# AMI and Smart Meter Data: 100 Year Flood or Gold Mine?

*Jan Harris, Pace Goodman and Erik Gilbert, Navigant Consulting Inc.*


## ABSTRACT

Smart Meters are being deployed by the millions across the country and the globe. These devices are generating enormous volumes of information. Effectively utilizing this information presents challenges and opportunities. With the application of the right data management and analytics techniques, this information can be used to:

- Identify opportunities for energy efficiency, such as targeting customers with specific energy signatures
- Provide near real-time feedback on Demand Side Management (DSM) and Demand Response program effectiveness
- Test program designs and communications strategies
- Identify specific geographic areas with concentrations of peak coincident loads

Interval data can provide a much more granular and timely view of a customer's load than traditional monthly meter reads. Applying analysis techniques throughout the year can provide insight into load profiles for various end uses. This information creates the opportunity for proactive marketing and targeting of specific DSM and DR programs.

Enhancing interval data with third party demographic information can enable detailed feedback of the effectiveness or reach of a DSM program or marketing message. Direct observation of consumption trends provides evidence of which approaches are resonating with specific customer segments.

Leveraging newly available tools, such as low-cost GIS software, can also provide unique insight into peak coincident load clusters. Targeting load reduction programs at these specific areas can help defer T&D upgrades.

To illustrate the growing potential, this paper will present real world examples of how some of this data is now being used.


## Introduction

Large scale data gathering and analytics is becoming a critical piece of all large business and the utility industry is no exception. Smart meters are being deployed by the millions across the country and the globe, generating huge amounts of data. Housing this data securely, ensuring its completeness, cleaning it and managing it are significant undertakings in and of themselves before even basic information can be gleaned from it. Much of this data is often never used and ends up merely being stored. Effectively utilizing this information presents its own challenges and opportunities. Interval data can provide a much more granular and timely view of a customer's load than traditional monthly meter reads. Applying analysis techniques throughout the year can provide numerous insights into load profiles for various end uses. When this data is enhanced, or "mashed up," with other sources of data such as customer demographics, and intelligent analysis and insights are applied, creative applications multiply. More creative uses for this data will undoubtedly continue to come to the fore as people continue to work with it. This paper will explore several creative applications that are being, or could be used today including:

1. Targeted demand side management program enhancements through smart meter data
2. Remote demand response program measurement and verification through smart meter data
3. Geo-targeted demand side management program enhancements through smart meter data
4. Near real-time feedback on Demand Side Management (DSM) program effectiveness through smart meter data

This paper aims to stimulate dialogue and thinking to continue movement toward wider and deeper energy savings across all customer classes.

## Targeted Demand Side Management Program Enhancements Through Smart Meter Data

Often DSM programs are marketed generically across customer segments. However, the energy savings from these programs are highly dependent on baseline conditions, such as furnace efficiencies, hours of lighting use, domestic hot water consumption and other conditions, which can vary greatly between customers. Thus, to increase the realized savings from energy efficiency and demand response rebate programs, energy providers can identify high impact customers (those with greatest potential for savings) through energy consumption data analysis and target them for DSM program participation through targeted marketing.

Established methods currently exist to target residential heating/cooling efficiency opportunities. Interval data can enhance those methods as well as expand the scope of targeting customers based on analysis of baseline energy use by enabling the following:

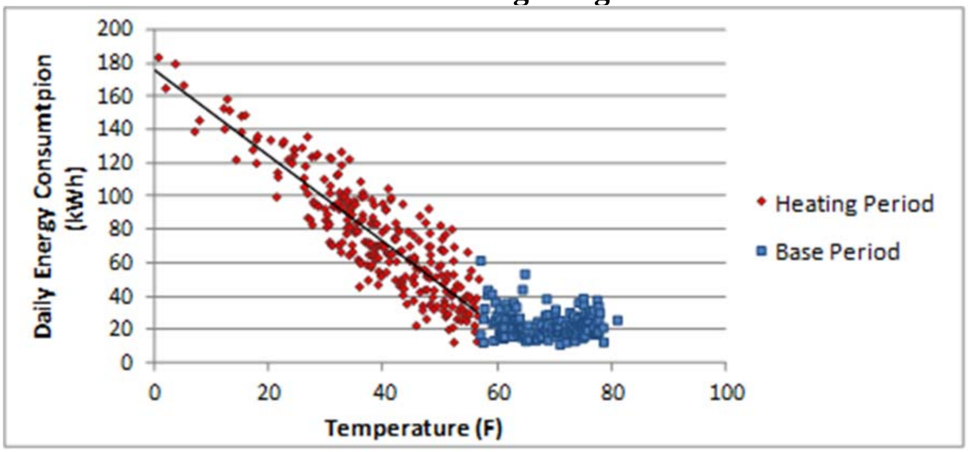
- Enhancing current methods to target residential heating/cooling efficiency opportunities:
  - Accurate results with shorter time periods of data
  - Estimating heating and cooling system capacities
  - Possibly differentiating between heating and cooling equipment inefficiency and building envelope inefficiency
- Expanding the scope of baseline-targeting:
  - Partial load disaggregation for unique end-uses (e.g. high equipment capacity, high reactive power consumption, etc.)

This section details a method to target heating/cooling efficiency opportunities as well as the benefits of interval data for overall baseline-targeted demand side management.

**Methods to Target Residential Heating/Cooling Efficiency Opportunities:**

The degree of weather dependent energy consumption for a customer can be analyzed by a customer's heat/cooling slope, their balance temperature and their base-load consumption. Although the following example is focused on an electric heating customer in a winter peaking utility, the concepts apply for customers with air conditioning who are served by summer peaking utilities as well.

**Figure 1. Typical Electric Energy Consumption for a Residence with Electric Heating and no Air Conditioning using Interval Data.**




When a residential customer uses electric (or natural gas) heating, their energy consumption generally follows a linear decrease in energy consumption as outdoor temperatures increase until a point where the outdoor temperatures are comfortable and there is no required heating energy (Figure 1). This trend can be evaluated using three primary variables, **heat slope**, **balance temperature**, and **base-load.** With these three variables, various customers' heating/cooling efficiencies can be compared in order to identify customers with the greatest potential savings.

- **Heat slope** refers to the linear change in energy consumption per change in outdoor temperature during the heating season. In Figure 1, heat slope appears as the slope of the linear regression of this customer's heating period (red data points).

$$HS = \frac{\Delta E}{\Delta T}$$

Where,

$HS$ = heat slope

$\Delta E$ = change in energy consumption during heating period (kWh)

$\Delta T$ = change in outdoor temperature during heating period (°F)

- The heating **balance temperature** (Tb) is the highest outdoor temperature at which a building requires heating. In Figure 1, the balance temperature occurs where the relationship between energy consumption and outdoor temperature flattens (approximately 58 $^{o}$F).

**Tb is such that:**

$$If\ t > T_b\ then\ \frac{\Delta E}{\Delta T} = 0$$
$$If\ t < T_b\ then\ \frac{\Delta E}{\Delta T} \neq 0$$

Where,

$t$ = outdoor temperature ($^{o}$F)

$T_b$ = balance temperature ($^{o}$F)

$\Delta E$ = change in energy consumption (kWh)

$\Delta T$ = change in outdoor temperature ($^{o}$F)

- **Base-load** is the average energy consumption independent of heating loads. In Figure 1, the base-load is the average energy consumption during the base period (blue data points).

$$BL = \frac{\sum E_{daily,t>Tb}}{\sum N_{days,t>Tb}}$$

Where,

$BL$ = weather independent energy consumption (kWh)

$E_{daily,t>Tb}$ = daily energy consumption where outdoor temperature is greater than balance temperature (kWh)

$N_{days,t>Tb}$ = number of days where outdoor temperature is greater than balance temperature

With these three energy metrics energy providers can identify customers with the greatest potential for savings from heating/cooling related energy efficiency programs. For heating related measures, these customers can be identified as those with high heat slopes (normalized by base-load) and high heating balance temperatures. For cooling related measures, these customers can be identified as those with high cooling slopes (normalized by base-load) and low cooling balance temperatures.

## Enhancing Current Methods to Target Residential Heating/Cooling Efficiency Opportunities with Interval Data

One of the primary benefits of using interval data is accurate results with shorter time periods of data. In certain cases longer periods of data are not available for a given customer. A customer may have moved recently, had an addition put on his/her home, or had any other number of issues that would alter energy consumption and affect the analysis. Using monthly data, these customers would have to be removed from the data sample. However, with interval data, accurate results can be pulled from limited available consumption data.

Another benefit is the identification of heating and cooling system capacities. Residences typically use a limited number of devices with electrical capacities in the same range as heating and cooling equipment. With interval data, the surge in consumption associated with these devices can be used to estimate the equipments' capacities.

Interval data may also enable energy providers to differentiate between heating and cooling equipment inefficiency and building envelope inefficiency using time lag. Basically, a significant change in outdoor temperature will cause a more immediate surge in energy consumption when the envelope is inefficient, whereas an efficient envelope will buffer the energy surge. This added level of detail can further improve targeted rebate program marketing.

### Expanding the Scope of Baseline-Targeting with Interval Data

Future iterations of smart meter technology may enable partial load disaggregation with easily stored real and reactive power monitoring at shorter time intervals. Using a method called Nonintrusive Load Monitoring (NILM), energy providers could partially disaggregate their peak, providing insights into what are the peak coincident end uses. This would create an even richer data set for DSM program implementers.

## Remote Demand Response Program Measurement and Verification through Smart Meter Data

This section reviews some of the new dimensions of Measurement & Verification (M&V) of demand response programs that are made possible by interval metering technology, as well as some of the accompanying challenges. Smart grid project evaluation requires new approaches to collecting, managing and analyzing the large volume of data that can be generated by smart grid technology. At the same time, new types of data provide the potential for rapid and powerful analyses and valuable new insights—for example, better understanding of customer behavior—that have not previously been possible.

This section uses real-world examples from ongoing utility smart grid pilot projects to illustrate various challenges and presents insights gained through analysis of smart grid generated data that has not been possible in the past.

### Upgrading an Existing Automated Meter Reading 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 Automated Meter Reading (AMR) system using smart grid technology. One goal of the pilot is to enable the AMR system with many of the capabilities of newer Advanced Metering Infrastructure (AMI) systems, but at a much lower installed cost.

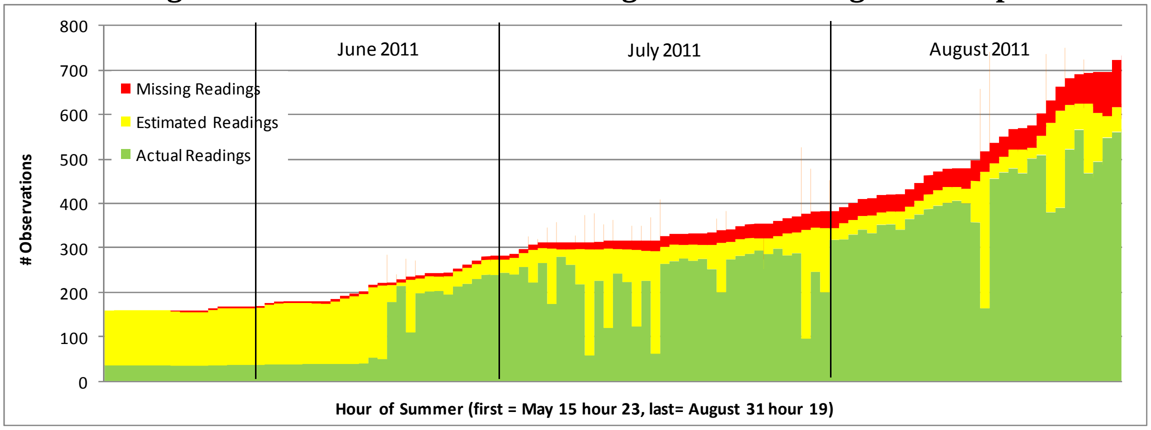
This program will help validate key technology objectives, including verifying that:

- Automated load management can be achieved using existing AMR infrastructure and
- Customer broadband can be successfully used for two-way communications.

One of the key questions was whether this system could retrieve interval data useful for billing and impact analysis. To understand the potential limitations of the system, interval data was constructed using the smart grid technology, and was analyzed to understand how it could be used for impact analysis.

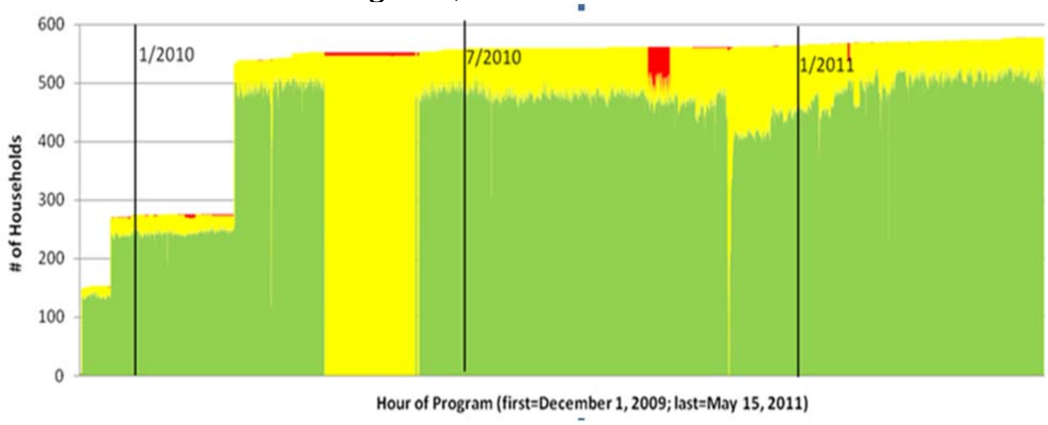
Figure 2 shows the proportion of interval[1] reads actually collected from the system as enrollment grows, along with gaps estimated by the VEE-like (Validation estimation and editing – a process used to estimate missing data - yellow) process and data that is still missing (red) after this process takes place.

**Figure 2. AMR Interval Data throughout Initial Program Ramp**




Although the data are still preliminary, the yellow vertical stripes in Figure 2 appear to show points of system outages where information from a large number of households is not collected and must be estimated. By contrast, a chart of more traditional AMI interval data, shown in Figure 3, which represents actual AMI meter data, looks similar to the enhanced AMR data above. So, the initial hypothesis that we should be able to leverage the AMR data for impact analysis seems reasonable.

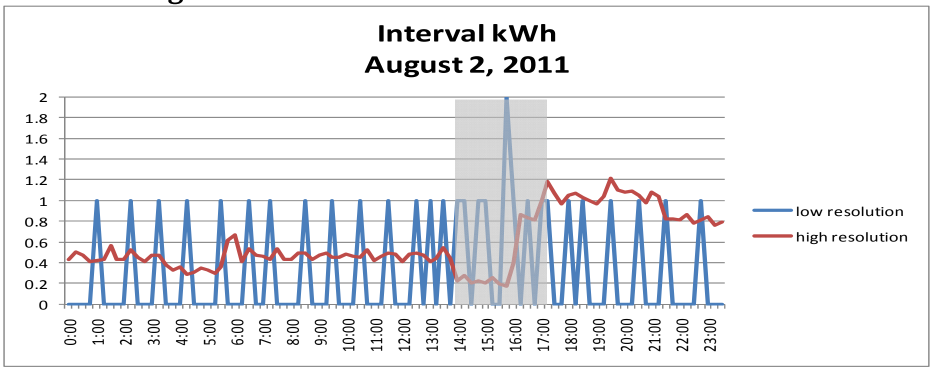
**Figure 3, AMI Meter Data**




[1] In this case "intervals" are constructed by the smart grid equipment using the nearest ERT meter consumption reading to each 15 minute interval boundary.

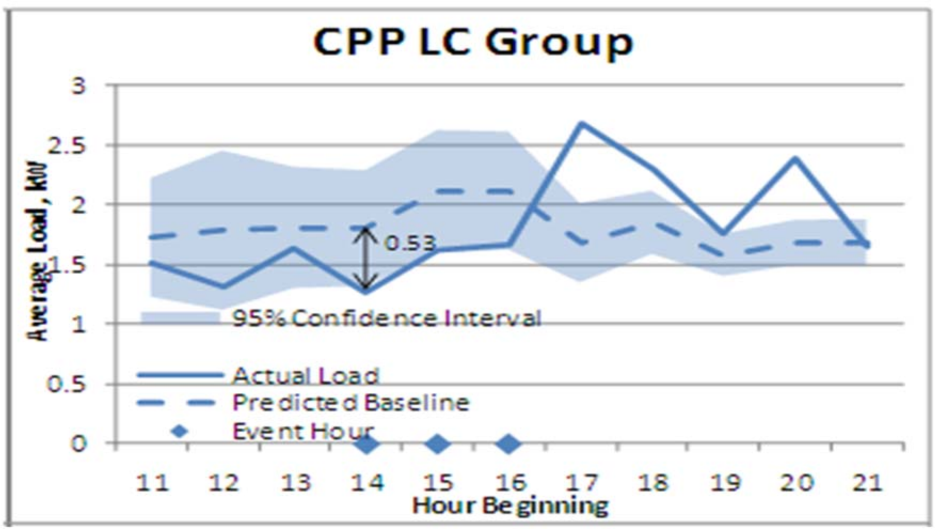
However, another issue discovered during the data analysis is that the AMR meters have two different resolutions for the information they provide, as shown in Figure 4.

**Figure 4. Resolution of AMR Meter Data**



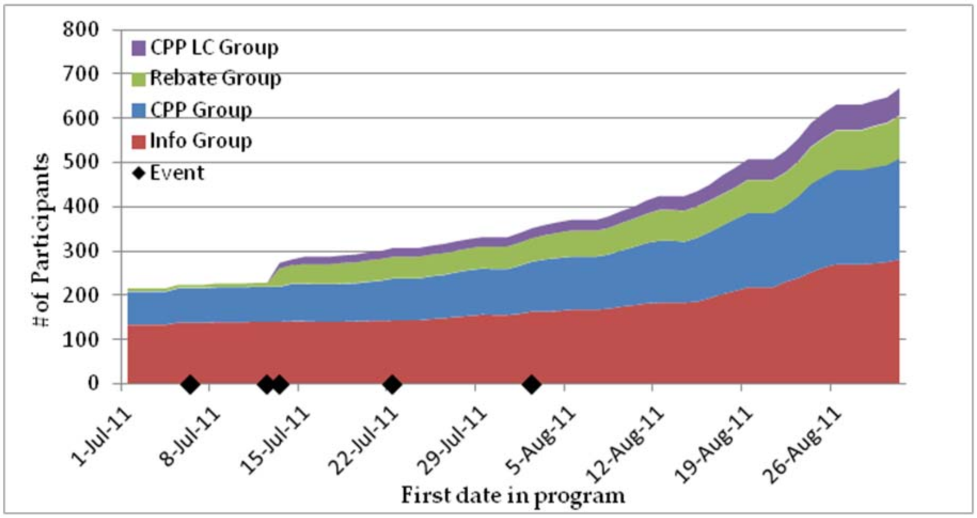

By adopting a slightly modified cleaning process, our econometrics group was able to leverage this data for impact analysis. Figure 5 shows the results of an initial load-event impact analysis with 95% confidence interval using this data. Some minor shortcomings of the data were successfully overcome to perform an hourly impact analysis.

**Figure 5. Event Impact Analysis**




Additionally, the data provided by the system can often be used for other purposes. Figure 6 shows initial program enrollment growing over a 3 month period, by program group. Information like this can be used to help analyze marketing program effectiveness, as well as track overall program progress.

**Figure 6. Program Enrollment by Group**




## Geo-Targeted Demand Side Management Program Enhancements through Smart Meter Data

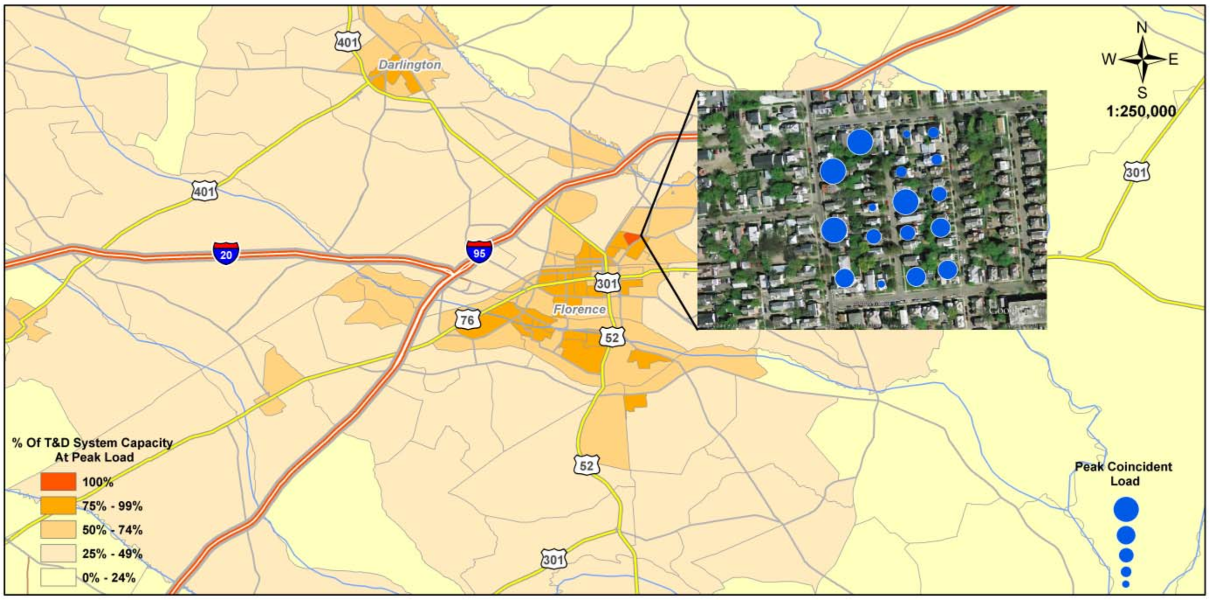
Energy data and analytics are also being used to optimize peak load management. When a utility's Transmission and Distribution (T&D) system is at or near capacity, expensive equipment upgrades are required. Concentrating energy efficiency or load management efforts in T&D constrained areas can defer the need for expensive upgrades.

Utilities identify areas in their transmission and distribution systems at the feeder zone level that are experiencing peak constraints. Once these geographic areas have been identified, data available from smart meters could allow for identification of specific premises with high peak coincidence within these geographic areas. Targeting demand response and or energy efficiency program outreach to specific end users within these geographic areas where the T&D system is at or near capacity during peak periods can defer the need for T&D upgrades as well as save energy and money for the customer.

Leveraging newly available tools, such as low-cost GIS software, allows for visual representation of consumption data that is easy to understand and digest. Such graphical representation of the data can provide unique insight into peak coincident load clusters. Targeting load shifting or load reduction programs at these specific areas can help enhance effectiveness of DSM efforts.

Figure 7 below shows how utility information regarding T&D constrained areas could be matched up with customer smart meter data to determine specific customers to target with DSM initiatives.

**Figure 7. Matching T&D Information with Customer Information**



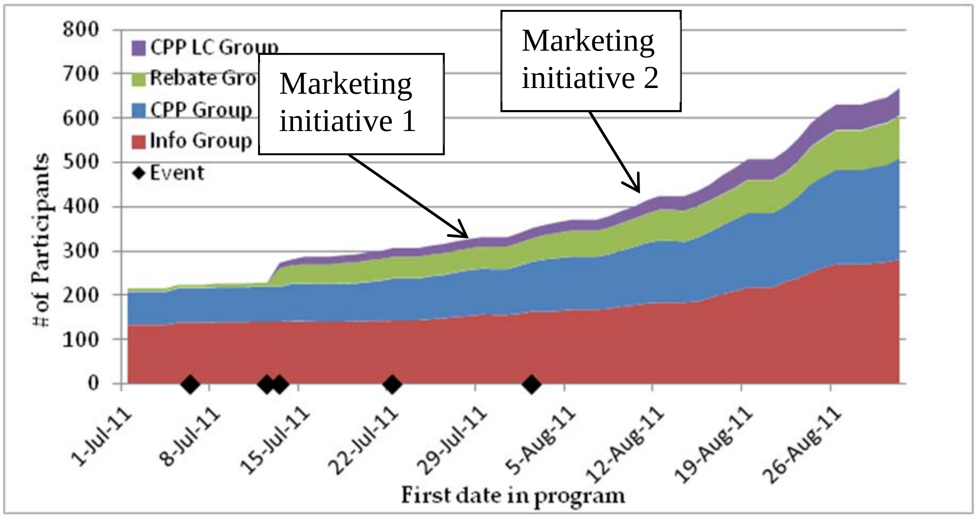

## Near Real-Time Feedback on Demand Side Management Program Effectiveness

There has been much backlash against installation of smart meters, and with good cause. Installing smart meters without employing them to add value to the customer experience makes them not so smart. Utility customers are not typically very engaged in their energy management. We as an industry need to figure out better ways to engage customers, and application of smart meter data can definitely help. It isn't *data* that will engage customers; it is insightful applications of data. Using AMI interval data and enhancing it with other available customer data can provide a rich and robust data set regarding customer's energy use, habits, and potential for realizing energy efficiency.

Enhancing interval data with third party demographic information can enable detailed feedback of the effectiveness and reach of a DSM program and/or marketing messages. Instead of waiting for a year's worth of data for evaluation of a new initiative, near real time observation of consumption trends provides evidence of which approaches are resonating with specific customer segments. By graphing customer usage pre and post program initiative and overlaying timing of introduction of new communication strategies or other program initiatives, changes in consumption can be viewed in near real time. This enables unprecedented access to customer behavior and the ability to tease out what actually motivates change in behavior.

By overlaying the timing of communication activities, or other program changes, over participation graphs, such as those in Figure 6 above, one can get rapid feedback to the effectiveness of the change.

**Figure 8. Tracking Effects of New Program Initiatives**




Even better, using interval data, one could graph kWh usage over time and overlay the timing of various program activities to see what messages actually lead to savings. One could enhance this analysis further by segmenting customers by any one of numerous ways such as size of home, age of home, income level. Or, by grouping customers based on analysis of other data sources, one could test program effectiveness with those customers who are cost conscious, or concerned about comfort, or oriented toward green altruism, or those who are tech enthusiasts, etc.

The same approach could be taken for demand response initiatives. Using interval data, one could track reductions in peak coincident consumption pre and post program initiative.

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