Unlocking Customer Insights on Energy Savings and Behavior through the Use of AMI Metering

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ABSTRACT

The paper presents the research results related to the use of large utility-managed customer datasets for identifying customer trends and variations that may provide insights to the potential for energy efficiency opportunities. The emphasis is residential customers although the results can be applied to other sectors and building types. An approach to guide the statistical analysis and research methods applicable to the ever growing volume of data being collected is discussed. It is the authors' belief that this approach facilitates a coherent method for analyzing big datasets.

Introduction

According to a recent EPRI report[1] advanced metering infrastructure (AMI) are comprised of state-of-the-art electronic/digital hardware and software that combine interval data measurement with continuously available remote communications. AMI systems typically refer to the full measurement and collection system that includes meters at the customer site, communication networks between the customer and service provider, such as an electric, gas, or water utility, and data reception and management systems that make the information available to the service provider.

According to the study the benefits of advanced metering infrastructure (AMI) systems to include:

- ✓ Direct Participation by Consumers: With AMI systems the consumer is informed, modifying the way electricity is used and purchased. They have choices, incentives, and disincentives.
- ✓ Generation and Storage Options: The AMI system accommodates most generation and storage options.
- ✓ New Products, Services, and Markets: The AMI system creates a market system that provides cost-benefit tradeoffs to consumers by creating opportunities to bid for competing services.
- ✓ Power Quality for the Digital Economy: The AMI system provides reliable power that is relatively interruption-free.
- ✓ Asset Utilization and Operational Efficiency: The AMI system optimizes assets and enables the utility grid to operate efficiently.
- ✓ Response to System Disturbances (Self-heal): The AMI system independently identifies and reacts to system disturbances and performs mitigation efforts to correct them.

[1] *Estimating the Costs and Benefits of the Smart Grid*, EPRI Technical Report, March 2011, 1022519

- ✓ Resilient Operation. The AMI system resists attacks on both the physical (substations, poles, transformers, etc.) and cyber infrastructure (markets, systems, software, communications) connected to the utility grid.

Customer Value

The question of customer value is an important subject, one of which may have conflicting answers. Recent studies have suggested that residential customers want choices in their electricity suppliers when it produces a cost savings, otherwise they are not interested. The stalling of retail customer access in 2002 and 2003 did not help support the case for lower prices as competitive choice did not seem to produce the expected lower prices. Customers also want rate and pricing choices in order to reduce their bills. In many cases when those choices are offered the cost savings do not seem to be enough to motivate them.

Other value questions for future investigation include: Do customers want load data from their smart meter on a real-time or post real-time basis? Do they want load data for their end-uses or appliances? Do they want to know if those appliances are operating efficiently or on the verge of needing maintenance or repair? The answers seem to be an intuitive yes but how much are customers willing to pay for those services is unclear. This is an area for further research for EPRI and the industry-at-large to consider in the coming years.

Utility Value

The same EPRI study, cited above[1], estimates the net benefits from AMI system savings at $1.3 to $2.2 trillion over a twenty year period. This represents a benefit-to- cost ratio ranging from 2.8 to 6.0 which reflects the operational avoided costs savings enabled by near real time information provided by these devices. These benefits are the net of financing and rate of return costs. The implication is that the industry rates will decline by the amount of cost savings as the AMI system savings accumulate.

To demonstrate AMI system savings utilities need to invest in additional IT systems and tools that enable customer data analytics. The electric utility industry continues to be largely regulated which means that in order for utilities to earn a return on those investments they must be either recovered through rates or through service offerings created under the unregulated business segment. But the question still remains - Are customers are willing to pay for the amortized costs and a premium for the utility return on the customer data analytics expenses. This poses significant risk to the utilities because the investments may not produce shareholder returns. This may be a significant hurdle and a significant business risk as utilities struggle with the huge capital outlays they are committed to for completing the AMI system deployments and in addition are being asked to invest in customer data analytics without some assurance of cost recovery. These are the same issues that were faced by utilities engaged in energy efficiency in the early 1990s. Investments in energy efficiency produced costs and sales reductions that discouraged utilities from actively participating in those markets until favorable regulatory treatment was made, either through deferred accounting, shared savings and lost revenue recovery or through revenue decoupling.

Likewise, the majority of expenses for utilities in the AMI system area is for rendering bills and to accommodate the increased data storage and processing requirements. Customer data analytics, if not carefully planned and managed, may never gain the needed momentum and may fail to create value to society.

Bridging the Gap

This paper documents the current level of customer data analytics activities within AMI systems and the challenges for future deployments. What is apparent in discussions with utilities is that they are coping with changing business systems and grappling with huge increases in data and data processing requirements which is magnifying the complexity of their business. For most utilities the value proposition of customer data analytics is unknown except for the uses shown in **Error! Reference source not found.**.

Table 1. Value proposition from customer data analytics

Category Focus	Customer Data Analytics Use Description	Value to Customer	Value to Utility
Customer	Better understand energy usage	Medium	High
	Billing dispute resolution	High	High
	Understand potential cause(s) of high energy bills	High	High
Utility	Better customer service (Example – based on meter data recommend remedial action or tips to lower energy bill,)	High	High
	Identify customer preferences, attitudes and behaviors to cater service according to customer need	Medium	High
	Customer segmentation, marketing benefit	Medium	High
	Fraud-detection	Low	High

Customers expect utilities to understand their needs and preferences and provide information regarding their consumption of electricity. What utilities require is some assurance that the investments they are making, or will be making, in customer data analytics will be recoverable, even if the results are less than expected.

It is this gap where research needs to focus to ensure the creation of value from these significant investments.

Data Analysis Framework

The flood of advanced meter infrastructure (AMI) system deployments has introduced a new quantity – a significantly large amount of meter data, which could possibly be the single largest volume of data collected and managed by utilities. In its August 2009 report, the Federal Energy Regulatory Commission (FERC) reported an estimated deployment of 140 million smart meters by the year 2019.[2] Assuming that to be the case, it would require the creation of data infrastructures capable of managing hundreds of petabytes (PB) of data, by the year 2019. Additionally, to translate such gigantic volumes of meter data into meaningful information, the utility industry may have to invest large amounts of capital and operational resources into data management infrastructures and information management tools such as business analytics. Global networking giant Cisco Systems predicts that utility spending on traditional data centers could make up “a large chunk” of the potential $20 billion that will spent on the AMI system over the next several years.[3]

This AMI meter “data deluge” presents both opportunities and challenges to the industry. Though managing the tremendous amounts of data seems highly challenging, utilities can approach this data challenge as a new business opportunity. The data can provide insights which utilities can use to develop strategic and quantifiable metrics for business case analysis, improve services, better understand customers and operate in a cost-effective manner. Aligning “good” data with business intelligence allows both utilities and customers to make good decisions that save energy, time and money, prevent losses and increase service levels. Assessing the potential of this data is the first step for evaluating value and for developing highly beneficial applications. Data mining techniques followed by detailed data analysis can provide insight into demand, usage, operational efficiency and the potential to optimize business processes and revolutionize operational efficiencies. The first challenge that utilities face is managing the high volumes of data with a system that provides high data quality and fast, easy access for users.

The key to unlocking the value from this data is to develop the means to analyze the data. Existing firms as well as new firms are entering this nascent market and providing the expertise to husband this new found data. A recent study by Pike Consulting[4] estimates the current market at $0.4 billion dollars to provide analytics services to the utility industry. They expect this to grow to $4.2 billion by 2015 as the penetration of smart meters increases.

The basic business model of the electric utility remains the same – to provide electric services to their customers and to earn a reasonable rate of return for their shareholders. The preponderance of a new found source of detailed usage data will probably not change this model, nor will it produce a huge profit center for utilities. But what it will likely do is increase the number of service offerings available and provide customers with many more ways to manage their usage.

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[2] FERC Staff report, “Assessment of Demand Response and Advanced Metering”, August 2009 Available: http://www.ferc.gov/legal/staff-reports/sep-09-demand-response.pdf

[3] LaMonica, M (2009, July) “Cisco looks to ride smart-grid data deluge”, CNET news Available :http://news.cnet.com/8301-11128_3-10296404-54.html

[4] Smart Grid Data Analytics, Pike Research, December 2010.

Granular data available through AMI holds the promise of enabling faster and better informed decision-making that drives operational improvements and enable consumers to better manage their own power consumption. Technical enablers such as data collection systems, AMI head-end systems and Meter Data Management systems are making great strides in establishing the business case for AMI system. It is important to note that the common thread through all of these technical enablers is data and the analysis of data. Data driven analytics, customer and business intelligence are foundational to facilitate AMI-enabled pricing structures and development of technologies which can yield system-wide distribution benefits. An example of such AMI data driven assessment is the Commonwealth Edison's Customer Application Program pilot which was designed to produce information that would allow analysts to quantify the impact of price structures, enabling technologies, pricing plans, and educational strategies facilitated by advanced metering infrastructure (AMI). The pilot was designed to reveal the extent to which customers change their pattern and level of electricity consumption when AMI enabled pricing and technologies are deployed.[5]

Defining the Objective – Value of the Customer's Loads

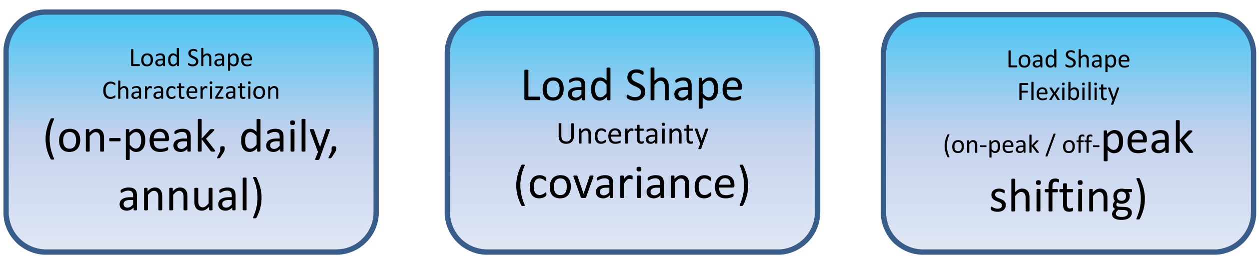

Figure 1 . Customer load shape valuation.

A load shape reflects the pattern of energy usage over time for a customer or household. The patterns reflect the loads the customer places on the electrical system and variations may result in significantly different market costs faced by the utility. One shape that is stable may produce a different cost to the utility than a similar but uncertain shape.

Segmenting customers into load shapes may be useful for utilities that have specific and well defined operating or business objectives. "Use Cases" are discussed at length later in this paper but the types of use cases for regulated utilities in the United States are fairly well defined. For competitive utilities and in the United States, examples are less prevalent. The European marketplace is subject to more competitive pressure in acquiring and keeping electric customers. Their use cases are different than in the U.S.

[5] *The Effect on Electricity Consumption of the Commonwealth Edison Customer Applications Program: Phase 2 Final Analysis*. EPRI, Palo Alto, CA: 2011. 1023644

Figure 2 shows an example of how categories of load shapes may be developed using AMI data. A load template may be established that reflects the pattern of many customers in a utility's service territory. EPRI is working with Stanford University to develop methods to characterize load shape patterns[6]. Much of this work is based on computer visualization algorithms that will allow quick and large scale identification of specific load patterns from AMI data.

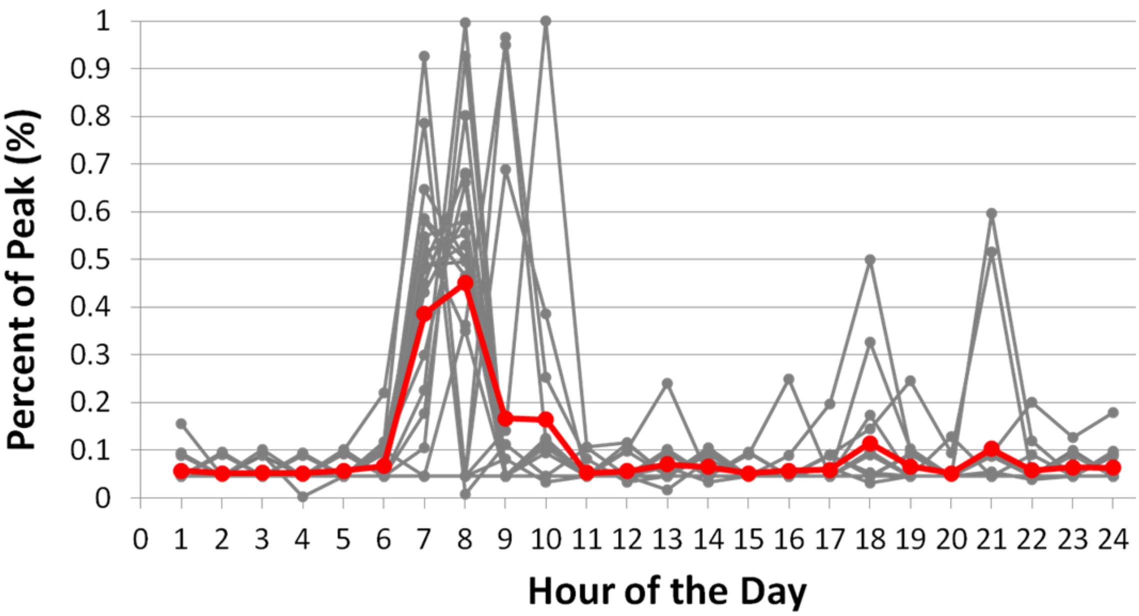

Figure 2. Sample load shape characterization.

The red line in Figure **2** provides an example of an average load shape for an individual customer across similar weekdays in a month. The data is normalized so that the consumption in each day is approximately the same. In aggregate all of these shapes produce slightly different patterns that can be combined into a distinct shape to it that were it to be priced at market prices would have the high usage hours occurring at high priced periods and the high usage hours would also be coincident with the low reliability hour on the system. The shape of the load is an important driver of customer cost.

Load Shape Uncertainty

Knowing the load shape does not guarantee that on any given day that the load will fall within a predicable level. Figure **2** also shows the short term variation that exists with load shapes. The pattern shown by the red line would appear to be stable but the underlying individual days produce an uncertainty that affect the ability of utilities to serve that load. Each customer and the equipment in the household have their own unique efficiencies and are affected by price, weather, economic conditions and consumer confidence in different ways.

[6] Stanford Sustainable Labs and EPRI, *Technology Insights: Demand Responses Analytics*, (3002002686), February 2014

Load shape uncertainty is also affected by the combination of occupants and stock of appliances within each business or household. The dominance of air conditioning and its correlation with high cost periods implies more expensive customers to serve. Moreover, longer term variability produced by changes in capital stock, employment, income and weather increases uncertainty which affects the ability of utilities to serve that load.

Flexibility

Customers derive value from the consumption of their electricity consuming appliances. Electricity is a derived demand whose consumption depends on the appliances meeting their particular needs. EPRI uses the five "C's to describe the needs of customers. These needs include the consideration of **cost, comfort, control, convenience and certainty**.

For each end-use there is an inherent load shape flexibility that each customer exhibits. For example, customers who are on a time-of–use rate are more likely to adjust their usage from high cost periods to low cost periods. Or similarly customers who participate in a demand response (DR) event will have a level of flexibility depending on the value they receive from enrolled appliances and the value of participation they receive by participating in a DR program.

Customer segmentation methods that recognize all of these cost components will be more successful at identifying customers who may help a utility meet its business objectives and the use cases they involve.

Use Cases – Business Objectives

It is sometimes forgotten that utilities, both vertically integrated and local distribution companies, are generally regulated in the United States. Such utilities have defined service territories with an obligation to serve. Customer acquisition or retention is not as significant an issue. Rather, of more significance are programs that allow the utilities to earn additional amounts above their authorized rates of return. Specifically, energy efficiency programs often have mechanisms that incent the utility above and beyond their authorized rate of return for meeting defined performance objectives.

Analysis can be defined as the determination of the drivers that help a utility achieve its objectives, given the available data. Data availability has leveled the playing field for AMI customer data analytics. Society now has more data than can be consumed, with the prospects of even more with each successive meter generation. But ultimately, utility customer data analytics needs to have relevant business objectives for which to focus and support the regulated market most utilities find themselves operating.

Examples of several business objectives for use of customer data analytics follow:

Measurement and Verification (M&V)

M&V of energy efficiency or demand response programs may be conducted with much less expense and greater speed than previously available. M&V may be performed to ensure that the desired actions are taken, impacts are measured and effects do not depreciate over time.

Cost of Service

The development of class loads shapes may be more accurately developed due to the presence of AMI data for constructing class load shapes. These are ultimately used to allocate fixed costs across classes. Accuracy of representative load shapes is important, since the more accurate, the fairer rates become.

Energy Audits

Combining usage data collected from AMI systems with customer supplied data regarding the number of occupants with appliance saturation and building envelop data can be powerful in identifying energy savings potential. This is already a fairly common use for AMI data particularly for commercial and industrial facilities where the audits costs can be expensive.

Appliance Diagnostics

This is an area that requires more end-use focused data collection methods such as non-intrusive load monitoring. However, most current NILMs system does not have the capacity to detect imminent failure of common appliances such as refrigerators and laundry equipment except in cases of high usage. This is an area that manufactures are working on but no devices are available that look at waveform patterns for diagnostics.

Customer Acquisition

In competitive markets customer acquisition is a main objective in terms of identifying customers who are the most profitable or the least costly. Furthermore providing some degree of usage insights can become a value-added service to existing customers and be applied help retain them when service contracts are due for renewal.

What Next?

The framework for analyzing customer AMI data is driven by three components, load shapes, load shape uncertainty and flexibility of the end-uses that drive that category of end-use load.

Research is being conducted into the development of load shape patterns that can be used for developing market segments that reflect the best candidates for a particular use case. However, research also needs to be conducted which captures the uncertainty and the flexibility of those loads.

The development of more robust and accurate end-use data collection becomes important to develop workable estimates of the shapes, uncertainty and flexibility. AMI data is extremely useful for developing shapes and uncertainty estimates but falls short of determining flexibility. Research that will produce coherence between all three of these cost components is needed.

Methods to capture the flexibility that customers have for each of their main end-uses is paramount. These end-uses include HVAC, water heating, pool pumps, laundry equipment and plug loads for residential which either have the capacity for time-shifted usage or can accommodate storage technology alternatives. Development of this type of information will be useful in creating more targeted and accurate product offerings tailored to the needs of customers.

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