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MAKING SENSE OF THE SMART HOME

Applications of Smart Grid and Smart Home Technologies for the Home Performance Industry

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Introduction

The emergence of new technologies that make accessing and measuring the energy use of our homes and buildings easier has the potential to be a game-changer for residential energy efficiency. It is difficult to understand and manage energy use when a household's total energy consumption is presented as a single number in a monthly bill. However, smart grid technologies including mobile and in-home communication devices may provide customers with nearly immediate feedback on energy use, helping make energy consumption visible and manageable, and providing additional opportunities for utility programs to incentivize customer energy use.

Smart grid technologies also provide home performance programs and contractors with the ability to more accurately measure the energy savings derived from energy efficiency upgrades to the home, which has important implications for establishing energy efficiency as a competitive energy resource that should participate in capacity, carbon, and other markets.

The ability for home performance to take advantage of the rapidly evolving smart grid technologies has been limited, in part, to the silos that exist between the two industries. Professionals working in each industry have had little communication with each other to date. Smart grid technologies are rarely incorporated into home performance upgrades or incentivized by home performance programs. Manufacturers that develop smart grid technologies rarely focus on the ways that these technologies could be integrated into whole-house upgrades. Government agencies and utilities that administer both smart grid and energy efficiency programs, almost invariably group their staff in separate silos that are not designed to explore or take advantage of the potential benefits between the two fields.[1]

Valuable opportunities are being lost as a result of this failure to communicate. Home performance professionals could use smart grid technologies to enhance and quantify their efforts to reduce the energy consumption of residential buildings. Home performance contracting represents a new and largely untapped market for firms that manufacture and market smart grid devices and its localized extension, the smart home.

This paper argues that the smart grid and home performance industries would benefit from a clearer understanding of the connections and points of intersection between whole-house upgrades and detailed information about energy consumption. Specifically, the paper identifies four ways that the smart grid and home performance industries could mutually benefit from further integration. These include:

1. Smart grid technologies have the potential to increase consumer awareness about energy use. This increased awareness could encourage further investment in comprehensive, whole-house energy efficiency upgrades, potentially benefiting programs and contractors that include these technologies in their retrofits, and creating greater market demand for smart grid technologies and products.
2. Utilities and other industry stakeholders should continue to bridge the gap between demand response and energy efficiency in the home performance market. Smart grid technologies coupled with dynamic pricing may provide customers with the tools they need to reduce energy use during peak times, resulting in lower customer electricity costs and a more stable electric grid. Demand response programs would be more effective if linked to energy efficiency because tighter envelopes keep the temperature in the house constant for longer, potentially increasing program participation and reducing the number of customers who override the demand response event.

1 A senior state public utility commission staffer lamented the disconnect by also sharing that between two of their utilities the larger one did not take advantage of the synergies between smart grid and energy efficiency while the smaller one was finding new opportunities at integration, stating "it is because one staff person manages both the smart grid and energy efficiency programs, so they see how important the interrelationship is."

3. Smart grid technologies provide richer and more detailed data, which support a variety of home performance tasks, including modeling, evaluation, measurement and verification (EM&V), prescreening, quality assurance and quality control, and better labeling. These technologies also support more accurate quantification of energy savings.
4. More precise quantification of energy savings, both by end use and for the entire home, can help promote the sale of energy efficiency in capacity and other energy markets, as well as the sale to customers, which is currently difficult or impossible.

These observations form the basis for five recommendations to policy makers, program implementers, manufacturers of smart grid technologies, and contractors.

1. Encourage partnerships between the energy efficiency industry and telecommunications and home security firms to market whole-house upgrades and install energy monitoring devices that encourage customers to implement upgrades.
2. Develop deliberate strategies for using home energy monitoring devices to promote implementation of whole-house upgrades among other behavioral changes.
3. Develop strategies to link demand response and home performance programs, for example, by marketing whole-house upgrades together with demand response initiatives, and targeting homes that have received an energy upgrade for enrollment in demand response programs.
4. Develop EM&V protocols for energy efficiency using smart grid technologies and data to increase the accuracy and quality of savings estimates.
5. Utilize smart meter data to build the case for energy efficiency as a competitive energy resource that should participate in capacity and carbon markets in addition to utility integrated resource planning and decoupling.

This paper both informed and was informed by the 2013 National Summit on Integrating Energy Efficiency and Smart Grid[2] that brought together, for the first time, stakeholders in the home performance, smart grid, and demand response industries.

This paper is not intended to provide an exhaustive list of current technologies, which are evolving so rapidly that any overview would be outdated in a matter of months, or to promote one method of communications over another. Rather, the paper makes recommendations for how stakeholders can begin to identify the tools needed to integrate smart grid technologies with home performance, and to recommend how to address barriers to integration.

Definitions

What is the smart grid?

The smart grid is the digital technology that enables two-way communication between the utility and its customers. It provides grid operators with greater visibility and control over the electrical grid infrastructure, including both conventional assets, such as transmission lines, substations, and transformers, and new grid assets, such as demand response, energy efficiency, distributed generation, and electricity storage.[3] Generally, the

2 The National Summit on Integrating Energy Efficiency and Smart Grid, October 15-16, 2013, http://energyefficiencysmartgrid.org/
3 Pratt et al., 2010

features of the smart grid include:

- Devices with sensors designed to measure and monitor changes in the flow of electricity through the grid;
- Two-way communications capacity that allows a flow of information between the devices and central control locations; and,
- Control functions that allow grid operators to use the smart grid's two-way communications facility to make alterations and adjustments to the grid's operations remotely.

The Pacific Northwest National Laboratory (PNNL) estimates that over the next 20 years smart grid technology will become pervasive in the U.S. because of the cost efficiencies it provides for the electric power system, which, among other benefits, may reduce the annual U.S. electrical energy production and resulting carbon emissions by 18 percent in 2030.[4]

Other benefits of the smart grid include:

- More efficient transmission of electricity;
- Quicker restoration of electricity after power disturbances;
- Reduced operations and management costs for utilities and customers;
- Reduced peak demand for a more reliable system;
- Increased integration of large-scale renewable energy systems;
- Better integration of customer-owned power generation systems; and,
- Improved security.[5]

The federal government has so far earmarked about $8 billion in public (American Recovery and Reinvestment Act funding) and private investment to modernize the electric power grid over the next decade including investments in customer systems, advanced metering infrastructure, distribution and transmission systems, and equipment manufacturing.[6]

In addition to providing benefits to utilities and other energy providers, the smart grid offers customers' greater information and control over energy consumption through advanced metering infrastructure (AMI),[7] or smart meters. Smart meters provide the smart grid interface between the utility and its customers. Unlike the traditional electromechanical meters, which are typically read manually once per month, and provide no information on when a customer used electricity that month, smart meters can provide information about energy consumption at much shorter intervals – days, hours, or minutes – to the utility, customer, and other systems in the house including appliances, lighting, or security systems. Smart meters provide the utility and its customer with real-time information about energy use, making it easier for the customer to identify and reduce energy waste, and manage peak demand.

What is the smart home?

Smart homes are equipped with devices and communications systems that provide their occupants with a much

4 Pratt et al., 2010
5 SmartGrid.gov, 2013, http://www.smartgrid.gov/the_smart_grid#smart_grid
6 SmartGrid.gov, 2013, http://www.smartgrid.gov/recovery_act/overview
7 AMI refers to the overall system that makes smart meters work and allows the system to provide detailed, time-based information and remote data collection between the utility, the smart meter, and the consumer. There are two main components to AMI that provide the infrastructure to establish communication between the utility and the house: a smart meter at the customer location that tracks electricity use and a communications network between the utility and the smart meter.

greater level of understanding and control over systems and appliances than is possible with traditional "dumb" homes. A smart home may include:

- Devices with a range of sensory capabilities such as programmable communicating thermostats, lighting and smart power strips;
- Communications systems that facilitate two-way information flow between devices and the occupant, and possibly between devices and the utility or other third-party firms such as security system providers; and,
- Monitoring and control systems that allow occupants to track energy usage and change the operations and functions of devices within the home.

The devices included in a smart home can vary tremendously in their design and function, but, in general, smart devices provide customers with one or both of the following two functions:

- Ability to monitor energy use in real-time or near real-time for the whole house and/or by device; and,
- Ability to remotely control systems or appliances in a home.

Smart home devices are not typically considered part of the smart grid, but they can complement and work with AMIs and other smart grid technologies in ways that make the smart home a localized extension of the smart grid. For example, computerized controls and appliances in the home can be set up to respond to signals from an energy provider to minimize their energy use at times when the electrical grid is under stress from high demand, or even to shift some of their energy use to times when energy is available at a lower cost.[8]

Home energy management (HEM) systems and other smart technologies such as web portals and interfaces, smart appliances, and in-home displays (IHDs) provide real-time or near real-time electricity use, energy consumption for the whole house or by individual load, and billing information to a home's occupants. Devices may also provide occupants with energy savings tips, emissions reductions, electricity savings (kilowatt hours), and comparisons with like cohorts (e.g., neighbors).

Dashboards, for example, give occupants greater control over a house's energy consumption by gathering a range of systems into a single unit to provide customers with a very sophisticated understanding of their home's energy consumption and of the consumption of individual devices or loads in a home, similar to a car that provides information on miles per gallon. These systems may also enable occupants to use a range of controls to reduce consumption, both overall and in response to peak load events or other pricing signals.

Providing detailed, real-time or near real-time information on energy use to the customer is intended to make the customer more aware of how his or her behavior impacts energy use, and to ultimately encourage energy saving behavior and load shifting.

Many smart devices have controls built into them so that they can be programmed and operated remotely through a smart phone or the internet to help a home's occupants better manage energy use. An increasingly wide range of stand-alone control systems also has the ability to communicate with other devices in a home.

Some devices also have sensors that allow them to reduce energy use based on changes in environmental conditions. For example, advanced power strips, which are used to eliminate "phantom" load – the power that electronic equipment, computers, space heaters, and other miscellaneous plug loads use even when turned

8 SmartGrid.gov, 2013, http://www.smartgrid.gov/the_smart_grid#smart_home

off [9] – may be programmed to shut off the power supply to a customer's home office or audio visual equipment after a period of disuse or may have motion sensing or occupancy sensing devices that turn off the controlled outlets when no motion has been detected for a period of time.

The key to smart home integration is that all "smart" devices, meters, appliances, HEM systems, security and cable systems, are linked in a way that allows each component to communicate and maximize its usefulness to the homeowner and, in many cases, the energy provider(s). As residents living in wireless environments add aspects of their home energy (e.g., automated thermostat control and lighting) to other automated systems in their homes (e.g., pre-programmed lawn sprinkler and security systems), what emerges is an inclusive, two-way communication system between the house and its occupants. These communication systems can potentially send a signal to a third-party, for example, a home performance contractor or an energy efficiency program administrator, indicating that a heating or air conditioning system is operating inefficiently and needs to be serviced. Without the homeowner doing much more than pressing a button or locking a door, a smart home may help homeowners and others to identify systems or homes in need of energy efficiency upgrades.

Each of the smart grid and smart home devices discussed above has potential relevance for the home performance industry, as discussed in the following section.

Benefits of Smart Grid Technology for the Home Performance Industry

Benefit 1: Real-time energy use data can serve as a catalyst for whole-house energy upgrades

The "Prius effect" is a phenomenon, named after Toyota's path-blazing hybrid vehicle, in which detailed consumer-facing feedback results in behavioral change. In the case of the Prius, the continuous real-time display of data about how many miles per gallon the driver is getting, and when the car is using its battery, charging its battery, or using gasoline, has encouraged drivers to drive in ways that decrease fuel consumption.[10]

Similarly, studies have shown that smart home devices that provide direct, real-time information or feedback on energy use and prices to customers through IHDs, web interfaces, or a combination of both have led to measureable reductions in electricity use, and in some cases, have encouraged customers to take additional efficiency-related actions such as installing new energy efficient lighting fixtures, increasing HVAC temperature, or using advanced power strips.[11]

For example, the Residential Smart Energy Monitoring Pilot program, run by the Cape Light Compact (CLC), a small distribution utility on Cape Cod and Martha's Vineyard, provided free home energy monitoring technologies, training how to use those technologies, and access to an online dashboard to 100 households participating in a year-long study of the behavioral aspects of energy use. The installation of a clip-on monitor

9 Earle et al., 2012. Phantom load may account for nearly 10 percent of household electricity use.
10 Seele, 2009
11 Foster, et al., 2012. This report is a follow-up to a 2010 ACEEE report that found that the household electricity savings from all types of feedback technologies, or technologies that provide customers with information on energy use, and programs ranged from 4 -12 percent, based on pilot studies with small sample sizes. The 2012 report aims to confirm these savings by looking at 9 more recent (2009-2011) large-scale or long-term, real-time feedback pilots conducted in the U.S. and Europe. The 2012 report found that customers reduce energy use by an average of 3.8 percent.

attached to the customer's electrical panel and web interface that shows electricity consumption led to an average energy savings of 9.3 percent for each participant, although energy savings were not evenly distributed across participants in the program.[12] The study also found that participants who frequently engaged with the web interface over the course of the study and who remained online longer than five minutes per day saved the most energy, more than 11 percent on average.

Similarly, Great Britain's Energy Demand Research Project (EDRP), a three-year study to test interventions to reduce residential energy use, which included more than 60,000 households, 18,000 of which had smart meters installed, found that households with smart meters averaged approximately three percent higher energy savings than households without smart meters, with some variation depending on fuel, customer group, and period.[13]

The trials also found that differences in the design of products such as IHDs led to differences in behavioral change. For example, IHDs that were connected to smart meters tended to have more features and were installed, retained, used, and rated more positively. Households also preferred visual cues to indicate relative consumption levels, such as a traffic signal, to a display with an audible alarm to indicate high consumption. This latter cue was rated poorly by participants, and did not yield energy savings.

The potential for feedback technologies and access to real-time energy use data to positively impact customer awareness in ways that encourage further investment in energy efficiency upgrades has two important implications for the home performance industry.

First, devices and implementation strategies that have been demonstrated to reduce energy consumption through behavioral change could be implemented as part of a home performance upgrade. The devices may be included in the projected energy savings or may be tied to an incentive payment from a utility or program sponsor.

Second, and probably more importantly from the home performance industry's perspective, the devices could be used as catalysts for comprehensive whole-house upgrades. As homeowners use IHDs and other devices designed to provide them with detailed and real-time information about their energy use, they may become more interested in how to reduce their energy consumption overall.

Benefit 2: Potential synergies between home performance and automated demand response

Not every kilowatt holds the same value, even if a customer pays the same price throughout the day. Electricity costs rise and fall over the course of a day and season. When demand for electricity is high, for example, during the daytime hours on summer and winter days, it is more expensive for utilities to provide power to customers, than when demand is low, such as in the middle of the night.[14] A report by the Government Accountability Office estimates that one percent of the year's 8,760 hours may account for up to 10 to 20 percent of the total electricity

12 Foster, et al., 2012. Tendril provided the hardware and online dashboard, which included a clip-on monitor attached to the home's electrical panel, a wireless base station to receive data from the monitor and send it to Tendril, and a web interface that provided real-time access to electricity usage and demand, energy savings in kilowatt-hours and carbon dioxide, comparisons with like cohorts, and energy saving actions. Five percent of participants reduced energy consumption by 13 to 25 percent, while 23 percent of participants actually increased their energy use from 2008 to 2009 (for reasons that were not specified in the report). The highest savings occurred from August to October, ranging from 11.5 to 15.7 percent, or 3.6 to 4.9 kilowatt-hours per day.

13 Foster, et al., 2012. Households with smart meters were given real-time IHDs (some with the ability to control space and water heating), energy efficiency advice, historic and peer-group consumption comparisons, financial incentives, and the use of other digital media to provide feedback information. Households that did not receive smart meters were provided with clip-on monitors, along with other interventions mentioned above.

14 While this paper focuses largely on devices that increase the electric energy performance of a home, heating and cooling peaks exist. Heating peaks in many parts of the country are associated with strains on natural gas/oil/propane supplies leading to rising costs of those fuels and not electrical spikes that may lead to black outs and brown outs.

costs for the year.[15] The high cost of providing electricity at peak time is passed on to residential customers in the form of higher flat rates.[16]

Demand response helps maintain system reliability by shifting energy consumption from on-peak to off-peak times when the cost of electricity is lower, and may reduce overall energy costs if utilities can reduce or avoid building inefficient and expensive "peaking plants" to meet short-term peak demand. Estimates from the World Energy Council, IBM, and others indicate that demand response could help ameliorate seasonal spikes in electricity costs by shaving up to 15 to 20 percent off a utility's or region's peak power demand.[17]

Utilities have typically offered demand response programs to large commercial and industrial facilities because it is easier to recruit a small number of large energy users than enroll multiple smaller users.[18] However residential (and small business) customers should not be overlooked for two reasons. First, residential energy demand makes up 60 percent of peak load in certain parts of the country, for example Texas, compared to 20 percent of total energy demand for all sectors.[19] The residential end-use sector has the largest seasonal variance, with significant peaks in demand every summer and winter due to increased heating and cooling.[20] Peaks in the residential sector can be as high as 67 billion kilowatt-hours, compared to only 18 billion kilowatt-hours for a summer peak in the industrial sector.[21]

Secondly, customers living in an air-sealed and well-insulated home may be more tolerant to the temperature adjustments that are necessary during demand response events, which could lead to higher program retention and enrollment rates. One study has shown that throughout the year, when normalized by home size, homes built within the last five years that have a green building certification such as LEED perform better (0.6 W/sq. ft.) than older homes that have and have not been weatherized (0.628 W/sq. ft. compared to 0.644 W/sq. ft., respectively).[22] In an air-sealed and well-insulated home, customers are less likely to feel uncomfortable when there is a temporary adjustment in the air conditioning than in a leaky, non-insulated home because a sealed home slows heat transfer and loss of conditioned air. This is analogous to putting ice in a cooler rather than a paper bag.

San Diego Gas and Electric (SDG&E)[23] and Oklahoma Gas and Electric (OG&E), among other programs, have experienced success in achieving reductions in residential peak demand using automated demand response technologies. After a successful pilot program, OG&E deployed its variable pricing residential demand response program, SmartHours, to about 40,000 homeowners in 2012.[24] Customers that sign up for the rate plan (which consists of higher rates during weekday afternoons in exchange for cheaper off-peak rates) receive free smart thermostats that can respond to price signals according to the customer's settings.[25] These price signals are sent by the utility through a smart meter enabled network. Customers also have access to 15-minute interval data through a web portal when they receive their smart meters.[26] OG&E provides advance notice of the peak prices from the previous day to enable more efficient energy use management.

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15 U.S. Government Accountability Office, 2004

16 U.S. Energy Information Administration, 2013

17 St. John, 2013, http://www.greentechmedia.com/articles/read/making-the-case-for-smart-grid-to-shave-peak-power. Article does not breakdown demand savings by end use sector.

18 Savenije, 2013, http://www.utilitydive.com/news/who-cares-about-residential-demand-response/202868/

19 Savenije, 2013, http://www.utilitydive.com/news/who-cares-about-residential-demand-response/202868/

20 U.S. Energy Information Administration, 2013

21 U.S. Energy Information Administration, 2013

22 McCracken, et al., 2013.

23 In 2012, SDG&E's Summer Saver program provided about 14 megawatts of demand response over six events and is forecasted to provide up to 30 megawatts of combined commercial and residential demand response in 2013, depending on weather conditions (Freeman, Sullivan & Co, http://fscgroup.com/index.php/publications/164-2012-ex-post-and-ex-ante-load-impact-evaluation-of-san-diego-gas-a-electric-companys-summer-saver-program-and-peak-time-rebate-program-for-summer-saver-customers).

24 St. John, 2013, http://www.greentechmedia.com/articles/read/oklahoma-gets-big-home-energy-savings-out-of-smart-grid

25 St. john, 2013, http://www.greentechmedia.com/articles/read/oklahoma-gets-big-home-energy-savings-out-of-smart-grid

26 Tweed, 2011, http://www.greentechmedia.com/articles/read/oklahoma-gas-electric-is-not-scared-of-the-home

After the first year, the program delivered a collective 70 megawatts of peak load reduction, or about 2 kilowatts per home, with more than 90 percent of program participants saving money.[27] These savings resulted exclusively from customers opting in to the program based on pricing signals.

The combination of energy control and dynamic pricing is the most effective way to encourage homeowners to significantly reduce energy use.[28] However, Arizona Public Service (APS) and Salt River Project (SRP), two Arizona utilities, have been able to reduce peak energy use without smart meters by offering customers time-based rates with a two-way Wi-Fi thermostat that runs on an open automated demand response (OpenADR) platform. OpenADR is described in greater detail in the *Interoperability* section of this paper.[29]

Many experts[30] agree that the largest barrier to residential demand response, and to fully realizing the benefits of the smart grid, is the absence of dynamic pricing, or time-based rates that accurately reflect the costs associated with electricity throughout the day. Compared to the number of smart meters installed, currently estimated at 46 million households,[31] only about one percent of U.S. residential customers are on a time-based rate.[32]

The slow implementation of dynamic prices could be linked to a number of factors.[33] First, enabling dynamic pricing is usually the last step in the smart meter automation process, following the installation of smart meters and the confirmation that they can transmit data. Regulators typically make decisions about AMI deployment before implementing dynamic pricing, resulting in regulatory lag time between smart meter deployment and the availability of time-based rates, even in states such as California that already offer dynamic pricing for business customers.

Second, in areas where dynamic pricing is offered to residential customers, there is often limited customer awareness of the benefits and availability of time-based rates, in part, because some utilities do not notify customers that these rates are available to them.[34] The exception to these factors is Ontario, Canada, which introduced smart meters and time-based rates simultaneously, with the result that nearly 90 percent Ontario's 4.5 million residential and small business customers who have smart meters are on TOU rates.[35]

Benefit 3: Using detailed data to enhance home performance programs through better modeling, EM&V, prescreening, QA/QC, and more accurate labeling

The detailed energy consumption information provided by smart grid and smart home devices has a wide range of applications for home performance. The data could be used to improve modeling and predictions, EM&V protocols, to conduct better prescreening of homes that would benefit from a home performance upgrade, and to conduct quality assurance and control. Each of these uses of smart grid data is described briefly below.

27 Vergetis Lundin, 2013, http://www.fierceenergy.com/story/smarthours-saves-money-90-percent-oge-customers-top-story-1-fe/2013-06-11?utm_medium=nl&utm_source=internal
28 See SmartGrid.gov, 2013, http://www.smartgrid.gov/sites/default/files/NSTAR%20Smart%20Grid%20TPR1_Final%203-19-13.pdf for more information about the impact of dynamic pricing on demand response.
29 Tweed, 2013, http://www.greentechmedia.com/articles/read/honeywell-launches-new-thermostat-for-auto-demand-response
30 Savenije, 2013, http://www.utilitydive.com/news/who-cares-about-residential-demand-response/202868/; Savenije, 2013, http://www.utilitydive.com/news/ron-binz-predicts-3-changes-coming-to-utility-regulation/183326/; Savenije, 2013, http://www.utilitydive.com/news/ferc-chairman-explains-why-utilities-must-adapt-or-die/182406/
31 IEE, 2013
32 King, 2012, http://www.emeter.com/smart-grid-watch/2012/time-of-use-electricity-prices-why-do-so-few-customers-have-them/
33 King, 2012, http://www.emeter.com/smart-grid-watch/2012/time-of-use-electricity-prices-why-do-so-few-customers-have-them/
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35 King, 2012, http://www.emeter.com/smart-grid-watch/2012/time-of-use-electricity-prices-why-do-so-few-customers-have-them/

Better modeling

Many home performance programs require contractors to model projected reductions in energy consumption resulting from the installation of energy efficiency measures. The extent to which these models provide accurate predictions of post-upgrade energy consumption has been the subject of extensive debate within the energy efficiency field.

One solution to improve model accuracy has been the development of calibration methods, such as the methods codified in the Building Performance Institute (BPI) standard ANSI/BPI-2400-S-2012 *Standard Practice for Standardized Qualification of Whole-House Energy Savings Predictions by Calibration to Energy Use History*.

ANSI/BPI-2400 and similar calibration methods are implemented prior to a home upgrade. The home's energy consumption before and after the upgrade is modeled and predicted. The model of the pre-upgrade energy consumption is then compared to actual consumption data, traditionally indicated by utility bills. If the model's prediction of pre-upgrade consumption is significantly off, the model is calibrated using several methods until it accurately models pre-upgrade consumption. These calibration methods are then applied to the post-upgrade consumption model to improve its accuracy, a procedure colloquially known as a "true-up."

Recently, legislation has been introduced in Congress recommending the use of utility data to establish the baseline of a home's energy consumption according to methods outlined in BPI-2400. In the 112th Congress, Senators Olympia Snowe (R-ME), Jeff Bingaman (D-NM), and Diane Feinstein (D-CA) introduced an innovative new tax credit, the Cut Energy Bills at Home Act (S. 1914). In the 113th Congress, Senators ben Cardin (D-MD), Feinstein, and Brian Schatz (D-HI) introduced the legislation S.2189 "Energy Efficiency Tax Incentives Act."

Although smart meter data is not necessary for these calibration methods, it could improve home performance predictions in two ways. First, to the extent that smart meter data becomes more accessible than traditional billing data, contractors and program administrators may spend less time on calibration. Second, and more importantly, granular smart meter data that indicates a home's load shape during a day or month may allow the development of more sophisticated calibration methods to enable the modeled energy consumption associated with specific end uses to be calibrated to the actual consumption of the same end uses, ultimately resulting in more accurate predictions.

More cost-effective and accurate program evaluation

Program administrators are required to conduct EM&V to estimate a program's first-year energy savings and the persistence of those savings over time. One of the most common methods of measuring a program's impact, or the energy savings that can be attributed to a program, is to compare the difference in consumption between the pre- and post-upgrade periods, after controlling to the greatest degree possible for weather conditions and other factors that influence customer energy use such as behavior.

In addition to billing analysis, the International Performance Measurement and Verification Protocol (IPMVP) recommends short-term metering to verify other types of energy savings estimates. However, short-term metering is labor-intensive because it requires metering equipment installation and data collection. Therefore, this approach is typically conducted on a relatively small sample of the population. The benefit to this method is that evaluators do not need to make assumptions about how customer-use schedules and behavior impact energy use, which aids in more accurate estimates of energy savings from installed measures.[36]

36 Pratt et al., 2010

Leveraging the smart grid's metering and communications abilities to expand sample size, improve data granularity, and make program evaluation more efficient is expected to provide more accurate and transparent evaluations at a lower cost. The significant increase in energy use data granularity will likely make it easier to measure persistence of energy savings because of the potential for continuous feedback before, during, and after the project is completed.[37]

Program evaluators also benefit from understanding how the energy use requirements of buildings, substations, or zip codes change over time. With these tools and data, evaluators can more easily develop control groups. These facilitate the evaluation of behavior-based programs, or those that rely at least in part on customers changing their behavior, for example by programming their thermostat or reacting to real-time feedback devices to reduce energy consumption.

In 2012, Freeman, Sullivan & Co. (FSC) evaluated SDG&E's SummerSaver program using smart meter interval data for the first time. Because the program participants had smart meters, there was no need to install expensive central air conditioning load loggers to verify performance, which reduced overall evaluation costs. In the future, FSC anticipates using smart meter data to facilitate quicker impact evaluations, with energy use estimates becoming available as soon as smart meter data is accessible, and forecasted estimates available soon after the end of summer.

The use of smart meter data in EM&V is still so rare that there is very little data on the cost of this approach. However, the Pacific Northwest National Laboratory (2010) estimates that if high-quality EM&V were implemented, it could displace a significant fraction of the costs of other evaluation methods, including short-term metering (although there would still be costs associated with data collection and cleaning), which could be standardized and automated as part of the utility billing process. Once the process is in place, the cost to deploy should be relatively independent of the number of customers, or the duration over which it is used, resulting in larger sample sizes, improved data quality, and improved ability to measure persistence, particularly for new energy efficiency technologies and behavior-based programs.

More effective prescreening

Smart meter data may be useful in identifying particular segments of the population or types of buildings that can benefit most from home performance improvements. This can potentially help program administrators to cost-effectively distribute resources to homes with the greatest need and potential for energy savings.

Studies have shown that when smart meter data is linked to demographic and building characteristic data, it can provide utilities and other program administrators with a better idea of their customer's structural demand for electricity over time and the energy intensity of the buildings they occupy.[38]

Linking household energy use data with information about the home's age, characteristics and condition may also help to identify unusual consumption patterns that might be indicative of malfunctioning HVAC equipment or an exceptionally leaky envelope. For example, Opower has developed algorithms based on 15 minute to hourly data intervals to target customers and provide site-specific recommendations on how to cost-effectively reduce energy use.[39]

In the first long-term research trial to measure customer energy use at the whole-home and circuit level, Pecan Street Research Institute's 2013 study, *Data-Driven Insights from the Nation's Deepest Ever Research on*

37 Barata et. al., 2012
38 Barata et al., 2012
39 Barata et al., 2012

Customer Energy Use, recorded electricity use, apparent power, and voltage levels for the whole home plus eight to 23 circuits at data intervals ranging from one minute to one second. The study gathered data from nearly 200 homes over the course of several years.[40] One hundred homes in the study were less than five years old and had a green building certification (“green-built” homes), and one hundred homes were between 10 and 90 years old and represented a broad range of home conditions, sizes, and appliance configurations.

One of the purposes of this study was to better understand the patterns of residential energy use in newer versus older homes, and homes with one or more green building certifications. The study also tried to identify seasonal load variations and the most cost-effective home energy efficiency improvements.

A preliminary report on the study noted that green-built homes exhibited a 27 percent lower energy intensity score (kilowatt-hours/square foot) than older homes without rebates when normalized for size, and had a lower sustained load (average kilowatts) in summer months when thermal loading was highest.

Although the study is not yet complete, it has demonstrated how smart meter data can be used by programs and contractors to identify homes that are consuming unusually large quantities of energy and appear to be good candidates for energy efficiency improvements.

Improved quality assurance

Home performance programs and their third-party contractors usually perform quality assurance (QA) and quality control (QC) on a selected number of projects after or near to completion to evaluate the effectiveness of their quality management systems and to provide feedback that may result in quality improvements.[41] Quality assurance also aids program evaluation by ensuring that program funds are spent in a manner consistent with contractor reporting.

Smart meter data could enhance QA/QC processes in two ways. First, it could allow a program to verify contractor-modeling assumptions by using or replicating a bill calibration method as described above. Second, if a smart meter is installed after a retrofit is completed, the interval meter data may be used to provide contractors and programs with information on whether the installed measures are functioning as anticipated, without the need for an independent evaluation of the project.

More accurate labeling of energy consumption

Residential green building certifications and labels, such as ENERGY STAR®, the U.S. Department of Energy’s (DOE) Home Energy Score (HES), LEED for Homes, and *BPI-2101-S-2013 Standard Requirements for a Certification of Completion for Residential Energy Efficiency Upgrades*, provide nationally recognized standards of building performance that can be used by homeowners and the home performance, real estate, and appraisal industries to verify that homes have a certain level of energy consumption or contain certain energy efficient features. At present, none of the rating systems for residential homes are explicitly tied to metered consumption data or are necessarily required to report energy savings or consumption derived from energy efficiency improvements.

Smart meter data could provide more detailed information on energy performance, taking into consideration a set of assumptions for occupant behavior, which may in turn improve how home performance is valued in the real estate industry and could serve as a useful addition or complement to existing scores and labels. Smart meter data

40 McCracken, et al., 2013
41 Building Performance Institute, 2013

also has the potential to allow the organizations that sponsor these scores and certifications to check the accuracy of their assumptions against actual consumption, ensuring that better-scoring homes do in fact consume less energy than worse scoring homes.

Over time, as the price differential increases between energy efficient homes and equivalent homes that are not as energy efficient, consumer interest in home performance upgrades should also increase, as homeowners realize that investments in energy efficiency measures can be recovered at the time of sale.

Benefit 4: More precise estimates of energy savings allow energy efficiency to be sold in new ways in new markets

One of the most significant applications of smart grid technologies for the home performance industry is the quantification of residential energy consumption. Because smart grid technologies can provide more detailed information about when and how energy is used in a home, compared to monthly bill estimates, home performance programs and contractors may be able to estimate the energy savings achieved through home energy upgrades with much greater precision and certainty. This has the potential to add value to the home performance industry by making it easier for contractors to market home energy upgrades to customers, and to create new opportunities for financing and for the sale of energy savings into carbon, capacity, and other markets.

More accurate consumer education and retrofits

More accurate estimates of energy savings will enhance home performance contractors' ability to sell upgrades to homeowners. A lower energy bill is one primary motivator for homeowners to invest in increasing the energy efficiency of their home. Therefore, it is critical that homeowners have confidence in the savings. Contractors who have achieved measured and verified savings could give potential customers assurance that the investments in energy efficiency measures will result in lower utility bills.

Utility bills have traditionally been used to analyze past energy consumption and as a basis for models of future consumption. Monthly bills, however, provide only a rough indication of how a home consumes energy. A monthly utility bill can show that a home consumes more energy in some months (typically winter and summer) than others. However, it cannot provide information about load shapes for individual days, which are useful for understanding the home's contribution to peak load, or for determining which devices are driving energy consumption.

Moreover, it is often difficult for contractors to obtain twelve consecutive months of utility bills, as some customers are reluctant or unable to allow third parties to access their online utility accounts, and some utilities still require paper requests with wet signatures. Program administrators and EM&V contractors can in theory obtain consumption data from the customer's utility, but in practice this data can be very difficult to obtain and is rarely provided in a digital, easy-to-download format.[42]

Smart grid and smart meter technologies make available a wealth of information about residential energy consumption. In combination, these devices can show a home's total load at any given time and the consumption of specific end-uses at given times, even down to the level of specific electronic devices or plugs. They can show periods of high-energy consumption and short-term spikes caused by use of appliances such as vacuum cleaners or dishwashers. Devices with occupancy sensors can also indicate how variations in consumption might be related to the number of occupants in a residence.

42 The need for data entry of paper bills can lead to unnecessary errors in analyzing energy use.

At the most general level, the smart grid has the ability to facilitate the flow of information to programs and contractors. In theory, if not yet always in practice, smart grid technologies should allow customers and contractors much easier access to traditional monthly billing data, for example.

Much more significantly, however, the richness of smart grid and smart home data can make a significant improvement in understanding how a home consumes energy. Home performance modeling typically seeks to disaggregate heating and cooling loads from baseload to estimate the potential for energy savings through measures such as such improvement and HVAC upgrades. Frequently used statistical programs such as PRISM[43] draw on conventional monthly billing data to disaggregate the home's heating and cooling loads from the baseload.

In general, these methods predict a relatively flat baseline, attributing most seasonal variation in billing to heating and cooling end uses. Analyses that draw on both smart meter and thermostat data to disaggregate energy consumption by end use, by contrast, demonstrate that baseload consumption often exhibits significant seasonal variation.[44] This more detailed and accurate picture is important for contractors to determine the most cost-effective improvements for a home, and it is also crucial for determining the specific effects of home performance upgrades.

Integration of smart home technologies into other sales processes

There are times apart from equipment failure when homeowners consider home improvements, for example, when buying a new home or renovating. According to a 2013 survey by the National Association of Realtors, 53 percent of buyers undertook a home improvement project within three months of their home purchase.[45] This creates an opportunity for the service providers that a homebuyer first calls, such as telecommunications and security firms, to market home performance to the homeowner.

New homeowners typically request service from their local telecommunications provider to establish phone, television, internet, and other services. Many also call security firms to set up home protection systems.[46] These telecommunications and security firms are already exploring ways to expand their business into energy services, as well as the digital automation business.

National companies like Verizon FiOS provide a home automation service that includes self-monitoring, energy management, and home control tools. Verizon's energy control kit includes a gateway device, smart thermostat, appliance switch, energy reader and a remote control.[47] AT&T has also launched a new product that allows customers to remotely adjust their thermostat, lights, appliances, and security systems.[48]

Security systems have been installing motion and occupancy sensors for years. Sensors that detect whether people are home are an important component of HEM systems, creating an opportunity for a single sensor to serve several systems (e.g., security and energy management) simultaneously.

Security and telecommunications firms also offer ways to combine automation of energy management with other household systems. According to Peter Rice of Alarm.com, the key to customer-friendly automation is having one

43 The PRISM method attempts to find the best statistical fit for three lines describing the heating, cooling, and baseload (all other loads) for a building. The baseload is estimated from the minimum monthly bills, assuming that it is relatively constant.
44 Pratt et al., 2010
45 Lautz, 2013
46 Lee, 2008. According to a 2008 study by Rutgers University, "the market for alarm systems, sold by the private security industry, is about $30 billion annually, growing at a compound annual rate of 7-8 percent."
47 Verizon, 2013
48 AT&T, 2013

homeowner action control many others. For example, locking a door may activate the security system, shut off the lights, and reduce the thermostat temperature. Taking into consideration why homeowners buy certain products can also be helpful in developing appropriate marketing strategies to target the right customers. Customers buy HEM systems for the increased comfort and energy savings they provide. However, a security system is an "emotional purchase that provides peace of mind."[49] Rice suggests that adding an energy management component to a security system would increase its value to the homeowner.

Measuring the value of home performance

The more accurate portrayal of a home's energy consumption has the potential to revolutionize the home performance industry. Renewable energy sources such as wind and solar produce energy that can be metered and measured. By contrast, home performance, and energy efficiency in general, has been constrained during the decades of clean energy standards and carbon trading by the fact that energy savings is neither tangible nor directly measured. Demand response is the first measured energy savings, but addresses peak and not baseload.

Home performance contractors help their customers reduce energy consumption. Their "product" is the difference between the energy actually consumed in the home following the upgrade and the energy that would have been consumed had the upgrade not taken place. (It should be noted that an energy efficiency upgrade also produces many other non-energy benefits such as increased occupant comfort.)

Despite the fact that the savings produced by an upgrade can never, by definition, be known with perfect certainty, there are now ways to estimate savings with a considerable degree of accuracy. Comparison between pre- and post-upgrade energy consumption, weather normalized, provides a reasonable estimate of energy saved by the upgrade. These comparisons are usually made with traditional monthly billing data – bills from twelve consecutive months before the upgrade are compared to bills from twelve consecutive months after the upgrade. The data from smart grid and smart home devices can greatly improve these analyses by allowing comparison not only between monthly consumption, but by showing the impact of an upgrade on daily consumption, on peak consumption, and on consumption by specific end uses.

The ability to more accurately estimate energy savings from whole-house upgrades may allow the savings to be bundled and sold into carbon, capacity, and other energy markets. Energy efficiency provides capacity to the grid in the form of "negawatts," a theoretical unit of power saved. The demand response industry has grown by producing negawatts on-demand at peak, when energy is most valuable to the utility. However, baseload reduction, which is achieved by increasing a home's efficiency, also produces negawatts and, if metered and measured, these energy savings could earn the same investment as installing renewables or building a power plant. The carbon offsets from increasing home energy efficiency could have clear value in some regions. Revenues from these sales could be used to subsidize the cost of the upgrade, making it more attractive to homeowners, and driving more upgrades.

Financing energy efficiency improvements

Making energy efficiency improvements to a home often require higher upfront costs, which can be a barrier for first-time homebuyers or moderate income households that may not have the equity or financial reserves to finance energy efficiency improvements. The most widely used mechanism today for financing energy efficiency in existing homes is direct borrowing either through consumer loans, a home equity loan secured by property, or a traditional or specialized mortgage, such as an energy-efficient mortgage (EEM).[50] EEMs give lenders the

49 Rice, 2013
50 Institute for Market Transformation, 2013

flexibility to make larger loans or offer lower interest rates to borrowers that would otherwise not qualify for these benefits. However, these products have received little market interest to date because of the transactional complexity, limited benefits for lenders, and lack of consumer information.[51]

One way to encourage investment in energy efficiency would be for mortgage pricing or underwriting flexibility to reflect the energy savings that result from energy efficiency improvements, creating additional opportunities for consumers to borrow to cover the costs of energy efficiency upgrades. Lenders and investors have been reluctant to make these changes in part due to the lack of reliable loan performance data on which to base underwriting decisions.[52] But a new study by the Institute for Market Transformation (2013) finds that energy efficiency and the degree of energy efficiency impact the customer's likelihood of defaulting on a loan or prepaying a mortgage.

The study reports that default risks are on average 32 percent lower in energy-efficient homes, controlling for other loan determinants, and that a borrower in an ENERGY STAR home is one quarter less likely to prepay the mortgage. Also, within the ENERGY STAR-rated homes, default risk is lower for more energy efficient homes.[53]

The lower risks associated with energy efficiency should be taken into consideration when underwriting mortgage risks or when making loans to contractors that could be repaid by the proceeds from sales from carbon, capacity, and other markets. Senators Michael Bennet (D-CO) and Johnny Isakson (R-GA) introduced the Sensible Accounting to Value Energy Act (SAVE Act), S.1106 in June 2013. The SAVE Act orders the U.S. Department of Housing and Urban Development (HUD) to issue updated underwriting and appraisal guidelines for borrowers. A home's expected energy cost savings, included in federal mortgage underwriting, will ensure that efficiency homes will have a higher value at sale or when refinanced.

Clean Air Act policy implications

As noted above, smart grid data could be used to more accurately measure and verify the energy savings from energy efficiency improvements, resulting in greater policy support for innovative energy efficiency programs and EM&V.

Energy efficiency has long been a part of federal, state, and utility incentive programs and policies, which typically attribute estimated or deemed energy savings to specific energy efficiency measures.[54] However, policymakers have been reluctant to give utilities credit for meeting pollution or carbon reduction goals because energy savings are estimated and not metered like supply-side energy resources. Methods have been developed to meter and measure renewable energy it order to quantify the extent to which it reduces carbon emissions or meets clean energy standards. In addition, demand response has been sold into capacity markets because it reduces peak demand. However, energy efficiency has played a relatively minor role so far in carbon, capacity, and other energy markets.

The EPA is currently reviewing legal and policy options to limit carbon dioxide emissions from existing power plants under section 111(d) of the Clean Air Act, including energy efficiency as a compliance mechanism for meeting state goals to limit carbon dioxide emissions. States would be required to establish performance standards and to determine how covered entities in their states will meet those standards, using EPA guidance as a reference.

51 Institute for Market Transformation, 2013
52 Institute for Market Transformation, 2013
53 Institute for Market Transformation, 2013
54 Deemed savings are pre-determined, validated estimates of energy savings attributable to energy efficiency measures in a particular type of application. Deemed savings are useful as a guide, but they are imprecise because they do not take into consideration the differing characteristics of each home, and the impact of how energy efficiency measures interact.

If states fail to comply with this provision, then the EPA may develop a plan for the state.[55]

Clean energy advocates are urging the EPA to include performance-based energy efficiency among the compliance tools. The National Home Performance Council and Efficiency First submitted joint comments to EPA recommending that EPA allow states to leverage the use of smart grid technologies and new national data standards including BPI – 2200 (*Standard for Home Performance-Related Data Collection*), BPI – 2100 (*Standard for Home Performance-Related Data Transfer*), and BPI – 2400 to better quantify energy savings for inclusion in state plans under 111(d).

Significant technological advancements that allow the collection and analysis of much larger quantities of energy consumption data, the development of national data standards, and new training methods are all contributing to better quantification of energy efficiency in a way that was not possible even a few years ago. These advancements in EM&V will help make it possible for the more than 130 million houses in the U.S. to participate in carbon reductions in a meaningful and measureable way.

Challenges of Integrating Two Industries

The previous sections demonstrated that smart grid and smart home technologies have the potential to significantly enhance home performance upgrades and provide homeowners with new ways of understanding and controlling their energy consumption that will complement whole-house energy improvements.

For this potential to be realized, however, a number of challenges must be addressed. These include the difficulties that customers have in accessing utility data and making it available to third parties, concerns about privacy and security of smart meters, and the interoperability issues that inevitably arise when devices made by many different manufacturers for many different purposes need to communicate seamlessly.

Consumer access to energy data

Energy customers typically have access to information provided in their monthly utility bills, which does not indicate specifically when energy was used over the month. Despite the large-scale deployment of smart meters across the country, most customers have yet to receive access to the detailed energy data generated by these meters. As a result, many of the potential benefits of smart meter deployment have yet to be realized.

While some states and public utility commissions (PUCs) have worked to advance consumer access to energy information, utilities typically collect and manage energy use data. A written customer request is required to release data, and that request often has to be made on paper, typically using a form provided by the utility. This makes it difficult for a third party to engage directly with the customer, leaving the choice of what program will be utilized and offered to the utility and the PUC.

Access to accurate, detailed data is also a necessary precondition to expand markets for energy efficiency. Both capacity and carbon markets rely heavily on measured savings and detailed meter data is crucial for accurately measuring these savings. As discussed above, data from smart devices such as thermostats can complement smart meter data to provide even more granular energy savings estimates.

55 Tarr et al., 2013

In 2012, the White House launched the national Green Button Initiative to begin addressing the obstacle of inefficient and difficult data access. As of March 2014, 38 utilities and energy suppliers have committed to participate.[56] Utilities and energy suppliers are projected to provide 30 million households in 17 states[57] and the District of Columbia with access to their energy use information.

However, progress in providing customers with access to Green Button data has been slow. Out of the 38 utilities that have committed to participate, only 23 have implemented the initiative so far.[58] Other obstacles include state privacy and liability laws that prevent customers from sharing their data with third parties, such as contractors.[59] Security concerns and the absence of federal framework for safe data access also present a hurdle, which is discussed later in this section.

As the Obama administration struggles with this problem, Congress has attempted to make progress on data access issues. In the 111th Congress, Rep. Ed Markey (D-MA.) introduced H.R. 4860, the Electric Consumer Right to Know Act, or "e-Know Act." The purpose of e-Know is to require utilities to make energy consumption data available to their customers or to a customer's third-party designee, which could be a contractor, energy management company, or smart grid technology provider, among others.

Sen. Mark Udall (D-CO) introduced a similar bill (S.1029) in the 112th Congress with Sen. Scott Brown (R-MA). On March 27, 2014, Senator Markey joined Senator Udall to introduce S.2165 the "Access to Consumer Energy Information Act" or "E-Access Act" that directs the DOE to release voluntary guidelines to encourage open access to electricity data and to establish model standards for implementation of retail electric energy information access in states.

A key aspect to data access policy is the ability for customers to allow third parties, such as an energy management services firm, to access their consumption data. A third party contractor may use a customer's consumption data as part of an energy efficiency upgrade to help the customer make informed decisions about where to target improvements. A contractor may also show the customer how to understand and use smart meter data, which may result in energy saving behavior.

Some utilities have claimed that complying with requirements for data access would lead to an increase in rates. However, in the absence of public policy, the private and public utility sector have started to develop solutions to make customer data more accessible. Internet giant Google announced in January 2013 that it is launching an effort to help realize the potential benefits of the data revolution. Google awarded a $2.65 million grant to the Energy Foundation to advance policy reforms to incentivize the use of smart grid technology, encourage the use of HEM systems and online platforms, and expand the use of time-based pricing, among other goals.[60] Google's effort is intended to build upon the Obama administration's Green Button Initiative, with the overarching goals of empowering customers to make smarter energy choices, improving real-time management of the electricity grid, and expanding renewable energy, while lowering a customer's overall energy costs.[61]

In the beginning of 2014, Google also announced that it was undertaking a $3.2 billion cash purchase of Nest, the makers of "learning" thermostats and smoke detectors. "Both companies believe in letting the technology do the hard work behind the scenes so that people can get on with their lives," Nest CEO Tony Fadell told WIRED in an

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56 Green button, 2014
57 Arkansas, California, Illinois, Indiana, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, North Carolina, Ohio, Oklahoma, Pennsylvania, Tennessee, Texas, Virginia, and West Virginia.
58 Green Button, 2014
59 Tweed, 2012
60 Colman, 2012
61 Colman, 2012

interview after the deal was announced.[62]

SDG&E also launched a program to incentivize customers to buy and install HAN devices to link them to the ZigBee radios inside their smart meters.[63] This creates a smart meter-to-home connection, which allows homeowners to monitor their energy use directly, rather than relying on the utility to provide data. With these devices, and the direct communication they create, homeowners can receive energy data updates as often as several times a minute, much faster than updates coming from the utility itself.

An individual paying for energy has the right to access their energy data. While utilities and the private sector have joined forces in some regions to advance access, and the White House has demonstrated leadership through its voluntary initiative, easy, efficient and digital access should be provided as a right to all energy customers so market forces can advance energy management, and home performance contractors and homeowners can better understand a building's energy use. Until Congress acts, state legislatures and PUCs must work with utilities and the private sector to ensure that data access is not a barrier to either technological innovation or increased energy efficiency.

Privacy and security

Security and customer privacy are priorities in all smart grid projects because digital information may be compromised either deliberately by data theft and misuse, or inadvertently from data leaks resulting from user errors, equipment failures, and natural disasters.

Recently, both states and the federal government have focused on how to reduce the risk of energy disruptions or unauthorized data access from cyber intrusions; avoid the loss of critical functions during an intentional cyber assault; and address customers' concerns about privacy and data misuse, particularly as the large-scale deployment of smart meters has started to rollout in many areas of the country.

For the last several years, the federal government, led by the DOE, has been advancing security of the electrical grid, including its control and communications systems that operate and monitor the energy infrastructure, through its Cybersecurity for Energy Delivery Systems (CEDS) program.[64] This program assists energy sector asset owners (electricity, gas, and oil) with developing solutions to protect the country's energy delivery systems by partnering with government, industry, universities, national laboratories, and end users to advance research and development in cybersecurity. The DOE Office of Electricity Delivery and Energy Reliability (OE) and the Federal Smart Grid Taskforce are also facilitating a multi-stakeholder process to develop a Voluntary Code of Conduct (VCC) for utilities and third parties that will address privacy issued related to smart grid data.[65]

Many customers perceive the flow of information from smart meters to be one-way, from the home to the utility, which has led to significant organized pushback against advanced metering infrastructure in many areas of the U.S. over the last decade, including Northern California, Maine, and Texas. In 2010, the Poneman Institute released a study called *Perceptions about Privacy on the Smart Grid*, which found that 58 percent of customers surveyed were concerned about government misuse and inadequate protection of personal information, a percentage which fell significantly to 32 percent when customers were educated about the purpose and function of smart meters, and when smart meter data was not identified by the customer's name.[66]

62 Wohlsen, 2014
63 St. John, 2013, http://www.greentechmedia.com/articles/read/california-expands-the-smart-meter-to-home-area-network-market
64 http://energy.gov/oe/technology-development/energy-delivery-systems-cybersecurity
65 https://smartgrid.gov/news/doe_addresses_privacy_data_enabled_smart_grid_technologies_convenes_multistakeholder_process
66 Poneman Institute , 2010, http://www.ok-safe.com/files/documents/1/Perceptions_About_Privacy_on_the_Smart_Grid.pdf

Regulated gas and electric utilities, and their state commissioners, have not turned a blind eye to this pushback, particularly because the smart grid has the potential to help utilities achieve regulatory energy efficiency and demand response goals, reduce customer service costs, and generate new revenue opportunities, among other benefits. To increase customer support and trust, many utilities have started to develop strategies to educate customers about smart meters.

In March 2013, NV Energy, with support of the DOE, published a handbook to inform utilities about how to develop a smart meter deployment approach that works.[67] The approach is based on the experiences that ComEd, NV Energy, and SDG&E have had with running successful campaigns to create a "neutral-to-positive customer experience" during their respective smart meter deployments. In other words, according to the handbook, if a customer's first experience with smart meters is negative, then they are more likely to distrust the smart meter system and to push back against advanced metering infrastructure. The DOE also held a series of peer-to-peer workshops with utilities between 2011 and 2013 to exchange experiences with customer engagement.[68] These workshops led to the development of a Smart Grid Customer Engagement Guide, which summarizes the key points that emerged from these sessions.

In September 2010, California became the first state to adopt comprehensive privacy rules for customer smart meters.[69] To note, existing state law prohibits electric and gas utilities that are regulated by a state utility commission from using customer data for any commercial purpose, unless authorized by the customer. However, the law requires commissions to conduct pilot studies with customers from each utility or electrical corporation to determine the relative value to ratepayers of information, rate design, and metering innovations using approaches specified by the law.

The California law that passed in 2010 repealed the provisions related to the pilot study, prohibiting a utility or electrical corporation from sharing or disclosing a customer's gas and electrical consumption data (except in aggregate), and other personally identifiable information, to a third party without prior consent of the customer. A utility using advanced metering infrastructure that allows a customer to access their consumption data must provide access to data without requiring the customer to agree to share their data with a third party. Moreover, utilities are prohibited from selling consumption data. If a utility contracts with a third party that allows a customer to monitor their electricity usage, the third party must disclose their intention to use consumption data for secondary commercial purposes to customers, if relevant.

These provisions do not apply to utilities or electrical corporations that are using customer consumption data in aggregate and without personally identifiable information for analysis, reporting, and program management purposes, or to utilities that contract with a third party to implement energy efficiency or demand response programs.

Interoperability

Interoperability is the ability for two or more networks, systems or devices to talk and securely share information with little or no inconvenience to the user. This is a significant issue for smart grid projects because technology deployments must be able to connect large numbers of smart devices and systems involving different hardware and software, and to securely exchange information to achieve requisite performance levels.[70] Similarly, smart devices that connect to a smart meter through an HAN must be able to communicate with each other, the smart

67 http://www.smartgrid.gov/document/nv_energy_smart_meter_deployment_handbook
68 http://www.smartgrid.gov/Voices
69 Senate Bill No. 1476, http://leginfo.legislature.ca.gov/faces/billVotesClient.xhtml
70 SmartGrid.gov, 2013, http://www.smartgrid.gov/recovery_act/overview/standards_interoperability_and_cyber_security/standards_interoperability

grid, and with the mobile phone or home computer system to generate accurate, reliable data for customers, home performance contractors, and programs.

Interoperability is an issue that is never fully "resolved." Smart grid technologies become either more or less interoperable. Over the last several years, the DOE and its partners have been driving increased interoperability through standards development. Two important standards have been developed to connect the smart grid with the smart home; the open automated demand response standard (OpenADR) and the smart energy profile 2.0 or SEP 2.0.

OpenADR is an "open and standardized way for electricity providers and system operators to communicate [demand response] signals with each other and with their customers using a common language over any existing IP-based communications network, such as the Internet."[71] The data model is designed to facilitate sending and receiving demand response signals from a utility to its electric customers. Rather than receiving a signal to defer or reduce load from a device that is installed on an air conditioner unit by the utility, products that are OpenADR-certified communicate directly with the utility and may be programmed to take action based on a demand response signal, enabling a demand response event to be fully automated, with no manual intervention.[72] This is intended, in part, to reduce implementation costs, and because the standard is an open standard to encourage adoption by a wide range of industry partners.

The SEP 2.0 is an IEEE standard that was ratified in April 2013 to make it possible for ZigBee, WiFi, and HomePlug power line carrier technologies to connect and control home energy management devices and networks.[73] Zigbee's low-power home energy networking technology is installed in millions of smart meters in the U.S. However, very few of these smart meters can actually "talk" to in-home communications devices because most installed smart meters run on a previous version of the standard, which was specific to ZigBee.[74]

SEP 2.0 offers IP-based HAN energy management functionality to address several market needs including smart meter deployments in large multi-family buildings (where direct wireless connections between smart meters in a basement and HAN device in an apartment may not be possible); plug-in hybrid vehicle charging; and support of internationally recognized standards to ensure long-term interoperability with multiple technologies, to name a few. The standard is also designed to provide communications functions for customers including pricing, demand response, metering, prepayment, distributed energy resources, and billing.

Identifying the opportunities for cross-functionality is the first step to develop technologies that address the needs of programs, utilities, and end-users. But having the technological capacity to provide seamless communications between the smart grid and the smart home is not usually enough. Beyond that are the implementation issues that must be addressed for programs that support these technologies. For example, programs promoting OpenADR-certified products must be able to know which customers to target, what will happen when customers receive a demand response signal, and which customers are opting out or not opting out of the program.[75] Data quality is also an issue. Automated processes do not negate the need for back-end intelligence to gather, clean, and interpret data. Building a program's capacity to perform these tasks will be critical to ensure that the data collected through smart meters leads to increased program performance.

71 http://www.openadr.org/overview
72 OpenADR Primer, www.openadr.org/assets/docs/openadr_primer.pdf
73 http://www.greentechmedia.com/articles/read/openadr-update-autogrid-fujitsu-get-2.0b-connected
74 http://www.greentechmedia.com/articles/read/home-energy-networking-alert-sep-2.0-goes-live
75 http://www.greentechmedia.com/articles/read/openadr-update-autogrid-fujitsu-get-2.0b-connected

Recommendations for Next Steps

Recommendation 1: Develop strategies for using home energy monitoring devices to promote implementation of whole-house upgrades

As discussed in the "benefits" section above, smart grid technologies and other feedback devices that provide information and control functions, have been shown to be effective at reducing residential energy use, and for some populations sampled, have led program participants to make additional energy efficiency improvements.

NHPC recommends that program sponsors draw on existing behavioral research to develop strategies for incorporating devices that provide homeowners with detailed information about their energy consumption into home performance programs. The monitoring device would have capacity to provide information about the functioning of a number of systems in the home, including HVAC, envelope, lighting, appliances and miscellaneous plug loads; to identify the systems that are not functioning at a high capacity; and to make recommendations about potential improvements.

The recommendations would provide the homeowner with an understanding of how to save energy, and would encourage the homeowner to contact a qualified contractor or auditor to provide a more specific diagnosis and recommendations for upgrades.

Recommendation 2: Encourage partnerships between the energy efficiency industry, and telecommunications and home security firms to market home performance upgrades and install energy monitoring devices that encourage customers to implement upgrades

NHPC recommends the development of pilot programs that will strengthen connections between home performance programs and telecommunication firms interested in home energy management. These pilots would feature two innovations. First, the telecommunications or security firms would develop a method for recommending a home performance assessment and upgrade at the same time when they install equipment.

Second, the telecommunications or security firm would offer HEM or IHD devices as part of their equipment package that would monitor usage and provide the homeowner with recommendations for reducing energy consumption through behavioral change and through improvements to the home. Monitoring systems that warn homeowners of impending equipment breakdown would be another related way to use HEMs to engage homeowners with home performance programs. This pilot could draw on devices and approaches developed through pilot programs as per the first recommendation described above.

Recommendation 3: Develop strategies to link demand response and home performance programs by marketing home performance upgrades together with demand response initiatives, and targeting homes that have received whole house upgrades for enrollment in demand response programs

During hot summers when air conditioners are running and there is increased demand for electricity, homes that are air-sealed and well insulated are more likely to remain cooler longer when the temperature is raised for several hours during a demand response event.

NHPC recommends that utilities continue to test the effectiveness of residential demand response, especially in homes that have undergone a home energy upgrade, using a combination of smart grid technologies and time-based rates. Home performance programs should also focus on marketing demand response programs and technologies that facilitate customer awareness of how electricity changes over time to program participants.

Recommendation 4: Develop EM&V protocols for energy efficiency upgrades that use smart grid technologies and data to accurately measure energy savings resulting from energy efficiency upgrades

The key to unlocking new public policies and support for energy efficiency is better and more accurate quantification of energy savings. Home performance programs typically measure energy savings resulting from improvements through deemed or estimated savings, models, or by comparing monthly billing data before and after the retrofit. This last approach to quantification can yield accurate results. However, these studies are expensive to conduct and the results are limited by reliance on monthly data.

Smart grid and smart home devices provide granular data on energy use, and offer the potential to cost-effectively quantify energy savings, both at the measure and the whole house level. However, at present few if any programs, utilities, commissions, capacity markets or other entities have developed a way to standardize the use of these technologies for EM&V, similar to what is captured in state technical reference manuals (TRM), the current primary resource for energy savings calculation methods.

NHPC recommends the development of several pilot programs that use smart meter data to measure the impact of the home performance program, by whole home and by end-use. These pilots should take into consideration a range of smart devices, consumer behavior, the persistence of energy savings, and the cost effectiveness of the evaluation methods compared with current EM&V approaches. These studies should also serve as research into developing evaluation protocols for smart meter data.

Recommendation 5: Utilize smart meter data to build the case for energy efficiency as a competitive energy resource that should participate in capacity and carbon markets

Energy efficiency is the least cost energy resource in many states, but has played a relatively minor role so far in carbon, capacity, and other energy markets because energy savings resulting from energy efficiency improvements are estimated and difficult to quantify. NHPC recommends that policymakers consider the extent to which energy efficiency can offset carbon emissions and meet the growing demand for clean, reliable energy.

Smart grid data, better EM&V, and the increased reliability of energy predictions from new software and data standards all have the potential to help program administrators and contractors better estimate energy use and the energy savings resulting from efficiency improvements. Smart grid data also has the ability to better connect customers to their energy use, influencing behavior and potentially leading to increased energy efficiency.

If the impact of energy efficiency can be better estimated and measured, then it is more likely to be considered an energy resource, similar to other renewable energy sources that can be traded and used to meet state or regional energy performance or carbon reduction goals.

Conclusion

There is a saying that Alexander Graham Bell would not recognize today's telephone system, but that Thomas Edison would be familiar with the current electricity system. The U.S. electrical grid has not changed much over the last 100 years, but our aging infrastructure and increasing demand for electricity threatens to tax the system and increase carbon dioxide emissions unless we embrace a different way of producing and managing electricity.

Smart grid technologies will likely accelerate the speed and scope of change for energy providers, customers, states, and energy efficiency programs. A future high performing home will not only have energy efficient walls, fenestration, ducts, and systems, but also will be equipped with the technologies that communicate with customers and utilities.

Utilities and PUCs across the country have reacted differently to smart grid technologies, either embracing these technologies or fighting adoption. Similarly, long-standing family contracting businesses either consider home performance as the future of their industry, or see it as a threat to their livelihoods.

As the U.S. continues to focus on fiscal responsibility and cutting waste, energy efficiency can provide a market-based, technology-neutral solution. State governments and PUCs are also primed to take action. Performance-based incentives for contractors, modifications to the rules associated with energy, carbon, and capacity markets, customer access to utility data, and policies that increase the use of energy efficiency will lead to new innovations in home performance, including home energy digital devices.

For the benefits of smart grid technologies for home performance to be realized, energy efficiency, demand response, and smart grid programs and policies will have to transcend silos so that "high performing," "efficient," and "smart" become equivalent terms for policymakers. There are many obstacles to integration, some of which have been outlined in this paper. But if these obstacles can be met and overcome, smart grid technologies have the potential to increase the profitability and sustainability of home performance.

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The National Home Performance Council, Inc. (NHPC) encourages the implementation of whole-house retrofits for increased home energy performance and facilitates coordination among federal governmental agencies, utilities, state energy offices, contractors and others to achieve improved whole-house energy performance. NHPC is a registered 501(3)(c) organization. Further information about our firm can be found at www.nhpci.org.

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