U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

The National Opportunity for Interoperability and its Benefits for a Reliable, Robust, and Future Grid Realized Through Buildings

February 2016

(This page intentionally left blank)

Preface

The electric industry is actively evaluating different potential business models of distributed utilities where core principles can help focus the design of the future power grid. Guiding principles for this focus have been developed by the Great Plains Institute and others as part of the e21 Initiative, which aims to develop “a more customer-centric and sustainable framework for utility regulation (in Minnesota) that better aligns how utilities earn revenue with public policy goals, new customer expectations, and the changing technology landscape.”[1] One of the potential principles, offered as a starting point for discussion, is to encourage and enable electricity consumers to take advantage of all cost-effective energy efficiency and other demand-side management opportunities. Another principle is to facilitate innovation, implementation of new technologies, and delivery of new energy services. Underlying both of these core principles is the need for interoperable, connected demand-side resources—i.e., the end-use devices in homes and buildings—to simply “work” without complications, complexity, or additional cost to the consumer in order, if the consumer so desires, to more effectively and efficiently coordinate electric system operations. Because about 74% of the electricity sold nationally by distribution utilities is used, or “consumed,”[2] by the residential and commercial buildings sectors,[3] interoperability of end-use appliances, equipment, and devices is essential, or the attendant integration costs will prohibit access to the value and benefits that coordinated operations provide.

Interoperability is an essential enabler for technology to scale, as it moves us away from today’s state of highly customized integration. For example, integrating legacy sensors and actuators in buildings with new retrofit control and automation systems requires development of customized device drivers that bind the legacy systems to the new integration architecture. This is expensive when the number of devices is large. The desired state of technology interoperability is where end-use resources (generation, storage, and loads) can seamlessly communicate and transact with a range of energy services. This exchange will occur across the meter with the utility and with other end-use loads or generation. Interoperability, in particular as embedded in software, reduces the cost (and time) of technology integration, including the cost of software installation. It offers the benefit of better choices of products with more features and price points and better security that enable enhanced energy management. An electric system with interoperable devices and systems spanning the delivery infrastructure and end-use facilities increases the overall reliability and performance of the grid while facilitating enhanced penetration of variable renewable generation.

This white paper discusses interoperability as it applies to buildings and building interactions with grids and other systems, its impact and opportunity for the grid and the economy, and policy ideas that support an interoperable future. We define interoperability as the ability to exchange actionable information between two or more systems and across and within organizational boundaries. Interoperability relies on the shared meaning of the exchanged information, with agreed-upon expectations and consequences for the response to the information exchange, which makes the interoperability problem about more than simple data exchange. This paper is an extension of another recent white paper, “Buildings-To-Grid Technical Opportunities: Introduction and Vision,” in which the Building Technologies Office enumerates the benefits for interacting with the grid and, more importantly, the benefits within buildings themselves (e.g., to scale energy efficiency), campuses (e.g., across buildings), and districts (e.g., to enhance or improve electricity delivery at the distribution feeder level) to accommodate larger national installations of wind power, electric vehicles, photovoltaics (PVs), and other energy efficiency and renewable energy technologies.[4]

1 Great Plains Institute, e21 Initiative. http://www.betterenergy.org/projects/e21-initiative

2 The Energy Information Administration (EIA) uses the word “consumption“ regularly in its reports and data. See for example: http://www.eia.gov/beta/aeo/#/?id=2-AEO2015&region=1-0&cases=ref2015&start=2012&end=2040&f=A&linechart=ref2015-d021915a.7-2-AEO2015.1-0&map=ref2015-d021915a.7-2-AEO2015.1-0&sourcekey=0

3 EIA, Annual Energy Outlook. 2015. Reference Case, Table 2. http://www.eia.gov/forecasts/aeo/data.cfm

4 J. Hagerman. 2014. Buildings-to-Grid Technical Opportunities: Introduction and Vision. Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy. Available from DOE at: http://energy.gov/eere/buildings/downloads/buildings-grid-technical-opportunities-introduction-and-vision This paper sets the stage for “buildings and beyond” in which interoperability is a key enabler—and stated industry need for government intervention. Furthermore, the Building Technologies Office has funded key research projects, such as the “Transactional Network” to demonstrate improved operation within a building and facility operations (e.g., between buildings), thereby enabling traditional demand response and other “grid services” after interoperability has been addressed across the deployed technologies. For more information about this multi-laboratory project, see http://transactionalnetwork.pnnl.gov/index.stm.

Summary

Today, increasing numbers of intermittent generation sources (e.g., wind and photovoltaic [PV] and new mobile intermittent loads (e.g., electric vehicles) can significantly affect traditional utility business practices and operations. At the same time, a growing number of technologies and devices, from appliances to lighting systems, are being deployed at consumer premises that have more sophisticated controls and information that remain underused for anything beyond basic building equipment operations. The intersection of these two drivers is an untapped opportunity and underused resource that, if appropriately configured and realized in open standards, can provide significant energy efficiency and commensurate savings on utility bills, enhanced and lower cost reliability to utilities, and national economic benefits in the creation of new markets, sectors, and businesses being fueled by the seamless coordination of energy and information through device and technology interoperability. Or, as the Quadrennial Energy Review puts it, "A plethora of both consumer-level and grid-level devices are either in the market, under development, or at the conceptual stage. When tied together through the information technology that is increasingly being deployed on electric utilities' distribution grids, they can be an important enabling part of the emerging grid of the future. However, what is missing is the ability for all of these devices to coordinate and communicate their operations with the grid, and among themselves, in a common language—an open standard."[5]

In this paper, we define interoperability as the ability to exchange actionable information between two or more systems within a home or building, or across and within organizational boundaries. Interoperability relies on the shared meaning of the exchanged information, with agreed-upon expectations and consequences, for the response to the information exchange. Fundamentally, seamless interoperability requires reliable, hi-fidelity, secure information exchange.

Government entities at many levels can play a strategic role in addressing and realizing the opportunity of interoperability, including:

- promoting "open standards for customer devices that enhance connectivity and interoperability"[6]
- leading by example in their procurements of equipment
- convening and building consensus with industry and other stakeholders to develop a shared interoperability vision
- recognizing explicitly the value connected smart equipment can play in helping to realize the goals of renewable portfolio standards
- developing foundational support for needed new approaches, technologies, and the requisite skilled work force to support the realization of the latent value that resides in buildings.

5 Quadrennial Energy Review: Energy Transmission, Storage and Distribution Infrastructure (QER). April 2015. Page 3 28. Available at: http://energy.gov/epsa/downloads/quadrennial-energy-review-full-report

6 QER, page S-18.

Acknowledgments

We would like to acknowledge the technical support we received from Pacific Northwest National Laboratory (Steve Widergren, Andrew Nicholls, Jeff Taft, George Hernandez, Srinivas Katipamula, Chad Corbin, and Dennis Stiles) and Oak Ridge National Laboratory (Teja Kuruganti and Patrick Hughes).

Acronyms and Abbreviations

ARRA	American Recovery and Reinvestment Act
BTO	Building Technologies Office
DDC	Direct digital control
DOE	U.S. Department of Energy
EIA	Energy Information Administration
EV	Electric vehicles
FERC	Federal Energy Regulatory Commission
hr	hour(s)
GW	gigawatt(s)
GWAC	GridWise Architecture Council
IoT	Internet of Things
MISO	Midcontinent Independent System Operator, Inc.
NETL	National Energy Technologies Laboratory
NREL	National Renewable Energy Laboratory
OE	Office of Electric Delivery and Energy Reliability
PNNL	Pacific Northwest National Laboratory
PV	Photovolotaic
TCP	Transmission Control Protocol

Table of Contents

List of Figures

(This page intentionally left blank)

1.0 Introduction

In 2009, the U.S. Government invested $4.5 billion in the large-scale implementation of a smarter national electric power grid through American Recovery and Reinvestment Act (ARRA) grants and demonstration projects.[7] ARRA funded the installation of the enabling technology of smart meters, and an additional 16.87 million smart meters were installed nationally through November 2014.[8] Many of these grid investments were enabled by the foundational work of the U.S. Department of Energy's (DOE's) Office of Electric Delivery and Reliability (OE), which focused on the deployment of enabling infrastructure for automated metering, substation automation, and grid modernization. Even before the ARRA grid investment programs, utilities were making large investments in clean energy technologies, such as solar power and wind turbines, as well as in smart grid technologies (e.g., smart meters) at unprecedented rates.[9] To achieve state-mandated renewable portfolio standards and the nation's carbon goals, utilities must further accommodate high levels of clean energy generation without degradation of reliability or the cost-effectiveness of the power grid. As a consequence, this new installed smart grid infrastructure must be used in a way that it is optimized day-to-day, and moment-by-moment, to match variable and/or renewable generation.

7 SmartGrid.Gov: http://www.smartgrid.gov/recovery_act/overview

8 SmartGrid.Gov: https://www.smartgrid.gov/recovery_act/deployment_status/ami_and_customer_systems##SmartMetersDeployed

9 For total installations of smart meters, see DOE/EIA: http://www.eia.gov/tools/faqs/faq.cfm?id=108&t=3 In 2013, U.S. electric utilities had nearly 52 million advanced ("smart") metering infrastructure (AMI) installations. About 89% of them were residential customer installations. For renewables growth, see DOE/EIA: http://www.eia.gov/forecasts/steo/report/renew_co2.cfm

2.0 Buildings Are a Grid and Energy Efficiency Resource at Scale

The DOE conducts advanced research development and demonstration to make new energy efficient technologies such as solar, wind, electric vehicles, and advanced building-related technologies (e.g., cooling, windows, lighting) more commercially viable. However, cost reduction alone does not ensure that large-scale deployment of advanced building technologies will contribute to overall system performance. As clean energy and energy efficient technologies become more prevalent on the consumer side of the meter, the distribution system must evolve to accommodate them. Much technological advancement supported by DOE investments needs to be integrated into the electric grid safely, reliably, efficiently, and cost-effectively. ***If a holistic approach to integrating these technologies into distribution systems is not developed, these technologies will not be deployed by utilities or in the market at the scale necessary to achieve national energy, economic, environmental, and consumer benefits.*** Extending interoperability to the buildings-to-grid case and beyond has enormous potential to enable consumer and energy-related benefits.

An example of the challenge variable generation can provide to system operations is provided by former chairman of Federal Energy Regulatory Commission (FERC) Jon Wellinghoff in his presentation, "A Day in the Life of the Grid" (an hour-by-hour analysis of the Midcontinent Independent System Operator, Inc. [MISO] grid on a hot peak summer day).[10] The timing (coincidence) of renewable generation and the demand for power can be quite different. In this MISO example, average wholesale energy prices at 3 AM in the western part of the MISO region plummeted to zero driven by the availability of significant wind power (3 GW/hr) and lack of demand. But at 1 PM, when the temperature neared 100ºF and all building rooftop air conditioners and other cooling systems were running flat out, only 1,800 of the 30,000 wind blades in the region were effectively producing at capacity. And at 4 PM, as the Pennsylvania-New Jersey-Maryland Interconnection set an all-time peak record of 160 GW, wind generation dropped to an even lower point.

Because nearly 75% of the nation's total electricity use is consumed in homes and commercial buildings, and most summer peaks are driven by building demand, integrating building electrical devices with the grid is critical to reducing peak loads and minimizing the associated costs of constructing new generation, transmission, and distribution infrastructure to meet that demand. Moreover, most of the projected electric load growth through 2040 is driven by use in buildings, which in turn drives projected the expansion of utility system capacity.[11] Many smart grid applications are designed to minimize peak demand.[12] Primary among them is demand response, but as costs come down, distributed generation and storage (both electric and thermal) may also make important contributions. The FERC projects that demand response could trim peak demand by as much as 20%.[13]

Utilities have employed simple forms of demand response, mostly in the form of interruptible contracts (which are used almost exclusively in emergencies) and direct load control. The opportunities before the nation involve vastly expanding the number of consumers and types of end-uses engaged, and the range of grid benefits derived by using the smart grid's communication technologies to signal consumers to respond, metering technologies to gauge their response, and creative ratemaking to provide incentives for that response. Historically, a few large loads within a service territory provided demand response "some of the time" (i.e., unscheduled and ad hoc, as the utility requires it). In the future, the goal is to both greatly expand the number and diversity of building devices that can participate, and expand the range of services that devices can offer beyond traditional demand response.

---

10 Presented at the Transactive Energy Conference, Portland, Oregon, May 23-24, 2013 and available at http://www.greentechmedia.com/articles/read/A-Day-in-the-Life-of-the-Grid-with-Jon-Wellinghoff-Chairman-of-FERC

11 DOE/EIA. Annual Energy Outlook 2015. See tables 2 and 9
http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2015&subject=2-AEO2015&table=2-AEO2015&region=1-0&cases=ref2015-d021915a
http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2015&subject=0-AEO2015&table=9-AEO2015&region=0-0&cases=ref2015-d021915a

12 Data on peak demand from DOE/EIA is available at: http://www.eia.gov/tools/faqs/faq.cfm?id=100&t=3

13 Federal Energy Regulatory Commission. 2009. A National Assessment of Demand Response Potential. Staff Report. http://www.ferc.gov/legal/staff-reports/06-09-demand-response.pdf

Such services may include 1) end-user services, 2) energy market services, 3) grid services, and 4) societal services as described in a recent Building Technologies Office (BTO) report,[14] which provides use cases for these service categories. Such service can only be achieved if the devices are all interconnected and interoperating across and within organizational boundaries.

In 2011, the National Energy Technologies Laboratory (NETL) found that the potential nation-wide value of "demand dispatch"[15] (i.e., transaction-based control of energy within and between buildings, also referred to as demand participation or responsive demand) could be several billion dollars per year in reduced energy costs to the United States, with only 10% participation.[16] NETL also found that more than one-fourth of the 713 GW of U.S. building-related electricity demand in 2010 could be "dispatchable" if buildings could respond to that dispatch. Responding to dispatch requires enhanced communication, much the same as generation dispatch being supported by communication protocols.

Even though responsive demand could offset new generation and transmission, and cost-effectively facilitate higher renewable penetration, existing buildings, building systems, and building components today cannot effectively respond to grid conditions. The reason: buildings are not currently able to share performance information or transact load and energy services within the building and with other surrounding facilities or electric distribution systems. Building loads and building-level generation or energy storage can also serve as resources to mitigate supply and demand imbalances in addition to other ancillary services.

[14] Somasundaram S, RG Pratt et al. 2014. Transaction-Based Building Controls Framework, Volume 1: Reference Guide. PNNL-23302, Pacific Northwest National Laboratory, Richland, Washington. http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23302.pdf

[15] The term "demand dispatch" is from the DOE/OE report "Demand Dispatch—Intelligent Demand for a More Efficient Grid," August 2011, and is defined as the complement to Supply Dispatch. Demand Dispatch represents a possible end state that can optimize grid operations beyond what can be achieved with Supply Dispatch alone. Supply Dispatch relies on "generation following the load," while Demand Dispatch allows "load to follow the generation," thereby enabling full optimization of both supply and demand. https://www.smartgrid.gov/document/demand_dispatch—intelligent_demand_more_efficient_grid

[16] DOE/OE. 2011. Demand Dispatch—Intelligent Demand for a More Efficient Grid. Prepared by NETL for DOE/OE. http://www.netl.doe.gov/File Library/Research/Energy Efficiency/smart grid/DemandDispatch_08112011.pdf

3.0 The Stranded and Trapped Opportunities in the U.S. Building Stock

Presently, controls for energy-related components and systems within residential and commercial buildings (when they exist) often deliver suboptimal energy operations. These systems are generally unaware of perturbations and potential opportunities for more efficient operations, both within and outside the building envelope.[17] Even though sophisticated, optimized control methods and concepts are known, deployed control and dispatch of loads and onsite generation are often still rudimentary, requiring heavy human interaction and extensive customization, which are neither cost-effective nor scalable. Advanced, distributed dispatch and control methods are known, but are not being deployed in large part because of the inability of existing building and grid systems to share information appropriately.

A significant amount of energy supply, energy use/consumption, and other operational information contained within the end-use systems is available today, because the deployment of energy efficient and renewable energy technologies, modern metering equipment, communications technologies and systems, and instrumentation has increased. However, making use of and leveraging this information remains challenging—the application of and agreements for information exchange tend to be specialized in definition, formats, and protocols.

The inability to easily communicate information limits innovation and adoption of technologies, and drives up the deployment cost for all technologies. These shortcomings may make energy efficiency and renewable energy solutions less affordable for consumers and utilities. These issues also impede effective integration of energy efficiency and renewable energy technologies at scale and limit the positive impact the coordination of these resources can have in reducing transmission and distribution challenges.

[17] For some examples in homes involving heating, ventilation, and air-conditioning systems, see the BTO 2012 report, *Energy Savings Potential and Research, Development, & Demonstration Opportunities for Residential Building Heating, Ventilation, and Air Conditioning Systems.* Available at: http://energy.gov/sites/prod/files/2014/09/f18/residential_hvac_research_opportunities.pdf

4.0 The Opportunity for Interoperability's Benefits Is Clear in the Buildings Energy Sector

Buildings have the potential to play a critical role in the realization of any grid modernization solution for a number of reasons. First, as stated previously, buildings consume most of the nation's electricity and also drive most of the growth projected for electricity use.[18] Second, buildings and industrial energy use/consumption drive system peak demands. Third, buildings are the physical location (i.e., ground zero) for the installation of the millions of new and exciting energy efficient, renewable, and "smart" technologies—such as smart meters, smart building controls, electric vehicles (EVs), operational diagnostics, and smart appliances. Fourth, building owners are adding hundreds of megawatts of distributed generation to their structures every year,[19] effectively changing the current paradigm of one-way delivery of power. And finally, gains in the energy efficiency of buildings, equipment, and appliances can transform them into bankable assets, acting as the lowest cost virtual storage that is already at scale and deployed in the market today (e.g., thermal storage, demand dispatch, and optimized state control, all without affecting operations and comfort).

DOE's vision is that the future energy economy will include an open, interoperable system that facilitates physical transactions of energy, energy-related services, and related financial settlements.[20] The building sector is ripe to be the primary driver of this change within the energy system that directly (and indirectly) delivers national economic and social benefits, including the following:

- **enabling the achievement of 50% energy savings in buildings** by unlocking new value streams and business models for building owners and homeowners through investments in energy efficiency;[21]
- **increasing the share of clean energy sources in the generation** of our electricity, and thereby reducing greenhouse gas emissions by easily accommodating or removing barriers to hosting clean local generation, such as solar PV, within existing distribution systems;
- **creating domestically based clean energy jobs** in several industries, such as operations and management, control technologies and applications, software development, and energy management services where local service providers must install, service, and physically maintain control equipment;
- **improving asset utilization** by relieving peak loads on generation, transmission, and local distribution systems;
- **reducing required investments in new generation, transmission, and distribution capacity;**
- **reducing the cost of providing balancing (ancillary) services** needed to keep the grid stable, thus reducing operating costs and mitigating future costs for capacity to manage the increasing penetration of variable renewable energy sources;
- **integrating utility-owned assets with increasing penetration of consumer-owned, -operated, and -deployed distributed generation solutions,** including PV systems and EVs, with efficiency and operational services.

---

[18] According to EIA's *Annual Energy Outlook 2015*, in the Reference Case, the residential and commercial building sectors are projected to be 66% of the growth in electricity use through 2040. http://www.eia.gov/analysis/projection-data.cfm#annualproj, see Table 2.

[19] National Renewable Energy Laboratory (NREL). 2013. *2013 Renewable Energy Data Book.* See page 64, U.S. Total Solar Electricity Installed Capacity and Generation. http://www.nrel.gov/news/press/2015/15450

[20] DOE Building Technologies Office. 2014. Buildings-to-Grid Technical Opportunities: Introduction and Vision. http://energy.gov/eere/buildings/downloads/buildings-grid-technical-opportunities-introduction-and-vision

[21] The Building Technologies Office goal is to develop and promote the adoption of cost-effective technologies and practices that, when fully deployed, will reduce U.S. building-related energy use by 50% (from a 2010 AEO baseline). Source: Building Technologies Office FY15 Budget At-A-Glance. http://energy.gov/sites/prod/files/2014/03/f9/fy15_at-a-glance_bto.pdf

Some quantitative assessments of the benefits of a smart grid exist. For example, McKinsey found that customer applications, deployed largely in residential and commercial buildings, could potentially be worth $59 billion (in 2009 dollars) in smart grid benefits annually by 2019, including packages of pricing, in-home displays, smart appliances, and information portals that would serve to reduce both demand and overall use.[22] In a preliminary analysis, researchers at Pacific Northwest National Laboratory (PNNL) found that the potential value of continuously engaging real-time flexible loads in both residential and commercial buildings is $22 billion in 2014 dollars to provide grid services at the national scale.[23] ***Simply, our current energy system does not fully leverage or exploit the electricity use of the nation's 5.6 million commercial buildings and 120 million households, which leaves billions of dollars in efficiency, energy, and infrastructure savings untapped.***

Interoperability will also open energy markets to new participants. For example, participants in new markets should be able to reconcile the cost and benefits of complementary transactions among all interested parties to support value streams (new or existing) in energy efficiency, cost reduction, customer-specific service needs, and enhanced reliability of the electricity infrastructure. This optimization can be facilitated by using a common approach to the exchange of energy-related data and any associated financial data.

[22] Booth, A., Greene, M., Tai, H. "US Smart Grid Value at Stake: the $130 Billion Question." *McKinsey on Smart Grid: Can the smart grid live up to its expectations?* New York City, NY: McKinsey & Co. Accessed February 14, 2014. http://www.mckinsey.com/client_service/electric_power_and_natural_gas/latest_thinking/mckinsey_on_smart_grid.

[23] This estimate was based on four value streams: capacity displacement, wholesale market/production cost reduction; supplying regulation, and providing spinning (contingency) reserve capacity.

5.0 Technical Changes Are Needed to Realize the Benefits

The main technical challenge to realizing buildings-to-grid integration at scale is in the design of a flexible and overarching framework that will seamlessly coordinate the appliances and end-use load control mechanisms, including collaboration with external systems.[24] These external systems include other buildings, adjacent distributed energy resources, and new loads such as EVs, as well as the larger electric grid. This coordination will require micro- and macro-level control tools that empower building operators and consumers to optimize their assets while creating new cash flows, and at the same time facilitating grid balancing by relaying appropriate price and feedback signals. These controls need to be highly interoperable, affordable, semi-autonomous, open, and easily embedded in devices across all buildings, as well as easily installed, commissioned, and maintained. Technical challenges common to all sectors are as follows:

- **Need for signals** (e.g., price or incentive signal, cost-effective feedback/response in buildings) for specified services from the grid and price discovery capabilities in buildings. Traditional building systems and end-uses are designed to deliver occupant services (such as comfort, air quality, illumination, and refrigeration) and are not capable of handling price and energy performance information for other services, such as may be requested from the electric grid or another building.
- **Need for low-cost control networks** and optimization capabilities focused on engaging assets while not disrupting the comfort of building occupants. Ideally, no significant end-use and building should be left behind.
- **Importance of accuracy, access to, and granularity of data** to develop bids. For example, in some buildings where data sets are accessible, the data may not be accurate or at the granularity required to develop bids to perform a transaction. Additional sensors to enable actuation of new end-use loads are needed.
- **Implementation of measurement and verification technologies** and protocols that can track whether systems actually deliver the response requested. This technology needs to be inexpensive, easy to install in existing buildings, and able to provide traceable data and reliable outcomes.
- **Need for open standard interfaces that do not limit (encourage) interoperability or impede new technologies** or development of new services, and decision support tools to plan, integrate, and operate distributed energy resources.
- **Need for a cyber-physical security framework** to categorize and manage the risk of attack and any resultant incorrect operation of systems, to ensure that consumers and utilities can understand their level of protection, and make different investment decisions, if necessary. We also need to address options for the rapid recovery of systems after an attack.

The benefits of interoperability address the affordability and reliability of the power system. Both of these benefits are described by the GridWise Architecture Council (GWAC) in "Financial Benefits of Interoperability: How Interoperability in the Electric Power Industry Will Benefit Stakeholders Financially"[25] and "Reliability Benefits of Interoperability."[26] However, to fully monetize the national benefits to consumers and utilities, further analysis is needed that specifically analyzes the state of interoperability and the primary and secondary benefits of an interoperable future.

---

[24] S. Kiliccote, M Piette, M. Bhandari. 2014. *Buildings-to-Grid Technical Opportunities: From the Buildings Perspective.* http://energy.gov/eere/buildings/downloads/buildings-grid-technical-opportunities-buildings-perspective

[25] Gridwise Architecture Council. 2009. Financial Benefits of Interoperability. Prepared for GWAC by Harbor Research, Inc., http://www.gridwiseac.org/pdfs/financial_interoperability.pdf. GWAC found that interoperability will lead to the following grid and system reliability improvements: identification of outage locations; supports more rapid customer restoration time; eliminates need for customer outage reporting; allows more accurate dispatching of repair crews; improves capacity utilization; enables monitoring of grid voltage and phase.

[26] Gridwise Architecture Council. 2009. Reliability Benefits of Interoperability. Prepared for GWAC by Alison Silverstein Consulting. http://www.gridwiseac.org/pdfs/reliability_interoperability.pdf. GWAC found that interoperability leads to the following financial benefits: lowers costs per transaction; increases operating efficiency; improves reliability and security; lowers design and installation costs; lowers operations and maintenance costs; lowers support, systems restoration, and upgrade costs; provides higher quality of service with fewer errors; catalyzes provision of new services through competitive innovation.

6.0 Governmental Entities Can Play a Key Role in Driving Interoperability

A key finding from the 2015 Quadrennial Energy Review is that "enhancing the communication to customer devices that control demand or generate power will improve the efficiency and reliability of the electric grid. For example, open interoperability standards for customer devices…will improve the operation of the grid."[27] Just as interoperability is a crucial enabler of smart grid capability, it plays the same role for enabling smart equipment capabilities within individual buildings and between buildings on campuses. Interoperability's challenge is not a lack of adequate protocols or standards, but the multiplicity of them. This field consists of competing standards and approaches to integration of automation technology that negatively affect cost, speed of installation, and solution alternatives, which increases overall transaction costs and degrades the value propositions of "smart" technology. No single entity dictates, or group has reached, consensus on a standard or method of integration. The task of advancing interoperability requires industry stakeholders and government and non-government organizations to closely coordinate their efforts in the development of an overall ecosystem of interoperable products and services. For these reasons, government entities can play an important role in facilitating the dialog about the nature of interoperability so that solutions are accessible and encourage a competitive environment, based on the performance of functional and economic requirements, and in which barriers to entry are reduced and consumer choice is encouraged.

The scope of this needed dialog includes agreement on the use cases, value propositions, and principles of the interoperability of equipment. This requires engaging smart buildings' stakeholders to establish an alignment of interface definitions, information models, deployment methods, testing and certification, and business community services (e.g., registries, directories, reference models) that simplifies the integration of communicating buildings devices and systems and supports their reliable performance within the building and with outside parties (e.g., utility service providers, diagnostic services, emergency responders).

An effective process would include the following attributes:

- **a process based upon the convening power of government** to nurture a level playing field for alignment of concepts, definitions, and objectives in a competitive business environment;
- **leverage existing open and transparent processes**;
- **support global requirements**, not just U.S. requirements, wherever possible, because of the global nature of the equipment and appliance industries;
- solutions structured to **facilitate effectiveness of market forces**; and
- consensus-**led discussions and outcomes**.

BTO recently commissioned an analysis to evaluate transactions-based controls in buildings, including identification of use cases for four different categories of services—end-use, grid, energy market, and societal.[28] Some of these interactions are inside the building, some are trades with other building systems, and others are interactions with third-party service providers of various sorts (e.g., diagnostics, air shed management, data center computation load-sharing). For these other types of interactions to succeed in the marketplace, a more flexible form of interface definition needs to be considered, and automation of the integration process itself must be included.

For these other types of interactions to be supported, an extended form of interface definition needs to be considered in which automation of the integration process itself must be included. Previous work by the National Institute of Standards and Technology and Smart Grid Interoperability Panel on interoperability standards, as well as the Interoperability Context-Setting Framework developed by the GWAC (the "GWAC Stack")[29], addressed useful as-

[27] Quadrennial Energy Review. 2015. Page S-14.

[28] Somasundaram, S, RG Pratt, S Katipamula, et al. 2014. Transaction-Based Building Controls Framework, Volume 1: Reference Guide. PNNL-23302, Pacific Northwest National Laboratory, Richland, Washington. http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23302.pdf

[29] Gridwise Architecture Council, Smart Grid Interoperability Maturity Model Summary webpage, accessed January 14, 2016: http://www.gridwiseac.org/about/imm.aspx

pects of the problem, but the scope of the interoperability issue has grown since that work was done. The emerging concept of buildings as not just responsive loads but as operational partners working with the grid and other entities has added significantly to the complexity of the interoperability challenge. In addition to raising issues about grid interaction, this emerging concept has highlighted the need to consider building internal systems in the context of external interactions, as opposed to stopping at the meter boundary.

To allow a broad range of innovative services to be realized, expanded interface issues should be considered as we seek a truly interoperable future. Furthermore, some level of agreement among the market actors is critical. Because interoperability enables automation devices and systems to simply connect and work together effectively, securely, and reliably, its relevance spans efforts across DOE wherever technology deployment integrates with other technologies and systems.[30] Investments are needed to advance an open building interoperability standard—and thereby reduce the cost to install, integrate, operate, upgrade, and maintain smart building devices and systems. Furthermore, interoperability has historically been a driver of more product choices with a greater variety of prices points and features.

Achieving interoperability among devices that span the continuum from generation to end-use involves technical, institutional, and economic challenges. Ongoing technical challenges will always exist because interoperability must address long-lived incumbent proprietary systems that need a way to communicate and interact, including methods of "discovery". Another ongoing challenge across all domains is that there is not a lack of standards, but a proliferation of standards (possibly 40 50 competing standards), all of which provide access to the capability of the device, but fundamentally limit the device to interact with others on an equitable basis.[31] A large number of incumbent proprietary systems simply do not communicate with each other, either because of technical limitations or a business limitation imposed by a business model that promotes proprietary and "vendor lock-in" solutions.

These difficult institutional and economic or organizational and human challenges may be quite difficult for the industry to resolve without government support. Therefore, any interoperability policy should emphasize the goal of simplifying reliable integration of devices and systems. Interoperability requirements should specify the characteristics and performance of equipment and system interfaces to support their integration, while accommodating legacy technology and new technology offerings that will evolve. Policy should avoid mandating specific technologies or standards, because doing so may create barriers to new and better approaches. Rather, policy should encourage industry alignment on the most effective approaches of the day, mindful of the evolution of emerging approaches.

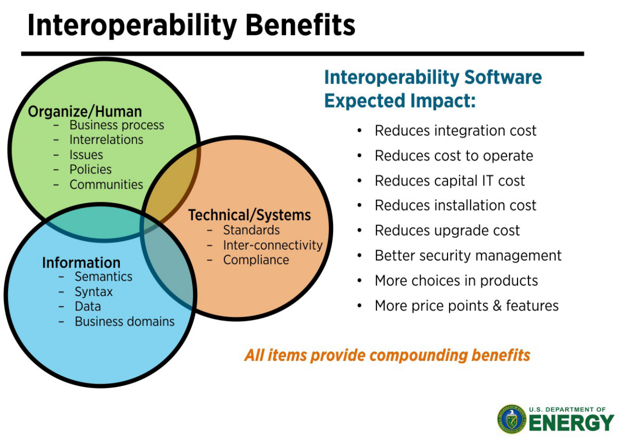

Figure 1. Interoperability Benefits across the Technical, Institutional, and Economic Domains. *Graphic credit the GridWise® Architecture Council.*

[30] Examples include the integration of renewable resources, the integration of technology in building automation systems, and the integration of electric power infrastructure technology and distributed resources.

[31] For an excellent overview of the universe of applicable codes, standards, and guidelines in the built environment, see the American National Standards Institute (ANSI) Energy Efficiency Standardization Coordination Collaborative (EESCC)'s *Standardization Roadmap: Energy Efficiency in the Built Environment*, June 2014. Available from ANSI at http://www.ansi.org/standards_activities/standards_boards_panels/eescc/overview.aspx?menuid=3 (accessed January 14, 2016). Also see the EESCC Inventory Database, a supplementary resource on standards, codes, guidelines, and conformity assessment programs related to energy efficiency in the built environment http://toolswiki.ansi.org/tiki-index.php?page=EESCCTabs

With standard interfaces (e.g., interfaces that are discoverable and self-identifying), information can be standardized and communicated through layering on multiple communication network technologies (e.g., via WiFi, TCP). With these interfaces, semantics are important because the underlying language serves as an agreement or "contract" between the two devices/parties. For example, a device may shed load for a time period, but only if the "buyer" and "seller" both have the same understanding of what that entails and what happens in the event of a contingency, such as a communication failure. Standard interfaces with agreed-upon semantics specifying the minimum set of information are important for ensuring that a contract can be established. Exposing the semantics, or the underlying language used, is more important than an underlying "standard," because it is overarching to the underlying service that is exchanged.

7.0 Policy Options to Realize the Opportunity of Interoperability

A central tenet of all policy options related to interoperability is that building and other operational controls must communicate and interoperate safely and securely with grid control systems (and other systems as well). Furthermore, government entities and interested stakeholders should work together to adequately address privacy, security, and cyber-security concerns. Policy options include, but are not limited to, the following:

- **Lead by Example**. Government entities at the municipal, state, and federal levels could elect to specify and purchase products that demonstrate transparent interoperability performance in their procurements of equipment and devices.

- **Convene and build consensus**. There are clear national benefits of government entities convening and collaborating with industry, non-governmental organizations, and other stakeholders to develop a vision for the interoperation of devices and systems in the future. The results of collaboration should articulate the promising ideas and trends in information technology that can contribute to a shared expectation for the process of easily and cost-effectively integrating devices and systems in the future. The importance of collaboration and building consensus cannot be understated, especially in light of recent efforts toward this goal[32].

    - Capture the interoperability requirements of the interfaces and processes necessary to realize this vision.

    - Encourage and facilitate stakeholder participation in the development of a roadmap of activities that lead toward the realization of the interoperability vision.

    - Convene and facilitate specific activities with stakeholders and the appropriate standards bodies to address gaps and challenges identified in the roadmap.

- **Promote open standards for interoperability**. "A plethora of both consumer-level and grid-level devices are either in the market, under development, or at the conceptual stage. When tied together through the information technology that is increasingly being deployed on electric utilities' distribution grids, these devices can be an important enabling part of the emerging grid of the future. However, what is missing is the ability for all of these devices to coordinate and communicate their operations with the grid, and among themselves, in a common language—an open standard. One analogy is the voluntary industry USB standard developed in the mid-1990s that allows simple plug-and-play between smart phones, tablets, computers, chargers, printers, games, and many other peripheral devices, and whose existence has greatly expanded both the usability and types of all these personal electronic devices."[33] Working with industry and other stakeholders, government entities can work to better promote open standards that enhance connectivity and interoperability.

- **Recognize the value connected equipment can provide in supporting renewable energy goals**. The trend of moving from only traditional generation to including renewable generation (such as solar and wind) is directly supported by public policy at various levels of government, including by states with renewable portfolio standards. Policies should embrace the value connected equipment can provide in actively accommodating an increasing share of renewable generation, as well as the related benefits of building energy efficiency (at scale) to meet these new goals.

- **Develop foundational support**. Faster system dynamics with many more new devices to control (with faster dynamics for each device) will lead to vast new data streams, increasing dependence on communication for data acquisition, and new strategies to analyze and automate decision/control. End-use devices are increasing their connectedness, so standard development organizations and other entities should ensure that they simply and reliably connect with one another (interoperability), and foster the development of new control algorithms and the supporting science discipline for how billions of devices work together to benefit the end-user and the larger population.

---

[32] This process has been initiated with a technical meeting held in March 2015, the results of which are summarized in Section 8.0. [33] Quadrennial Energy Review. 2015. Page 3 28.

8.0 Initial Lessons from Industry Collaboration

On March 11-12, 2015, BTO and PNNL convened a meeting with industry stakeholders to begin the process of developing a vision for building interoperability. Included in this meeting were representatives from heating, ventilation, and air-conditioning and control systems manufacturing companies; data analytics companies with a focus on efficient building energy use and operations; device and appliance manufacturers; academia; research organizations; and electric utilities.[34]

While there is general consensus among stakeholders that interoperability would enable 1) more efficient operations, installation, commissioning and maintenance of buildings; 2) opportunities for unlocking new value streams on both sides of the electric meter; and 3) growth and diversity in products and consumer choice, the path to achieving interoperability is not altogether clear. A number of obstacles raised during the meeting must be overcome to realize DOE's vision.

- As noted previously, the large number of standards and protocols already in use within buildings present challenges for connecting existing buildings, and hinder development of a unified standard.
- While an increasing number of solutions are aimed at addressing point and equipment identification, current practice largely relies on manual naming of these components within building automation systems, thereby limiting scale and higher levels of abstraction. In addition, there is no agreement on standard forms of interaction for services, such as those described in use cases for building-to-grid services or buildings diagnostics.
- Many existing buildings are not capable of communicating simply because they lack direct digital control (DDC) systems. Furthermore, many of the existing DDC systems are proprietary (despite using a standard protocol such as BACNET), resulting in vendor lock-in.
- For manufacturers, service providers, and consumers, the current value of buildings interoperability is not clear. Business cases must be developed to prove the benefits of interoperability and the transactive system interoperability supports.
- A number of regulatory hurdles must be overcome as energy markets become more open and transactive in nature.

These challenges do not suggest that the buildings interoperability vision is too grand or unrealistic. Rather, these findings illustrate the high degree to which industry stakeholders recognize and agree upon the current interoperability landscape, firmly establishing a common baseline from which to build. Although the specifics of buildings interoperability challenges are unique, many challenges parallel those that exist in the burgeoning Internet of Things (IoT). Efforts to address these obstacles will necessarily leverage many of the lessons learned in the IoT realm, suggesting that DOE's efforts include broader involvement by stakeholders in this domain. Indeed, with so much interest and activity in the IoT area, the potential for applying information technology mechanisms to realize this vision is high, provided that there is engagement and consensus in the buildings community.[35]

[34] Materials from this meeting, including the meeting book, presentation slides, and proceedings, can be downloaded from the DOE Building Technologies Office Buildings-to-Grid website: http://energy.gov/eere/buildings/downloads/technical-meeting-buildings-interoperability-vision A 2015 report, Buildings Interoperability Landscape, also describes the current landscape of interoperability for connected buildings and outlines an initial list of requirements to be addressed going forward; see the DOE BTO Buildings-to-Grid website at: http://energy.gov/eere/buildings/downloads/buildings-interoperability-landscape

[35] For other thinking on future directions for interoperability, see Chapter 10 in Hardin D, EG Stephan, W Wang, CD Corbin, and SE Widergren. 2015. Buildings Interoperability Landscape. PNNL-25124, Pacific Northwest National Laboratory, Richland, Washington. Available from DOE/BTO at: http://energy.gov/eere/buildings/downloads/buildings-interoperability-landscape

(This page intentionally left blank)

U.S. DEPARTMENT OF ENERGY

Energy Efficiency & Renewable Energy

For more information, visit: buildings.energy.gov

DOE/EE-1341 • February 2016