Unlocking the Smart Grid Through Building Codes and Communication Standards: Code Opportunities to Increase DR Transactions

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ABSTRACT

The smart grid and the technologies embodied within it will be a key investment in bringing our electricity system into the 21st century. With these technologies, we can unlock a diversity of demand-side management (DSM) mechanisms, including demand response (DR) transactions, behavior based programs, semi and/or permanent load shifting, deeper energy efficiency savings, and greater renewables firming capacity. However, a challenging chicken and egg market failure stands in the way of realizing the full benefits. Broader participation in smart grid markets will not occur until there is a significant investment in infrastructure that will allow seamless transactions. On the other hand, infrastructure investments will not occur until there is wider participation in DR transactions and customers' responses to DR signals are classified with more certainty. Building codes and communication standards (C&S) can be an effective solution for overcoming this market barrier. C&S can facilitate participation in smart grid markets by increasing prevalence of enabled and/or connected loads and making the smart grid system more coherent and reliable thereby making DR transactions easier for all market actors. This paper delves into four sections related to C&S deployment of the smart grid: (1) key triggers for successful code adoption of smart grid measures, (2) evaluation of market pathways with and without communication standards, (3) opportunities within building codes, and (4) the state of the union of appliance standards. We conclude with a call to action to industry, regulators, manufacturers, and utilities to play a role in expanding C&S efforts to accelerate the smart grid deployments and realize its benefits.

Introduction

The smart grid will be a key investment in ensuring our electrification system is more reliable, resilient, and responsive to our nation's environmental, economic and security constraints. The smart grid is comprised of the technologies, knowledge-capital, and mechanisms associated with smarter, more integrated supply, demand, and delivery of power. In particular, one study by Federal Energy Resource Commission (FERC) estimates that the United States (U.S.) could reduce peak demand by as much as 188 GW by 2019, which represents a 20 percent reduction in peak demand from business-as-usual, by deploying cost-effectively Demand Response (DR) strategies (2009).

While the smart grid may evolve differently in unique geographic regions based on how each market actor embraces and adapts to innovations, the innovations will have an impact on the power delivery markets from generation to transmission and distribution and to wholesale and retail pricing. In this paper, we focus on codes and standards (C&S) mechanisms that affect the demand side of the smart grid, which encompasses the devices, technologies, and communication infrastructure downstream of a utility, grid-operator, or third-party service provider. This includes curtailable loads within buildings, automated or logic-based controls that can respond to DR signals, a standards-based communication infrastructure that can support two-way messaging and signaling, and feedback mechanisms for relaying insights and information between consumers and their service providers (see Figure 1 below).

Figure 1. Smart grid scope applicable to this paper.

The C&S mechanisms presented in this paper should have the dual effect of increasing DR transactions and lowering the capital costs to purchase and install DR enabled equipment. According to FERC(FERC), a DR transaction is a change in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times when high wholesale market prices are high or when system reliability is jeopardized. Logic-driven controls allow customers to program response strategies based on market interactions. DR transactions that are implemented on an automated basis are known as Automated Demand Response (AutoDR). When this paper refers to DR transactions, it includes both AutoDR and non-automated DR transactions. Another important aspect of C&S is that it decouples technology investments from the current market structure, which facilitates faster, more effective market transformation and participation without the need to invest in new technology all the time. The focus of this paper is on C&S mechanisms that will enable transactions; we do not address the different types of transactions or strategies market actors might deploy to optimize cost and power savings.

Despite the significant opportunity for peak power savings, DR transactions remain relatively low due to a market failure. Market actors (e.g., manufacturers, utilities, power users, and third party service providers) have been slow to invest in DR infrastructure due to the stranded asset risk if communication protocol changes and equipment becomes obsolete, and uncertainty related to the cost effectiveness of their investments. Estimates of cost effectiveness are uncertain in part because customer participation in smart grid markets has not been high enough to draw undisputed conclusions about how consumers will choose to respond to DR signals and the benefits they realize from participation. In turn, consumer participation in smart grid markets has remained low because the smart grid infrastructure is not fully developed (i.e., advanced metering infrastructure paired with cost-effective technologies that enable optimized curtailment for the customer). These barriers are characteristic of the classic chicken-and-egg fallacy. Another contributing factor to the failure is that there are a myriad of competing visions among the market actors for how the smart grid will operate in the future. Unfortunately, no single market actor can fully address this market failure or the realization of the smart grid on their own.

Intervention in the form of building codes, appliance standards and communication standards, (C&S) could help overcome these challenges. Communications standards, such as the standards established by the National Institute of Standards and Technology and the Smart Grid

Interoperability Panel (NIST-SGIP), improve interoperability of components in the smart grid network and address the dependability of signals reaching curtailable loads and loads subsequently responding appropriately to the signal. Communication specifications also serve to ensure security, reduce technology deployment costs, and mitigate the risk of stranded assets. Building codes, and to a lesser extent appliance standard, can increase the prevalence of loads that are capable of modulating power use in response to a DR signal thereby increasing the magnitude of potential power curtailment from the grid as a whole. Together C&S can lead to a system that is more coherent and reliable, which will make successful DR transactions easier for all market actors.

Capable devices have curtailable load and comply with design specifications for communication. Fully connected devices have been commissioned on site to receive signals. Building codes could specify measures requiring loads to be either capable or fully connected. Requiring fully connected equipment would better position the customer and its service provider to take advantage of these controls in DR transactions.

Setting the Stage for C&S for Smart Grid Deployment

This section of the paper addresses the regulatory, technology, and market triggers that can help facilitate DR mechanisms in C&S.

Regulatory Triggers

One of the challenges of establishing DR code requirements is that the existing regulatory framework for many codes was established to promote energy efficiency – not to curb peak power demand. In California, a proposed standard must be deemed cost effective before it can be adopted into the building code (Title 24) or appliance standards (Title 20). Prior to 2005, the methodology used to determine cost effectiveness used average annual electricity savings and average annual electricity rates. This methodology captured benefits associated only with reductions in energy consumption, but the methodology was not capable of valuing benefits associated with shifting energy consumption away from peak hours, when power is typically most expensive, reliability concerns are greatest, and emissions may be highest. Since most DR measures do not result in an overall reduction in annual energy consumption but shift energy use away from peak periods, the old methodology did not capture the benefits of DR measures; DR measures could not be justified on a cost-effectiveness basis, and therefore could not be adopted into the code.

To address this regulatory barrier (among other reasons) in 2005 California adopted Time Dependent Valuation (TDV) to evaluate cost effectiveness of proposed changes to Title 24. The TDV methodology uses an hourly valuation of energy savings coupled with a unique energy price valuation for each hour of the year, which better reflects the actual costs of energy to consumers, utility system, and society (CEC 2011). This has the effect of making the evaluation of DR measures more representative of their actual benefits to society, thereby increasing cost-effectiveness. While California has addressed this regulatory barrier, the barrier remains elsewhere in the country.

Another, regulatory mechanism that can facilitate both successful adoption of codes and increased participation in programs is the availability of Time-of-Use (TOU) pricing tariffs. Regulatory approval is generally needed to authorize TDV and tariffs.

Technology Triggers

Before a C&S measure is adopted, the entity establishing the standard has to demonstrate that the technology is proven and reliable, and that complying with the proposed measure will not cause an undue burden to any market actor. If there is ambiguity on how the system or a component of the system is supposed to work, it can be difficult to establish an effective and enforceable code. When DR thermostat requirements were first considered for Title 24 in 2008, efforts to establish consensus specifications for the smart grid to ensure interoperability, security, and protect against stranded assets were in the early stages. During the 2008 Title 24 rulemaking process, there was debate about how communications across the smart grid infrastructure would work, including concerns about consumers' privacy, data security, and ability to opt out of AutoDR transactions. These concerns were not as prominent during the 2013 Title 24 rulemaking in part because the NIST-SGIP standard was nearly complete and market actors had started to converge on uniformity standards for smart grid infrastructure and operation.

Advanced metering infrastructure (AMI) that includes smart meters and one and two-way signaling devices are not necessary to adopt DR C&S measures, but could facilitate DR program and TOU tariff development and participant enrollment in voluntary smart grid markets. AMIs provide detailed information about how and when power is used, which can be used to calculate baseline loads and validate load shed during events. About seven states have AMI saturation exceeding 75%, and 16 states have at least 25% saturation (GTM 2013). Expanding coverage of AMI will help prime the market for more robust codes in the future.

Market Triggers

While consumer awareness of smart grid is at an all-time high in the U.S. (ZYPRME 2014), privacy concerns associated with the potential threat of the interception of data from smart meters or connected loads within buildings, persist. In theory, information collected could reveal information about how people use energy in their homes, their daily routines, changes in those routines, and other details (Nunez 2012). Vetting these issues and addressing other cyber security challenges is pertinent to the successful deployment of the smart grid and adoption of C&S measures. Voluntary communication standards have already helped reduce the security and privacy concerns associated with the smart grid.

Maintaining consumer choice is another important factor to consider when considering a C&S measure. Since participation in DR transactions is still limited, it is important that the C&S proposals provide power users with sufficient freedom to explore ways to respond to DR signals that will maintain building comfort and minimize interruptions. Currently DR transactions are new to most power users. In time, customers will become familiar with the smart grid markets, preferred methods of responding to DR events will be better understood, and participating in DR transactions will become routine. In other words, C&S will drive the market toward a more seamless experience with the smart grid. Other aspects such as the improved ability to manage loads, lower cost investments typically afforded by C&S, and simplicity of DR-ready controls from vendors will also help motivate customers to participate in DR transactions.

Oftentimes C&S measures are adopted only when sufficient market penetration has been achieved. In the case of DR, C&S proposals can correct this market failure that is inhibiting broader market penetration of DR technologies and participation in transactions. It is important that well-designed incentive and code compliance programs, which aim to inform market actors of the changes and help them comply with the new requirements, accompany the adopted C&S measures. In addition to improving code compliance, DR programs can play a role in ensuring that consumers have a favorable first experience with the smart grid and technologies embodied within it. DR programs can help customers see that participating in DR transactions is easy, does not necessarily cause disruption, and can offer energy-cost savings in return. Data collected through programs can also inform subsequent revisions to C&S requirements.

C&S Role in Ensuring Consistent Communication Standards and Transaction Automation

DR transactions, including AutoDR transactions, require communication between customers and their service providers. Communication standards adopted into code afford the following system-wide benefits: (1) testing and certification for interoperability, (2) asset reuse (or mitigation of stranded asset problem), (3) low cost technologies, and (4) cyber security. In this section, we look at the role communication standards play in ensuring these system-wide benefits.

While building codes suggest that the power users' control systems and loads must meet a performance standard or comply with certain prescriptive measures, communication standards (inclusive of testing and certification) function as an additional mechanism that can support a building code or an appliance standard. We discuss three scenarios indicative of (1) a market in which no communication standards exist and proprietary protocols proliferate, (2) a market dominated by the voluntary/industry-backed U.S. Smart Grid Interoperability Panel's (SGIP) communication standards, and (3) a market in which communication standards are included in mandatory building standards, thereby becoming legally binding.

Under the second and third scenarios, well-established data specifications for the communication between end-users and DR signalers exist. A load capable of transacting with these communications standards is referred to as *Certified AutoDR Client;* the client receives and responds to the communication standards-based signals from a DR service provider. The DR service provider supports a server, known as a *Certified AutoDR Server* that can communicate with any Certified AutoDR Client. AutoDR *logic* translates the communication signals into actionable requests, as preprogrammed and specified by the customer for load curtailment of end uses (Ghatikar 2014). The system and communication architecture of such interactions with the loads could be integrated into an energy management system, control system or other equipment, or exist as a standalone hardware piece (e.g., gateway, control systems) (Koch 2008). Figure 2 below illustrates how the communication between the Client and the Server could work. Note that the communication standard merely specifics a type of secure communication data model and would not necessarily hinder or specify a business model or group of market actors.

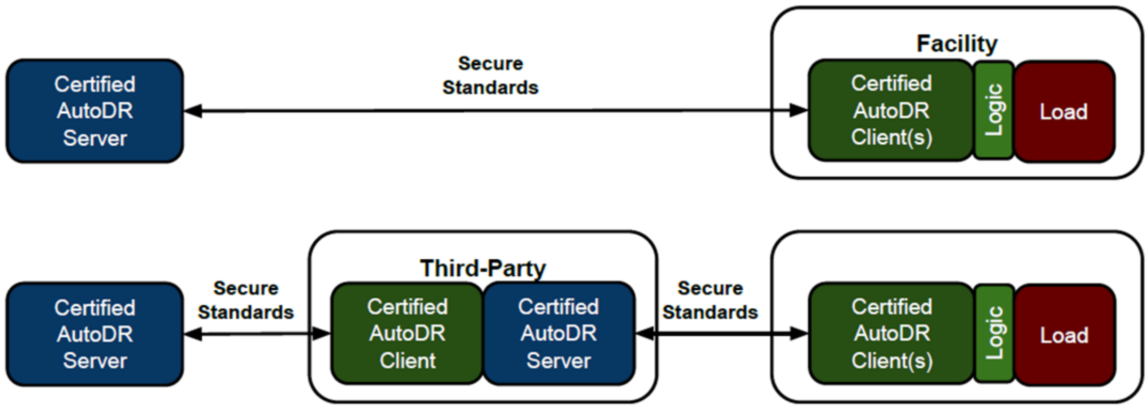

Figure 2. Standards-based communication between certified AutoDR server and clients (**Top**: Direct communication between DR service provider's AutoDR server and facility's AutoDR client; **Bottom**: In-direct communication, through a third-party, AutoDR server and facility's AutoDR client.).

The certifying authority typically carries out the certification of a standard for interoperability in accordance to national and other guidelines. The certified clients ensure that building control systems and loads have the capability to receive and respond to certified signalers.

The benefits associated with this type of automation system are analogous to the benefits consumer reaped when Wi-Fi became prevalent, albeit Wi-Fi is a wireless protocol and communication standard is a data model. In the early-days of Wi-Fi standards proliferation, the computer-interface cards and universal serial bus devices were sold as Wi-Fi clients to support computers to access Wi-Fi signals through a standardized Wi-Fi access point. Both The Wi-Fi Alliance® certified both the Wi-Fi access point and the client. Widespread adoption of Wi-Fi led to local support of Wi-Fi clients' interoperability in millions of devices (e.g., computers, laptops, smart phones). This had the benefits of reducing the cost of technology integration in these devices and allowed the reuse of these clients all over the world for ubiquitous and secure access to the Internet.

We anticipate similar benefits with standardized communications for DR, and assert that a certified client and server is a good mechanism to achieve systems interoperability and security, while maintaining customer choice (Ghatikar 2014). In a typical scenario of standards-based AutoDR implementation, the *server* communicates with the *client(s)* within the facility. In these two scenarios (in Figure 2 above) any DR service provider's AutoDR server can always interact with a facility's system or sub-system that supports AutoDR client(s), with or without the third-party intermediary, thus enabling end-to-end interoperability and asset re-use.

Figure 3 below shows the issues with interoperability and asset reuse (for a hardware or software AutoDR Client) when the market is comprised of a patchwork of proprietary communication protocols (i.e., the 1st scenario). By virtue of the proprietary protocol, a customer may be locked into their service providers or be left with devices that cannot communicate with other vendors.

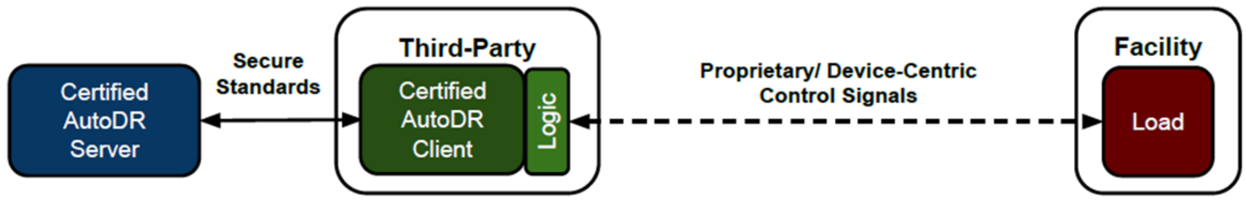

Figure 3. Standards-based communication between certified AutoDR server and third-party AutoDR Client; Proprietary or device-centric controls signals between third-party and facility loads.

If the voluntary communication standards outlined in Scenario 2 are fully adopted into mandatory C&S efforts (representative of Scenario 3), the benefits associated with interoperability and mitigation of stranded assets (e.g., AutoDR Clients) are increased significantly. In particular, adopting these communication standards into building codes enables vendors to scale DR-ready technologies (similar to aforementioned Wi-Fi clients) and thus lower the enablement and technology deployment costs. These standards can also be tested and certified for any base-case cyber security requirements to provide any message-level security needed during the communications (SGIP 2010).

Table 1 below summarizes key characteristics of communication architecture for DR enabled energy systems against the three scenarios: (1) non-existence of standards (or where proprietary communications exist); (2) voluntary SGIP interoperability standards for DR; and (3) C&S enforcement of SGIP to achieve full-interoperability and lowest cost of DR technology deployment. In addition, we consider other characteristics such as intellectual property and licensing, effect on market actors, and enforceability of communication standards.

Table 1. Key Characteristics of three scenarios for DR enabled energy systems for Smart Grid

C&S Characteristics	**No standards exist (Proprietary Communications)**	**SGIP Smart Grid DR Interoperability Standards**	**Ideal C&S Landscape Integration, Lowest Cost**
Interoperability (Smart Grid & Facility "Interface")[a]	Proprietary technologies & communications lock in consumers – a significant interoperability issue.	Interoperability is ensured under most circumstances; consumer has freedom to switch service provider.	Interoperability is ensured and natively integrated and enabled with systems; consumer has freedom to switch DR service provider.
Interoperability of Facility Interface to Load(s) [b]	A significant issue that can limit DR adoption.	Vendors can alleviate issues through control systems' integration.	Systems and loads provide functional support to low-cost grid-communications.
Asset Reuse [c] (Stranded Asset Mitigation)	Significant issue – devices typically support proprietary technologies.	Systems can be re-used with minimal or no reprogramming; backward compatibility could be an issue	Use for the device lifecycle (standards must ensure backward compatibility).
Cyber Security (Privacy is program design centric)	Security depends on vendor technology communication protocol.	Standards tested and certified against base-case high security	Presumed high cyber- and physical-security are offered with any additional encryption.
Intellectual Property and Licensing	Standards owned by vendors – likely not open or available for licensing	Publicly accessible open standards – to develop compliant products.	Presumed fully developed testing and certification program, supporting authority, and open source offerings.

Effect on Market Actors	ALL market actors need to select specific technology and vendor to support different programs.	Like the Internet, markets can leverage eco-system to offer program and cost benefits to consumers; R&D focus shifted to other design factors.	Similar to the Internet, markets can leverage eco-system to offer program and cost benefits to consumers; R&D focus shifted to other design considerations
Potential to enforce non-ambiguous C&S measures [d]	Cannot ascertain vendor interoperability and asset reuse for multiple providers and programs	Facilitate large-scale adoption if C&S is well prescribed with standards language.	Integrated systems and code-compliance check tools that are C&S enabled, thus easy to test and certify compliance.

[a] Interoperability of Smart grid and Facility Interface refers to the facility system(s) or sub-system(s) that connect to the electric grid to receive and respond to communications.

[b] Interoperability of Facility Interface and Load(s) refers to harmonization of grid to facility communications and their interactions with internal facility controls and protocols. This interoperability is not needed with the loads directly interact with the electric grid.

[c] Asset reuse describes the ability to reuse a given asset when the consumer changes DSM program enrollment or when communication protocols/standards are updated. Assets that cannot be used when enrollment changes or protocols are updated are considered to be "stranded". We believe C&S should help to mitigate the stranded assets, and ensure their capacity to be reused.

[d] Within C&S, it is necessary to establish measures that are clear and enforceable. This row describes the potential to establish clear and enforceable C&S measures under each pathway.

Opportunities within Building Codes

There are a number of different building codes and rating systems in the U.S., all of which include provisions that set the stage for participation in DR transactions. This section provides a summary of general approaches building codes can, and are, taking to achieve the goal of widespread participation in DR transactions.

Two main types of energy building codes exist: base and reach. Base codes typically become the legally binding minimum energy efficiency requirements for states. Reach codes typically include more aggressive energy efficiency, renewable energy, and load management provisions. Local jurisdictions, organizations, or unique building projects can voluntarily adopt reach codes. For example, in December 2010, the U.S. Army adopted ASHRAE 189.1 as the minimum energy efficiency code for all new Army buildings built in the U.S. and in U.S. territories. Reach codes serve the important purpose of identifying measures that could later be incorporated into mandatory buildings codes. As expected, the reach standards have blazed the trail with more aggressive mechanisms to encourage DR transactions while the base codes have taken a slower and more conservative approach. Establishing new standards in base codes is more challenging than establishing standards in reach codes because base codes become legally binding standards for which compliance among builders, installers, distributors, and other stakeholders is needed. While current federal law does not require states to have building energy codes, 46 states have adopted building codes, many of which are based on ASHRAE 90.1, International Residential Code (IRC), or the International Energy Conservation Code (IECC).

Building codes can deploy several strategies to facilitate participation in DR transactions. Specifically, building codes can be used to: (1) ensure buildings have curtailable load, (2) ensure loads are equipped DR controls, (3) require that DR systems have been commissioned and certified to confirm they are capable of responding to DR signals as designed, (4) require participation in DR transitions, and (5) require building energy use to be measured to enable better DSM management in the future. Table 3 identifies which strategies are currently deployed by various building codes and building rating systems.

Table 3. Code and rating systems strategies for encouraging DR transactions

Building Code	**Strategy for Encouraging Participation in DR Transactions**				
	Curtailable Load	DR Controls	Certification of DR Systems	Participation in DR Transactions	Monitoring & Reporting
Base Codes					
2013 Title 24 (Part 6), California Building Energy Efficiency Standards	Yes	Yes	Yes	No	Yes
ASHRAE 90.1-2013, Energy Standard for Buildings Except Low-Rise Residential Buildings	Yes	No	No	No	Yes
2012 International Energy Conservation Code (IECC)	Yes	No	No	No	No
2012 International Res. Code (IRC)	Yes	No	No	No	No
Reach Codes and Building Rating Systems					
2013 CALGreen (Title 24, Part 11), California Green Building Standards	Yes	Yes	Yes	No	Yes
ASHRAE 189.1-2011, Standard for the Design of High Performance Green Buildings Except Low-Rise Residential Buildings	Yes	Yes	No	No	No
International Green Construction Code (IGCC)	Yes	Yes	No	No	No
LEED (pilot credit 8)	Yes	Yes	Yes	Yes	No
National Home Energy Rating System (HERS)	No	No	No	No	No
California HERS	No	No	No	No	No

Ensure Buildings Have Curtailable Load

Three strategies building codes have deployed to ensure buildings have curtailable load are described below. First, building codes can include performance provisions that require buildings to have the capability of adjusting a given load. The magnitude of the load change can be defined in terms of absolute demand (kW), a percentage of the building's peak load, load factor, or demand factor. For example, section 7.4.5.1 of ASHRAE 189.1-2011 states, "Building projects shall contain automatic systems, such as demand limiting or load shifting, that are capable of reducing electric peak demand of the building by not less than 10% of the projected peak demand." This approach does not specify *how* the building will meet the curtailable load requirements. The builder can deploy any number of strategies to meet the performance requirement of a 10% reduction in peak demand.

Second, the code can include prescriptive requirements for targeted building systems and equipment used in buildings. On the systems side, for example, ASHRAE 90.1 and Title 24 require ventilation systems to meet demand control ventilation requirements. The ventilation systems must be capable of modulating output based on the ventilation needs of a particular space at the time (CEC 2013a, section 120.1(c); ASHRAE 2013, section 6.4.3.9). Similarly, lighting systems must be capable of modulating output based on the need for lighting in a particular space at a particular time. Lighting power may be curbed based on available daylight, time of day, occupancy, etc. (CEC 2013a, section 110.9; ASHRAE 2013, sections 9.4.1.1 and 9.4.1.5). On the equipment side, the building code can require the use of equipment that enables responses to DR signals. For example, Title 24 requires the use of adjustable speed fans and motors that can be adjusted to manage load.

Third, building codes can capture curtailable load from plug loads by requiring circuit-level controls that have the ability to manage power to certain electricity receptacles (outlets). In 2013, Title 24 added standards for circuit-level control in nonresidential buildings, but the standard did not include requirements for the controls to be DR-enabled. Rather, the controlled receptacles are controlled using automatic shut-OFF controls (CEC 2013a, section 130.5(d)).

Ensure Buildings are Equipped with DR Controls

Historically, building codes have required controls that adjust building systems based on schedules, occupancy or vacancy, or a sensor's perceived need for the system (e.g., daylight controls, carbon monoxide sensors, etc.). Requiring controls that are capable of responding to DR signals are relatively new to building codes. ASHRAE 189.1-2011 has an open-ended requirement that does not specify the type of controls or how that control will direct the building to adjust load. If the building has a control that is capable of adjusting load to the specified level, the building complies with ASHRAE 189.1-2011 (ASHREA 2011, Section 7.4.5.1).

On the other hand, Title 24 includes more explicit control requirements. Heating Ventilation and Air Conditioning (HVAC) systems in nonresidential buildings with direct digital controls to the zone level must be equipped with controls that are capable of automatically responding to DR signals and the controls must be programmed to allow demand shed in the form of specified temperature resets in non-critical zones (Title 24 120.2(h). Title 24 also includes specific controls requirements for Occupancy Sensing Smart Thermostats (OCST) and Energy Management Control Systems (ECMS) (CEC 2013a, section110.2(c); CEC 2013b, JA5).

A Title 24-compliant OCST must meet a number of detailed specifications intended to ensure the device can communicate with the signaler and can automatically respond to DR signals as programmed by the user, among other requirements specified in the code. While Title 24 does include communications requirements, the code does not go so far as require one particular standards-based messaging protocol. In effect, California a market dominated by the voluntary/industry-backed standards (Scenario 2 described in the previous section of this paper). Building codes can ensure interoperability and security by adopting a single standards-based messaging protocol by reference, which would in effect move the market towards Scenario 3 described above. This would move the jurisdiction into scenario 3 describe above. To accomplish this, the building code could specify that any control that is intended to receive and respond to DR signals must comply with one protocol, the NIST/SGIP standard for example. When the most recent version of Title 24 was adopted, the NIST/SGIP protocol had not been finalized, so Title 24 could not include a reference to the protocol. Now that the NIST/SGIP standard is final, the language in Title 24 could be revised to include reference to the NIST/SGIP standard and remove references to other communications standards.

One potential concern in adopting communications protocols by reference is that the building code typically needs to reference a specific version of the reference standard. If the reference code is updated frequently, the building code may inadvertently require controls to comply with outdated versions of the reference communication protocol. Another concern arises if there are two or more reference standards that deploy different technologies or approaches to achieve the same end goal. For example, Wi-Fi and ZigBee are both means of conveying a message to a control in a building area network. Adopting one of the two reference standards into the building code effectively picks one over the other. This could lead to the unintended consequences of inhibiting innovation by eliminating competition.

Ensure DR Systems Have Been Certified as Capable of Responding to DR Signals

Building codes can establish testing requirements to confirm that DR-enabled systems have been installed and commissioned as specified so they are capable of responding to DR signals. For example, to verify compliance with the demand responsive lighting controls requirements in Title 24, a certified field technician must complete an acceptance test to validate the DR control that modulates the lighting system power is installed, is capable of receiving and responding to DR signals, and reduces lighting power to the level required by code (Title 24 NA7.6.3). Similar acceptance testing exists for the Title 24 automated demand shed control requirements for direct digital control systems for zonal HVAC systems (NA7.5.19). Acceptance testing could be improved upon in future code cycles by requiring end-to-end commissioning between the building and service provider to ensure that signals are *received* and responded to as planned.

Currently, third-party aggregators or utilities commission DR systems after the consumer signs up for a DR program. If a mandatory building code requires acceptance testing before the building is occupied, the building may not be equipped with internet service and other prerequisites to complete the commissioning process to verify that signals can be received. The local code official would also assume responsibility for certifying that the commissioning has taken place, which means the local code officials would need the appropriate training to execute the new certification duties.

Require Building Occupants to Participate in DR Transactions

Building codes can make buildings physically capable of participating in DR transactions, but *requiring* participation in DR transactions is at the customer's discretion and usually outside the scope of building codes because participation in events is an ongoing activity that cannot be enforced through existing compliance mechanisms. Nonetheless, LEED is currently piloting a credit that requires building occupants to enroll in a 1-year "DR-Participation Amount Contractual Commitment (DR-PACC) with a qualified DR program provider with the intention of multi-year renewal.

LEED specifies that the DR-PACC must include a provision that the participant must be able to reduce demand by a minimum of 20kW or 10% of the estimated peak demand, whichever is greater. This DR-PACC requirement helps achieve greater participation in DR transactions by withholding the DR credit until the applicant has committed to participate in DR transactions. To receive the LEED credit, the building must have a system that is capable of participating in AutoDR transactions. The building operator must have a plan that documents how the building will meet the demand reduction commitment, and the scope of work for the commissioning authority must include a test of the DR system, including participation in at least one test of the DR response plan. LEED does not include specific requirements for the DR plan; however, voluntary consensus standards on energy planning, such as the International Organization for Standardization (ISO) 50001: 2011 – Energy Management, provide guidance on what should be included in a management plan (ISO 2011). LEED or other building standards could reference the existing energy management plan standards like ISO 50001 by reference, which would make energy plans uniform and could help with compliance determination.

While compliance and enforcement barriers will likely inhibit this type of enrollment measure from being adopted into this base code, this is a great example of how reach codes and building rating systems can adopt more aggressive and less typical codes to promote participation in DR beyond what is possible in base codes (LEED 2009).

Monitoring and Reporting to Help Inform Future Code Changes

ASHRAE 90.1-2013 requires that new buildings over 25,000 square feet (SF) be equipped with monitoring devices that are capable of measuring electricity use from the following systems at least on a 15-minute basis: total electricity use, HVAC systems, interior lighting, exterior lighting, and receptacle circuits. The monitoring systems must measure each tenant space over 10,000 SF separately and the system must be capable of reporting hourly, daily, monthly, and annual usage information. Monitoring and reporting requirements like that found in ASHRAE 90.1 can provide valuable information that can inform future DR programs and C&S measures (ASHRAE 90.1-2013, section 8.4.3).

Opportunities to Scale DR Capacity within Appliances

Figure 4 below illustrates the per transaction DR technical potential of various plug loads, in terms of technical potential for peak demand (kW) reduction. The results are based on a series of studies by Southern California Edison (SCE) in which the utility was evaluating the potential of Demand Response Integration into Title 20 (California's Appliance Standard), and they do not incorporate assumptions about program enrollment or participation rates. While a DR or smart grid measure has yet to be adopted into Title 20, and more studies will be needed to fully vet the technical and economic potential of appliances, California could consider DR measures for pool pumps, portable spas, and other measures in future code cycles. Refrigerators, water heaters, and dryers are likely to have the largest DR potential among white goods.

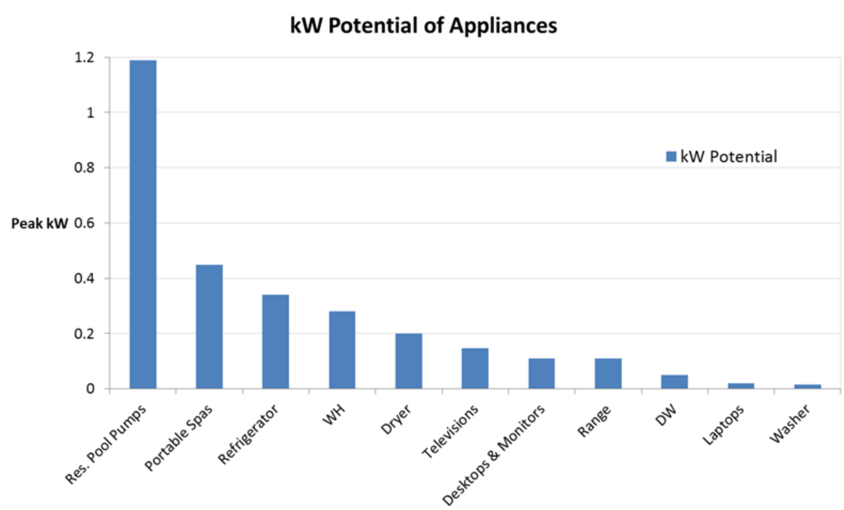

Figure 4. Per DR event technical energy savings potential for various appliances
Sources: SCE 2012, SCE 2011, SCE 2010, SCE 2009, SCE 2008.

State of the Union on DR Standards in Appliances

Currently, there are no mandatory federal or state standards for smart grid features for appliances or non-HVAC equipment, however, the Environmental Protection Agency's (EPA) voluntary ENERGY STAR® Program does reward smart grid features for clothes washers and residential refrigerators and freezers (Energy Star 2013a, 2013b, 2013c). Specifically, Energy Star gives a 5 percent allowance, or energy credit, for products that meet "connected criteria" requirements that specify the product can provide feedback on energy consumption, alerts, remote management, interoperability, and DR functionality (Energy Star 2011). To receive the credit, the product has to use an open communication standard developed by a number of listed standard-setting entities, including but not limited to NIST and SGIP. EPA's intent in establishing the DR credit is to help drive near-term, consumer value through the availability of new energy savings and convenience features (Energy Star 2012).

Energy Star has also launched a specification development process for residential climate control. Energy Star found that recent research and industry discussions indicated that today's programmable thermostat is evolving into a more usable, capable and connected device. EPA states, "An Energy Management System that includes a Communicating Climate Control will provide energy users with vastly improved and potentially real-time information on HVAC energy consumption and cost. Similar results are possible for Communicating Climate Controls integrated into utility AMI and/or DR systems" (EPA 2012). Within this process, Energy Star is considering energy efficiency and connected criteria, remote interfaces, an ease of use metric and test method, and power consumption test method.

The Lawrence Berkeley National Lab (LBNL) Demand to Grid Lab (D2G) has conducted research on and a laboratory demonstration of automating DR technologies including residential grid connected appliances. These included washers, dryers, heat pump water heaters, and refrigerators with home area network (HAN) integration and verification of responses from signaling. The D2G team found that open standards that have a compliance and certification framework play a role in information interoperability and could ease DR program participation (Ghatikar 2013). In order to more tangibly evaluate the consumer benefits associated with DR capable appliances we need to, develop and adopt test procedures to rate designs, identify and integrate DR strategies, and measure the ability of units to curtail load under different conditions. With this knowledge, consumers, industry, and policy makers will be better equipped with the information needed to create programs and or establish standards for DR ready appliances that can transform the market.

Conclusions and a Call to Action

Deployment of the smart grid will be a necessary step if we hope to bring our electrification system into the 21st century. As discussed in this paper, C&S can be an effective mechanism in helping us to take this step through active engagement of power users and demand-side loads. First, we identified a series of market, technology, and regulatory triggers that can aid in the success of C&S efforts such as regulatory authorization of Time Dependent Valuation (TDV), expansion of an automated metering infrastructure (AMI), and increasing consumer awareness and confidence in the smart grid's capabilities. We also discussed the value of not only creating communication standards, but the increased value associated with adopting these as mandatory into building codes. We looked at three distinct pathways for communication standard adoption (i.e., free-market, voluntary design specifications, and mandatory adoption of design specifications), and the pros and cons associated with each. In the section on appliance standards, we looked at the DR potential associated with various appliances, and the role that Energy Star is playing in motivating manufacturer R&D in connected features. In the building code section, we also discussed ways in which smart grid measures could be incorporated into code, as well as some of the opportunities and barriers associated with these different methods.

Ultimately, the success of the smart grid deployment will be dependent upon active participation from utilities, regulators, industry, code bodies, and consumers. As we asserted in this paper, C&S will be fundamental in helping each of these market actors realize the benefits associated with the smart grid more swiftly and in a manner that ensures greater security, interoperability, and reduced cost to society.

Acknowledgements

Lawrence Berkeley National Laboratory author contribution was coordinated by the Demand Response Research Center and funded by the California Energy Commission, Public Interest Energy Research (PIER) Program, under Work for Others Contract No. 500-03-026, and by the U.S. Department of Energy (DOE) under Contract No. DE-AC02-05CH11231.

References

ASHRAE. 2011. *ANSI/ASHRAE/USGBC/IES Standard 189.1-2013 -- Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings.*

ASHRAE. 2013. *ANSI/ASHRAE/IES Standard 90.1-2013 -- Energy Standard for Buildings Except Low-Rise Residential Buildings.*

California Building Standards Commission. 2013. *California Green Building Standards Code California Code of Regulations, Title 24, Part 11 (CALGreen).* http://www.ecodes.biz/ecodes_support/Free_Resources/2013California/13Green/13Green_main.html

CEC (California Energy Commission). 2008. *California Home Energy Rating System Technical Manual.* http://www.energy.ca.gov/2008publications/CEC-400-2008-012/CEC-400-2008-012-CMF.PDF.

CEC . 2011. *Time Dependent Valuation of Energy for Developing Building Efficiency Standards: 2013 TDV Data Sources & Inputs*. http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/general_cec_documents/Title24_2013_TDV_Methodology_Report_23Feb2011.pdf

CEC. 2013a. *2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings – Revised.* http://www.energy.ca.gov/2012publications/CEC-400-2012-004/CEC-400-2012-004-CMF-REV2.pdf.

CEC. 2013b. *2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings ; Reference Appendices.* http://www.energy.ca.gov/2012publications/CEC-400-2012-005/CEC-400-2012-005-CMF-REV2.pdf.

Energy Star. 2011. *Energy Star: Approaching Smart Grid*. November 9, 2011. PPT prepared by Amanda Stevens.

http://www.energystar.gov/ia/partners/downloads/meetings/2011/ES%20Approaching%20Smart%20Grid.pdf

Energy Star. 2012a. *Energy Star Residential Climate Controls. Draft 3 Version 1.0. Stakeholder Meeting* April 17. PPT prepared by Abigail Daken and Doug Frazee. http://www.energystar.gov/products/specs/system/files/EPA_Climate_Controls_Draft_3_Webinar_Slides.pdf

Energy Star. 2012b. *Summary and Response to Stakeholder Comments Received on the Energy Star Program Final Draft Version 5.0 Refrigerator Freezer Specification*. https://www.energystar.gov/products/specs/sites/products/files/ENERGY%20STAR%20Final%20Draft%20Version%205.0%20Refrigerators%20and%20Freezers%20Comment%20Response%20Summary.pdf

Energy Star. 2013a. ENERGY STAR® Program Requirements Product Specification for Clothes Washers Eligibility Criteria Version 7.0. March 2017. https://www.energystar.gov/products/specs/sites/products/files/ENERGY%20STAR%20Final%20Version%207.0%20Clothes%20Washer%20Program%20Requirements.pdf.

Energy Star. 2013b. *ENERGY STAR® Program Requirements Product Specification for Residential Refrigerators and Freezers Eligibility Criteria Version 5.0.* May 2013. https://www.energystar.gov/products/specs/sites/products/files/ENERGY%20STAR%20Final%20Version%205.0%20Residential%20Refrigerators%20and%20Freezers%20Specification.pdf.

Energy Star. 2013c. *Energy Star Program Requirements Product Specification for Residential Refrigerators, Refrigerator-Freezers, and Freezers: Test Method to Validate Demand Response May-2013.* https://www.energystar.gov/products/specs/sites/products/files/ENERGY%20STAR%20Final%20Refrigerators%20and%20Freezers%20Demand%20Response%20Test%20Method.pdf

FERC (Federal Energy Regulatory Commission). 2009. *A National Assessment of Demand Response Potential*. https://www.ferc.gov/legal/staff-reports/06-09-demand-response.pdf

Ghatikar, Girish, David Reisss, and Mary Piette . 2014. *Analysis of Open Automated Demand Response Deployments in California and Guidelines to Transition to Industry Standards.* Lawrence Berkeley National Laboratory. http://drrc.lbl.gov/sites/drrc.lbl.gov/files/LBNL-6560E.pdf

Ghatikar, Girish and Ed Koch. 2012. *Deploying Systems Interoperability and Customer Choice with the Smart Grid.* Lawrence Berkeley National Laboratory. http://drrc.lbl.gov/sites/drrc.lbl.gov/files/LBNL-6016E.pdf

Ghatikar, G., V. Ganti, M. A. Piette, J. Page, S. Kiliccote, And C. McParland (Lawrence Berkeley National Laboratory), And D. Watson (Slice Energy, Inc.); *Demonstration And Results Of Grid Integrated Technologies At The Demand To Grid Laboratory (D2G Lab): Phase 1 Operations Report.* 2013. LBNL-6368E. http://eetd.lbl.gov/sites/all/files/lbnl-6368e.pdf

GTM (Green Tech Media). 2013. *The US Smart Meter Market is Far from Saturated.* http://www.greentechmedia.com/articles/read/smart-meter-penetration

International Code Council (ICC). 2012. *2012 International Energy Conservation Code.*

Koch, Ed and Mary Piette. 2008. *Scenarios for Consuming Standardized Automated Demand Response Signals.* Lawrence Berkeley National Laboratory. http://drrc.lbl.gov/sites/drrc.lbl.gov/files/1362.pdf

ISO (International Organization for Standards). Standard ISO 50001 – Energy Management: 2011. 2011. Available for download: http://www.iso.org/iso/home/standards/management-standards/iso50001.htm.

LEED (Leadership in Energy & Environmental Design). 2009. *Demand Response Pilot Credit, EApc8.* http://www.usgbc.org/credits/demandresponse.

Nunez, Christina. (2012). Who's Watching? Privacy Concerns Persist as Smart Meters Roll Out. National Geographic. http://news.nationalgeographic.com/news/energy/2012/12/121212-smart-meter-privacy/

PNNL (Pacific Northwest National Laboratory). 2010. *The Smart Grid: An Estimation of the Energy and* CO_2 *Benefits.* http://energyenvironment.pnnl.gov/news/pdf/PNNL-19112_Revision_1_Final.pdf

Residential Energy Services Network , Inc. (RESNET). 2013. *Mortgage Industyr National Home Energy Rating Systems Standards.* http://www.resnet.us/standards/RESNET_Mortgage_Industry_National_HERS_Standards.pdf.

SCE (Southern California Edison). 2008. *Integration of Demand Response into Title 20 for Residential Portable Spas,* September 05. http://www.etcc-ca.com/sites/default/files/OLD/images/stories/dr_09.05.08_residential_portable_spas_v8_10-0311.pdf

SCE (Southern California Edison). 2010. *Integration of Demand Response into Title 20 for Pool Pumps,* September 05. http://www.etcc-ca.com/sites/default/files/OLD/images/stories/dr_09.05.10_residentialpoolpumps_v7_10-0312.pdf

SCE (Southern California Edison). 2012. *Integration of Demand Response into Title 20 for Home Entertainment Equipment,* September 05. http://www.etcc-ca.com/sites/default/files/OLD/images/stories/dr_09.05.12_home_entertainment_equip_v10_10-0312.pdf

SCE (Southern California Edison). 2011. *Integration of Demand Response into Title 20 for Home Office Equipment,* September 05. http://www.etcc-ca.com/sites/default/files/OLD/images/stories/dr_09.05.11_home_office_equipment_v9_10-0312.pdf

SCE (Southern California Edison). 2011. *Integration of Demand Response into Title 20 for Residential Appliances,* September 05. http://www.etcc-ca.com/sites/default/files/OLD/images/stories/dr_09.05.09_residential_appliances_v10_10-0312.pdf

SGIP (The Smart Grid Interoperability Panel). 2010. *Introduction to NISTIR 7628 Guidelines for Smart Cyber Security*, September. http://csrc.nist.gov/publications/nistir/ir7628/introduction-to-nistir-7628.pdf