claims of interoperability aimed at utilities and their vendors.

THE INTEROPERABILITY CHECKLIST

Architecture and design

Grid Architecture is the application of system architecture, network theory, and control theory to the electric power grid. A grid architecture is the highest level description of the complete grid, and is a key tool to help understand and define the many complex interactions that exist in present and future grids.[15]

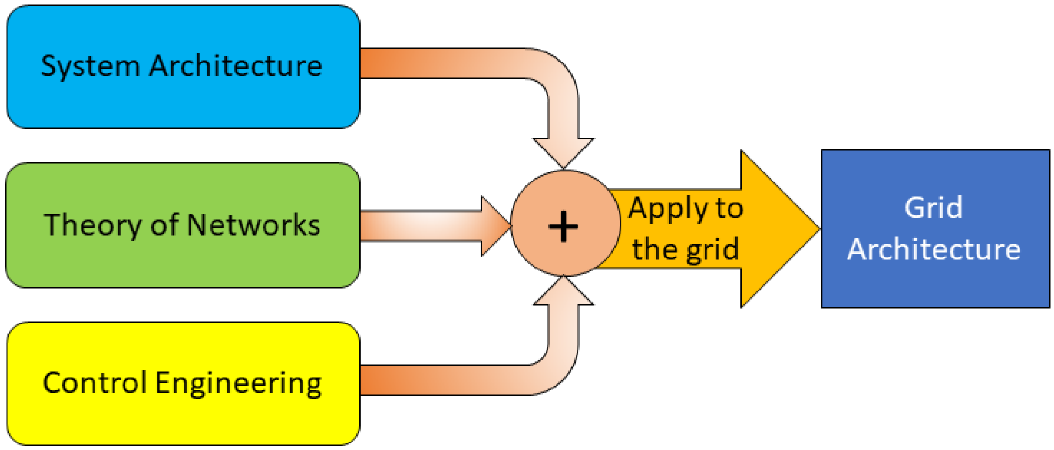

Figure 3- Disciplines of Grid Architecture (provided by Jeff Taft, PNNL Grid Architecture)

1) **Does the proposal specify the points of interface, where this part of the system interacts with other elements (whether that interaction is with grid equipment, software, the market, other business organizations, or human users or operators)? Does the proposal lay out what information or functionality will flow across these interfaces? Does the proposal specify technology and information requirements only at the points of interface (and not inside the subsystem at issue)?**
Clarity about how things fit together at the interfaces within a system is crucial to avoid over-specifying or crushing innovation and competition for the elements inside or on either side of the interfaces. This allows designers and vendors to lower the cost of system integration; with the proper functional specifications and appropriate enabling technologies, it can even enable "plug and play" relationships (which require a higher degree of interoperability). This relationship is shown in Figure 1- Distance to Integrate.

2) **Does the device/system use an open architecture? Does the proposed approach consider the technical, informational, and organizational aspects of interoperability?**
An open architecture is publicly known, so any and all vendors can build hardware or software that fits within that architecture and the architecture stands outside the control of any single individual or group of vendors. In contrast, a closed architecture is vendor-specific and proprietary, and prevents other vendors from adoption. An open architecture encourages multi-vendor competition because every vendor can provide interchangeable hardware or software that works with other elements within the system.

3) **Does the proposal maintain technology neutrality, in that it specifies performance results and outcome requirements rather than prescribing a specific technology or method to achieve those results?**
This allows vendors to innovate and compete by developing and improving technologies, which can create significant opportunities for new value.

4) **Can the device or system be supplied by multiple vendors?**
Competition between vendors encourages innovation in features and performance while driving down costs. This also reduces the likelihood that the buyer will become captive to "vendor lock-in" or that the system will be stranded if the vendor stops supporting the device.

5) **Does the system or device rely on openly available standards, specifications, or generally agreed-upon conventions? Do profiles and/or testing and certification programs exist to support implementations based on such standards, specifications, or generally agreed-upon conventions? Does the device or system connect to the electric system and communications network elements in ways that comply with applicable standards for its type?**
Organizations promulgating relevant standards include American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the International Electrotechnical Commission (IEC) and International

Organization for Standardization (ISO), NERC, Institute of Electrical and Electronics Engineers (IEEE), and industrial consortia such as OpenADR, UCA® International Users Group (UCAIug), SunSpec, BACnet, ANSI, and EICTA. The Smart Electric Power Alliance (SEPA) provides a Catalog of Standards (CoS)[16] tool to aid in determining which standards and practices apply to a project under development.

<u>Interconnectivity</u>

Interconnectivity includes the physical interface and the interoperability of the devices and systems. ISO/IEC/IEEE Standard 24765 states that interoperability is, "The ability of two or more systems or components to exchange information and to use the information that has been exchanged."[17]

6) **Does the device have the physical and electronic capability to interconnect with communications media (e.g., network, fiber optic or broadcast capabilities to access Ethernet or other communications capabilities)? Can the communications networks used by the system or device coexist or exchange data with the networks used by other devices or systems, built by other vendors or electricity providers?**
As communications technologies and protocols evolve, every device should have the capability for two-way data exchange with the rest of the system using more than one communications method.

7) **Does the device/system use standard communications protocols? Are such communication protocols and information models supported by commonly identified profiles? Is there widely used and generally agreed upon standards or specifications for the data formats (and the information models) used by the system or device so it can be understood by a variety of communications technologies and devices?**
For data and meaning to flow effectively and be actionable, all of the related devices and systems must be able to communicate effectively across the interface. Communications protocols commonly used in the electric and related industries include Modbus, DNP3, and IEC 61850, and IEEE Std. 2030.5. Common Information Model (the CIM) related standards include IEC 61968/61970/62325, IEC 61850-7 and ANSI C12.19.

8) **Does the device or system make basic data or information available to all authorized devices and users, such as energy usage, asset availability, and costs over metered intervals, grid condition metrics, or operational instructions, consistent with requirements of the applicable regulatory authority?**
As information is made more widely available, it often creates greater insight and value for the networked community of users. Flexibility in the types of data and information that can be managed and shared is valuable as system needs and capabilities evolve over time.

9) **Can the system manage multiple devices (or influence multiple users) within the system using common commands or an information feed from a central source?**
This promotes greater efficiency and speed of action and response.

<u>Security</u>

Interconnectivity of devices and systems leads to an increase in security risks. A high level of security requires a deep understanding of systems, platforms, and devices.

10) **In addition to NERC Critical Infrastructure Protection standards where required, does the device/system follow the basic cyber-security best practices as identified by the NIST Cyber Security Framework and DOE Cybersecurity Capability Maturity Model (C2M2)[18]? Does the device/system follow industry consortia (e.g. DOE DataGuard) security and privacy recommendations?**
As grid interconnectivity and interdependence increases, the grid becomes more vulnerable to threats from the failure of its information technology nervous system. This means that every element of the grid must incorporate cyber-security protections. Privacy protections are necessary to protect users' and grid entities' information and identities.

11) **If the device or system is mission-critical to the delivery of electricity or the well-being of the user, does it have sufficient redundancy or design to fail in a way that does not harm the system or the user?**

As collaboration and interconnectedness between grid elements increases, steps must be taken to ensure that the failure of one device does not compromise the integrity of the rest of the system.

Evolutionary capability and service life

Equipment and system upgrades, scaling, and components such as DER entering or leaving should have minimal impact on interoperability of existing systems or devices.

12) **Can the device be updated or have its functionalities upgraded by downloading new software and configuration information?**
A device that lacks built-in intelligence, upgradeability, and connectivity and requires physical modification, whether to replace a chipset or bolt on new equipment, is more difficult and more costly to upgrade and is likely to become obsolete and “stranded” faster.

13) **Can the device or system integrate easily with earlier versions and equipment on the system?**
A device that can work with legacy installed equipment and systems will help to extract continuing value from the legacy base, while laying the foundation for other new equipment and systems to upgrade their capabilities over time without disrupting overall system operation (such as supporting a rolling upgrade process).

Collaborator independence

14) **Does the device or system allow collaborators or users to make independent decisions (within defined parameters such as contractual provisions, NAESB wholesale agreements, electric market rules, or tariff)?**
As the complexity of the electricity system grows, most interactions and transactions will require willing, consensual partners rather than command-and-control relationships. Therefore, it should allow users and other collaborators to modify automatic responses by user over-rides or permissions.

Supplemental Decision-Makers Interoperability Checklist

The questions below are intended to probe proposals to deepen the understanding of the commitment to interoperability and claims of conformance and interoperability. As Smart Grid standards and technologies mature, the need for such additional probing will decline. But almost all projects today face major hurdles and costs to achieving interoperability. The risks are significant that projects will be more expensive and take longer than planned. Probing the issues around interoperability can illuminate these risks and lead to revisions to the plans and proposals that will end up being more accurate.

For Utilities, key supplemental questions include:

1) **Does the utility subscribe to the Interoperability Framework of the GridWise Architecture Council?**
Evidence of such commitment shows that the organization is at least aware of and supports interoperability as a key factor enabling future Smart Grid implementations. Asking for specific evidence – e.g. such as attendance at a GWAC meeting, internal minutes adopting the Framework or some other evidence that is has been reviewed and adopted internally – will quickly reveal the level of commitment to interoperability principals.

2) **Does the utility support and follow recommended national-level smart grid interoperability guidance, such as provided by the NIST Smart Grid Interoperability Framework, NIST Cyber Security Framework[19], and the SEPA Catalog of Standards?**
NIST is charged by the US Congress with establishing a national framework for Smart Grid Interoperability Standards and is doing so through collaboration with industry including support for SEPA, a broad-based electric power membership organization. SEPA has many valuable resources such as the Catalog of Standards (CoS) and a number of working groups whose members include vendors, utilities, research organizations, and more.

3) **Has the utility adopted requirements for meeting specific open interoperability standards? Does the utility require vendors to conform to these standards in their proposed products?**
Asking for specific evidence of such requirements – e.g., RFP mandated requirements or general RFP guidelines used for acquiring grid assets – will quickly reveal whether the organization is following through on its commitment to interoperability.

4) **Where standards are not yet identified or generally agreed upon, how does the utility support adoption of such standards? Do they belong to the Standard Setting Organization (SSO) working groups? Are they active in standard and/or testing and certification development? Which ones?**
The level and internal reputation of those identified to support and further standardization efforts tells a lot about the organizations' commitment to implement open, interoperable Smart Grid standard technologies. Smaller utilities could encourage their industry associations to participate in the standardization efforts.

5) **When specifying standards, how does the utility deal with optional and proprietary extensions that could render a product non-operable with other products? Is the utility utilizing a profile that collects a subset of these extensions into one implementation?**
Most adopted standards allow for optional features that can render otherwise interoperable components non-operable. How well an organization deals with this issue is indicative of the level of sophistication they bring to the challenge of interoperability.

6) **When requesting proposals for grid components, does the utility look for at least two competing and comparable solutions that claim to meet the same standard(s)? Further, do they have an efficient method for validating the claimed interchangeability of the products?**
Until Smart Grid products can be easily substituted for one another the promise of lower costs through competition among vendors will not be realized.

7) **What does a utility do when only one vendor exists for a particular solution? If possible, does the utility re-design the project so that each component can be supplied by multiple vendors? Do they actively cultivate competition when a re-design is not feasible?**
Simply accepting that only one vendor can supply a critical project component furthers the status quo of expensive, non-interoperable one-of-a-kind solutions. The benefits that Smart Grid interoperability can achieve won't be realized if utilities continue to accept unique, non- standard solutions.

8) **How does a utility validate claims of conformance to specified open standards? Does it require evidence from vendors such as a recognized independent certification? Do they perform internal validation testing? Do they contract with a third party to do validation testing?**
Regardless of the type of validation, it is important that conformance and interoperability claims are validated. SEPA offers a Catalog of Test Programs[20] as a resource to identify standards that have certified conformance testing available from independent test labs and providers.

9) **What happens if the testing shows a lack of conformance to the claimed standard?**
Setting clear conformance and interoperability standards is critical. Just as critical is holding vendors accountable for meeting those standards. This might be done through withholding partial payments until a conformance or certification test is passed or the product meets internal testing criteria. Alternatively, products can be rejected from a bid outright until they meet the specified standards and interoperability requirements.

10) **How does the utility plan for evolution of adopted standards? Is there an intentional feedback mechanism to the Standards Setting Organization (SSO) for improvement?**
This is part of the overall commitment to furthering interoperability of Smart Grid technology. An active feedback loop to the SSO can have a significant impact on standards development. Planning for and achieving active feedback to the SSO responsible for a standard is evidence of both a sophisticated and committed organization relative to Smart Grid interoperability.

The supplemental questions for ***vendors*** (by utilities) are similar:

1) **Does the vendor subscribe to the Interoperability Framework of the GridWise Architecture Council?**
Evidence of such commitment shows at least that the organization is aware of and supports interoperability as a key enabling factor in future Smart Grid implementations. Asking for specific evidence –e.g. such as attendance at a GWAC meeting, internal minutes adopting the Framework or some other means of showing that it has been reviewed and adopted internally – will quickly reveal the level of commitment to interoperability principals.

2) **Does the vendor support and follow recommended national-level smart grid interoperability guidance, such as provided by the NIST Smart Grid Interoperability Framework, NIST Cyber Security Framework, and the SEPA Catalog of Standards?)?**
NIST is charged by the US Congress with establishing a national framework for Smart Grid Interoperability Standards and is doing so through collaboration with industry including support for SEPA, a broad-based electric power membership organization. SEPA has many valuable resources such as the Catalog of Standards (CoS) and a number of working groups whose members include vendors, utilities, research organizations, and more.

3) **Which Smart Grid Interoperability Standards does the vendor Support and Implement in their Products? How does the vendor demonstrate conformance to these standards?**
The focus of a specific project will only be on a few specific standards. Ensuring the vendor supports and implements those standards should be a standard part of an acquisition process.

4) **What specific aspects of the vendor's offerings further the interoperability goals of the industry?**
Vendors can support the industry interoperability goals both organizationally and with product architecture. Questions about commitment and the level of staff involved with national and international standards illuminate the overall commitment to interoperability. Product architecture can support or hinder interoperability speed and quality. For instance, software architectures that separate communications or interface functions from internal functionality should be faster and cheaper to adapt to changes in standards. Also, hardware architectures with easily re-programmed or replaced controller and interface modules can enhance progress towards interoperability.

5) **Where standards are not yet identified or generally agreed upon, how does the vendor support development and implementation of such standards? Do they belong to Standards Setting Organization (SSO) working groups? Are they active in them? Which ones?**
The level and internal reputation of those identified to support and further the standardization efforts tells a lot about the organizations' commitment to implement the Smart Grid.

6) **When implementing standards, how does the vendor deal with optional and proprietary extensions that could render a product inoperable with other products? Is the vendor utilizing a profile that collects a subset of these extensions into one implementation?**
Most adopted standards allow for optional features that can render otherwise interoperable components inoperable. How a vendor implements the standard can either enhance or inhibit interoperability. Decision-makers may well want to look for commitments to ensuring that a product will interoperate easily with any other product that conforms to the standard.

7) **When standardization is not possible, does the vendor make available interface specifications of their products under a reasonable licensing agreement to encourage interoperability?**
Even when a vendor uses a proprietary interface, they can encourage interoperability by licensing the interface specification and test harnesses to other vendors in the field. This encourages interoperability and allows the vendor to build an eco-system around their products.

8) **How does the vendor support standards and promote the interoperability of its products?**
While successful vendors have a strong incentive to ensure that their offerings are unique, the most successful ones recognize that being the first to develop products based on standardized, open technology yields far

greater benefits than resisting competition. These companies implement new technologies that becomes de facto and then adopted standards for the industry – e.g., Microsoft, HP, Google, IBM, etc.

9) **How does a vendor validate claims of conformance to specified open standards? Do they submit their products for recognized independent certification? Do they perform internal validation testing using industry-standard tests? Do they contract with a third party to do validation testing?**
Regardless of the type of validation, it is important that claims of conformance and interoperability are supported by valid evidence. SEPA offers a Catalog of Test Programs as a resource to identify standards that have certified conformance testing available from independent test labs and providers.

10) **What do they do if the testing shows a lack of conformance to the claimed standard?**
Setting clear conformance and interoperability standards is critical. Do vendors deliver products that are not thoroughly tested and certified to the standard? Do they offer strong commitments to correct interoperability issues based on the industry-standard tests and criteria for interoperability? Vendors should expect their customers to demand conformance and interoperability and should be aggressively pursuing such before having to be asked by their customers.

11) **How does the vendor plan for evolution of adopted standards? Is there an intentional feedback mechanism to the Standards Setting Organization (SSO) for improvement?**
This is part of the overall commitment to furthering interoperability of Smart Grid technology. An active feedback loop to the SSO can have a significant impact on standards development. Planning for and achieving active feedback to the SSO responsible for a standard is evidence of both a sophisticated and committed organization relative to Smart Grid interoperability.

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INTEROPERABILITY CHECKLIST WORKSHEETS

The following worksheets are provided as a simplified form to fill in when reviewing informational and procurement documentation as well as when clarifying the services and equipment being suggested or provided for a project. The questions in this section are identical to those described in the body of the document however, clarification of the questions and their goals are not repeated.

✓	Interoperability Checklist Question	Notes
	1. Does the proposal specify the points of interface, where this part of the system interacts with other elements (whether that interaction is with grid equipment, software, the market, other business organizations, or human users or operators)? Does the proposal lay out what information or functionality will flow across these interfaces? Does the proposal specify technology and information requirements only at the points of interface (and not inside the subsystem at issue)?	
	2. Does the device/system use an open architecture? Does the proposed approach consider the technical, informational, and organizational aspects of interoperability?	
	3. Does the proposal maintain technology neutrality; in that it specifies performance results and outcome requirements rather than prescribing a specific technology or method to achieve those results?	
	4. Can the device or system be supplied by multiple vendors?	
	5. Does the system or device rely on openly available standards, specifications, or generally agreed-upon conventions? Do profiles and/or testing and certification programs exist to support implementations based on such standards, specifications, or generally agreed-upon conventions? Does the device or system connect to the electric system and communications network elements in ways that comply with applicable standards for its type?	
	6. Does the device have the physical and electronic capability to interconnect with communications media (e.g., network, fiber optic or broadcast capabilities to access Ethernet or other communications capabilities)? Can the communications networks used by the system or device coexist or exchange data with the networks used by other devices or systems, built by other vendors or electricity providers?	
	7. Does the device/system use standard communications protocols? Are such communication protocols and information models supported by commonly identified profiles? Is there widely used and generally agreed upon standards or specifications for the data formats (and the information models) used by the system or device so it can be understood by a variety of communications technologies and devices?	
	8. Does the device or system make basic data or information available to all authorized devices and users, such as energy usage, asset availability, and costs over metered intervals, grid condition metrics, or operational instructions, consistent with requirements of the applicable regulatory authority?	
	9. Can the system manage multiple devices (or influence multiple users) within the system using common commands or an information feed from a central source?	
	10. In addition to NERC Critical Infrastructure Protection standards where required, does the device/system follow the basic cyber-security best practices as identified by the NIST Cyber Security Framework and DOE Cybersecurity Capability Maturity Model (C2M2)? Does the device/system	

	follow industry consortia (e.g. UtilityAMI, DOE DataGuard) security and privacy recommendations?	
	11. If the device or system is mission-critical to the delivery of electricity or the well-being of the user, does it have sufficient redundancy or design to fail in a way that does not harm the system or the user?	
	12. Can the device be updated or have its functionalities upgraded by downloading new software and configuration information?	
	13. Can the device or system integrate easily with earlier versions and equipment on the system?	
	14. Does the device or system allow collaborators or users to make independent decisions (within defined parameters such as contractual provisions, NAESB wholesale agreements, electric market rules, or tariff)?	

Supplemental Interoperability Checklist for Utilities

✓	**Interoperability Checklist Question (Utilities)**	**Notes**
	1 Does the utility subscribe to the Interoperability Framework of the GridWise Architecture Council?	
	2. Does the utility support and follow recommended national-level smart grid interoperability guidance, such as provided by the NIST Smart Grid Interoperability Framework, NIST Cyber Security Framework, and the SEPA Catalog of Standards?	
	3. Has the utility adopted requirements for meeting specific open interoperability standards? Does the utility require vendors to conform to these standards in their proposed products?	
	4. Where standards are not yet identified or generally agreed upon, how does the utility support adoption of such standards? Do they belong to the Standard Setting Organization (SSO) working groups? Are they active in standard and/or testing and certification development? Which ones?	
	5. When specifying standards, how does the utility deal with optional and proprietary extensions that could render a product non-operable with other products? Is the utility utilizing a profile that collects a subset of these extensions into one implementation?	
	6. When requesting proposals for grid components, does the utility look for at least two competing and comparable solutions that claim to meet the same standard(s)? Further, do they have an efficient method for validating the claimed interchangeability of the products?	
	7. What does a utility do when only one vendor exists for a particular solution? If possible, does the utility re-design the project so that each component can be supplied by multiple vendors? Do they actively cultivate competition when a re-design is not feasible?	
	8. How does a utility validate claims of conformance to specified open standards? Does it require evidence from vendors such as a recognized independent certification? Do they perform internal validation testing? Do they contract with a third party to do validation testing?	
	9. What happens if the testing shows a lack of conformance to the claimed standard?	
	10. How does the utility plan for evolution of adopted standards? Is there an intentional feedback mechanism to the Standards Setting Organization (SSO) for improvement?	

Supplemental Interoperability Checklist for Vendors

✓	Interoperability Checklist Question (Vendors)	Notes
	1 Does the vendor subscribe to the Interoperability Framework of the GridWise Architecture Council?	
	2. Does the vendor support and follow recommended national-level smart grid interoperability guidance, such as provided by the NIST Smart Grid Interoperability Framework, NIST Cyber Security Framework, and the SEPA Catalog of Standards?)?	
	3. Which Smart Grid Interoperability Standards does the vendor Support and Implement in their Products?	
	4. What specific aspects of the vendor's offerings further the interoperability goals of the industry?	
	5. Where standards are not yet identified or generally agreed upon, how does the vendor support development and implementation of such standards? Do they belong to Standards Setting Organization (SSO) working groups? Are they active in them? Which ones?	
	6. When implementing standards, how does the vendor deal with optional and proprietary extensions that could render a product inoperable with other products? Is the vendor utilizing a profile that collects a subset of these extensions into one implementation?	
	7. When standardization is not possible, does the vendor make available interface specifications of their products under a reasonable licensing agreement to encourage interoperability?	
	8. How does the vendor enhance or inhibit competition for its products?	
	9. How does a vendor validate claims of conformance to specified open standards? Do they submit their products for recognized independent certification? Do they perform internal validation testing using industry-standard tests? Do they contract with a third party to do validation testing?	
	10. What do they do if the testing shows a lack of conformance to the claimed standard?	
	11. How does the vendor plan for evolution of adopted standards? Is there an intentional feedback mechanism to the Standards Setting Organization (SSO) for improvement?	