Is More Data a Smarter Choice? Benchmarking the Energy Impacts Associated with Smart Meter Feedback Programs and the Techniques used to Evaluate Them

Anne Dougherty, Founding Advisor, ILLUME Advising, LLC, Tucson, AZ
Courtney Henderson, Project Manager, ILLUME Advising, LLC, Truckee, CA

ABSTRACT

Smart meters promise to make energy efficiency programs and their evaluations more effective. But do they? In this paper, we examine energy impacts from smart grid enabled feedback programs that provide more frequent, granular data, which we term "real-time" data, to programs that use less "smart" approaches, such as month-to-month billing comparisons.

To deliver these findings, we draw on a Minnesota Department of Commerce Division of Energy Resources and United States Department of Energy funded review of 170 different feedback programs to examine learnings from over 40 smart meter enabled feedback programs implemented to residential and commercial customers in the United States that leverage smart meter data. Drawing on a careful and systematically reviewed body of studies conducted throughout North America, we explore if, how, and to what extent smart meter data has produced more effective feedback programs by benchmarking smart meter programs against feedback programs that use other forms of information (billing and other behavioral strategies).

To conclude, we present recommendations for smart meter programs based on our observations and the work conducted to date. The goal is to identify how smart meter data might be best leveraged and where existing billing-based data may be sufficient to meet energy efficiency goals.

Introduction

In this paper, we discuss the use of Advanced Metering Infrastructure (AMI)-enabled programs currently implemented in North America. According to the U.S. Energy Information Administration (EIA), AMI meters measure and record electric usage data in hourly and up to one-minute intervals and provide these data to energy companies, who may, in turn, provide these data to customers (EIA, 2014). For the purposes of this paper, we term this type of data as "real time".

According the the US International Trade Commission (2014), the estimated worldwide market value for smart meters was estimated at approximately $4 billion in 2011, and it is expected to grow to an estimated $20 billion by 2018. The largest markets of global growth have been North America, Europe and eastern Asia (particularly China), with noteworthy a decline in the pace of meter rollouts in the United States (US International Trade Commission, 2014). Within North America, electric cooperatives have been the most aggressive in AMI infrastructure investment, followed by investor owned utilities (GreenTech Media, 2015). Among the states within the US, California, Nevada, New York, Vermont, and Georgia have over 80% penetration of AMI meters (Ibid, 2015).

As adoption of AMI meters has increased throughout North America, regulators and electric utilities have sought ways to realize the benefits of their AMI infrastructure investments and to pass these benefits on to rate payers. Energy efficiency, demand response, and time-varying rate programs have been looked to as one mechanism to return the benefits of AMI infrastructure on to consumers.

In this paper, we describe and compare the effects of real-time pricing customer-facing programs that utilize AMI meter data to programs that rely on standard billing. To do so, we draw on a benchmarking study of behavior-based energy efficiency programs sponsored by the Minnesota Department of Commerce's Division of Energy Resources (DER) (ILLUME Advising LLC et al., 2015) as its primary source and subsequent research conducted for the US Department of Energy as a secondary source (ILLUME Advising LLC et al, 2015).

In the following pages, we first discuss the state of smart meter deployment in North America and then describe each of these program models and their benefit to consumers. We conclude by discussing those efforts that offer the greatest promise for demand side management programs and services.

Monthly Billing Program Models and Associated Energy Impacts

Most energy information-based programs implemented to date have utilized monthly billing data to provide customers with insight into their energy usage. On average, monthly billing feedback data has demonstrated energy savings between 1% and 2% on average per household among electric customers, varying widely based on their baseline energy usage (ILLUME Advising LLC et al., 2015). However, information provided in the form of monthly feedback data does not have sufficient granularity to provide customers with feedback on the magnitude and variability of their energy usage across the day and throughout the month and how their behaviors impact these trends. The table below summarizes effects seen with these types of programs.

Table 1. First-Year Net Savings Associated with Monthly Billing Feedback Programs for Residential Sector (ILLUME Advising LLC et al., 2015)

Program	Design[a]	Participant n	# of Cohorts with First-Year Savings[b]	Average Duration for Savings Estimation (years)	Net Unadjusted Electric Savings	Net Unadjusted Gas Savings
Ameren IL Behavioral Modification	Opt-out	198,183	3	0.67	0.9%-1.3%	0.4%-1.0%
ComEd HER (IL)	Opt-out	259,261	3	0.75	1.2%-1.7%	NA
CUB Energy Saver (IL)	Opt-out	8,793	1	1.00	2.0%	NA
MN Enerlyte	Opt-out	24,326	1	1.00	2.2%	NA
NGRID RI Statewide	Opt-out	269,174	6	0.50	-2.2%-1.6%	0.3%-0.5%
PG&E HER (CA)	Opt-out	542,411	6	1.08	0.9%-	0.4%-

Program	Design[a]	Participant n	# of Cohorts with First-Year Savings [b]	Average Duration for Savings Estimation (years)	Net Unadjusted Electric Savings	Net Unadjusted Gas Savings
					1.5%	0.9%
Puget Sound Energy HER (WA)	Opt-out	31,618	1	1.00	1.7%	1.2%
SMUD HER (CA)	Opt-out	100,347	3	1.00	1.6%-1.8%	NA
Xcel HER (MN)	Opt-out	32,762	1	1.00	2.1%	0.6%
NGRID HER (MA)	Opt-out	653,908	12	1.00	1.0%-1.7%	0.5%-1.2%
NSTAR HER (MA)	Opt-out	144,739	5	0.73	1.5%-1.6%	1.0%-1.6%
WMECo Western Mass Saves	Opt-out	92,485	3	0.61	0.0%-1.9%	NA

[a] Note: We did not report opt-out rates for these programs, because they are typically quite small.
[b] Note: Number of cohorts with first-year savings is only relevant for Home Energy Reports. Other program classes either do not have waves or cohorts, or report them separately (whereas here, we collapse the number of cohorts with first-year energy savings).

AMI-Enabled Program Models and Associated Energy Impacts

One of the primary benefits to program design gained with AMI meter deployment is access to, and subsequent utilization of, energy information at significantly more granular levels. Those interested in expanding the potential of energy feedback programs have looked to AMI-enabled real-time (within 1 minute) and near real-time (within one hour) interval data as an opportunity to garner even greater savings by providing more detailed information to customers. Specifically, we see AMI-enabled information programs taking three primary forms of feedback:

- **Residential feedback programs** that use energy information to inform customers of their electricity use in order to elicit a conservation response;
- **Commercial diagnostic programs** that utilize energy consumption information to identify ways for businesses to save electricity; and
- **Residential real-time pricing programs** that utilize real-time pricing and AMI-enabled feedback to prompt changes in the way customers use electricity throughout the day.

Each program design model is discussed in greater detail in the following sections.

Residential Feedback Programs

By definition, feedback programs that are AMI-enabled are typically considered "real time" because they utilize close to instantaneous feedback on behavior and electric consumption. Prior to the deployment of AMI meters, programs that sought to provide customers with real-time feedback relied on current clamps and analog meter auxiliary devices to gather and relay information to consumers – typically in the form of an in-home, stand alone display. Such programs were costly to utilities and cumbersome to customers, requiring additional equipment, trained electricians to install the equipment, and patient customers willing to schedule in-home visits with technicians. Only the most motivated customers saw such programs through the installation phases. AMI deployments have resolved the technical challenges associated with earlier real-time feedback programs (though many utilities still implement these programs as work-around's to analog and AMR meters).

The results of the benchmarking analysis (ILLUME Advising LLC et al., 2015) found that residential feedback programs generate net unadjusted electric savings ranging from 0%-3.1% (Table 2). While earlier studies have suggested that real-time feedback programs are capable of generating energy savings upwards of 5-10% reductions in overall consumption (Ehrhardt-Martinez et al., 2010), such numbers have not been widely replicated as evaluation approaches to estimating energy savings associated with opt-in programs (in which customers must agree to opt in and participate) have grown more sophisticated (ILLUME Advising LLC et al., 2015).

The results from these studies suggest that real-time data feedback, as enabled by AMI meters, may not result in dramatically greater energy savings than monthly billing feedback. This raises two questions: (1) is there a threshold at which more granular information fails to return energy savings? and (2) is information presented in ways that are not sufficient to drive savings among customers?

With respect to the first question, there are no studies that we are aware of that specifically explore the relationship between the granularity, intensity, and level of feedback and behavior modification. There is a lay belief that more information equates to greater changes in behavior; however social science research has demonstrated that this is not necessarily the case and that the timing, placement, and delivery of energy information can dramatically enhance how customers respond to information (ILLUME Advising LLC et al., 2015, Ignelzi et al., 2013). Can we gain greater savings with less information or are there ways to better utilize or present smart meter data to improve customer responses to energy information?

Table 2. Participation and Savings in Residential Real-Time Feedback Programs without Real-Time Pricing (ILLUME Advising LLC et al., 2015).

Program	Participant (n)	Average Duration for Savings Estimation	Net Unadjusted Electric Savings	Summer Peak Load Reduction (%)[a]
Edison SmartConnect: Budget Assistant	117,377	6 mos.	0.92% (but diminish over time)	NA
Edison SmartConnect: IHDs	163	6 mos.	3% in first 30 days; 0 thereafter	NA
Minnesota Power AMI Pilot	2,523	1 year	0%	NA
Minnesota MyMeter	14,156	1-3 years	1.8% - 2.8%[b]	NA
National Grid: EmPower (RI)	90	1 year	1.7%	Range from 30% savings to 19% increase in consumption
Tuscon Electric Power: Power Partners	1,521	8 mos.	1.2%-3.1%[c]	NA

[a] For the cohorts with critical peak pricing, the percent reduction is during critical peak periods.

[b] Results cover a three-year period, so they may not be comparable to first-year savings results for other programs

[c] Billing analysis covers an eight-month period.

Commercial Diagnostic Programs

In this paper, diagnostic programs are defined as those programs that utilize AMI-enabled energy usage information to identify ways to save electricity. Typically conducted remotely using an online interface, these differ from standard feedback programs by moving beyond general building-level usage information to provide specific recommendations for ways to reduce consumption overall and by time of day. There are two primary diagnostic programs that utilize AMI-enabled data analysis and feedback: remote audits and business energy analyzers.

Currently, commercial and industrial (C&I) "remote audits" are gaining traction as energy efficiency programs in the United States. Most widely implemented in the US by two companies, FirstFuel and PulseEnergy, remote audits use AMI energy information to examine the performance of buildings with a goal of providing both energy efficiency and operational recommendations to reduce energy use as a customer solution. Unfortunately, there are no third-party evaluations of energy savings associated with these programs.

“Business Energy Analyzers”, such as those implemented by Commonwealth Edison (ComEd) and Agentis Energy, provide information on consumption to business and personalized recommendations typically articulated in the form of price savings. This particular tool not only identifies potential energy efficiency opportunities, but also identifies operational savings potential by time of day combined with peer-based comparisons and analyses. Similar to remote audits, energy savings impacts from such program designs have not been evaluated.

In addition to these two program models, AMI meter “disaggregation” software is in active development by academic groups such as Stanford’s Precourt Energy Efficiency Center (2011) and companies such as Bidgley, which utilized real-time AMI data at the premise level to develop appliance level “signatures” of usage in order to determine the primary drivers of energy consumption at the premise level by end use.

These technologies are actively touted as targeting solutions for marketing and outreach, in that customers can be segmented by usage and specific marketing and outreach solutions can be implemented that are customized to those customers. By providing utilities with information on customers’ end use profiles, electric utilities are better able to identify and target customers with the programs, products, and services that directly address their individual needs. Similarly, there are no public data available on the effectiveness of diagnostic information for premise-level targeting, however Dwelley and Dougherty (2012) have found that customized premise-level targeting can increase response rates to program offerings by 400%.

Residential Real-time Pricing Programs

Like feedback programs, time-varying pricing approaches, such as critical peak pricing (CPP) and peak time of use (TOU), enabled by AMI meters are typically referred to as “real time pricing.” These types of approaches utilize pricing information stated in the form of a changing rate to prompt customers to shift their electricity use. For example, CPP programs aim to prompt customers to shift their electricity use off-peak, whereas TOU programs typically apply to usage over broad hours of time during which rates are higher. A review of these programs illustrates that real-time pricing can be effective at reducing peak usage by as much as 26% for CPP programs (Nexant, 2014a) (Table 3). Further, two other studies conducted meta-analyses and found that real-time pricing feedback, enabled by AMI meters, can have a significant impact on the time of day when customers use electricity (Faruqui & Sergici, 2010; Newsham & Bowker, 2010).

In a recent paper, Faruqui (2013) compiled peak savings results from multiple dynamic pricing trials and examined the relationship between behavior change in response to the rate and enabling technology. The authors found that that enabling technologies such as in-home displays, energy orbs, and smart thermostats increased the price response by providing feedback. These results indicate that the rate itself, as well as the physical presentment of a rate signal, can have dramatic impacts on behavior change.

Table 3. Participation and Savings in Residential Real-Time Pricing Feedback (ILLUME Advising LLC et al., 2015)

Program	Participant (n)	Average Duration for Savings Estimation	Net Unadjusted Electric Savings	Summer Peak Load Reduction (%)[b]
SMUD SmartPricing Options: CPP	1,651	12 CPP events	NA	26%
SMUD SmartPricing Options: CPP	701	12 CPP events	NA	12%
SMUD SmartPricing Options: TOU	2,199	4 mos.	NA	13%
SMUD SmartPricing Options: TOU	2,018	4 mos.	NA	6%
SMUD SmartPricing Options: CPP	223	12 CPP events	NA	22%
SMUD SmartPricing Options: TOU	1,229	4 mos.	NA	10%
SMUD SmartPricing Options: TOU+CPP	588	4 mos.	NA	8% summer peak; 13% critical peak
Edison SmartConnect: IHDs	183	6 mos.	6% in first 60 days; 0 thereafter	NA

Discussion

The question remains, is more data better? The answer is, it depends on our goals. Our review of AMI-enabled energy programs indicates that more information does not necessarily equate to dramatically enhanced savings unless AMI-data is used to facilitate a specific service or program goal, such as reducing usage during peak hours through time-varying rates. Here, we discuss the differences in efficacy of AMI data in generating energy savings for efficiency- and demand-based programs.

Energy Efficiency and Conservation

In the case of energy efficiency, the added impacts for achieving energy efficiency savings have not materialized using AMI data. In fact, monthly billing data appears to be more widely used, and scalable, than real-time meter feedback initiatives that require technology adoption to implement. However, AMI data disaggregation and AMI data for targeting illustrate ways in which AMI data can be leveraged to provide a *service* rather than usage *information.* The distinction is important when considering AMI-enabled programs for energy efficiency.

Previously, we noted that the gains from AMI information, when provided to consumers, are not dramatically different than savings obtained through monthly billing data. However, the use of AMI data to deliver directed and targeted services and offerings to consumers, such as customized business and home improvement recommendations and targeted incentives and offers, may better deliver on the promise of AMI data. Future evaluation efforts will need to confirm the effectiveness of these efforts.

Demand Impacts

Demand- and rate-focused programs appear to benefit more from AMI data, given the need for a clear, time-specific response to a variable pricing rate. The previously discussed differences between real-time energy usage data and real-time pricing bring forth a number of questions when considering the effectiveness of AMI data in prompting behavior change. Specifically:

1. Are rates themselves simply more effective due to price-based incentives and penalties? E.g. are the economics of decision-making a stronger signal than usage information?
2. Are there important non-economic differences between rate-based feedback and general AMI usage feedback that could be instructive for program design?

While the answer to the first question might very well be yes, this should be examined only in the context of the relative cost of energy during peak, which these studies do not directly compare. For this reason, the second question is worth exploring systematically. For instance, when examined closely, rate-based initiatives offer customers a very clear and time bound call to action: use less electricity during specific periods of the day for a particular day(s). In contrast, feedback programs provide information and have a more amorphous task: reduce usage overall. It is possible that some customers, particularly those who are highly motivated to save energy, will go to great lengths to explore the cause and effect relationships between their actions and their energy usage feedback. Yet others will likely look for their utility and provider of AMI-meter data to direct them toward specific actions within the home.

Most importantly, these results highlight our general lack of understanding on how customers' respond to energy information. While past research suggests that providing more specific recommendations to customers can improve their response to AMI information, there are few systematic studies that examine the relationship between information frequency, presentment, feedback, and incentives on changes in energy usage. While diagnostic programs and AMI data disaggregation may offer some potential, the devil appears to be in the detail of the delivery of energy information when looking at the effects of information (without external effects, such as the economy, household factors, etc.).

Recommendations

We have suggested that AMI data may be best suited to developing energy-related services and specific, targeted diagnostics and solutions. That said, these conclusions should be born out in future research, and we suggest that entities interested in leveraging AMI data for the purposes of developing energy programs and services consider, and research, the following:

- **Systematically explore the benefit of varying levels of granular data and varying frequencies of delivery.** As noted, more information may not be better, but very little has been done to systematically test when we experience diminishing returns on customers' behavioral response to information. This insight will help determine whether or not AMI data need be used to elicit a conservation response.

- **Carefully identify data presentment strategies that are the most effective in delivering AMI data.** In addition to the granularity and frequency of data provided to customers, little research has been conducted on the visual presentment of information to consumers. Customers are increasingly sophisticated and expectant of carefully presented and tailored information. We also have significant insight into behavior change strategies that make information more meaningful and impactful. To date, most information feedback is delivered in the form of charts, graphs, or states of usage levels. While this information may be meaningful to those in the energy industry, it is likely less meaningful to consumers.

- **Explore the benefits of AMI data integration into existing feedback technologies, such as Wi-Fi thermostats, smart phones, and other commonly uses devices.** Many early AMI-enabled programs used stand alone technologies to deliver feedback to customers on their energy usage. With increased use of whole home automation technologies, AMI-based services can be delivered to sites where customers are already engaged, such as the thermostat or on their smart phone.

- **Consider mechanisms to develop solutions for customers vs. putting the onus on them to identify solutions based on AMI data.** While there is limited information on the impacts associated with remote audit and data disaggregation technologies, these offer promising uses of AMI data with a focus on customized recommendations and solution for consumers. Moving beyond usage feedback, these services are instructive and specific – two attributes widely requested by consumers in process findings on feedback programs.

- **Evaluate how customers respond to AMI and how they make decisions on investing in energy efficiency.** Future evaluation research should explore the value that customers place on having more information to specifically answer the question, are AMI data necessary for promoting energy efficiency?

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