Realizing the Energy Efficiency Potential of Smart Grid

An Alliance to Save Energy White Paper

May 2011

Tom Simchak
Lowell Ungar

ALLIANCE TO SAVE ENERGY

Creating an Energy-Efficient World

Abstract

Smart grid systems can provide significant opportunities for both consumers and utilities to save energy. Data provided by smart meters allows consumers to better understand their own energy use, helping them identify energy saving opportunities. Utilities and third-party energy service providers may provide critical assistance in realizing these opportunities. For utilities, a better understanding of the status of the electrical grid at a second-by-second level allows the grid to be operated at much tighter tolerances, resulting in greater efficiencies and reliability. Consumer demand response activities enabled by a smart grid can improve grid efficiency as well, reducing grid congestion during peak periods. Additionally, a smart grid could help improve transportation efficiency by facilitating charging of plug-in electric vehicles.

Intelligently planned smart grid and smart meter systems that integrate energy efficiency and conservation as central goals will have a great potential to reap rewards for consumers. But if poorly executed without active attention to energy efficiency and net demand reductions, the potential energy saving benefits of smart grid systems could be missed. Issues of data access and ownership, privacy and liability, interoperability, and full system deployment must be addressed in order to achieve the potential benefits. As consumer acceptance is key to smart meter program success, reduced energy bills enabled by smart technologies can foster the needed good will.

Contents

Introduction

Modernizing the electrical transmission and distribution network to create a smart grid, along with the incorporation of 'smart' meters and 'smart' appliances into consumers' homes and businesses, has become a major policy focus in recent years. The smart grid offers various potential benefits, including greater energy efficiency for end-users and in the grid. But while the potential for such operational benefits as grid reliability, smoothing peak loads, and eased meter reading seems clear and large, the impact on overall energy use seems much less certain. Energy efficiency is often listed in the litany of benefits that smart grid and advanced metering infrastructure (AMI, or, more commonly, smart meters) systems will offer, yet discussions and implementation of such systems often neglect energy efficiency and net demand reductions.

In short, the smart grid is a system of interconnected technologies that enable two-way communications between different parts of the electric power system from generation through to the appliances that consume electricity.[1] It includes sensors along the transmission and distribution system to allow grid operators to know the condition of the grid at any given location. It includes advanced meters in homes and businesses that can automatically measure and report electricity usage throughout the day. It also includes appliances that can respond to signals from grid operators or their owners based on conditions of the grid. This system of monitoring and communication allows grid operators to have a greater awareness of the condition of the electrical grid at different locations and allows consumers to have a better understanding of their own energy use – potentially down to individual appliances.

Intelligently planned smart grid and smart meter systems that integrate energy efficiency and conservation as central goals will have a great potential to reap rewards for consumers. Greater awareness of energy use may allow consumers to better understand how they consume energy in their homes or businesses, allowing them to target cost-effective and convenient energy saving measures. But if poorly executed without active attention to energy efficiency and net demand reductions, the potential energy saving benefits of smart grid systems could be missed.

Notable benefits also exist for improving the efficiency of the grid itself. Greater situational awareness of grid conditions and real-time understanding of demand may allow for improved efficiency of grid operations (i.e. transmission and distribution) and more optimal deployment of generation resources. Demand response activities can improve grid efficiency as well, reducing grid congestion during peak periods.

Consumer-Level Benefits and Challenges

The energy-saving benefits for end-use consumers should be of particular interest in developing policies for implementing smart grid systems, especially in regards to smart meters, because these benefits may be readily apparent to consumers.

Consumer opposition has slowed smart meter rollouts in some regions.[2] In California, local opposition including by some municipal and county governments has slowed Pacific Gas & Electric's smart meter program. Around Baltimore, Maryland, the Maryland Public Services Commission's initial rejection of Baltimore Gas & Electric's proposed smart meter program was based on what it saw as BG&E both placing the majority of financial risk on consumers and not offering sufficient benefit to them. Elsewhere, momentum has grown to require utilities to offer consumers the ability to opt out of smart meter programs. Given recent opposition to smart meter programs by consumers, buy-in by consumers and public utility commissions (PUCs) is critical for any real progress to be made in large-scale smart meter build-outs.

Benefits other than those directly reflected in energy bill savings may be very important to consumers, so it is important that these benefits be made visible, though this can be a challenge. Grid stability (reduced blackouts), improved renewable energy integration and reduced environmental impact all offer tangible benefits. And reduced operational costs, such as meter reading, and energy savings from grid efficiency may benefit consumers as well.

However, increased information on and control over energy usage enabled by smart meters, and the resulting direct savings on energy bills from reduced consumer energy usage, are likely to be the most readily apparent benefit to consumers and thus may help make comprehensive smart grid build-out and electric power system modernization a realistic prospect.

This white paper discusses three areas of smart grid policies and planning relevant to energy savings for consumers:

- Energy use data display for consumers and how consumers engage with that data;
- The use of data for ongoing commissioning activities and the planning and evaluation of energy upgrades; and
- Who can access the data, who owns it, and how it is managed.

Reasons for **consumer opposition** have included:

- Cost of meters and related infrastructure
- Difficulty in adapting to time-of-use pricing programs, or the perceived complexity of such programs
- Claimed health effects from electromagnetic radiation emitted from smart meters
- Privacy concerns
- Suspicion of utility motives, and that the meters are over-reporting energy use

Data Display and Engagement

Smart meters create a valuable opportunity for home or business owners: access to near-real-time data on their energy use. Studies by the Brattle Group have projected 6.5% energy savings for consumers with energy use displays, on average;[3] other studies[4] have shown similar savings from data display systems with or without smart grid integration. Yet few current smart meter programs make these data available to consumers at intervals significantly more frequent than monthly meter readings of non-smart meters.

Of course, merely making such information available to consumers does not automatically result in energy savings;[5] the provision of information is not the same as providing useful feedback. Large data streams may be of interest to a small number of technically savvy consumers who have the time, interest, and knowledge to interpret them and adjust their own behavior accordingly, but the typical consumer will likely find this overwhelming, difficult, or simply of little interest. Consumers must be able to make sense of the data and, indeed, actually want to see the data in the first place. The system for data display is critical. For the casual user, the system should be easy to use and the content should be useful and engaging to the consumer. Inconvenient access, such as requiring one to log onto an online system to view energy use data is unlikely to regularly attract the majority of users, especially among populations where computer literacy or ownership is low. Also, those interested initially may not remain interested over time, as the novelty of the display system wears off and behavior returns to pre-display patterns; the information and its presentation must remain compelling for consumers.

The means and knowledge to turn understood data into meaningful action to reduce energy use will also be necessary. Thus systems that can analyze the data and give consumers specific and actionable information on energy use and what they can do about it, or can automate responses to the data, may be most useful. The data also would likely prove most useful in the context of utility or other programs by providing a rationale for financing and support of larger efficiency measures.

Consumers also will need ready access to such data in a timely manner and with a useful data interval.[6] Google PowerMeter, an online interface used by several utilities to present data gathered from smart meter systems, displays a minimum of ten-minute intervals. While such intervals are useful for getting a sense of general levels of energy use (e.g. that energy use went way up shortly after coming home from work), they are less useful for identifying effects of turning on a specific appliance or fully disaggregating and analyzing energy uses. They also may not provide sufficient timeliness to allow real-time reactions to increases in energy use. Home energy monitors, which gather data on energy use by means other than a utility-installed smart meter, can offer near-real time energy use data (e.g. one second intervals on a two second delay with an Energy, Inc. TED5000 device), but this level of data granularity does not seem forthcoming from utility programs.

Providing consumers with data on their homes' or businesses' energy use helps consumers reduce energy use in several ways. Understandable energy data can help:

- Identify sources of high energy use,
- Identify aberrant energy loads,
- Provide a detailed comparison with similar consumers' use,
- Demonstrate success or failure of efficiency improvements, and
- Engage consumers in thinking about their energy consumption.

Unhelpfully, greater awareness of appliance and device energy use could lead to greater energy use at times. Consumers may decide that the cost of energy consumed by certain devices is comparatively trivial, for example a desk lamp compared to an electric hot water heater. One study of consumer responses to data display systems identified consumers who took a more cavalier attitude toward use of certain electronic devices when they learned how comparatively little energy those devices used.[7]

Ongoing Commissioning, Energy Assessment, and Evaluation of Savings

Improved understanding of building energy use, such as could be offered by smart meter data collection, also holds a number of opportunities for improving building performance and understanding the results of retrofits through professional analysis of the data.

Combining real-time or near-real-time data on energy use with periodic or ongoing building commissioning could provide a comprehensive understanding of building performance metrics and effectively diagnose performance issues. Access to shorter-interval data than is currently offered by conventional energy meters would help identify building performance problems with much greater rapidity and could allow for more rapid trouble-shooting of building energy performance problems. Where appliances have monitoring and communications capability, they could provide performance data and could automatically alert managers when problems arose. Greater awareness of building systems would allow greater optimization of those systems' performance.

The collection of detailed, time-resolved building energy use data would also ease the prediction of savings from retrofit measures in energy assessments as well as evaluation, measurement, and verification (EM&V) of energy efficiency retrofits. Data logging equipment managed through smart meters, or even plausibly in individual smart appliances, could assist in establishing pre-project baselines and track gross energy savings quite effectively. On the other hand, too much data could swamp evaluators, reducing its usefulness for analyzing energy efficiency programs. Without submetering or disaggregation, short-interval data on energy use may provide few benefits that manually-read meters did not.

Data Access, Ownership, and Management

Energy usage data has the potential to help consumers reduce their energy use, but as these data will most likely be gathered at an electrical meter owned and managed by the utility, the question of who owns those data is a significant one. Consumers are concerned with the privacy of, and access to, their data. Utilities are concerned with potential liabilities that may arise from data transfer and management, including responsibilities for data accuracy, availability, security, timeliness, and authority to access and transfer such data – as well as the costs associated with managing such a large amount of data while being sensitive to these issues. Third parties see potential markets in access to consumer data.

These issues are of particular importance if third-party[8] energy management providers are to be able to use the data to assist consumers with programmed responses to grid events and to real time pricing, aggregation of demand response, presentation and interpretation of energy use data, building energy efficiency audits, and measurement of energy savings. Historically, the relation between utilities and their customers has been an almost entirely bilateral one; customers draw electricity from their utility, and the utility bills them for it. The possibility of introducing one or more third parties into this relationship challenges traditional utility-consumer relationships. It may be difficult in some instances to encourage utilities to open the traditional model to outside entities and provide information to potential competitors. On the other hand, attempts to encourage electricity and natural gas suppliers to compete with distribution utilities for retail customers have largely failed to convince large numbers of consumers to change their traditional relationship with utilities. Similar problems may be faced in attempts to engage large numbers of consumers in smart grid programs.

Submetering refers to having meters not only on a given building (measuring the building's overall energy consumption as is conventional), but also on individual building components of building systems and/or for individual building sectors or tenants.

Currently regulations vary state to state as to whether it is the utility or the consumer who owns a consumer's usage data. This detail is important as it will greatly affect how easily consumers may grant third-party access to their data. This will have implications for federal privacy and access regulation and may require some sort of standardization across states. Beyond this, however, standardizing who owns utility data (the consumer or the utility) will benefit data access and related energy management projects.

Privacy issues are also significant. Load profiles of appliances and other electrical loads could be identified in a smart meter's time-stamped readings, and smart appliances could inform utilities (or a third party with access to the data) when they were operating. Some find this sort of data collection overly intrusive and with a potential for abuse. Whether and how a consumer opts in or opts out of a program or parts of a program (and whether one must opt in or out) will be critical both for how effective a program can be and for consumer acceptance.

In addition to data management costs, equipment and infrastructure to support data display will incur costs that someone will have to pay. State regulators or others will need to decide whether the benefits outweigh the costs, so the energy savings impact may need to be clear, and whether those costs will be borne by all ratepayers or by the customers who receive the service or by someone else.

Utility-Side Benefits and Challenges

A smart grid not only can promote end-user efficiency but also promises to be a more efficient grid, reducing losses on the utility side of the meter in generation, transmission, and distribution of power. Precise control of customer loads is essential to achieve these benefits as well.

Smart grid capabilities across the transmission and distribution (T&D) network can allow T&D systems to operate more efficiently and responsively, reducing line losses and reducing excess generation needed to ensure grid stability. Smart grid systems would allow improved awareness of T&D system conditions in real time. This would allow the grid to be operated with tighter margins of error – and thus more efficiently.[9] The Electric Power Research Institute (EPRI) estimates that reductions in line loss attributable to voltage regulation[10] could save from 3.5 to 28 billion kWh in 2030.[11]

In addition, as explained below, customer demand response can smooth loads and can shift loads in response to supply-side fluctuations and disruptions, allowing more use of efficient base-load power plants, fewer unused-but-operating power plants, and less strain on the grid.[12]

As such cost savings directly accrue to utilities, efficiency gains in the grid should provide a significant incentive to the utilities and their regulators. Smart grid capabilities should also help utilities comply with existing Federal Energy Regulatory Commission (FERC) and North American Electric Reliability Corporation (NERC) regulations regarding grid stability and address consumer concerns about blackouts.

Demand Response

One of the major selling points of smart grids is the ability of various elements of the smart system – from end-user appliances to generators – to coordinate with one another to respond to the needs of other elements of the grid. In peak load situations, commands can be sent to appliances to power down temporarily; for intermittent renewable generation, some loads can be shifted to coincide with periods when extra power is available.

While these opportunities for more efficient operation of the electrical grid from demand response programs (DR) are clear, whether or not they reduce consumers' energy use is less certain. While demand response provides some of the same economic benefits as overall efficiency, it may not reduce greenhouse gas emissions or fossil fuel demand when peak loads are merely shifted into off-peak periods, leaving net energy use relatively unchanged. Some DR activities will result in net energy savings while others will not. For example, slightly dimming lights in a facility for the duration of a DR event will not cause those lights to be even brighter before or after, but turning air conditioning down will likely result in it running harder before or after the DR event to bring the building temperature back into the desired range. Focusing DR efforts on those actions that do result in less overall usage will provide greater benefits (e.g., air quality) while also creating greater energy savings for participant consumers even in the absence of time-of-use pricing.

Even if it does not reduce customer energy use, DR may reduce energy losses in the grid. Shifting loads on the time scale of hours away from periods of peak load will allow more use of base-load power plants and less use of expensive peaking units; since the least efficient older generators are typically the last to be brought online, this will often improve overall generation efficiency. Load shifting can also improve grid efficiency by reducing operation of the electrical grid at levels beyond its intended capacity. On the time scale of minutes DR may provide spinning reserve capability in lieu of power plants that are operating but in an idle state (yet still consuming some fuel), allowing the plants to begin generating at very short notice. One study suggests the value of spinning reserves that could be provided by smart residential appliances may actually be greater than the value of load shifting.[13]

Demand response actions can be taken either automatically by smart meters and appliances (in which case they need to be programmed appropriately) or by consumers taking action in response to some signal (in which case the signal and controls would have to be broadly accessible to a non-expert user base). The former may require unprecedented utility or third-party control over household functions. Consumers may resist the idea of granting utilities direct control over appliances; they are likely to do so only in response to apparent benefits of granting such control to utilities or other parties.[14] The ability for consumers to override demand response systems could be critical for general acceptance. For consumers to act themselves, they will have to be aware of the capacity and have appropriate policy and regulatory frameworks in place to encourage them to act in a timely fashion.

As utilities seek greater implementation of DR resources, many are proposing pricing based on the time that energy is used – putting a cost on more expensive peak period electricity with corresponding reductions in base electricity rates – in order to incentivize actions to reduce peak loads. This may come in the form of prices that vary throughout the day based on actual wholesale electricity rates, simply a higher tier of pricing for certain times of day and seasons, or very high rates for occasional periods of critical peak demand. The ability of smart meters to record the time energy is used is necessary for time-based pricing. While a small number of customers have traditional meters able to record more than one energy rate (more common in some regions internationally),[15] smart meters can react more dynamically to grid conditions and wholesale prices, allowing more complex pricing systems and the better communications that would be required. Time-based pricing will only affect loads if consumers react effectively to the prices; complex pricing that consumers do not understand or changes in price of which consumers are not aware will achieve little but raise energy bills. It is also important that time-based pricing structures are not overly onerous on those who are unable to reduce their energy use at peak times; the elderly at home during the day may not be able to turn off their air conditioners and the low-income may not have smart appliances. Striking a balance between this and providing sufficient incentive to spur action may be a challenge.

Smart Appliances and Smart Meter-Connected Devices

Customer-owned smart grid-enabled equipment that can communicate with smart meters and with utilities is key to the better awareness and management of energy demand that enable DR and other smart grid benefits. Smart appliances could include typical appliances (refrigerators, air conditioners, water heaters, etc.), electric and plug-in hybrid vehicles, and smart building components like lighting and window shading. For example about half of a refrigerator's energy use is for defrosting and ice-making cycles that can be run at any time of day. Dishwashers and clothes washers can often have delayed start times. Air conditioners and water heaters can be turned off briefly, or even run in advance of their need. In theory almost any electrical or gas-powered device could be designed to shift or reduce consumption in response to grid conditions.

Encouraging consumers to purchase smart appliances may be difficult unless those consumers recognize benefits to themselves. Thus it is critical to identify clear consumer benefits from smart appliances, and ways to convince consumers of the benefits, or to find ways to convince the manufacturers to include smart capability as a standard feature. Also, consumers are unlikely to justify the replacement of still-useful appliances based solely on smart grid capabilities even if they see the benefits.[16] Thus add-on devices that provide some level of smart capability for conventional appliances could act as a stopgap or shortcut in the early years (or decades) of smart grid roll-out.[17]

Incorporating Electric Vehicles and Renewable Energy into the Grid

Smart grid technologies in generation, transmission, and distribution systems, coupled with smart meters and appliances, can play an important part in managing potential problems that may arise from increased loads caused by electric vehicles and intermittent generation from renewable energy sources.

Smart grid technologies could improve transportation efficiency by helping to incorporate electric vehicles (EVs) into the grid and could mitigate grid disruptions caused by their widespread adoption. Smart technologies would help shift EV charging away from times of peak power use. Without smart technologies, EV charging stations could strain local distribution systems if large numbers of vehicles were charged on-peak. Smart charging stations could keep most load off-peak or pause charging during periods of grid instability. According to one estimate, existing off-peak capacity could accommodate 73% market penetration of plug-in hybrid and battery-electric vehicles.[18]

Other DR activities enabled by a smart grid could free existing generation and transmission capacity for residual EV charging during peak periods. Smart grid technologies may also help plug-in vehicles enhance grid stability. Small amounts of energy may be pulled back from the batteries as needed to balance local fluctuations in demand or compensate for small local supply problems. To drive consumer demand for these capabilities, it is important that EV purchasers see incentives, such as time-based electricity pricing or financial incentives for consumers and manufacturers, to ensure their vehicles are stabilizing the grid rather than crippling it. Smart technology also could facilitate charging EV owners for the electricity they use regardless of where the vehicles are charged.

Renewable electricity sources such as wind and solar only produce power a fraction of the time, and can change suddenly and unpredictably. Thus large amounts of spinning reserves and backup generation are required, and some renewable electricity goes to waste. Both fast and slow DR from appliances and EVs can be used to match loads to renewable supply, addressing reliability concerns and avoiding wasted power.

Regional, State, and Local Policies

Most of the government regulation, guidance, and other policies that foster and determine the shape of a smart grid are taken at a sub-national level, especially by state public utility commissions (PUCs) but also by the regional transmission coordinating entities – independent system operators (ISOs) and regional transmission operators (RTOs) – and sometimes by state and local governments.

PUCs approve most utilities' investments in capital-intensive projects like smart grids, as well as their requests for cost recovery or investment returns, and often have a guiding role. It is important that they ensure that smart grid systems will serve customers beyond automated meter reading, that energy efficiency and demand response are an integral part of the grid planning. PUCs set customer rates, including any time-based rates. Absent federal or state legislative intervention, they also need to set policies around customer and third-party access, and ensure interoperability between meters and customer equipment. PUCs generally are highly attuned to the costs and benefits of smart grid investments, but are still accountable to state and local governments, and hence to public opinion.

RTOs and ISOs, which coordinate grid operations for roughly two-thirds of US electricity customers, are primarily concerned with projects that affect the transmission system, rather than direct interface with consumers. As such, their decisions are focused on reliability and wholesale markets. They may set requirements or markets for spinning reserve and for demand response, as well as smart grid components on the transmission system. Their actions are also governed in many aspects by FERC's regulations and directives.

State legislatures and local governments may take action in some cases. To date much local action seems to have been oriented towards regulating or stopping smart meter roll-outs in response to public outcry, as discussed earlier. To that end, ensuring positive public perception of smart metering and the smart grid more broadly is critical to ensure that local government action is not taken to block such projects. States also have an important role to play in regulating data ownership and associated privacy, access, and liability issues.

Federal Support for Smart Grid and Smart Meters

While much of the policymaking that will determine the face of the smart grid in the coming years will be determined by public utility commissions, grid operation organizations, and state-level government bodies, the federal government is in the best position to create some incentives and regulations that encourage greater production and adoption of smart grid technologies, with possible collateral benefits fostering smart grids internationally.

Both manufacturers and consumers may need incentives to encourage the availability and use of smart grid-enabled appliances. This will be more difficult because smart meters and grid capability are being rolled out on a regional basis, while most appliances are manufactured for a national or international market. While utilities would be the logical providers of consumer incentives as the benefits accrue to the grid, manufacturers are likely to need consistent nationwide policies to affect the national markets for appliances. They are less likely to manufacture an appliance in response to one utility's criteria or incentives. Tax incentives, informational labels, and equipment standards, along with coordinated utility programs, may provide the "carrots and sticks" to bring smart technologies into consumer appliances and other equipment.

Energy Star label criteria could be used to encourage smart capabilities in labeled products. Use of Energy Star labels may be effective for early adoption, especially as they often apply to premium models, and the first smart grid-enabled appliances are likely to be premium models as well. A bill in the United States Senate, the Implementation of National Consensus Appliance Agreements Act (S. 398), would direct federal officials to consider whether smart grid and demand response features ought to receive credit against energy savings in Energy Star criteria, and EPA has said they will consider this on a case-by-case basis.

The use of tax incentives to encourage residential and commercial energy efficiency improvements and the manufacture of energy-efficient appliances (in sections 25C, 45L and 45M of the tax code, respectively) is well established. The section 48C Advanced Energy Manufacturing Tax Credit, created by the American Recovery and Reinvestment Act, was applied to investments in smart grid technology manufacture by several awardees.[19] Sections 25C and 45M both expire at the end of 2011. Future versions of these tax credits could include smart grid capabilities in efficient appliances. Eventually, incorporating smart grid capabilities into appliance standards could ensure effective and consistent capabilities in all models of a given appliance type.[20]

It will also be necessary to ensure that the smart appliances and equipment and data display systems, manufactured for a national or international market, can communicate with and respond to signals from regional utilities and their smart meters. Thus communications standards (and hardware standards where appropriate) are being developed by the National Institute of Science and Technology (NIST) and associated organizations under direction of the Energy Independence and Security Act of 2007. Ensuring that energy use and grid data are provided in a readily accessible manner via a standardized protocol would greatly help its use by both consumers and third-party entities that might manage that data for them. Standardized interoperability protocols, and "plug-and-play" capability for appliances across various utility smart grid systems, are important to ensure that consumers are not locked in to one utility's, manufacturer's or other vendor's proprietary system and that data transfer can be done without inconvenience to consumers. Interoperability should also increase competition and economies of scale among manufacturers, driving down prices as equipment becomes more of a swappable commodity.[21]

Relevant federal energy efficiency tax incentives:

25C Non-business Energy Property tax credits provide residential taxpayers with incentives to purchase certain types of energy efficient appliances, to insulate their homes, and to install energy efficient windows and doors.

45L New Energy Efficient Home Credit provides an incentive to home builders for new homes that certain meet energy efficiency levels.

45M Energy Efficient Appliance Credit for manufacturers incentivizes the manufacture of certain types of energy efficient appliances.

48C Advanced Energy Manufacturing Tax Credit is a competitively-awarded incentive for new, expanded, or retrofitted facilities to manufacture clean energy technologies, including transmission and smart grid products.

Federal policies also may be necessary to ensure that consumers have timely access to the data collected by their smart meters and are able to assign data access to third parties, and to address associated privacy, liability, cost assignment, and interoperability issues. Legislation proposed by Senators Udall (D-Co.) and Brown (R-Mass.), the Electric Consumer Right to Know Act,[22] would require that utilities provide energy use data to consumers – particularly data generated by smart meters. But further action may be needed to ensure that the data are provided in a useful format and time frame for a variety of purposes, to address utility liability concerns, and to prevent third parties from misusing data that they access.

The **Electric Consumer Right to Know Act**, or "**e-Know Act**," (S. 1029) proposed in the 112th Congress, would require utilities to make energy consumption data available to their customers at relatively short intervals or allow them to access it directly from smart meters. It would also let consumers assign access to that data to third parties. Slightly different versions were proposed in the 111th Congress by Representative Ed Markey (D-Mass.) and Senator Mark Udall (D-Co.).

Direct federal support could also be critical to accelerate key areas of technology development and deployment. $3.4 billion in matching funds from the American Recovery and Reinvestment Act's (ARRA) Smart Grid Investment Grant Program has been committed to projects across the country, but additional opportunities exist beyond ARRA funding. The Department of Energy's Office of Electricity Delivery and Energy Reliability and the Advanced Research Projects Agency – Energy (ARPA-E) can support the development of smart grid-related technologies. The Clean Energy Deployment Administration, proposed in legislation including the House-passed American Clean Energy and Security Act (H.R. 2454, during the 111th Congress), could provide valuable financing and credit support for deployment of new smart grid technologies. An energy innovation hub devoted to smart grid technology (such as already exists for building efficiency technologies)[23] could catalyze significant public-private collaborations for the development and commercialization of smart grid technologies. Research into consumers' interactions with data display systems, as discussed previously, would be of particularly great benefit; it could expand understanding of how consumers can realize the personal benefits from smart grid technologies and inform the creation of improved systems for informing consumers and encouraging them to act.

The federal government is also in a unique position to be an "implementer of first-resort." Widespread implementation of smart grid and smart meter systems in Federal facilities would provide a boost to the technologies and encourage quicker economies of scale that would benefit general consumers. Federal procurement of energy efficient goods has been used in the past to drive development and commercialization of such products.[24] As a potentially huge market for smart grid products and services, the federal government stands in a unique position to drive the market.

Solutions Without Smart Grid

In considering support for smart grid infrastructure, it is worth considering what smart grid systems' goals are and whether these same goals might be more easily – or cheaply – met with simpler technologies. Many of the benefits of smart systems, particularly on the consumer side, can be achieved with non-smart, or at least non- or less-interconnected systems. For example, Maryland customers of the utility Pepco can participate in a demand response program, 'Energy Wise Rewards' that cycles participants' air conditioning on and off during peak periods via radio signal to either a special programmable thermostat or a receiver attached directly to the external air conditioning unit. No smart meter or smart grid is required. A refrigerator could have a clock that simply tells it not to defrost until 2 am when grid loads are low. Energy monitors and sensors can provide consumers with accurate energy use data at much more granular intervals than that which smart meters provide, as discussed earlier. Advanced home automation systems can realize many of the automation benefits of smart grid without a smart meter or direct utility communication connection. As noted previously, some electricity customers (largely internationally) have analog meters that are able to record two separate tiers of energy use at different times of day.

Other benefits, however, cannot be achieved without smart grid systems. While a timer in a refrigerator may be able to defer defrost cycles to times that are normally off-peak, it would be unable to take action based on unexpected events on the grid, for example an unplanned loss of transmission capacity, harsh weather conditions, or the intermittency of renewable energy sources. Sensors throughout electrical transmission and distribution systems offer unique benefits in the information they provide, allowing for more efficient and reliable grid operation.

Conclusions

Positive consumer opinion is essential for smart grid's success. Without broadly positive consumer attitudes, public utility commissions are unlikely to be willing to approve utility investments in smart grid upgrades, and consumers will not allow control of their appliances or use energy information they receive. Consumers must recognize that smart grid systems and the advanced meters attached to their homes and businesses provide real value and are worth the costs they are required to pay on their utility bills. While grid reliability, operational savings, and reduced need for power plants are real benefits to all those connected to the grid, their relation to smart meters, time-based rates, and utility charges for smart grid may not be obvious. As such, it is important that consumers see useful information coming from the smart grid and realize real energy savings that bring down their energy bills.

The primary recommendations discussed in this white paper include:

- Energy efficiency must be an integral goal of smart grid programs, from planning through to operation.

- Consumers must receive perceptible benefits from smart grid systems, especially smart meters and appliances; the ability to analyze and reduce energy use can provide such a benefit, provided that ability is easily accessible and easy-to-use. Therefore consumers should be given access to their data and the tools to use the information, including technical assistance and financing.

- Federal support for research into consumers' interactions with data display systems is needed to enable more consumer engagement with smart technologies and better understand how to turn information into energy savings.

- Policies fostering appropriate third-party energy management could make the benefits of smart grid more accessible for consumers. Access issues, interoperability standards, cost allocation, and privacy questions will need to be addressed.

- Demand response should be used to smooth load and match load to generation, thus avoiding the use of inefficient and idle generators. Planning for demand response programs should pursue activities that reduce net energy use in addition to reducing peak loads.

- Continued Federal action on interoperability standards may be needed to ensure cross-compatibility of equipment nationwide or worldwide.

- Federal appliance standards, incentives and labeling have proven useful in encouraging improved energy efficiency in appliances and other equipment; similar policies should prove fruitful to encourage the manufacture of smart grid-capable equipment and for consumers to purchase it.

Smart grid technologies have the potential to offer real and significant benefits to consumers, grid operators, and the nation if sufficient attention is paid to the customer side of the meter and energy efficiency is planned into smart grid roll-outs. Failure to make energy savings a central part of the smart grid planning process risks missing these opportunities and may fail to produce the benefits that are so often touted for smart grid systems.

Endnotes

1 Though less often a topic for public debate and less common than electrical smart meters, smart meter systems for gas and water also exist and face some of the same issues discussed in this white paper. Nonetheless, the focus here is largely on electrical energy.

2 See, for example, AARP, et al. The Need for Essential Consumer Protections: Smart Metering Proposals and the Move to Time-Based Pricing. August 2010.

3 Ahmad Faruqui. 'Sizing Up the Smart Grid.' ISO New England Smart Grid Forum. May 20, 2009.

4 For example:
Sarah Darby. 'The Effectiveness of Feedback on Energy Consumption.' Environmental Change Institute, University of Oxford. April 2006.
EPRI. Residential Energy Use Feedback: A Research Synthesis and Economic Framework. February 2009.
Karen Ehrhardt-Martinez; Kat Donnelly; and John Laitner. Advanced Metering Initiatives and Residential Feedback Programs: A Meta-Review for Household Electricity-Saving Opportunities. American Council for an Energy Efficient Economy. June 2010.

5 Sarah Darby. 'Smart Metering: What Potential for Householder Engagement?' Building Research and Information. Volume 38, Issue 5. September 2010. 442 - 457.

6 For example, the e-KNOW Act as proposed by Rep. Markey (D-Mass.), discussed later, would require fifteen minute intervals; Senator Udall's (D-Co.) version of the bill would require intervals of at most one hour.

7 Beth Karlin. 'A Profile of Early Adopter Feedback Users.' Behavior, Energy & Climate Change Conference. Washington, DC. November 15, 2010.

8 Where building tenants are involved, this could become a four-way interaction. Tenant-occupied space accounts for about half of the total non-governmental commercial floor space, much of which is not even separately metered. Very little attention has gone to understanding the incentive structure or the best means to provide demand response-related information to commercial tenants.

9 For further discussion, see R.G. Pratt, et al. The Smart Grid: An Estimation of the Energy and CO2 Benefits. Pacific Northwest National Laboratory. January 2010. 3.27 – 3.29.

10 Optimizing the range of voltages at which a distribution system operates can result in operational efficiencies. Better awareness of grid conditions may allow a distribution utility to operate its system at tighter tolerances, thus allowing lower voltages with reduced worry of grid instability or problems for consumers. Other smart grid and demand response technologies can back up grid stability. Studies have estimated that for every 1% reduction in voltage, energy savings of 0.8% result. Ken Gudger, Mark Reedy, Omar Siddiqui. Distribution Efficiency Initiative: Market Progress Evaluation Report, No. 1. Northeast Energy Efficiency Alliance. May 18, 2005.

11 EPRI. The Green Grid. 2008. 5-3.

12 Line loss is equal to the square of current flow, so line loss increases exponentially relative to current. Nourai, et al. projected efficiency savings of 1-3% (out of an estimated 10-15% line loss) resulting from a load shifting experiment using a 1MW storage battery on an American Electric Power transmission system. They note, however, that savings will vary greatly depending on the system and environmental conditions.
Ali Nourai, V.I. Kogan, Chris Schafer. 'Load Leveling Reduces T&D Line Losses.' IEEE Transactions on Power Delivery. Volume 23, Issue 4. 2008.

13 Chellury Sastry, Viraj Srivastava, Rob Pratt, Shun Li. Use of Residential Smart Appliances for Peak-Load

Shifting and Spinning Reserves: Cost/Benefit Analysis. PNNL-19083. December 2010.

14 ASHRAE. Comments to the Department of Energy regarding 'Smart Grid RFI: Addressing Policy and Logistical Challenges.' November 1, 2010.

15 For example, a meter may have effectively two separate registers attached to clocks or timers, or be able to respond to a radio signal: one for an off-peak price and one for an on-peak price. In the UK, certain types of meters with "radio-activated switching" can respond to a signal transmitted via longwave radio on the BBC Radio 4 channel, directing them to switch registers to account for nighttime and daytime prices.

16 ASHRAE. Comments to the Department of Energy regarding 'Smart Grid RFI: Addressing Policy and Logistical Challenges.' November 1, 2010.

17 For example an appliance could be plugged into a device that could receive smart grid signals to cycle on and off while reporting back data on energy use.

18 McKinsey & Company. Unlocking Energy Efficiency in the US Economy. July 2009.

19 These included facilities to manufacture advanced transformers, energy storage modules, smart meters, and other distribution-related equipment. Department of Energy. 'Fact Sheet: $2.3 Billion in New Clean Energy Manufacturing Tax Credits.' January 8, 2010. http://www.energy.gov/news/8503.htm.

Internal Revenue Service. 'Selections for Section 48C Manufacturing Tax Credit.' http://www.whitehouse.gov/sites/default/files/100108-48c-Selection-Final-With%20Projects.xls.

20 An earlier version of the Implementation of National Consensus Appliance Agreements Act (S. 3925 in the 111th Congress) would have allowed smart capabilities to be incorporated into appliance standards either as a credit against the standard or as an additional performance or design requirement.

21 Smart Grid Today. 'Industry Coming to Terms With Realistic Expectations, Arnold says.' December 3, 2010.

22 For further information, see Alliance to Save Energy. "e-KNOW:' The Electric Consumer Right to Know Act.' March 2010. http://www.ase.org/resources/e-know-electric-consumer-right-know-act.

23 Three "Energy Innovation Hubs" are operated by the DOE, including one for building energy efficiency based at the Philadelphia Naval Yard. A proposed Obama Administration FY2012 budget would include funding for additional energy innovation hubs, including one for research and development of smart grid-related technologies.

24 Alison ten Cate, Jeff Harris, John Shugars, Hans Westling. 'Technology Procurement as a Market Transformation Tool.' Proceedings of the 1998 ACEEE Summer Study on Energy-Efficient Buildings. Asilomar, CA. August 2002.

Bibliography

AARP, National Consumer Law Center, National Association of State Utility Consumer Advocates, Consumers Union, Public Citizen. *The Need for Essential Consumer Protections: Smart Metering Proposals and the Move to Time-Based Pricing*. August 2010.

Alliance to Save Energy. "e-KNOW:' The Electric Consumer Right to Know Act.' March 2010. http://ase.org/resources/e-know-electric-consumer-right-know-act.

ASHRAE. Comments to the Department of Energy regarding 'Smart Grid RFI: Addressing Policy and Logistical Challenges.' November 1, 2010.

Darby, Sarah. 'The Effectiveness of Feedback on Energy Consumption.' Environmental Change Institute, University of Oxford. April 2006.

Darby, Sarah. 'Smart Metering: What Potential for Householder Engagement?' *Building Research and Information*. Volume 38, Issue 5. September 2010. 442-457.

Department of Energy. 'Fact Sheet: $2.3 Billion in New Clean Energy Manufacturing Tax Credits.' January 8, 2010. http://www.energy.gov/news/8503.htm.

Ehrhardt-Martinez, Karen; Kat Donnelly; and John Laitner. Advanced Metering Initiatives and Residential Feedback Programs: A Meta-Review for Household Electricity-Saving Opportunities. American Council for an Energy Efficient Economy. June 2010.

EPRI. *The Green Grid*. 2008. 5-3.

EPRI. *Residential Energy Use Feedback: A Research Synthesis and Economic Framework*. February 2009.

Faruqui, Ahmad. 'Sizing Up the Smart Grid.' ISO New England Smart Grid Forum. May 20, 2009.

Gudger, Ken; Mark Reedy; Omar Siddiqui. *Distribution Efficiency Initiative: Market Progress Evaluation Report, No. 1*. Northeast Energy Efficiency Alliance. May 18, 2005.

Internal Revenue Service. 'Selections for Section 48C Manufacturing Tax Credit.' http://www.whitehouse.gov/sites/default/files/100108-48c-Selection-Final-With%20Projects.xls.

Karlin, Beth. 'A Profile of Early Adopter Feedback Users.' Behavior, Energy & Climate Change Conference. Washington, DC. November 15, 2010.

McKinsey & Company. *Unlocking Energy Efficiency in the US Economy*. July 2009.

Nourai, Ali; V.I. Kogan; Chris Schafer. 'Load Leveling Reduces T&D Line Losses.' *IEEE Transactions on Power Delivery*. Volume 23, Issue 4. 2008.

Pratt, R.G.; P.J. Balducci; C. Gerkensmeyer; S. Katipamula; M.C.W. Kinter-Meyer; T.F. Sanquist; K.P. Schneider; T.J. Secrest. *The Smart Grid: An Estimation of the Energy and CO_2 Benefits*. Pacific Northwest National Laboratory. January 2010. 3.27 – 3.29.

Sastry, Chellury; Viraj Srivastava; Rob Pratt; Shun Li. *Use of Residential Smart Appliances for Peak-Load Shifting and Spinning Reserves: Cost/Benefit Analysis*. PNNL-19083. December 2010.

Smart Grid Today. 'Industry Coming to Terms With Realistic Expectations, Arnold says.' December 3, 2010. http://www.smartgridtoday.com/public/Industry_coming_to_terms_with_ltbrgtrealistic_expectations_Arnold_says.cfm.

ten Cate, Alison; Jeff Harris; John Shugars; Hans Westling. 'Technology Procurement as a Market Transformation Tool.' Proceedings of the 1998 ACEEE Summer Study on Energy-Efficient Buildings. Asilomar, CA. August 2002.

About the Alliance to Save Energy

The Alliance to Save Energy is a coalition of prominent business, government, environmental and consumer leaders who promote the efficient and clean use of energy worldwide to benefit consumers, the environment, the economy and national security. The Alliance advances energy efficiency policies, conducts research on various energy-related topics, and increases awareness and knowledge about the many ways that energy consumption can be reduced in the United States and throughout the world. For more information about the Alliance and its activities, please visit www.ase.org.

Acknowledgements

This white paper is made possible by the Kresge Foundation and the Associates of the Alliance to Save Energy. The authors would also like to thank Rodney Sobin, Floyd DesChamps, Jeff Harris, Steve Goldman, and Sarah Wendel for their invaluable help in the crafting of this report.