# Interoperability Lessons from Ongoing Residential Smart Grid Deployments

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## Abstract

This paper presents three residential smart grid programs currently being deployed across the U.S. and discusses some of the interoperability challenges involved in each program. All three programs test the efficacy of residential dynamic pricing strategies combined with different technology configurations.

The first pilot program leverages customer-provided broadband and HAN equipment to interoperate with an existing automated meter reading (AMR) system. The deployment provides much of the functionality of advanced metering infrastructure (AMI**)** but without the full investment or risk of stranded costs.

The second pilot program tests five pilot customer groups with a mix of interoperability configurations. Customer broadband communications will be compared to AMI-backhaul for providing load control and customer information.

The third program discussed is one of Xcel Energy's *Smart Grid City* programs in Boulder, Colorado. This paper looks at the interoperability challenges for this program from the perspective of a program participant.

The results from these evaluations, and others occurring around the country, will help select and value the most beneficial smart grid approaches and technologies for future investment.


## 1. INTRODUCTION

This paper discusses three residential smart grid pilots currently being deployed by North American utilities and presents interoperability lessons being learned from each. The paper examines some data collection and analysis challenges and also anecdotally discusses some of the customer-side interoperability issues observed first hand. All three programs represent multi-year smart grid deployments with state-of-the-practice technology.

The first pilot program leverages customer-provided broadband with Zigbee and ERT[1] radios to interoperate with an existing automated meter reading (AMR) system. The deployment provides much of the functionality of advanced metering infrastructure (AMI**)** but without the full investment or risk of stranded costs. A central objective of the pilot is to enable residential dynamic pricing (time-of-use and critical peak rates/rebates) and two-way direct load control.

The second pilot program tests five pilot customer groups with a mix of interoperability configurations. Customer broadband communications will be compared to AMI-backhaul for providing load control and customer information.

Both of these pilot programs have *technology interoperability* assessment as a key aspect of their regulatory evaluations, in addition to the more traditional *process* and *impact* evaluations. This paper reviews the various test (or "treatment") groups, the technology configurations, and some of the initial interoperability issues that are being encountered.

The third program discussed is one of Xcel Energy's *Smart Grid City* programs in Boulder, Colorado. This paper looks at the interoperability challenges for this program from the perspective of a program participant.

The authors serve as evaluators for a number of utility programs and pilots, including several programs trialing residential smart grid technology options and pricing plans. Two of the case examples provided below are currently being evaluated, however the names of the utilities and

[1] Itron® ERT™ radio

vendors involved have not been used due to the ongoing and preliminary nature of the information discussed. The third example is provided from the perspective of a program participant, and so information provided to participants, such as specific vendor information available to consumers, has been used.

Each of the next three sections discusses one of these three programs.

## 2. UPGRADING AN EXISTING AMR SYSTEM

An East Coast Investor Owned Utility (IOU) is undertaking a multi-year residential pilot to examine the feasibility of upgrading their existing drive-by AMR system using smart grid technology. One of the goals of the pilot is to enable the AMR system with many of the capabilities of newer AMI systems, but at a much lower installed cost.

This program will help validate key technology interoperability objectives, including verifying that:

1. automated load management can be achieved using existing AMR infrastructure and
2. customer broadband can be successfully used for two-way communications.

This pilot will also help the utility meet state statutory requirements to examine real-time measurement and communication of energy consumption, as well as the use of automated load management. The goal is to help meet load reduction targets, which include reduction of system peak and average loads, by a minimum of 5 percent for participating customers.

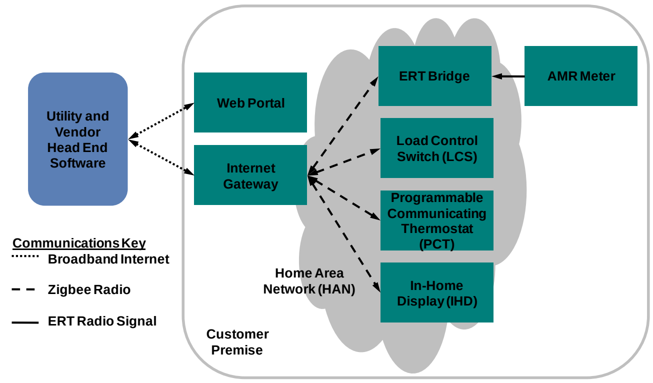
### 2.1. Technology Configuration

The existing AMR metering system leverages a low-power radio in each meter to send out the household consumption level. These meters, like many AMR meters, use an ERT type radio, which is a 900 megahertz (MHz) radio signal that can be picked up for several hundred feet in almost any direction. The AMR radio system "chirps" a signal every few seconds that contains household consumption information, as well as other information like meter identifying information. This information has previously been collected by drive-by tracks and captured for billing purposes.

A key component to this smart grid pilot is an ERT radio bridge that can be installed in the home to pick up and translate the ERT signal from the meter, so the signal can be received by the Home Area Networking (HAN) equipment.

The ERT bridge and other components of the technology system being used in this pilot are shown in Figure 1. The HAN uses Zigbee radio to communicate with a variety of devices in the home. One of these devices is an Internet gateway, which communicates via Zigbee radio and also connects to the participant's broadband Internet connection to allow Internet connectivity for all HAN attached devices.

**Figure 1:** System Technology Components




Other HAN devices include the In-Home Display (IHD), Programmable Communicating Thermostat (PCT), and Load Control Switch (LCS). These devices provide energy information to the participant, interface directly with the energy-consuming devices, and can be used in various combinations to provide different consumer experiences and load-control capabilities.

Connectivity to operational controls (e.g., demand response event generation, peak-price alerts, etc.) is provided through the customer-supplied broadband as shown in Figure 1.

Operational control of the system is provided via a vendor head-end at a hosted data-center, which in turn is integrated with some of the utility back-office systems and operations. Since this program is a pilot and, in its current form, is not planned to be rolled out to the broader service territory, back-office systems integration has been kept to a minimum (e.g., with no direct Customer Information System (CIS) integration) to avoid risk to production operations and systems.

### 2.2. Upgraded AMR to AMI Functionality Comparison

Once operational, the upgraded AMR system is expected to provide much of the functionality typically seen in advanced AMI systems. Figure 2 shows a comparison of expected functionality in the smart grid-enabled AMR system versus that of a typical AMI system.

**Figure 2:** Upgraded AMR vs. AMI Functionality

| Description | AMI w/HAN | Upgraded AMR w/HAN |
|---|---|---|
| Interval Data | X | X |
| Customer Information | X | X |
| Direct Load Control | X | X |
| Temperature Setbacks | X | X |
| Remote Upgrades | X | X |
| Revenue Protection | X | X* |
| Meter Diagnostics | X | X* |
| Remote Disconnect | X | |
| Automated Outage Reporting | X | X** |

*Interval data can be used to determine some level of revenue protection and meter diagnostics. **Future enhancement proposed.

Source: Based on assessments by utility's engineering team, third-party vendor, and Summit Blue/Navigant and UISOL.

Based on this initial comparison, the AMR system should provide almost all the functionality of an AMI system, with the notable exception of remote disconnect.

### 2.3. Experimental Design

The utility has defined four different experimental treatment groups to examine combinations of technology and pricing plan approaches. These groups are shown in Figure 3 below.

**Figure 3:** AMR-Based Dynamic Pricing Treatment Groups

| # | Treatment Group | AC Load Control? | Target Enrollment |
|---|---|---|---|
| 1 | TOU Rate plus Critical Peak Pricing (CPP) | | 700 |
| 2 | | X | 700 |
| 3 | Critical Peak Rebate | X | 700 |
| 4 | Technology-Only | | 700 |
| 5 | Control Group | | 250 |
| | **Total** | | **3,050** |

Note: All groups except the control group will receive an Internet gateway and an in-home energy display.

Results from groups 1-4 will allow examination of both energy and demand impacts of the technology, when contrasted with the Control group.

### 2.4. Interoperability Issues and Challenges

Even in the initial stages of this pilot, several interoperability issues and challenges have arisen that are interesting and may be instructive for other residential smart grid programs.

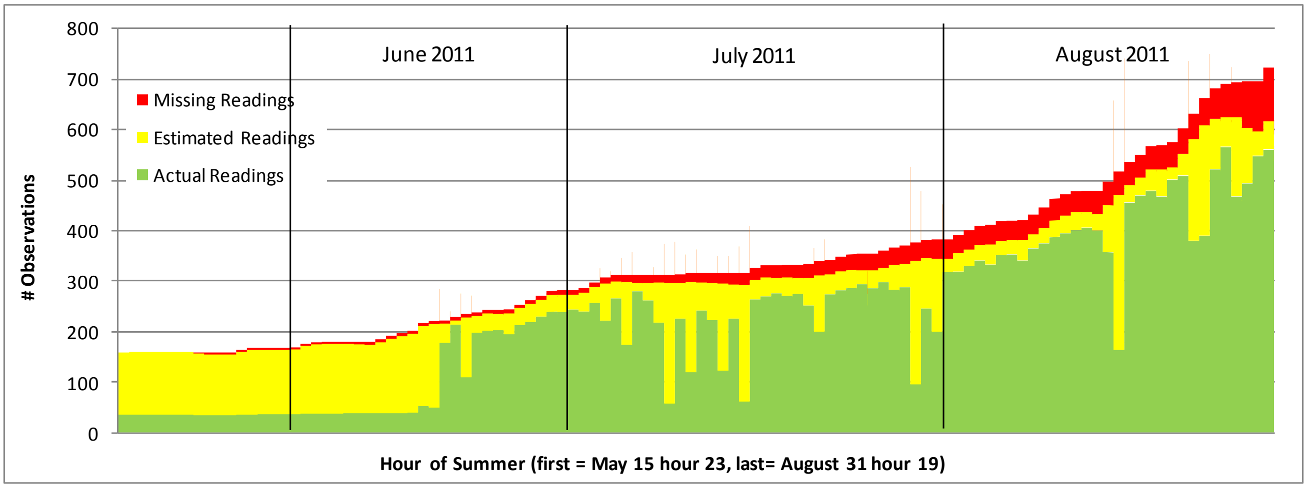
The utility must first integrate a variety of back-end systems, such as CIS, Information Technology (IT), and information exchanges with third-party vendors. Given the testing-focused nature of the pilot, integration at various interface points has been done in an expedient fashion (e.g., batch file transfer and some manual processes), which are adequate for the pilot, but which would be difficult to scale up for a full rollout. This is a limitation on the testing of solution scalability, but one that is understandable.

The information required to understand and evaluate the overall technical solution must be integrated from a number of sources, including installation data from installer systems, vendor data from head-end and other sources, load-research (i.e., Loadstar) data for the control group, billing data from the CIS system, customer service system information from the call center, technical support/service line information, and problem tracking system data. Setting up methods to collect and analyze all of this data can be a difficult and labor-intensive process, but is a critical step for successful evaluations.

For a variety of reasons, some of the information that would be very useful for some aspects of program evaluation cannot be made available, even though smart grid solutions hold potential for providing this type of information. For example, while customer response could theoretically be measured by collecting customer thermostat readings, the current software release does not support collecting this type of information. Similarly, while the utility can roughly assess the success and health of the HAN by tracking how frequently the HAN is not properly transmitting data, the vendor systems in place are unable to identify *why* the HAN is not functioning. Going forward, this information will be useful for utilities to help determine whether the HAN is offline due to customer broadband issues, the customer unplugging the gateway device, a malfunctioning gateway device, etc.

Such challenges can typically be overcome through upfront collaborative efforts between the utility, evaluator, and third-parties to yield useful analysis of the technology performance and program effectiveness. Once this is done, it is possible to start evaluating system performance and effectiveness. For example, Figure 4 shows the proportion of interval reads actually collected from the system as enrollment grows, along with gaps estimated by the VEE (validation, estimation and editing) process and data that is still missing after this process takes place.

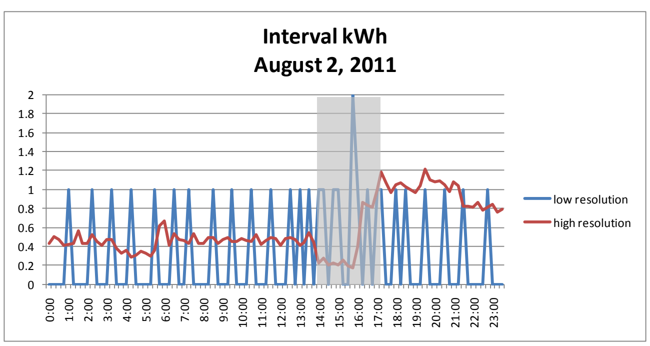
**Figure 4:** Data Collection




The data shown above is preliminary and is still being examined, but it seems to show points of system outages where information from a large number of households is not collected and must be estimated. Also, some portion of the missing data is from other causes (e.g., participant drop outs) that have not been separately identified in the figure.

Another interesting, if not entirely unanticipated, result from the analysis shows a clear difference between two types of ERT meters. Figure 5 below shows a set of meters with 1kWh (low) resolution and another with 10Wh (high) resolution. The low resolution shows spikes of either 0, 1, or 2kWh in the 15 minute interval where the counter has accumulated a full kWh. The higher resolution meters show a smoother graph as they are able to account for energy usage at much higher granularity.

**Figure 5:** Comparison of Low and High Resolution ERT Meters




This difference, although not critical to standard AMR systems used to collect billing data, needs to be carefully examined to see if it presents problems for time of use and variable rate pricing plans. It is also being examined for how it affects the impact analysis, which will be required to show system effectiveness for demand management.

The challenges discussed above are simple examples of interoperability issues, amongst numerous potential issues for any project, and can impact operation and use of a new technology system.

## 3. ALTERNATE TECHNOLOGY APPROACHES TO MEETING DEMAND-SIDE TARGETS

A Western IOU is undertaking a multi-year residential smart grid pilot to examine different technology options for meeting their Energy Efficiency (EE) and Demand Side Management (DSM) targets. The targets have been established by the state regulatory commission, and the IOU has decided to pilot test several technology combinations to help establish an approach that can be rolled out on a broader scale to help meet these targets.

### 3.1. Technology Configurations

The technology configurations have been constructed to test alternate approaches to several of the key architectural elements:

- Customer broadband vs. AMI communications
- Vendor A vs. Vendor B IHD options
- Vendor A vs. Vendor B PCT options
- Pricing options to provide the incentive for time-shifting of consumer loads

### 3.2. Experimental Design

The IOU has constructed the pilot groups shown in Figure 6 to test the different technology configurations and pricing options of interest.

**Figure 6:** Pilot Groups with Technology Options

| # | Group Description | Equipment | Target Enroll-ment |
|---|---|---|---|
| 1 | CPP with Customer Energy Control Device | Vendor A PCT:AMI vs. Vendor B PCT: BBand | 300 |
| 2 | In-Home Energy Information Display | Vendor A IHD: AMI vs. Vendor B IHD: AMI | 300 |
| 3 | Direct Load Control | Vendor A PCT:AMI vs. Vendor B PCT: BBand | 300 |
| 4 | Smart Phone or PDA App | Home gateway: BBand | 300 |
| | **Total** | | **1,200** |

The experimental design allows sufficient enrollment sample size to do statistical analysis on the load impacts, as well as provide a fairly clear understanding of reliability and operational issues.

### 3.3. Interoperability Lessons

The structure and organization of this pilot within the utility has proceeded in an efficient manner. However, in this case, interoperability issues outside the control of the utility have necessitated a delay in the program rollout. Software release delays from at least two of the vendors have pushed out the rollout beyond the summer 2011 season.

This is a similar lesson learned at other residential smart grid rollouts: vendor system software release delays (in each case from an entirely different set of vendors) can cause the entire program schedule to slip.

In this case, as with the first pilot case described, integration with production systems has been carefully limited to avoid risk to production operations. As mentioned previously, this prevents these pilots from testing certain aspects of system integration and scalability.

Given program delays with this risk limitation, it seems likely that larger rollout efforts, which at some point will require integration of the new smart grid technology into existing production systems, will encounter other types of delays due to these additional systems integration requirements.

## 4. PARALLEL METERING FOR RESIDENTIAL SMART GRID

Xcel Energy has invested in a wide range of smart grid technology, including distribution automation, AMI infrastructure and various in-home technologies, as well as new rate plans, all of which are being trialed in Boulder, Colorado under the marketing name *Smart Grid City*.

One of the programs offered to residents, called the *In-Home Device Program*, offers a combination of devices for “qualifying customers.” This offering is interesting in that it uses a metering technique outside the actual revenue meter on a residence, which in this case is an AMI meter, to provide better real-time (or near-real-time) information to the participant.

### 4.1. Technology Configuration

The in-home technology provided as part of the program includes the following devices:

- In-home display (Energy Hub “Home Base”)
- Wireless Programmable Thermostat (Honeywell)
- Two Appliance Sockets (Energy Hub)
- Wireless Current Transformer (CT) Sensor (Energy Hub)

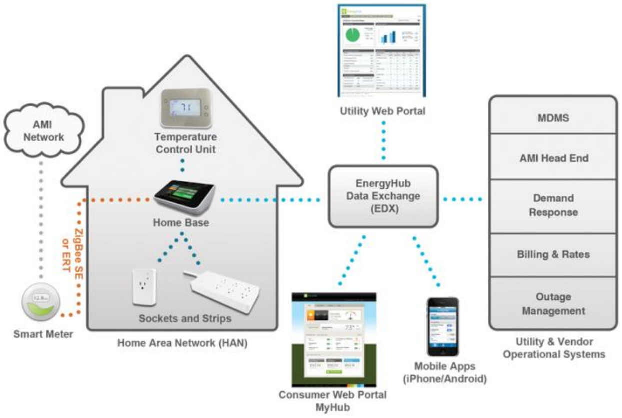
The topology of the various in-home devices is shown in Figure 6 below.

These devices communicate to each other using ZigBee radios and Smart Energy Profile (SEP). The customers’ ZigBee-enabled AMI meter can also participate in the HAN, so that meter readings can be sent real-time to the IHD and information or events sent on the AMI network can also be directly conveyed to the customer via this connection.[2]

The IHD also contains a WiFi radio that allows it to connect to customer broadband. This provides a second communication path that can be leveraged by the utility, and possibly by other service providers serving the customer or the utility. Of course, this communication path is typically capable of much higher bandwidth than an AMI connection, so more information and real-time signaling can potentially be conveyed via this communication path.

[2] The manufacturers’ literature shows the IHD communicating with a meter that uses Itron ERT protocol as part of an AMR implementation, so this system should be able to provide similar functionality to that described in the first pilot example.

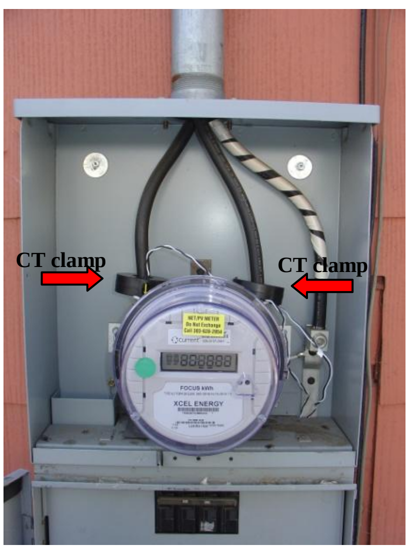
**Figure 6:** In-Home Network Configuration[3]

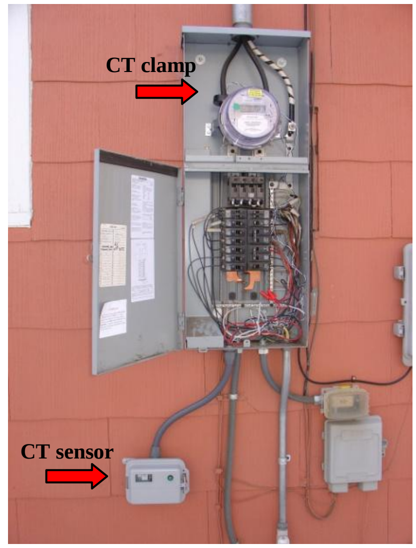



The key component that allows near real-time information to be provided to the customer is the wireless CT sensor shown in Figure 7.

This sensor interfaces to the consumers' electrical power lines and enables energy consumption readings to be made and transmitted to the IHD in near real-time for the consumer.

**Figure 7:** Wireless CT Sensor




These CT clamps and attached device must be professionally installed by a licensed electrician, which is a heavy cost burden. However, it provides quicker feedback to the customer and provides energy consumption information that is more granular and available more quickly than what many AMI meters can provide.

The sensor provides independent metering of the customers' power consumption, which makes this technology configuration different from many other implementations that rely on the AMI meter to provide consumption information.

While it does duplicate some of the metering functionality of the AMI meter, it has the advantage that it does not have to be deployed on an AMI metered home, but can be installed in virtually any type of meter.

The real-time capability of the CT device is actually a key aspect to consumer engagement, in that it allows real-time feedback to be displayed as the consumer turns on and off different devices in the home. This provides a much richer understanding of home consumption than 15-minute meter interval data that has been delayed by a day as it passes through the utility back-office systems, as is done with many implementations.

The Energy Hub "Home Base" IHD, shown in Figure 8, serves as a wireless network translator between a consumer's WiFi network, which provides Internet connectivity, and a ZigBee SEP-enabled meter. It also provides a ZigBee communications node to enhance device connectivity in the HAN.

[3] This figure is sourced from the vendor's web site at: http://www.energyhub.com/utilities/han/

**Figure 8:** Energy Hub "Home Base" In-Home Display


This device has a capable and responsive user interface that allows fairly easy control and programming of the other home devices. Ease-of-use is an important aspect of consumer behavior change relative to energy consumption, which is of course one of the key goals for any utility program that is spending money on such devices.

These devices allow selected household loads to be plugged in (see Figure 9) and controlled remotely via the HAN connectivity.

**Figure 9:** Load Control Socket

Figure 10 shows a home appliance plugged into a load control socket. The power to this dishwasher can be turned on or off, or programmed to be on only during low periods in a time-of-use electricity rate. Programming can be done from anywhere with an Internet connection by logging into the customer web portal and changing the settings.

Appliances like this one can be turned into virtual "smart appliances" by this configuration. Ironically, some older appliances like this dishwasher, which do not have on-board smart circuitry, etc., are simpler to control this way and have fewer problems with devices like the integrated clocks and internal timers and sensors that are used on more up-to-date, ENERGY STAR® appliances; although the older appliances are still less energy efficient overall.

Customers are also given the option to allow the load control sockets to participate in load shed events. If the customer chooses this option the socket will be turned off for the duration of load shed events.

**Figure 10:** Dishwasher Plugged into Load Control Socket

Figure 10 shows the web interface to the wireless programmable thermostat. This allows the customer to view and change the set point and setback programming from any web interface. The web interface is considerably easier to use than the digital programming interfaces on some programmable thermostats.

**Figure 10**: Near Real-Time Feedback from the Web Interface

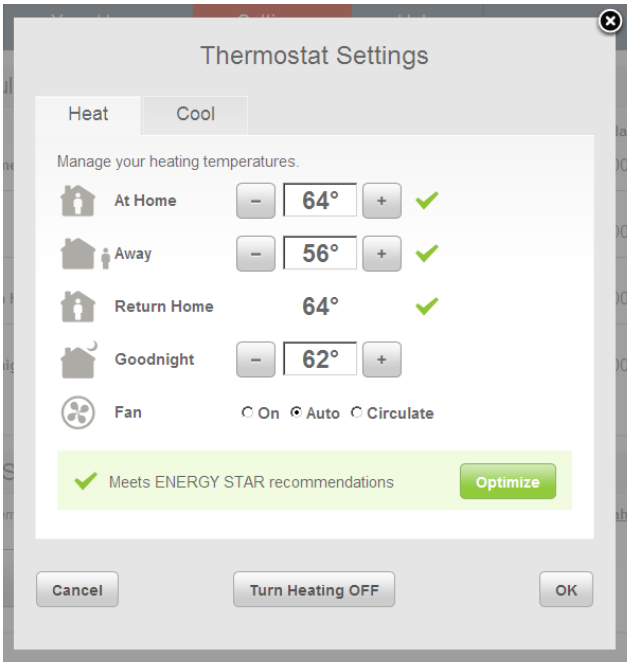



Figure 11 shows the granularity of 15 minute interval consumption that is available from the system, while Figure 12 shows more granular consumption information available to examine the effects of turning on and off certain appliances.

**Figure 11:** Display of Home Consumption Intervals

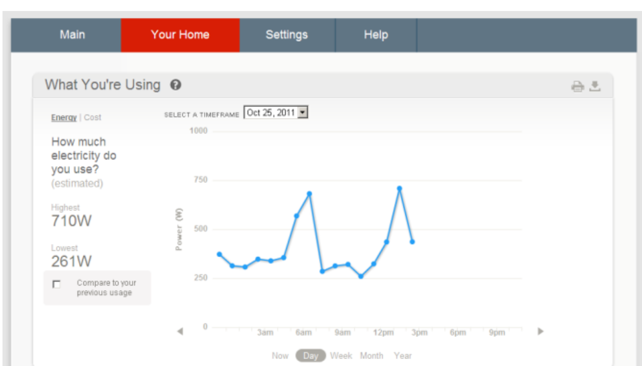
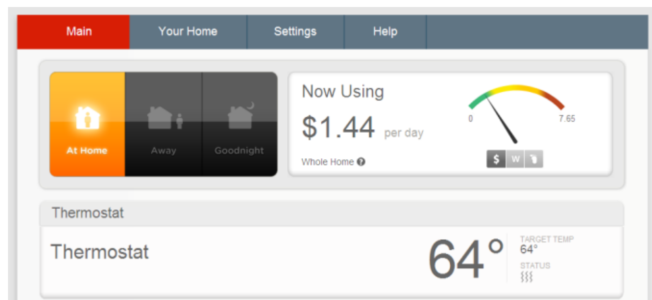



**Figure 12:** Granular Display of Home Consumption


Figure 13 shows a summary screen on the system web interface.

**Figure 13**: Enabling Behavior Change




Remote and convenient programming of thermostats, real-time information, and access to key household energy information in a concise and elegant format might be a key to behavior change that can finally change behavior to significantly impact energy use.

### 4.2. Installation Discussion

Key issues with interoperability and considerations for this technology approach can be gleaned from an example of one participant's installation experience, including observations by and about the installer: The installation required a licensed electrician who must also be IT and Heating, Ventilation, and Air Conditioning (HVAC) savvy. Specifically, the installation required support calls regarding software updates via the wireless network to the IHD, which took 45 minutes, and wiring of the programmable thermostat. The Energy Hub equipment must recognize and correctly configure to any number of wireless routers found in participant homes.

In the case of Boulder, the municipality required the electricians on site to verify that every house was properly grounded—despite the Energy Hub equipment having no bearing on the grounding of the house. All of this upfront work coupled with the actual installation of the Wireless Programmable Thermostat, Wireless CT Sensor, CT clamps, and programming of the IHD allowed the installer to complete two installations a day at best.

The complexity of the installation presented numerous walk-away opportunities throughout the entire process. Customer equipment issues included a non-functioning furnace or AC unit, improperly grounded breaker panel, no common wire for the wireless programmable thermostat, no one-to-one ratio of cooling thermostats to outside AC compressors, and a non-functioning or inaccessible wireless network.

The IHD had its own technical requirements including recognizing the router in the home (not all are recognized), access to the customer's Wi-Fi SSID and password, a visible (not hidden) SSID, and a requirement of five or fewer reboots of the IHD during the installation process (the installer noted reboots happened frequently). All of these potential issues were cause for a walk-away.

Installation time restraints caused the customer to be asked to program At Home, Away, Return, and Goodnight times and temperatures into the thermostat including a 5-degree temperature offset to be utilized during load shed events, and to identify the two outlets to control and the appliances to be controlled by each.

Before the installation was complete, the customer was required to reply to an automated email with instructions to create an Xcel Energy/Energy Hub online account to monitor energy and control home energy use via the internet. Further system functionality training was left to the customer due to the limited time the installation technician had in the home.

### 4.3. Program Economics

Participation in the program is advertized as a "$1200 value," which includes a number of devices that can be used in the home, as well as system installation that requires an electrician as well as someone capable of replacing a thermostat. A price point this high is impractical for broad deployment of most residential programs.

## 5. CONCLUDING THOUGHTS

The three examples discussed here lead to the conclusion that interoperability of these new systems is hugely challenging. This issue is true even for these pilot programs that have not reached the point of production rollout and are not necessarily integrating directly with a utility's key production systems yet (e.g., CIS, DMS, etc.).

A few key takeaways include:

- Interoperability between systems that were not originally envisioned to interoperate can present unanticipated challenges, not just in operation, but in data availability, resolution, and format.
- Delays in key vendor delivery dates can jeopardize the entire program schedule. This includes hardware availability in volume, software release testing schedules and availability, and potentially other issues.
- Back-office systems integration is substantial, even if not all production systems are being integrated. Interoperability has to be designed manually in many cases, and via batch and file transfer processes initially (which are not necessarily as robust as would be desirable).
- Municipality engagement is a possibility and can add to program cost and schedule.
- Some installations require technicians educated in multiple disciplines (electric, HVAC, and IT) or supported real-time by remote experts.
- Heavy reliance on technology, customer wireless networks for instance, introduces numerous walk away opportunities and limit wide spread participation.
- Highly capable and interesting systems may end up being much more expensive than AMI alone.

These three examples provide a snap-shot of the state of the practice in residential smart grid today. The next few years should see enormous advances and lessons learned from across the country.

### Biography

**Erik Gilbert** is an Associate Director with Navigant Consulting Inc.'s (Navigant's) Energy Practice. His focus is on smart grid and demand response program analysis and technology strategy, including cost-benefit assessment. Mr. Gilbert has over twenty years of experience in developing and managing complex products and market programs as well as performing program evaluations and assessments.

Prior to joining Navigant, Mr. Gilbert served as Director of smart-energy products for residential energy management system vendor Tendril Networks, Inc., where he defined and executed their hardware roadmap, including in-home energy displays, IP-to-HAN gateways, AMR/ERT-to-ZigBee bridges, and other products.

Previously, Mr. Gilbert held various management positions at Internet infrastructure provider Cisco Systems, Inc., as well as several years of technology strategy development with Ernst & Young Management Consulting. Mr. Gilbert began his career as a design engineer. He holds a B.S. in Electrical Engineering and Computer Science from the Massachusetts Institute of Technology and an M.B.A. in Marketing from the University of California at Berkeley.

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**Robin Maslowski** is a Senior Consultant with Navigant in Boulder, CO. Her current and previous engagements include developing a regional business case for smart grid deployment in the Pacific Northwest; building tools in an Analytica modeling platform to assist utilities with smart grid cost-benefit analysis and demand response potential modeling; assessing the market transformation effects of utility programs for a variety of markets; and providing support for the evaluation efforts and reporting requirements of American Recovery and Reinvestment Act (ARRA) smart grid grant recipients. Ms. Maslowski's other areas of expertise include demand-side management program evaluation, research on emerging energy-related technologies, quantification of energy efficiency measure costs and savings, survey analysis, and other engineering analysis work. She earned a B.S. in Mechanical Engineering from the Franklin W. Olin College of Engineering in Needham, MA and received her Engineer-In-Training certification in Spring 2010.

**Stuart Schare** is a Director with Navigant Consulting and formerly the Practice Area Lead in Smart Grid, Demand Response, and Pricing at Summit Blue Consulting, LLC prior to the firm's acquisition in December 2009. Mr. Schare began his career in the electric industry in 1991 and has since served in a variety of positions at government entities, trade associations and other not-for-profit organizations, and energy consulting firms. His recent efforts have focused on evaluation and design of utility energy efficiency, demand response, and innovative pricing programs. In 2002, Mr. Schare founded the Rocky Mountain Chapter of the Association of Energy Services Professionals International (AESP), and he serves as Vice Chair of AESP's Pricing and Demand Response Committee. He was recently appointed to the Board of the Peak Load Management Alliance (PLMA) and was elected as a member of PLMA's Executive Committee. Prior to joining Summit Blue in 2002, Mr. Schare spent four years as a consultant with PA Consulting Group and its predecessor companies, including Hagler Bailly, Inc. He earned an M.S. in Environmental Science and a Master of Public Affairs from Indiana University in 1995, and he holds a B.A. from the University of California at Berkeley.