The Smart Grid: What Is It and What Do Policymakers Need to Know About It?

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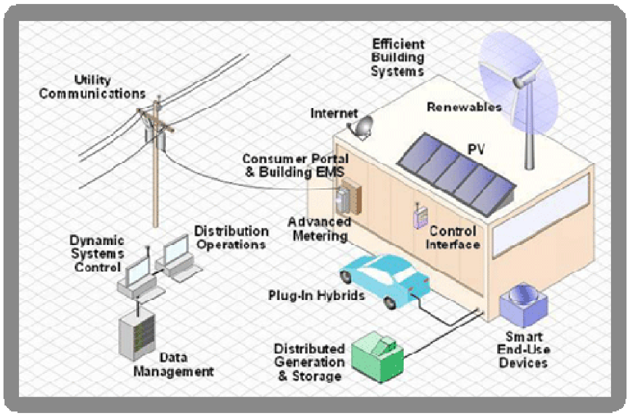


Source: Electric Power Research Institute

Introduction

A few billion dollars tends to attract attention, and the new federal stimulus bill that provided $3.99 billion dollars to support new "smart grid" technology certainly garnered its share of attention. The utility industry, smart meter and equipment suppliers, environmental advocates and state and federal policymakers are just a few of those who have begun to take a serious look at the smart grid.

This paper is meant to help policymakers in particular by describing what the smart grid is and isn't, examining its potential, surveying who is investing in smart grid, and examining its potential costs and savings. It is worth noting at the outset that the term smart grid means many things to many people, and the state of technological development, the savings, and the benefits from some elements of the smart grid are far clearer than from other elements of the smart grid. As a result, it is useful to begin this discussion with some background and a statement of the potential benefits and some of the questions outstanding about the smart grid.

Background

The smart grid holds potential to benefit customers, the environment and utilities. Yet still remaining are questions about its costs, the need for still-nascent technologies to further develop and how attractive the smart grid will be for the average energy consumer. This section summarizes these potential benefits and questions.

Potential Benefits of Smart Grid

- Customers could benefit from lower energy bills if they take advantage of the opportunities that a smart grid encourages them to reduce their energy usage or to shift their usage to off-peak hours – assuming that rate structures exist to reward customers for this shift.
- Customers and utilities can both benefit from a more reliable electric system that results from preventing outages by taking corrective action prior to a problem,

and faster and more accurate response times to power system outages, assuming that the smart grid system incorporates sensors to detect outages, that automated communications devices transmit outage information to utility control centers, and automatic corrective action can be taken to end outages.

- Customers and utilities can benefit from environmental improvements that result from more efficient use of the grid and better integration into the power grid of small and large scale renewable energy installations such as generators with a naturally variable output like wind and solar plants.
- Customers and utilities may benefit from long-term cost savings that result from the ability to use automated meter reading systems and other savings that could result from more efficient transmission and distribution of electricity. The cost savings from automated meter reading are compelling and are often the simplest to achieve.

Questions About Smart Grid

- Is the significant investment in smart grid justified by long term cost reductions that may stem from operational savings or reliability benefits?
- Will smart grid investments produce verifiable and sustainable energy savings on the customer side of the meter?
- Will smart grid investments result in significant environmental benefits?
- To the extent that the smart grid's success relies on customers acquiring, using and responding to new technologies, how much verifiable and sustained energy savings will result from the smart grid?
- How will industry ensure interoperability among the many new devices involved in the smart grid (a bit akin to ensuring that a music download could operate not only in an iPod but also in other MP3 devices)?
- Who will pay for smart grid investments?

The full-scale transition to a smart grid would represent one of the most fundamental shifts that the electric power industry has ever experienced; yet most aspects of the smart grid exist now only in the form of large-scale pilot programs. Some of the devices upon which the smart grid will incorporate, such as plug-in hybrid vehicles or sophisticated battery technology, are still under development; others are well developed. Similarly, the policies, regulations and operating protocols that would govern the smart grid are still under development.

This short document aims to respond to a few of the issues identified above by providing a brief description of the smart grid and its potential and then laying out a series of questions that state policymakers may find helpful as they confront the burgeoning interest in smart grid.

The Smart Grid: What it is, what it isn't

What <u>is</u> Smart Grid?

Think of the smart grid as a set of technologies that can work together to make the power grid operate more efficiently and reliably, and enable more services than it currently does. Smart grid consists of technologies like sensors that automatically detect power system outages or potential system overloads, and communications devices that alert energy consumers to times when energy use is at its highest – and as a result rates are higher too. In its most promising form, the smart grid is an enabling set of technologies that make possible the better use of renewable energy, energy efficiency, voltage control, and other means to make the power grid more reliable and efficient. One U.S. Department of Energy workshop concluded that the smart grid should have the following major characteristics – involving an integration of suppliers and users of energy in unprecedented ways. The workshop concluded that the smart grid should:

- Enable active participation by consumers
- Accommodate all generation and storage options
- Enable new products, services and markets
- Provide power quality for the range of needs in a digital economy
- Optimize asset utilization and operating efficiency
- Anticipate and responds to system disturbances in a self-correcting manner
- Operate resiliently against physical and cyber attack and natural disasters.[i]

> The Electric Power Research Institute defines the smart grid as a "two way flow of electricity and information in an automated electricity delivery network. The smart grid is interconnected by a communication fabric that reaches every device and is highly instrumented with advanced sensors and computing. *Source: Ellen Petrill, Electric Power Research Institute, August, 2009)*

Smart grid technologies fall into a couple of categories:

1. Utility-focused technologies that utilities will adopt and operate on their transmission and distribution system. These will be largely invisible to most consumers except that their power system should operate more efficiently and reliably.

2. Consumer-focused technologies that will require the active participation of consumers, meaning they may have to install or purchase smart appliances or devices and either have those devices automatically control their energy use or customers will manually manage their energy usage by turning appliances off in response to price signals.

Utility-Focused Technologies

Utility companies can use smart grid technologies to improve the reliability and efficiency of their power delivery systems. The following are examples of some of these technologies and functions.

- An example of a smart grid technology that operates on the transmission system is one that regularly and frequently checks the state of the transmission system to determine if there are areas that are or are about to be overloaded. Operated through technologies known as synchrophasors, this element of the smart grid helps to maintain reliability. According to the North American Synchrophasor Initiative:

  > Synchrophasors are precise grid measurements…taken at high speed (typically 30 observations per second – compared to one every 4 seconds using conventional technology). Each measurement is time-stamped according to a common time reference. Time stamping allows synchrophasors from different utilities to be time-aligned (or "synchronized") and combined together providing a precise and comprehensive view of the entire interconnection. Synchrophasors enable a better indication of grid stress, and can be used to trigger corrective actions to maintain reliability. (Source: http://www.naspi.org/)

  Sensors like this can be paired with the capability to take corrective action, such as reconfigure power flow on the grid.

- Technologies that operate on the distribution system can make substations operate more efficiently and reliably. Substations are the equipment that utilities use to reduce voltages from the high levels that exist on the transmission system to the lower voltages of the distribution system that delivers power to homes, offices and other end users of the electric system. Certain smart grid technologies are focused on making these substations and other elements of the distribution system operate more efficiently and reliability.

- One promising function of the smart grid is one that will enable more effective integration of small-scale renewable resources into the power system. This integration is important because today's power system is designed to deliver power to end-users. It is not designed to both deliver power to end users and take in power from those same users who have an interconnected solar power or other generator on their property. Smart grid communication technologies will enable power system operators to integrate these customer-sited resources in to the power system. Two such technologies are:

- Solar, wind or fuel cell generators and a host of new generating technologies distributed around the utility system.
- Plug-in hybrid electric vehicles that can feed power into the grid when an advanced meter communicates that the grid requires power to meet a peak in demand, and pull power from the grid to charge batteries when the power system is not under stress.

The Evolution of the Power Meter: A Set of Definitions

The power meter has been around for about a century, but the smart grid would depend on new advances in metering technology. The following set of definitions describes this evolution.

The Dumb Meter: A meter mounted to the wall of a house, business or other institution measures the amount of electricity or gas going into that home or business. A small dial spins to track the consumption of kilowatt hours or therms of gas each month. A meter reader stops by to note the meter setting at the end of the month, from which usage can be detected by subtracting the previous month's setting.

The Dumb Meter with the Kind-of-Smart Communications: A Dumb meter gets a new feature – the ability to transmit usage data wirelessly, so that a meter reader can gather that data without actually stopping by a house but instead by simply driving or walking by the house.

The Advanced Meter: In the next evolution, the smart communications device on the Dumb Meter transmits data directly to the utility control center, obviating the need for a meter reader to drive by the home or business. This advanced meter results in considerable operational savings for a utility, largely from labor costs. But it does not take advantage of many of the potential benefits of a smart grid.

The Advanced Meter with Two Way Communications: This is about as close to smart grid as one can get without actually becoming smart grid. An advanced meter becomes a kind of portal into a home or a business that offers the potential for a utility or the customer to monitor and control energy usage within that location. An advanced meter is also a Smart Communicator, meaning that it transmits data on energy use back to the utility and obviates the need for a meter reader to even drive by. This advanced meter in and of itself is not smart grid unless it is integrated with a series of other technologies and tools such as smart appliances, two way communication devices, software, and a set of dynamic rates.

Customer-Focused Technologies

The smart grid gets a lot of attention because of its potential to encourage customers to reduce their energy use or shift it to other times. This potential relies on advanced meters, appropriate rate structures that reward people for reducing their consumption when the demand on the power grid is at its highest, and on people actually responding to the price or other informational signals designed to encourage this behavior.

One way to encourage ongoing response to signals is to automate the customers' appliances. If power lines or power plants are reaching the limits of their capacity on a hot summer day, the smart grid can send signals that automatically turn down an air conditioner or a pool pump based on the consumer's preferences and the utility's needs.

Samples of these technologies that play a part in the smart grid are:

- Advanced meters are a tool and a means for communication between the suppliers of energy and the users of energy. They are one of the key enabling technologies that make a smart grid work.
- Smart appliances –thermostats, pool pumps, dryers, air conditioners, lighting systems – that can receive communications and respond to indications that the energy system may be nearly overloaded.
- Display devices and automated controls that let consumers see when their energy use is highest – and respond by turning down air conditioning, lights or other energy using devices.

Because the primary interest in the Midwestern Governors Association Energy Efficiency Advisory Group is on customer-focused technologies and end-use energy efficiency, the majority of this document focuses on customer-focused technologies. It is important to note, however, that customer-focused technologies are only one element of the total smart grid picture.

A Smart Grid is More Than Just Smart Devices: It is Smart Integration of Devices

The key to a smart grid is not just creating a collection of smart technologies. The key is the intelligent ability to not only gather data but also to use that data to make a more efficient, more reliable and perhaps a more environmentally-friendly grid.

A smart grid integrates huge amounts of information (one study suggested that a smart grid would take in about 22 gigabytes of information each day for a utility serving 2 million customers).[ii] It integrates that information to serve both immediate and longer term needs. For example:

1. Immediate Needs: If a power line, a substation or a gas line fails, the intelligent system notifies the control station immediately. In some cases, a smart grid is self-healing, meaning it can fix the problem and bring the power line back on immediately. This function meets an immediate reliability need.
2. Medium to long term needs: Utility planners can use the massive amounts of data arriving from the smart grid to forecast their medium and long term requirements for building new power lines, power plants and substations or can target specific areas for targeted energy efficiency installations.

The New England Independent System Operator describes the process of moving to a smart grid as evolutionary. "Traditional generating, transmission, and demand-response facilities, which are essential for meeting today's reliability requirements and electricity demand, will serve as the starting point and cornerstone for the smart grid…these traditional technologies will evolve into the smart grid through the addition of intelligent functions that improve their overall efficiency."[iii]

The transition to a smart grid is not without challenges. New technology and new uses of old technology will require the nation's most capital intensive industry to change the way it operates, plans and invests. The energy industry that has grown up by building large power plants and transmission lines to bring power from those plants to energy users is going to have to use the power of computers and sophisticated electronics to integrate thousands of devices, some of which generate power, some of which reduce the need for power and some of which monitor the state of the power delivery system. The industry that supplies high technology smart meters, appliances, sensors and other devices to the energy industry will need to be sure that all of these technologies can communicate with and integrate with one another in one coherent and coordinated smart grid system -- a function referred to inter-operability. Customers will need to adopt, use and respond to technologies, price signals and information in new ways that are as yet unproven on a national scale.

Standards and Interoperability

It is important to note that smart grid technologies exist today, but that many of them are still under development and the ways in which the technologies communicate, integrate and work with one another are still under development. The National Institute for Standards and Technology (NIST) has been engaged in a major effort to develop what are known as interoperability standards designed to ensure that the many different smart grid technologies do indeed integrate seamlessly into one large coordinated system. Many people refer to this effort as a way to get all devices to be able to "plug and play," meaning that users (whether utilities, power system operators or consumers) do not have to worry about trying to get unique and proprietary technologies and systems to work with each other. As the NIST puts it, "without standards, there is the potential for [smart grid] investments to become prematurely obsolete or to be implemented without necessary measures to ensure security."[iv] Information on the NIST effort is available at http://www.nist.gov/smartgrid/.

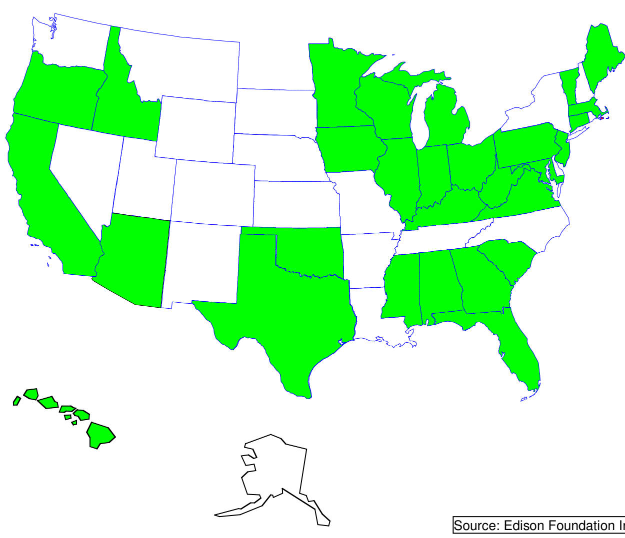
Where is the Smart Grid? Who is investing in it?

Smart grid investments are taking place in several countries and in a growing number of states across the United States.

Sweden, Italy and New Zealand have already completed a transition to 100% advanced metering. Several provinces in Canada, most notably Ontario, have also begun a large scale transition to advanced metering and, like these other countries, are conducting experiments with the smart grid.[v]

Within the United States, the following map illustrates the states in which utilities have a planned rollout of smart meters – although this map does not indicate how utilities will be using those meters, beyond the automated sending of usage data to central control centers. Close to one-half of the states are now considering a deployment of smart meters.[vi] Note that this map reflects locations that have invested in smart meters – with a focus on the customer side of smart grid investments. Many of these utilities and others are making parallel investments in the utility-focused side of the smart grid.

States with Smart Grid Pilots or Programs Proposed or in Place: April, 2009



Source: Edison Foundation Institute for Energy Efficiency, 2009

The profiles below illustrate several utility smart grid programs underway in the Midwest.

Commonwealth Edison

Commonwealth Edison, based in Chicago, is an example of a utility that is pursuing a pilot focusing on smart meters and advanced metering infrastructure and associated customer side applications of AMI. The utility is proposing to deploy 130,000 advanced meters and conducting 24 different variations on the effect of different technologies and applications of pricing structures and customer technologies to assess both the customer behavioral response to more granular consumption and pricing data and customer acceptance of these applications. The rate structures will include (1) a day ahead real time pricing structure (2) a time of use rate (3) a critical peak pricing structure (4) a rebate for reductions conducted at peak times. And (4) an inverted block energy pricing structure

In addition to the advanced meter, Commonwealth Edison pilot builds on four different technology options.

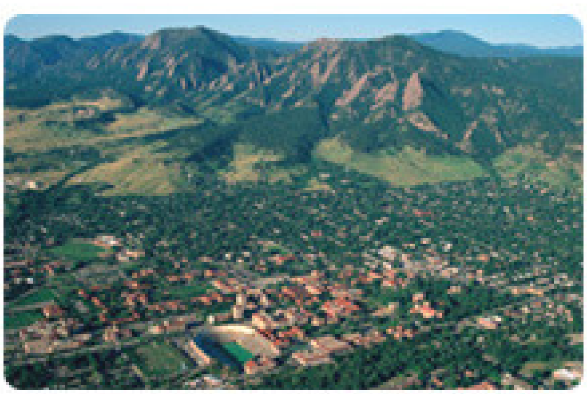
- A basic web portal that will show consumers their hourly consumption and cost of energy.
- A basic in-home display that will show real-time energy usage.
- An advanced in-home display combined with a programmable-controllable thermostat that shows energy use and also allows consumers to control their thermostat. Consumers can use this device to control other devices as well, but at their own cost.

Commonwealth Edison will be testing the extent to which the combination of rates and technology changes consumer's energy usage, to what extent that change is the result of the technology or the rate structures.

Providing that the results of the pilot program are positive, Commonwealth Edison plans to expand its program across all of its 3.8 million customers. The utility proposes to pay for the pilot through a small charge placed on all of its delivery service customers – meaning for the most part, only its small commercial and residential consumers.

Xcel Energy Smart Grid City Program

Xcel Energy, a multi-state electricity and natural gas energy company based in Minneapolis but with operations through Public Service Company of Colorado, is developing a pilot program called SmartGridCity purported to be the nation's first fully integrated smart grid community in Boulder, Colorado. Nearly 15,000 volunteer households have installed smart meters so far.


City of Boulder, CO

In addition, Xcel has connected 25,000 homes onto a BPL network (Broadband over Power Line) by installing more than 100 miles' worth of fiber optic cable in Boulder over the last year. The cable network will allow the company to track down and fix power outages more quickly than in the past. Xcel Energy will request the ability to replace its flat rate pricing structure with a time of use structure.

In addition to the advanced meter, the Xcel pilot builds on the following technology options for household consumers.

- "Smart plugs," which will allow customers to control their appliances, programmable thermostats and battery-backup kits remotely.
- The option to allow Xcel to turn down power to household appliances when power demand spikes.
- The option to power-up appliances when more energy is being produced by alternative sources such as solar and wind power.

Detroit Edison

Detroit Edison (DTE) is developing an AMI (Advanced Metering Infrastructure) Pilot Program in Gross Isle, Michigan. Its goal of installing 10,000 gas and electric smart meters is nearly reached with approximately 6,000 electric and 3,000 gas endpoints installed. Following a technology and benefit review of the pilot program, the installation of an additional 20,000 combined endpoints is planned across DTE's territory with implementation expected to start in 2010.

The meters will provide cost savings associated with eliminating estimated and manual meter reads, better locating the cause of outages and reducing uncollectibles due to remote disconnect functionality.

Consumers Energy Company

Consumers Energy in Michigan has chosen to observe and follow early adapters of smart grid technology. The company has proposed an AMI Pilot Program consisting of 6,000 to 10,000 electric and gas smart meters along with integrated systems that will measure, collect and analyze energy usage information. The utility uses a demand based rate structure.

In addition to the advanced meters, the proposed pilot builds on the following technology options.

- A system that will show consumers their hourly consumption and cost of real-time energy usage allowing them to better control their energy use.
- The option to allow the utility to turn down power delivered to large industrial customers as well smaller businesses and households when power demand spikes.

Consumers plans to transition from the AMI Pilot Program to full-scale electric smart meter deployment beginning in 2010 with the goal of creating a fully integrated smart grid in the future.

How much will the Smart Grid Cost and Save?

Smart Grid Costs

The smart grid entails so many different kinds of technology deployed in so many different ways at such differing scales that it is difficult to assign a precise figure for installing smart grid. That said, however, it is possible to provide some general guidance. This section focuses on costs and savings from customer-focused initiatives, since this is the primary focus of the Midwestern Governors Association Energy Efficiency Advisory Group.

The Edison Electric Foundation Institute for Energy Efficiency commissioned a paper that lays out many of the basic costs of a smart grid investment, with a focus on smart meters. This paper lays out several cost categories for meters only and for the additional technologies that are necessary to integrate that meter into a smart grid. The following table illustrates these costs.

Smart Grid Component Costs

Technology Type	*Cost*	*Notes*
Automated Meter Reading (provided for comparison only, not a typically considered smart grid)	$50-$90	Provided for comparison only -- this is a meter with a communications device to send out consumption information to a meter reading who walks or drives by the customer location.
Smart Meter	$100-$175	This is the smart meter with two-way communications and serving as the basic communications device between energy user and the power provider.
Additional Devices for Smart Grid	$100-$350 for the first appliance managed	This figure is highly variable depending on how many devices are managed (thermostat, water heater etc.) and will typically be $100 per additional device

Source: Deciding on "Smart" Meters: The Technology Implications of Section 1252 of the Energy Policy Act of 2005, Prepared by Plexus Research, Inc. for the Edison Electric Institute, 2006.

If there is a single conclusion to be drawn from these pilot programs and their costs, it is that the smart grid represents a substantial investment – an investment that government policymakers will need to consider in the context of the smart grid's promise of far better system efficiency, reliability, control and reduced emissions. The investments total in the billions of dollars in states like California and in the tens of millions of dollars in smaller states like Vermont. According to a press release from Central Vermont Public Service, "[Smart grid] will be one of the most important technological changes and one of the largest single capital investments - estimated at $40 million - in CVPS history."[vii] Table 2 provides the estimated costs of several pilot programs focused primarily on advanced meters and varying levels of infrastructure deployment.

Table 2: Sample Utility Programs for Smart Grid/AMI

Utility	*Characteristics of Program*	*Cost*	*# of customers*	*Data Source*
Connecticut Light and Power	Proposed program in 200, subsequently revised	$255 million	1.2 million	http://online.wsj.com/article/SB124050416142448555.html
Connecticut Light and Power	Revision of above program	$13 million	3,000	http://online.wsj.com/article/SB124050416142448555.html
Commonwealth Edison	Program scaled down from a larger AMI rollout. Will focus on examining consumer response.		130,000	Val Jensen, Commonwealth Edison, Personal Communication
Consumers Energy	Pilot program to focus on both AMI and interaction with demand response	$45,000,000	20,000 customers	Michigan PSC Rate Case #15645
DTE Energy		$12,000,000	30,000 total of which 10,000 are gas and 20,000 electric	Michigan PSC Rate Case #15768
Xcel Energy	Smart Grid City – pilot in development in Boulder, Colorado	Shared between utility and equipment vendors		www.xcelenergy.com/smartgridcity

Smart Grid Energy and Cost Savings

Financial savings from the smart grid will come from a number of areas including (1) the labor costs of automated, centralized meter reading and (2) from the ability of smart grid to defer the need to build new power plants or power transmission and distribution lines as a result of a more efficient use of the existing power grid (3) energy savings that result from reduced consumption. Again, this section focuses on savings that result from customer-focused smart grid technology.

Precise estimates of the savings will vary a great deal because smart grid means something a little different in each program; the savings (and costs) of a program involving only installation of smart meters differ substantially from one that involves installation of smart meters, in-home displays, automated (smart appliances) and the like. One study in the Pacific Northwest estimated that a smart grid that integrated smart appliances such as dryers or water heaters could reduce peak electric loads by 15% per year and defer $70 billion of power plant construction expenditures over a 20 year period.[viii] Note that this estimate is based on projections of what could happen, rather than actual experience.

Energy Savings

Few studies of the effect of the smart grid on energy consumption (as distinct from shifting load away from peak usage periods) exist. Some studies do provide insight into what may occur however. A caution, however, is that these are based on limited pilot programs, the results of which may or may not translate into large scale impacts within the population as a whole.

Ontario Energy Board Pricing Pilot

The Ontario Energy Board initiated a pilot program in 2006 to test reactions of customers to different electric rate structures including time of use, critical peak pricing and critical peak rebates. Participants in the pilot program were in one of three rate structures. The rates and the associated reductions in total energy use, by rate structure, were as follows:

Price Group	*Pricing Structure*		*Percent Reduction in Total Electricity Use*
Time of Use	Off-Peak	\$0.034-\$0.035/kWh	6.0%
	Mid-Peak	\$0.071-\$0.075/kWh	
	On-Peak	\$0.97-\$0.105/kWh	
Critical Peak Pricing	\$0.30/kWh		4.7%
Critical Peak Rebate	Refund of \$0.30 for each reduction in kWh usage during critical peak hours		7.4%
Average Reduction in Energy Use			6.0%

Source: Ontario Energy Board Smart Price Pilot Final Report, July 2007, IBM Strategic Consulting.

In Home Displays

A survey of energy conservation impacts conducted by Ahmad Faruqui, Sanem Sergici and Ahmed Sharif of the Brattle Group summarizes the results pilot programs that tested one component of the smart grid – information feedback devices. Informational feedback devices can come in a variety of forms including a screen showing actual energy use or rates in other forms. One example of such an in home display follows.

Source: http://www.comverge.com/assets/images/Productpage_energyaware_actual.jpg

Pacific Gas and Electric Company conducted a pilot program that used a device called an Energy Orb that turns different colors when energy usage increases.

Pacific Gas and Electric's web site states:

> It's always important to conserve energy, but the Ambient Devices PG&E Energy Orb lets you know when it's really important to reduce energy consumption.

Source: Pacific Gas & Electric

> With the Energy Orb, you can do your part to fully participate in critical demand periods and help reduce the negative effects of electrical supply shortages.[ix]

The Orb is blue during off peak hours, green in on peak hours, flashes red four hour prior to a critical peak period and turns red during the critical peak.

The effect that the in-home display devices showing electric rates and consumption exerted on energy consumption varied from a low of three percent to a high of 13 percent reduction in energy use, with an average energy savings of seven percent. Survey results did not attempt to quantify precise energy savings from the energy orb, but did present information based on survey data showing that 70 percent of residential customers and 65 percent of commercial customers had reduced their energy use as a result of the Orb. The results from all of the pilot programs are limited; as the authors of the study point out, it is hard to conclude for certain that the limited-time savings that result from these pilot programs will extend over many months or years once the novelty factor of the new device in the home wears off.[x]

What are the Essential Considerations for Policymakers and Regulators who are Examining Smart Grid?

With the explosion of interest in smart grid, government officials are now confronted with myriad issues that they will need to consider. The following suggests a number of considerations that these officials may need to examine as they are faced with requests to build – and pay for – new smart grid technologies.

What are some alternatives to Smart Grid?

Smart grid is not cheap, nor is it simple. It relies on the successful integration of a host of new technologies and on public acceptance of rate structures that offer significant encouragement for certain kinds of energy consumption behaviors. Although the benefits do appear to be significant based on initial pilot programs, it is worth considering two major alternatives to smart grid.

1. Direct load control is the most common alternative to the smart grid. In most direct load control programs a customer agrees to install a "saver switch" on a central air conditioning system. The switch allows the utility to cycle the customer's air conditioner down for a few minutes during a time of particular stress on the power system. The utility typically makes a fixed payment of, perhaps, $30 to the customer. The payment is not directly tied to the actual value of the energy savings that the "saver switch" and could conceivably exceed the value of the energy savings. A report prepared for the Edison Electric Institute points out that all ratepayers – even those who have not installed the Saver Switch (perhaps because they do not have central air conditioning) pay for this excess of cost over savings, should it occur.

   Another less common kind of direct load control has been adopted by Hydro One in Ontario, and is a device that allows either the customer or the utility to adjust a thermostat remotely, over the internet by a maximum of two degrees Celsius.

2. Time of Use rates are a simple rate structure that, based on a season or a time of day, charge higher rates for generally higher use periods (mid-afternoons, for example) and lower rates at generally lower use periods (during the night, for instance). The differential between the high and low rate periods is generally not large, and the pre-established rates bear a relationship to average peak or off peak usage periods but do not reflect actual critical peak periods, as would a more dynamic rate structure. Time of use rates do offer potential as a means to shift usage to off peak periods, particularly if the differential between the peak and off peak rate is significant enough to influence behavior. As an example, Ontario is gradually transitioning to a system wide Time of Use rate system in which the peak period rate is three times the off-peak rate.

3. Non-Technology Based Conservation Programs may be a substitute for higher technology in-home displays or energy orbs. The New York State Energy Research and Development Authority and the California Flex Your Power program have realized measurable energy savings from programs based primarily on education and outreach through various types of media.[xi]

What rate structures should likely accompany a Smart Grid rollout?

States utility commissions will consider rate structures that encourage customers to take advantage of the capabilities of the smart grid. So, for instance, one of the benefits of smart grid is that it allows people to enable automated devices that adjust their air conditioners or hot water heaters on a hot summer day when the utility system is strained. Dynamic rate structures that give customers a financial benefit for making these adjustments are an important companion to the smart grid technology.

Typical rate structures that accompany a smart grid roll out are:

- Critical peak pricing: Critical peak pricing is applied only when the utility's power system reaches its critical peak usage -- on the hottest days of the year, for example. Critical peak pricing involves charging a rate that is significantly higher than the typical non-critical peak rate. The utility likely notifies customers about an upcoming critical peak rate period the day before that rate goes into effect.
- Critical peak rebate: A critical peak rebate serves the same function as the critical peak rate but gives consumers a rebate for reducing their usage at critical peak times rather than charging them a high rate at those times. It is an incentive rather than a penalty.
- Hourly pricing: Hourly pricing changes by the hour depending on the load on the utility system. Hourly pricing could be supplemented by a critical peak pricing mechanism.

What response can be expected from these new rate structures?

The response to these critical peak pricing rate structures varies to some extent based on climate (hotter climates with high penetrations of air conditioning tend to have the most impressive results) and on the characteristics of the customer. The Edison Electric Institute commissioned a study of many residential dynamic rate programs and concluded that, overall, the customers on these rates structures saw lower overall bills – even though their rates may have gone up at certain critical peak periods. This was the case across customer classes and in different parts of the country. In New Jersey, for example, the utility concluded that a 100% increase in rates decreased usage overall by 8.5%.

Critical Peak Pricing Example

Period	Charge	Applicable
Base Price	$0.09/kW	All hours
Night Discount	-$0.05/kWh	10 p.m.-9 a.m. daily
On Peak Adder*	$0.08/kW	1 p.m.-6 p.m. weekdays
Critical Peak*	$0.69/kW	1 p.m.-6 p.m. weekdays when called

*(added to the base price when called.)
Source: PSEG-CPP Pilot, page 3 and Quantifying the Benefits of Dynamic Pricing in the Mass Market, Ahmad Faruqui and Lisa Wood, prepared for the Edison Electric Institute, 2008.

What public and consumer education will be needed to encourage public buy-in to Smart Grid?

Smart grid relies on a new and, in the energy industry, unprecedented level of communication between energy providers and energy consumers. The idea that a utility – with government permission – could wield the physical ability to turn an appliance down or even off requires an adjustment of expectations. The idea that a utility even has the ability to monitor – on a minute by minute basis – a home or business's energy use may also require a re-adjustment of the utility-consumer relationship.

Although extreme, perhaps, on-line comments posted to a Wall Street Journal article about smart grid provide a window on some perceptions of smart grid.

A few perceptions of the smart grid…

"Looks like an attempt by the government to pass the inherent instability of deregulated electric utility system off to the consumer and have him/her pay for it at the same time. Cool, huh?"

"Doesn't this mean government mandated utility meters gives the PUC and utility companies the ability to decide how much energy we use and when? The utility touches the totality of every day living to the smallest detail."

"I like the idea of monitoring and managing my home gas and electricity usage, to include shifting usage to lower cost, off peak time periods. But as soon as the government wants to control my usage and settings remotely, then I will not participate and disconnect or block any such connections."

Quotes accessed May 2, 2009
http://online.wsj.com/article/SB124050416142448555.html#project%3DGRID09%26articleTabs%3Dcomments

These comments show, if nothing else, that the public acceptance of smart grid, regardless of its overall benefit to energy system reliability, the environment or even the economy, will face hurdles.

But communicating about the smart grid in general is only part of the picture. It will be important to communicate to customers about the rates they pay and the options that they have to manage their bills using the Smart grid technologies. Customers need to understand the prices that they will pay, at what times they will pay those prices and their options to reduce their bills. Perhaps one of the most critical elements of the Smart grid's success or failure is this communication.

What Process Should the State Use to Develop a Smart Grid strategy?

States have used a number of different processes to reach consensus on a Smart grid strategy.

- Most have used a traditional ratemaking process through which utilities devise a pilot program or a full scale roll-out for smart meters and experimentation with different smart grid technologies.
- Massachusetts, Texas, Vermont and other states have adopted smart grid policies through legislation. http://www.mass.gov/legis/laws/seslaw08/sl080169.htm, Vermont Act 92 of 2007.
- Vermont adopted a multi-stakeholder collaborative approach to develop a smart grid strategy led by the state's major utility, Central Vermont Public Service and the state's Department of Public Service. (see Department of Public Service (DPS). http://www.cvps.com/AboutUs/news/viewStory.aspx?storyid=190

What level of certainty should utilities have prior to making large-scale investments in Smart Grid?

The smart grid investments will be large – and equivalent in many cases to a large power plant. Yet the regulatory approval process differs between a power plant and approval of the smart grid. In many states, the power plant approval process involves the regulatory commission's approval of a Certificate of Public Convenience and Necessity (CPCN) that implies a regulatory commission's agreement that a power plant is needed. Although the magnitude of the investment in smart grid may be similar to that of an investment in a power plant, no equivalent CPCN process exists to provide the comfort to a utility that it will be able to recover its investments in smart grid. Regulatory commissions may need to explore means that they can use to provide for cost recovery for smart grid investments.

What will be the expectation for cost recovery if technologies evolve and improve? Will the high technology sensors, smart appliances or advanced meters of 2009 be the low tech meters of 2016?

Smart grid involves an integration of many new technologies through complex electronic systems that are likely to evolve over the coming years and become obsolete far faster than, for instance, a traditional power plant. Regulatory commissions will need to examine ways to both give utilities cost recovery for investments made today despite likely technology advancements in the future that could make today's investments obsolete.

How will Smart Grid affect the pattern of investments in the power grid and power plants? How will the need for those investments change?

The smart grid could spark a radical change to the way the power companies must plan and invest in the power grid because it requires a way to integrate small scale micro-grids, distributed and intermittent renewable energy, energy efficiency and demand response. The need for new investments in the power grid overall will change – and means that regulatory commissions will probably need to examine transmission, distribution and generation in a much more integrated way than has happened in the past.

How will customers interact with the Smart Grid? How will it change their behavior?

The smart grid, if it reaches its potential, could be one of the more dramatic changes to utility industry in many years because it enables an unprecedented amount of interaction and response between the customer and the power supplier. Yet despite large scale pilot programs, the smart grid has yet to be tested over multiple years and with a full-scale roll-out to all customers. All the analysis is now based on limited experience – and customers are often unpredictable. Regulatory commissions will need to monitor and be cognizant of the actual changes that the smart grid engenders in customer behavior.

What changes to rate recovery mechanisms may be necessary in order to avoid a situation in which utility profits suffer as a result of successful Smart Grid programs?

One result of a successful smart grid program is that a utility may end up selling less electricity, or at least less electricity at peak hours. These reduced electricity sales translate, in most states, into lower profits because utility profits depend on throughput (earning a small rate of return on each kWh of electricity sold). Regulatory structures that in some way remove this embedded incentive for utilities to increase their profits by selling more will be important in the eventual success of smart grid programs. One of the objectives of the Xcel smart grid City project is to identify policy or regulatory mechanisms that will reward the company for greater efficiency (or remove the embedded disincentives to energy efficiency).

What costs will be spread across all ratepayers vs. participants in smart grid programs only?

Some smart grid technologies have typically been spread across all ratepayers through a rider on all their bills. Additional devices such as systems that display customers' usage, energy cost or that may allow them to control their smart appliances from that display device may also be paid for through a rider on all ratepayers. Additional items such as the cost of a Home Area Network that controls not only lighting but also other home devices are typically paid for by the individual customer.

Will lower or higher income customers benefit from or face disadvantages from the Smart Grid? Will lower income customers take advantage of Smart Grid?

[1]

As a rule lower income customers use less energy than higher income customers. Many of them have fewer energy consuming appliances than higher income consumers, for example, and they live in smaller homes. At least two important questions arise with smart grid and lower income consumers.

1. Will lower income consumers respond to dynamic rate structures – and therefore will they be able to reduce their energy usage and energy bills even at the times when critical peak rates are at their highest?
    a. It appears that although lower income consumers of energy do not respond to critical peak pricing and other similar rate structures to the same degree as do higher income and higher usage customers, that they still do respond at approximately the same rate as a typical customer. Results of a study in California show that lower income consumers (defined as a family with an income of less than $40,000/year) reduced their energy usage by 11-12% and their bills by 4%.[xii]

2. If energy rates rise as a result of smart grid installations, will lower income consumers be disadvantaged to a greater degree?
    a. This is an issue that regulators and other state officials will need to explore in the context of broader lower income programs, perhaps considering ways to divert some overall savings to assist lower income consumers with higher bills that may result from any bill rider added to pay for a large scale adoption of smart meters.

Who will have access to the information that the Smart Grid generates?

The tremendous amount of data about consumer energy usage that the smart grid will generate will undoubtedly raise issues of privacy of information, and questions about who should be able to have access that information. This will be an important topic for regulators and other officials to address both in terms of security of information as well as for competitive reasons – such information about customer usage could be very valuable to a third party energy efficiency service provider, for example.

APPENDIX: SMART GRID TECHNOLOGY CATEGORIES

Distributed Generation

Distributed generation is decentralized, small scale electricity generation - largely composed of renewable technologies such as residential solar panels - that inject power into the distribution grid. When these sources add additional power to a traditional transmission system, the system is not able to monitor and control the new input. Negative consequences include impact on upstream transmission reliability, impact on the operation and maintenance of the distribution equipment and compromised worker safety.

A smart grid can help address these technical issues by allowing distribution lines to accommodate more generation without impacting overall grid reliability and safety. Distributors are investigating cost-effective solutions that allow for increased monitoring of generation and equipment condition, and may involve the ability to limit the output of certain generators on occasion.

Storage

Storage can be used to capture energy that would otherwise go unused at the time of its generation and make it available to meet peak demand. Storage can be used to address the variable output of renewables such as wind and solar and moderate price differentials by storing off-peak energy and providing it on-peak.

In addition, storage can provide ancillary services such as load following, area regulation and black start capability and may also be used for grid stabilization. On the distribution system, storage can be used to defer investment in substations and can also be used to improve local area reliability.

Several technologies have the potential to provide storage including: conventional lead acid batteries, advanced batteries, flywheels, pumped generation storage (PGS), compressed air storage and superconducting magnetic energy storage (SMES).

Demand Response

Demand Response (DR) is a mechanism used to encourage changes in the timing of electricity consumption to better meet supply conditions. DR employs market pricing and consumer cooperation to promote load shedding during peak periods and increase demand during times of high production. DR can also involve actually curtailing power used or by starting on site generation.

DR can provide significant benefits to the electricity system by reducing the use of expensive peak generation and making better use of variable generation sources when they are available.

Transmission

Transmission lines are designed to efficiently move large volumes of electricity from power plants to substations. The transmission grid in the United States was not constructed as a smart grid in that it does not currently incorporate smart sensors to identify system failures nor are transmission system operations now designed to optimally integrate intermittent renewable resources or smaller scale distributed resources. As older equipment is replaced more smart grid technologies will be incorporated, resulting in a more sophisticated, reliable, efficient and flexible system.

Electric Vehicles

The potential adoption of electric vehicles (Eves) and plug-in hybrid electric vehicles (PHEVs) presents challenges and opportunities for the electric grid system. Where there is a high concentration of consumers charging vehicles at their homes and workplaces, a significant new load is created. The infrastructure could be adversely impacted in any area along the grid including: building wiring, transformers, lines and substation equipment and local distribution equipment.

The traditional grid systems may serve as a barrier to the widespread acceptance of electric vehicles. Since charging EVs can require up to eight hours, the extent to which this new demand can be managed solely through prices or other controls is questionable. The regional energy supply can be affected and additional peaking generation resources may be required.

On the other hand, smart grids can employ sensing, communications and computer analytics technology to accommodate EV charging in a flexible, cost-efficient manner - maximizing the use of available generation resources and minimizing peak demand. For example, a smart grid would make staged charging feasible. In addition, sensing technology can potentially be utilized to track the cost of charging vehicles from various locations and incorporate that cost into customers' utility bills.

Furthermore, smart grid technology provides the exciting possibility of employing electric vehicle batteries as widely dispersed storage for use during peak demand. Of course, using EV batteries for storage is complicated by the mobility of the vehicles and the vehicle owners' competing demand for fully charged batteries.

Endnotes

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