

Testimony of

George W. Arnold
National Coordinator
For Smart Grid Interoperability

National Institute of Standards and Technology
United States Department of Commerce

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“Smart Grid Architecture and Standards: Assessing
Coordination and Progress”

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Introduction

Chairman Wu, Ranking Member Smith, and Members of the Subcommittee, I am George Arnold, the National Coordinator for Smart Grid Interoperability at the Department of Commerce's National Institute of Standards and Technology (NIST).

Thank you for the opportunity to appear before you today to discuss NIST's progress in accelerating the development of standards needed to realize a secure and interoperable nationwide Smart Grid. I last testified about our progress and plans before the Subcommittee on Environment and Energy on July 23, 2009. Today I would like to update you on what we have accomplished since then, where we are going, and some of the key issues on the horizon that we are addressing.

The Smart Grid, which will modernize the United States electric power delivery system, is central to the Nation's efforts to increase the reliability, efficiency and security of the electric delivery system and also to help build the infrastructure that will facilitate clean, energy sources to American homes and businesses. The Smart Grid utilizes advanced information and communications technologies to replace the one-way flow of electricity and information in the current grid with a two-way flow of electricity and information. This marriage of energy and information technologies will create capabilities to integrate solar, wind, and other forms of renewable energy, enable widespread use of distributed energy sources, provide consumers with tools to reduce energy usage and potentially save money, make the grid more efficient by reducing peak demand, and facilitate electrification of vehicles.

The Smart Grid is an important piece of the Administration's overall goal of fostering innovation and creating millions of jobs in a green economy through the creation of whole new industries and green entrepreneurs. NIST's mission to advance innovation and U.S. industrial competitiveness fits perfectly with this goal and we're committed to helping make that vision a reality.

Modernizing and digitizing the nation's electrical power grid—the largest interconnected machine on Earth—is an enormous challenge and a tremendous opportunity. Several years ago, the National Academy of Engineering described the electric grid as the greatest engineering achievement of the 20th century, and the largest industrial investment in the history of humankind. The basic structure of the present grid has changed little over its hundred-year history. The U.S. grid, which is operated by over 3100 electric utilities using equipment and systems from hundreds of suppliers, has historically not had much emphasis on standardization and thus incorporates many proprietary interfaces and technologies that result in the equivalents of stand-alone silos.

Transforming this infrastructure into an interoperable system capable of supporting the nation's vision of extensive distributed and renewable resources, energy efficiency, improved reliability and electric transportation may well be described by future generations as the first great engineering achievement of the 21st century.

NIST's Standards Role: A Framework for Interoperability

Moving towards nationwide North American, interoperable and secure Smart Grid cannot be done without establishing standards that are, preferably, harmonized with international standards. Under the Energy Independence and Security Act of 2007 (EISA), Congress assigned the National Institute of Standards and Technology (NIST) the “primary responsibility to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of Smart Grid devices and systems...” [EISA Title XIII, Section 1305]. The act further specifies that the interoperability framework should be “flexible, uniform, and technology neutral.” The law also instructs that the framework should accommodate “traditional, centralized generation and distribution resources” while also facilitating incorporation of new, innovative Smart Grid technologies, such as distributed and renewable energy resources and energy storage.

There is an urgent need to establish protocols and standards for the Smart Grid. Deployment of various Smart Grid elements, including smart sensors on distribution lines, smart meters in homes, and widely dispersed sources of renewable energy, is already underway and will be accelerated as a result of Department of Energy (DOE) Smart Grid Investment Grants and other incentives, such as loan guarantees for renewable energy generation projects. Without standards, there is the potential for technologies developed or implemented with sizable public and private investments to become obsolete prematurely or to be implemented without measures necessary to ensure security.

NIST is providing strong national and international leadership to drive the creation of interoperability standards needed to make the Smart Grid a reality. We are engaging industry, government, and consumer stakeholders in an unprecedented, open, public process. As I will detail shortly, in January of this year the NIST-led process reached a major milestone with the publication of the Release 1.0 Framework and Roadmap for Smart Grid Interoperability (NIST Special Publication 1108). This document provides the initial foundation for an interoperable and secure Smart Grid and has been widely praised by the Smart Grid stakeholder community. It has also provided direction for Smart Grid efforts around the world.

Comparatively Speaking: Off to a Fast Start

We are calling this framework “Release 1.0” because, while it provides a very comprehensive foundation for the Smart Grid, our work to develop the standards is far from complete. A similar effort to develop foundational standards for the Next Generation Networks (NGN) in the telecom domain – the broadband networks we use today to provide integrated telephone, television and internet services – took two years to develop their “Release 1.0” and five years to develop “Release 2.0”. With the Smart Grid we have accomplished in about a year what took two years to do for the NGN. This is in spite of the fact that the Smart Grid is a far more complex system. The fast pace reflects the intensity and urgency with which we are and our partners working.

While we are driving this program with a strong sense of urgency, we must also keep in mind that the foundation we lay with these standards likely will establish the basic architecture of the grid for the next 100 years. Any fundamental mistakes made at this stage may be difficult and costly to correct later. We especially cannot afford to make incorrect architectural choices or adopt weak standards that would compromise the security, reliability or stability of the grid. We need to work both quickly and carefully.

Accomplishments

In April 2009, NIST launched a three-phase plan to expedite development and promote widespread adoption of Smart Grid interoperability standards. This plan was developed after consulting with numerous stakeholders in industry, the standards community, and federal and state government. The plan, which I described in my testimony last July, reflects the need to rapidly establish an initial set of standards, while providing a robust, well governed process for the evolution of smart grid standards. I am pleased to tell you that the plan we laid out is on course and on schedule.

In May 2009, U.S. Secretary of Commerce Gary Locke and U.S. Secretary of Energy Steven Chu chaired a meeting of nearly 70 executives from the power, information technology, and other industries at which the executives expressed their commitment to support NIST's plan.

Initial Framework

In Phase 1, we engaged over 1,500 stakeholders representing hundreds of organizations in a series of public workshops over a six-month period. In a recent letter, the U.S. Chamber of Commerce commended NIST for its "willingness to reach out to the private sector on these issues." The Chamber described the NIST-led process as "transparent and inclusive."

Through this process, we and our collaborators created a high-level architectural model for the Smart Grid, analyzed use cases, identified applicable standards, determined gaps in currently available standards, and agreed on priorities for new standardization activities. The result of this phase, "NIST Special Publication 1108 - NIST Framework and Roadmap for Smart Grid Interoperability Release 1.0," was published in January 2010.

The Release 1.0 Framework describes a high-level conceptual reference model for the Smart Grid, identifies 75 existing standards that are applicable to the ongoing development of the Smart Grid, specifies 16 high-priority gaps and harmonization issues for which new or revised standards and requirements are needed, documents action plans by which designated standards-setting organizations (SSOs) are addressing these gaps, and describes the strategy to establish requirements and standards to help ensure Smart Grid cyber security.

The Smart Grid is a complex system of systems for which a common understanding of its major building blocks and how they interrelate must be broadly shared. The reference

model described in the Release 1.0 Framework provides a foundation to ensure alignment among the many Standards Setting Organizations that are working with NIST on achieving the Smart Grid vision.

The Smart Grid will ultimately require hundreds of standards, specifications, and requirements. Some are needed more urgently than others. To prioritize its work, NIST chose to focus initially on standards needed to address the priorities identified in the Federal Energy Regulatory Commission (FERC) Policy Statement, plus additional areas identified by NIST. The eight priority areas are:

- Demand Response and Consumer Energy Efficiency
- Wide-Area Situational Awareness
- Energy Storage
- Electric Transportation
- Advanced Metering Infrastructure
- Distribution Grid Management
- Cyber Security
- Network Communications

Many of the standards identified by NIST are mature and already widely used by industry, others require revisions to accommodate Smart Grid applications and requirements, and still others are in the draft stage and not yet publicly available. Collectively, these 75 standards provide an extensive foundation for the Smart Grid. They address such issues as standardizing the data captured by smart meters, common information models for the grid, protocols for communicating price and demand response signals between the grid and smart appliances, and the interface between plug-in electric vehicles and the grid for charging at 110 or 220 volts, to provide a few examples. However, there are many gaps in the standards portfolio that must be filled in.

Through the NIST workshops, NIST determined that many potentially useful standards will require revision or enhancement before they can be implemented to address Smart Grid requirements. In addition, stakeholders identified gaps requiring entirely new standards to be developed. In all, a total of 70 such gaps or related issues were initially identified. Of these, NIST selected 16 for which resolution is most urgently needed to support one or more of the Smart Grid priority areas. For each, an action plan involving relevant stakeholders was launched. These Priority Action Plans specify organizations that have agreed to accomplish defined tasks with specified deliverables. One key action plan, to develop a standard to ensure software upgradeability of the millions of smart meters that will be deployed over the next several years, has already been completed. Substantive progress has been made in meeting the milestones of other action plans addressing gaps in the standards portfolio.

Establishing a New Partnership to Maintain Momentum

Phase 2 of the NIST plan saw the establishment of a more permanent public-private partnership, the Smart Grid Interoperability Panel (SGIP), to guide the development and

evolution of the standards. This body is also guiding the establishment of a testing and certification framework for the Smart Grid, which is Phase 3 of the NIST plan. The SGIP was formalized and launched in November 2009 and is now in execution mode. During its eight months in existence, membership in the SGIP has grown to over 580 organizations, representing private companies, universities, research institutes, industry associations, standards setting organizations, testing laboratories, and government agencies at the federal, state and local levels. Nearly 1600 individuals who participate in the committees, working groups, and priority action plans working under the panel, represent these hundreds of organizations. An elected 27-member governing board representing 22 different stakeholder groups ranging from electric utilities, electric equipment manufacturers, building automation providers, information and communications technology companies, state regulators, and even venture capital firms oversees the SGIP. Membership in the SGIP is open to international participants, and 52 organizations from other countries around the world participate in its work. This is helping to ensure that standards used for the Smart Grid in the U.S. are based wherever possible on international standards that are harmonized globally. This provides a double benefit to the U.S. It enables Smart Grid suppliers to cost-effectively address the global market, and it promotes greater supplier competition, which in turn reduces costs for utilities and consumers.

Cyber Security: A Paramount Concern from the Very Beginning

Cyber security of the Smart Grid is a paramount concern, and this has been a major focus of our effort. A NIST-led cyber security working group, consisting of over 460 participants from the private and public sectors, is leading the development of a cyber security strategy and guidelines for the Smart Grid. The working group has developed an overall cyber security strategy; selected and revised security requirements for the Smart Grid; identified vulnerability classes and specific cyber security issues applicable to the Smart Grid; performed a privacy impact assessment; specified research and development topics; and is assessing relevant standards and developing a security architecture linked to the Smart Grid conceptual reference model. Results of the group's work have been published in two drafts of *NIST Interagency Report 7628 (Smart Grid Cyber Security Strategy and Requirements)*, issued in September 2009 and February 2010, which have gone through public review. This draft is now being finalized addressing all comments received and will be published as NIST IR 7628: *Guidelines for Smart Grid Cyber Security* in July of this year.

Where Are We Headed

Our most immediate priority is completion of the Priority Action Plans that are now tackling the highest-priority needs in the standards portfolio. One action plan, the Smart Meter Upgradeability Standard, has already been completed. The other Priority Action Plans currently underway are:

- Data standard for consumer energy usage information
- Common specification for communicating electricity price and product definition

- Common scheduling mechanism for energy transactions
- Common information model for distribution grid management
- Standard demand response signals
- DNP3 Mapping to IEC 61850 Objects
- Harmonization of IEEE C37.118 with IEC 61850 and precision time synchronization
- Transmission and distribution power systems models mapping
- Guidelines for use of the Internet Protocol suite in the Smart Grid
- Guidelines for use of wireless communications in the Smart Grid
- Energy storage interconnection guidelines
- Interoperability standards to support plug-in electric vehicles
- Standard meter data profiles
- Harmonize power line carrier standards for appliance communications in the home
- Standards for Wind Plant Communication

One action plan I wish to highlight is the work to create a standard for consumer energy usage information. Today, the only information available to most consumers about their electricity usage is their monthly utility bill. Consumers need more timely and detailed electronic access to their data in order to reduce energy usage. Under the NIST action plan, the North American Energy Standards Board is developing a standard that will define the data on energy usage that smart meters and utility information systems must make available to consumers. A draft of this standard will be available by the end of 2010. As these highest priority action plans are completed in 2010, new action plans will be launched by the Smart Grid Interoperability Panel to address additional gaps that still need to be filled, as well as new requirements and technologies that emerge.

Another high priority for NIST is supporting the forthcoming FERC rulemaking. EISA directs FERC to institute a rulemaking proceeding to adopt such standards and protocols as may be necessary to ensure smart-grid functionality and interoperability in interstate transmission of electric power, and regional and wholesale electricity markets, at any time after NIST's work has led to sufficient consensus in the Commission's judgment. NIST has been working very closely with FERC throughout the entire process.

The evolving nature of the Smart Grid implies that the regulatory adoption of standards will be an ongoing process rather than a one-time action. Therefore I anticipate that FERC's initial rulemaking will focus on a subset of the standards identified by NIST that are the most mature and the most critically needed for end-to-end Smart Grid interoperability and security. NIST, working closely with FERC staff, is preparing additional technical documentation and analysis of these standards to inform FERC's decision about which standards to include in its initial rulemaking. NIST is working to complete these documents by the end of July.

It is important for federal and state regulators to keep in mind, when considering the adoption of standards, that while all of the standards identified through the NIST process are needed for the Smart Grid, it is not necessary or appropriate for all of them to be adopted in regulations. Many consensus standards are already widely used by industry

on a strictly voluntary basis. In some cases their adoption in regulations can be counterproductive. A careful balance must be struck to ensure that the most critical standards needed to ensure end-to-end interoperability and security are adopted in regulations, without impeding continuing innovation and technology improvement.

Another major priority is the establishment of a testing and certification framework for the Smart Grid. The standards specifications are necessary but not sufficient to ensure interoperability and security. A robust and well-defined testing and certification program is needed.

A new Testing and Certification Committee that has been established under the Smart Grid Interoperability Panel is guiding the development of a testing and certification framework for the Smart Grid. This committee is co-chaired by a leading expert from the private sector and a manager in the NIST Office of the National Coordinator for Smart Grid Interoperability. The committee includes representatives of leading testing laboratories, industry associations, electric utilities, and smart grid suppliers. The committee is working to prioritize the types of interoperability testing needed, laboratory qualification criteria, and requirements for Testing Organizations and Certification Organizations to successfully facilitate conformity assessment to product or system interoperability and cyber security standards.

There are few formalized test programs currently in existence focused on the Smart Grid. One of the most urgent areas of need is a formalized program to test the conformance of smart meters against applicable Smart Grid cyber security requirements and standards. NIST is using a portion of its Recovery Act funds to develop a smart meter cyber security conformance program. A solicitation for a private sector contractor to support NIST in developing this program closed on June 10, 2010, and our goal is to have the initial test methodology developed and ready for deployment within 12 months from the contract award date.

Challenges and Opportunities

The task of developing standards for an infrastructure like the Smart Grid is a large and complex undertaking; however, it is eminently doable. There have been several previous infrastructure standards projects of similar magnitude that were accomplished successfully and with which I have personal experience.

Thirty years ago, Bell Laboratories successfully put in place architecture for the complete automation of maintenance and operations in the nationwide telecommunications network, with an underlying foundation of protocols and standards that utilized distributed computing and data networking technology of that era. That job was comparable in scale to the current challenge of the Smart Grid; however the coordination challenge was a bit easier because the national network at that time was owned and operated by a single entity with a captive manufacturer rather than 3100 utilities and hundreds of suppliers.

The evolution of the internet provides another example of a global infrastructure that has evolved over the course of decades, using open standards to achieve interoperability in a flexible way to support new applications and technologies that were never imagined at the outset. Like the Internet, the Smart Grid will need to evolve over the 15-20 years in which its deployment will likely occur, and in that sense the development of the standards will be an ongoing process.

One of the key challenges that we face is to ensure that our standards are, wherever possible, harmonized internationally. This provides a double benefit. It ensures the broadest possible market for U.S. Smart Grid suppliers, helping U.S. companies export their smart grid products, technologies, and services overseas, while creating high technology and jobs within the United States. The Administration's National Export Initiative (NEI) aims to double U.S. exports in five years, with the goal of creating 2 million new jobs in the United States. Smart Grid companies and technology providers based in the United States will be instrumental in advancing Smart Grid deployment in overseas markets while creating jobs at home. This will support NEI's efforts on international standards, promote greater supplier competition, and lower equipment prices for utilities and consumers. Our policy has been to base our U.S. Smart Grid on international standards wherever possible. Of the 75 standards identified in the NIST Release 1.0 Framework, 77 percent are produced by international standards organizations.

The U.S. is ahead of every other country in establishing a standards framework for its Smart Grid. We have intentionally opened our process to the international community and expressed a preference for international standards to encourage harmonization. We have also invested significant effort in establishing bilateral and multilateral dialogs with other nations that are working on Smart Grids, including Canada, Mexico, Brazil, the EU (and many of its member states), Japan, Korea, Australia, India and China. It will not be possible to harmonize all our standards, given the historical differences that exist between electrical systems in different parts of the world, but we are making harmonization a very high priority.

China in particular is making very large investments to create a Smart Grid, with significant emphasis on transmission and distribution infrastructure. By one estimate, China will spend \$10 billion annually on Smart Grid/smart infrastructure systems. There is great opportunity for foreign investment. Companies that specialize in transmission and transformation equipment, automation equipment, and information and communications technology components are well-positioned to contribute to China's grid development projects. I have read some reports that predict that China's preference for indigenous innovation will extend to the Smart Grid, and that China may seek to establish its own standards for the Smart Grid in the belief that the size of its market will lead to their adoption as de facto global standards. I hope that this will not be the case, and that China will take action to strengthen collaboration with the U.S. in creating harmonized international standards.

Another challenge that we face is accelerating the resolution of some key standards issues that could impede development of the market if not settled soon.

Several major appliance manufacturers have announced their intention to bring to market Smart Grid-enabled consumer appliances beginning in late 2011, provided that standards for communication between appliances and the grid for pricing and demand response signals are resolved by the end of 2010. The existence of too many competing standards has the potential to fragment the market and impede its development. Recognizing the urgency, a task group of the SGIP Governing Board including representatives from the appliance, consumer electronics, electric utility, building automation, and IT industries, and other stakeholders including state regulators, has been addressing the issue. In conjunction with a related effort being undertaken by the Association of Home Appliance Manufacturers, we are on target to achieve a timely resolution of the standards for smart appliances to communicate with the grid to meet the needs of the appliance industry.

Another issue that will be more difficult to resolve is the interconnection standard between electric vehicles and the grid for high-voltage, rapid charging. As I indicated earlier, the standards for charging at 110 or 220 volts have been settled and this will support the deployment of first generation electric vehicles. Charging stations that support rapid charging in minutes rather than hours will be needed, however, for widespread adoption of electric vehicles. There are at least four different competing proposals advocated by auto manufacturers headquartered in the U.S., Japan, Europe and China on what this interface should be. Lack of clarity on what the standard will be could impede development of a charging infrastructure in the U.S. Our Priority Action Plan on electric vehicles includes the timely resolution of this difficult issue as a key goal.

An overarching challenge that we face in setting standards for the Smart Grid is ensuring that they are sufficiently flexible to preserve options for the evolution of the grid as we gain experience with early deployment. The fact is that there are still many unknowns in such issues as the degree of centralized vs. distributed control of the grid. For example as we move toward more distributed renewable generation, with households and buildings not only consuming power but also generating power and selling it back into the grid, and appliances behaving in different ways in response to price signals, having effective controls to ensure stability of the grid will become increasingly important. New, more dynamic measurements and models of grid performance will be needed. Measurements, characterization, and models of storage devices, electric vehicles, and distribution system loads have to be developed. These are areas in which NIST's expertise in measurement science can contribute and we are addressing them in the program planning for our research efforts related to the Smart Grid. Cyber security will remain a significant challenge as threats continue to evolve, and application of NIST's expertise in computer and network security to the Smart Grid will continue to be a top priority.

Finally, I would like to mention an opportunity. Basing the Smart Grid architecture on open standards, as we are doing, may facilitate multi-use scenarios, in much the same way as the Internet has evolved over time to provide a common set of protocols and standards supporting voice, video and data applications. Japan, which is following what we are doing very closely, is moving in this direction. Japan has recently unveiled their national Smart Grid program, which they have called the "Smart Community". Their roadmap envisions a common architecture supporting automation in their electric grid,

water and gas networks, energy efficient buildings, and intelligent transportation. I believe that the architecture and standards for the U.S. Smart Grid should consider this broader concept and not limit our future direction.

The knowledge gained by rigorous analysis of the performance of the Smart Grid under the Department of Energy's (DOE) ARRA programs will give us valuable information to determine whether or not benefits could be gained by applying the standards based intelligence infrastructure to other domains important to our society.

Conclusion

The Smart Grid, with the unique investment opportunity afforded by the American Recovery and Reinvestment Act, represents a once in a lifetime opportunity to renew and modernize one of the Nation's most important infrastructures. NIST is proud to have been given such an important role and is committed to achieving the Administration's vision of a cleaner, more reliable, more efficient and effective electricity grid that creates jobs and reduces our dependence on others.

Thank you for the opportunity to testify today on NIST's work on Smart Grid interoperability. I would be happy to answer any questions you may have.