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Using Smart Meter Data to Develop Customer Insights

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Abstract

Smart meter deployment in the United States has grown steadily in recent years, and market penetration will continue to increase. Globally, smart meters are evolving into a huge market. This flood of smart meter 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. The potential benefits are significant, but many utilities are assessing methods to manage the volume of data being collected, and customer data analytics have yet to be fully realized. A systematic method is needed to manage and create customer value.

This report from the Electric Power Research Institute (EPRI) describes current utility applications of smart meter data and potential applications for translating smart meter data into beneficial uses for both the utility and the customer.

The report was developed with the following objectives:

- To list potential utility applications and identify the value propositions of smart meter data
- To collect utility perspectives on current applications and activities as well as proposed plans to develop high-value uses of smart meter data.
- To develop a framework for characterizing smart meter customer data
- To draw conclusions about where data analytics will go

Ultimately, the key to unlocking value from the data obtained by smart meters is to develop the means to analyze the data. Accordingly, a primary focus of the report is on data analysis.

Keywords
Advanced metering infrastructure (AMI)
Customer data analytics
Interval data
Smart meter
Load research
Meter data management system (MDMS)

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Section 1: Introduction

Smart meter deployment in the United States has grown steadily over the past three years. According to a survey conducted by the Federal Energy Regulatory Commission (FERC), the market penetration of smart meters reached 8.7 percent in the U.S. in the year 2010 compared to 4.7 percent in 2008.[1] The Institute for Electric Efficiency (IEE) estimates about 27 million smart meters installed in the United States as of September 2011. By 2015, IEE estimates that approximately 65 million smart meters will be deployed representing 54% of U.S. households. The three largest California utilities namely San Diego Gas & Electric Co., Pacific Gas & Electric, and Southern California Edison together have installed more than 8.75 million smart meters and expect to complete installing 12 million meters by the end of 2012. Similarly, the three largest utilities in Texas namely Oncor, American Electric Power Co. Inc. and CenterPoint Energy together have installed more than 3.8 million smart meters and expect to complete 6.6 million smart meter installations between 2012 and 2013.[2]

The Smart meter market is evolving into a huge global market. According to IDC Energy Insights, a research-based advisory and consulting services provider focused on market and technology developments in the energy and utility industry sector, a worldwide compound annual growth rate (CAGR) of 13.0% in smart meter unit shipments is forecasted from 2010 through 2015. A total of 460.9 million smart meters are forecasted to ship globally during the period of 2010 to 2015. In dollar value, Frost & Sullivan analysis shows that smart meter sales were around $1.01 billion in 2010. This market is expected to reach $2.3 billion in annual sales by 2017.[3]

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[1] FERC Staff report, "Assessment of Demand Response and Advanced Metering", February 2011 Available: http://www.ferc.gov/legal/staff-reports/2010-dr-report.pdf

2 The Institute for Energy Efficiency, "Utility-scale smart meter deployments, plans & proposals", September 2011.
Available: http://www.edisonfoundation.net/iee/issueBriefs/SmartMeter_Rollouts_0911.pdf

3 Saeed. F, (2011, September) "Smart meter market thrives despite setbacks", PowerGrid International Magazine
Available : http://www.elp.com/index/display/article-display/5198014181/articles/electric-light-power/volume-89/issue-4/sections/smart-meter-market-thrives-despite-setbacks.html

The flood of Smart meter deployments has introduced a new variable – a significantly large amount of meter data, which could possibly be the single largest volume of data collected and managed by utilities. This smart meter "data deluge" presents both opportunities and challenges to the industry. The data can provide insights which utilities can use to develop strategic and quantifiable metrics for business case analysis, improved services, better understanding of customers and cost effective operations. Aligning "good" data with business intelligence allows both utilities and customers to make 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.

Table 1-1
U.S. Energy Sales by Sector, 2010

	Sales ($billion)	**Sales (GWh)**	**Sales (cents/kWh)**
Residential	$166.8	1,445.7	11.5¢
Commercial	$135.6	1,330.2	10.2¢
Industrial	$65.8	970.9	6.8¢
Transportation	$0.8	7.7	10.4¢
Total	$368.9	3754.5	9.8¢

(Source: EIA, Summary Statisitcs for the United States, 1999-2010, 2011)

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

The residential sector spent $166.8 billion on electricity in the year 2010. Using this value as the baseline for potential bill savings through customer data analysis and using the estimated cost effective realistic energy potential savings of 4.8% by 2020 from EPRI's National Potential Study[5] produces a level of savings of $8.0 billion. If, as predicted by Pike Research, customer data analytics will become a $4.2 billion effort then it seems likely that customer data analytics will have favorable economics.

[5] Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S. (2010 - 2030), EPRI, Technical Report, January 2009, 1016987

Section 2: Smart Meter Data Analytics

Smart meters are a rich source of data for utilities. Interval usage data—probably the most important data collected through AMI—can be collected over as little as 1-minute intervals and delivered multiple times per day. Other data associated with the smart meter is of great use to customers as well, such as time-stamped meter status and identification data. For smart meters used as a gateway to home-area networks, data associated with appliances and thermostats can be made available.

At this point in time, meter data is primarily being used to support the regulated activities of the utilities, namely, the utilities' rendering of bills and the presentation to the customer. Much more can be gained from analyzing meter data. Users throughout the utility could create value for customers from basic and more advanced analytics activities. Customer value and needs will drive the type of applications companies will deploy. These applications can be grouped into three categories: those that affect customer needs, those that affect future cost of service and those that improve system reliability.

Customer Needs

Billing Information and Customer Management

Utilities can leverage smart meter data to achieve better service and improve customer satisfaction.

Helping customers understand their electric usage and effective resolution of bill-related disputes are the primary benefits of meter data. Analyzing smart meter data to identify potential causes of high energy bills and recommending helpful tips or actions, such as servicing an air conditioner or replacing an inefficient refrigerator, can also be of high value to the customer. Data analytics performed on smart meter data can help identify customer preferences, attitudes and behaviors which allow the utility to focus and cater service according to customer needs. Every customer is different, so segmenting the market by customer type and implementing appropriate marketing plans for each segment helps promote effective marketing and solicit greater customer participation. Smart meter data can also be highly valuable to design cost-effective programs such as energy efficiency, solar incentives, and time-of-use rates and demand response. Meter data analysis along with account and billing history can help utilities identify potential fraud. Through analysis of customer payment patterns utilities can provide appropriate assistance for customers based on their payment histories and determine if a late-paying customer is chronically late and might require additional utility support.

Customer Choice and Decision Making

Utilities can leverage more frequent consumption information from smart meters to help customers sort through billing questions and provide more services to customers. For example, analyzing energy usage data can help customers pinpoint the causes of high energy bills. Then utilities can recommend action, such as servicing an air conditioner or replacing an inefficient refrigerator. In some cases, analyzing meter data alongside account and billing history can help utilities identify potential fraud.

Through analysis of customer payment patterns, utilities can provide appropriate assistance for customers based on their payment histories. Utilities can use analytics to determine if a late-paying customer is chronically late and might require additional utility support. Utilities can advise customers who have bill troubles about lowering costs through energy conservation.

Using analytics to better understand customer preferences, attitudes and behaviors, utilities can identify and better satisfy customers' needs. Utilities offer many programs—energy efficiency, rate options, solar incentives, and demand response—and more programs are coming available every day. Every customer is not the same, so segmenting the market and implementing appropriate marketing plans for each segment will help reach more customers and produce greater participation. More advanced analytics will enable customers to plug in and manage energy devices in their homes and businesses, such as electric vehicles, renewable and distributed energy resources, smart appliances and home energy management systems.

Managing Future Costs

Some of these devices will enable energy consumers to become power producers, as well. Advanced customer data analytics will be necessary to help consumers to understand the power-trading marketplace and efficiently manage power consumption and production on-site.

With the availability of detailed usage data virtually any rate structure may be designed and implemented. This means customers can select pricing plans that better serve their needs based on their lifestyles. Customer smart meter data, customer segment information, weather information and pricing data can enable utilities to refine pricing in real time based on customer responses to price signals.

These changes could ultimately reduce the future cost to serve and could reduce pressure on costs, help reduce customer's bills and lower rates.

Improved System Reliability

Interval data from smart meters, demand response program information systems and spatial data can provide utilities with the information needed to support the dispatch of demand response as a variable resource, much like how utility-owned wind and solar are incorporated into the grid.

Demographic information, revenue data, production data and spatial distributions can help utilities better forecast demand growth and capital investment requirements for the lowest levels of the distribution grid. Utilities can determine through analytics whether new or upgraded infrastructure is needed in a particular area to meet the area's changes in energy demand. The utility can also use transformer-level analysis of revenue smart meter data to plan replacement of transformers before they fail.

Utilities are investigating the value of having smart meters on the grid from an operational perspective. With interval data and the ability to aggregate data based on location, there is more information to pinpoint faults so workers can go more quickly and directly to the source of problems.

New customer technologies coming online may also impact utility capital investments. These technologies could include plug-in electric vehicles (PEVs), energy storage devices and small-scale power generation sources. Plugging EVs onto a single feeder, for example, can stress an undersized transformer and risk outages for a neighborhood or a larger portion of the grid. Installing distributed generation introduces bidirectional power flow on a grid built for one-way power flow. Utilities can use analytics to begin to understand which areas will be most likely to gain these new components and to better plan for capital investments in those areas.

What new technologies evolve is anybody's guess. Increased flexibility to respond to those needs is valuable. Once more new technologies of the grid deploy, utilities can use interval data from these components to optimize capital-investment decisions. As the intelligent grid rolls out, for example, utilities no longer will have to assume their customers' energy needs. They will have access to consumption patterns through smart meters. With more customer data that can feed into models, utilities can make fewer assumptions to make their capital investment decisions.

Utilities will need to find ways to incorporate distributed and renewable generation resources into their supply portfolios. Many moving parts in the generation portfolio will require analytics to process the increasingly complex and dispersed data sources. As carbon pressure builds, utilities will seek ways to defer carbon-emitting generation investments through better peak–demand management, renewable generation integration and supporting the electrification of transportation.

Risks and Challenges

Smart meters provide interval data at a lower cost than in the past. With this availability come potential risks and challenges.

Data Security and Privacy

California is the first state to initiate a rulemaking on the use and obligations by utilities to protect the privacy and security of electricity usage data of its retail customers[6]. The rulemaking was approved in July of 20011 and provides for both data access but also requires certain amounts of useful information to the consumers. These requirements include pricing, usage, and cost (rate) data to customers. They must also include customer bill-to-date, forecast bill data, projected month-end tiered rate levels and provide notification when customers cross rate tiers. Prices must be "all in" prices. Furthermore utilities are directed to develop a methodology to make wholesale prices available to customers on the utility's website.

The order also provides for a roll-out of a pilot of up to 5,000 home area network (HAN) devices that would allow smart meters to transmit their owners energy usage data to the home so that it can be received by the HAN device.

The California order limits the use of smart meter data to **primary purposes** which consist of interval data so as: <u>to provide for billing; to provide for system, grid, or operational needs; for services required by state or federal law or specifically authorized by the California Commission; or to plan implement, or evaluate demand response, energy management, or energy efficiency programs under contract with the utility.</u>

The utility may use third parties to collect and analyze the data for any of the "primary" purposes without customer permission. They may also transfer that data to additional third parties as long as the data is being used for a primary purpose.

Customers are allowed "convenient and secure" access to their usage data.

Data may be disclosed as part of a request under federal or state wiretapping laws or under a legal procedure or authority. Generally customers would be provided a notice and allowed seven days to appear and contest he legal claim.

Utilities are obligated to implement reasonable administrative, technical, and practical safeguards to protect covered information. At the same time utilities are not liable for disclosures by customer authorized or Commission authorized third parties.

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[6] Decision Adopting Rules to Protect the Privacy and Security of the Electricity Usage Data of the Customers of Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas and Electric Company, Decision 11-07-056, July 28, 2011, Public Utilities Commission of the State of California

Data Management and Data Integrity

Conversations with utility members reveal an important point - the first priority of the utility is to ensure that bills are rendered in a timely and accurate fashion. All else is secondary to that activity.

This puts data analytics down on the list of priorities at least in the short run. It seems likely that as utilities overcome many of the technical issues created by the sheer volume of load data being collected and develop the skills and tools to access the customer data that data analytics will become much more sophisticated.

In some cases the volume of interval data is overwhelming. Utilities have taken steps to manage this data volume problem by limiting the interval over which the data is collected. That is some utilities are only collecting sixty minutes data when 5 or 15 minute data is available. Some are only collecting daily usage rather than hourly in an effort to reduce the volume. Some may look to provide systems that will allow the turning on and off of the data collection method in order to rotate samples of interval data across the entire population of smart meters. This parsimony functionality may need to be developed by the MDMS system developers.

Data and Revenue Adequacy

The applicability of interval data depends on the extensibility of the data. Are smart meters available to all segments of a class of customers or are they concentrated in certain areas. Does the resultant load data reflect the population of customers as a whole? In many instances the costs of installing smart meters have started in homogenous residential neighborhoods of a similar type of housing type where the economics of the meter investments are most favorable. For those housing types without smart meter investments the use of the interval data for data analytics may be limited.

Alternatively then customer segments with access to smart meter data and who have alternative rate options and technologies which may allow them to reduce their costs and therefore reduce their bills. This tightening of rates to underlying costs has the potential to shift costs to the remaining population of non-smart metered customers. This effect, the cost shifting effect from better price design, also occurs within smart metered and non-smart metered segments.

If the starting point for the rates is a base rate or default rate that is not in alignment with the underlying costs then the movement towards more precise pricing designs will reveal this gap as customers choose alternative design that fit their underlying cost profile and as customers respond through behavioral changes and apply technology solutions to their situations.

It will become more difficult to keep base rates aligned between non-smart metered customers and smart metered customers as customer migrations and price and behavioral responses evolve. Ultimately the revenue allocation issues from improved rate design will be determined by customer choice but in the short term may produce levels of increased satisfaction and dissatisfaction.

Survey Results

EPRI surveyed a number of utility representatives who are involved with either the collection of interval data collected by smart meters or have the desire to utilize their smart meter data for their core activities. In order to obtain unbiased and objective comments no utility names or individuals are being used in summarizing the status of and uses for customer data analytics - unless specific reports are referenced. Twelve utilities were contacted and phone conversations were made to gain insight into how each utility was approaching their current and future customer data analytics activities using the smart grid data.

The focus of the survey conversations were in regards to the use of the data collected by the smart meters and the functionality of the smart meter for **customer data analytics**. In the context of this report customer data analytics refers to organizing customer usage data obtained from smart meters and using the data to satisfy regulatory requirements, meet customer needs, plan the business or to produce shareholder value with the main emphasis on meeting customer needs.

The questions were conversationally based; no formal survey instrument was developed or used. There were three basic directions of questioning. What is the current status of their smart meter implementation activities, what are the current uses of the collected data and what are the future plans for customer data analytics.

The main conclusion from the combined experiences of the survey members is that there is much that they intend to do with the interval data. However, the thrust for nearly all respondents was that data integrity must be assured. Some were, in fact, delaying the full scale customer data collection and analytics until systems, procedures and IT capacity were in place.

For those utilities that had immediate needs for customer data analytics most were forced to use the meter data management system (MDMS) vendors or third party vendors. They are the ones most familiar with the structure of the stored data. Surveyed commenter's also suggested that this latter approach has been very expensive.

Southern Utilities

There is a significant amount of smart meter installations in the South that have produced challenges in managing the volume of data. Regulatory requirements for posting the data for customer presentation and settlement purposes have also driven the efforts.

Feedback for customers concerning their energy usage was a primary use of the smart meter data listed by these utilities. Several pilots were being conducted.

For some utilities the use of customer interval data was focused on customer segmentation analysis to support their rate offerings. The data has also been used for implementing conservation voltage reduction programs as well as for conventional load research in order to construct class diversified load shapes.

One utility surveyed was interested in using statistical methods to disaggregate end-use data for presentation to customers. This approach would be slightly different than a non-intrusive load monitoring approach done on a real time site basis as it would use a statistical average across a large number of customers to produce the disaggregation.

Western Utilities

Much of the efforts in the western states have been driven by a regulatory timetable. Full functionality of the smart meter has not been enabled specifically for home area network (HAN) capabilities as a consequence. As outlined in the data privacy and security section of this report the California PUC has ordered a 5,000 site pilot for each of the three main utilities to enable the HAN capabilities to assess the response by customers to that functionality.

To date, most of the customer data analytics has been in the development of time based retail rates including time-of-use and critical peak pricing designs.

Going forward the effort will be to develop customer segmentation strategies using this data to promote pricing structures for demand response and energy efficiency.

Midwestern Utilities

One of the largest pilots using smart meter customer data has been conducted in the Midwest. The pilot looked at alternative rate structures that promote demand response and energy efficiency. There were options that provided detailed feedback for the customers to respond. There were also technology based rate solutions that responded to real time price signals sent through the smart meter.

The customer data analytics have shown mixed results[7]. The report … *"confirms that none of the treatments resulted in any significant change in average customer usage, even when customers paid an additional $1.74/kWh for electricity. However, an important subset of customers facing dynamic rates—about 10%— responded to elevated event-day prices by reducing usage. These event-responders exhibited load reductions in excess of 20% for critical peak pricing and around 14% for peak-time rebate and day ahead real-time pricing. It also appears that event load reductions were undertaken by some customers on the other rates tested, despite there being no financial advantage to doing so.*

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[7] The Effect on Electricity Consumption of the Commonwealth Edison Customer Applications Program: Phase 2 Final Analysis, Technical Update 1023644, EPRI, October 2011

This might be the result of ComEd's education and event notification to CAP participants that raised awareness of supply cost on certain days of the year."

This suggests that perhaps further customer data analysis may reveal those drivers of customer behavior and price response.

Another Midwest utility has used third party customer data analytics assistance to produce their analysis on an ad hoc basis. The costs to produce these reports have been expensive.

Northeastern Utilities

Most of the efforts in the Northeast have been involved with presentation of the data to customers and for energy efficiency measurement and valuation activities.

Advanced metering infrastructure (AMI) demonstration pilots are ongoing. The AMI data collected is used for testing AMI features such as automatic outage notification, remote meter reading, remote reconnection and the ability to communicate energy usage information via other smart building technology to web portals or in-home displays. The web portals and in-home displays can show energy usage by appliance.

Section 3: Customer Data Analytics Template

Based on the survey results of current and planned activities EPRI has categorized their responses into a template. This template follows the California definition for the primary uses of smart grid data which reflect the basic regulated activities provided by electric utilities. Customer data analytics beyond the primary purposes would need to be conducted by unregulated or third party entities who arrange for these services directly with the customer. Table 3-1 provides a list of potential activities identified by survey.

Table 3-1
Customer Data Analytics Template of Activities

Regulated Activities	Unregulated Activities
Bill Rendering and Presentation Price Response Rate Design	Open Market Pricing Equipment Performance Measurement & Monitoring
Energy Efficiency and Demand Response Evaluation	Utility Marketing
Load Research	Bill Analysis (not primary use)

The variations within each of these categories are virtually unlimited and in some instances may cross over form regulated to unregulated or vice versa. Some activities may fall into gray areas as to what constitutes a utility primary activity where utility access to the interval data is unfettered and those that may be considered load building or fuel switching activities on the part of the utility. In those cases the utility must keep separate those activities between their regulated and unregulated activities. A brief description of each follows.

Bill Rendering and Presentation

This represents one of the core activities by utilities and their distribution areas.

Rendering may take the form of paper or electronic. The pricing interval dictates the level of display, for example real time pricing would require the presentation of interval prices for each hour of the billing cycle. Rendering may occur on a real time basis and not limited to billing cycles set by the rate so that customers may determine the amount of their bill to that point. Flexible rendering is a possibility although dependent upon the rate structures. Although a possibility no examples have been found.

Presentation may occur on a flexible basis. Usage since the close of the last billing cycle, projected billing cycle bill, and marginal prices are becoming more commonplace.

Presentation may also be used to provide feedback on consumption levels and patterns. Most presentation is done on a proxy basis. This means that estimates of usage can be made based on inputs provided by the customer and compared to others actual usage. Actual usage may be made using either statistical methods, see below, or measured. Measured data has been more expensive but new technologies are being developed and evaluated by research organizations including EPRI to determine their cost and accuracy.

Price Response

Price response is largely driven by rate design. Response is driven by price elasticity and income effects. Price elasticity is a function of complements and substitutes which in the case of electricity few short run alternatives are available to customers other than consumption avoidance. Long run substitutes are limited as well.

Flat rates, although producing some response, do not produce as much as time of use or critical peak pricing. Price response may take the form of customer action and behavior versus technology enabled. This is an area where much effort is being devoted particularly with the advent of home area networks and price enabled thermostats.

Rate Design

The basic building blocks of electricity pricing consist of level, interval, duration, updates, quantity and contract term. It is the advent of interval meeting through smart metering that can and will produce an explosion of rate structure alternatives which can be responded to through behaviors or technology.

EPRI has completed work this year on classifying alternative rates structures[8]. This report showed that with price and quantity overlays that hundreds of alternative rate structures can be constructed. However, nearly all can be rendered through the interval data collected through a smart meter.

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8 A System for Understanding Retail Electric Rate Structures, Technical Update, EPRI, July 2011, 1021962

Energy Efficiency and Demand Response Evaluation

Whole premise interval data is a good start for evaluating the impacts of many if not most energy efficiency and demand response products. However, if the impacts are small or there are larger confounding factors not captured like changes in household members, new equipment purchases, change in employment etc., then smart meter data may not be sufficient. Instead other methods may be considered. For instance new non-intrusive methods are being investigated by EPRI and others with the whole house smart meter data providing the backstop.

There are statistical methods as well. These methods combine whole premise interval data with survey data to disaggregate the interval data into its component parts. The degree of accuracy for this approach is an area for further research by EPRI and others[9].

Load Research

Load research activities using the smart gird may be grouped into two categories whole premise and end-use.

Whole premise load research data is fast becoming much cheaper and more readily available to utilities. This should help in base rate design activities to allocate fixed costs and for the use in rate design.

Disaggregated load data or end-use load data will likely also be more widely available but at this point there still exist technical and implementation barriers that prevent its use on a more wide scale basis. The expectation by most researchers is that this is an area that will produce breakthrough results in the coming few years.

Open Market Pricing

In competitive market where consumers are provided a choice of suppliers the use of interval data by the aggregators and retail energy providers is crucial. This is an area where new methods to predict customer load shapes and load shape uncertainty are critical in profitably procuring supplies. Predictive methods for determining those load characteristics are generally proprietary and not widely available.

Equipment Performance and Monitoring

This is a new area that may produce significant customer value. Most consumers do not care about kilowatt hours or kilowatts. They are only concerned with the services their appliances provide: heating, cooling, hot water, food storage, entertainment, etc. The difficulty most consumers have is whether their

9 End-Use Load Research in a Smart Grid World, EPRI, Product Solicitation, October 2011, 1023280

appliances are operating properly, if there are electric circuit faults, if they require maintenance or if they should be replaced. This is a potentially huge area of customer interest and a potential area for further research.

This technology is being worked on by major firms including Intel and General Electric and others. Most of the approaches use non-intrusive methods but these techniques are still unproven.

Utility Marketing

Utility marketing was noticeably absent from the California rulemaking decision regarding primary interval data usage and therefore permission is required to use interval data. Utility marketing activities typically involve fuel switching activities but may also include economic development, load building in new and retrofit construction and commercial and industrial contract arrangements.

At least according to the California rulemaking on data privacy and security the use of interval data from smart meters would require either permission from the customer or through unregulated subsidies or other third parties.

Bill Analysis

Similar to the utility marketing activity billing analysis falls into a gray area of primary data use in the California data security and privacy rules.

For some utilities this requirement may prevent them from reviewing customer loads to determine optimal rate choices for their customers. This may have the effect of reducing customer choice and reducing the potential savings from their investment in the smart gird.

Section 4: Data Analytics and Meter Data Management

Data Challenges

Advanced metering infrastructure (AMI) buildouts which include the smart meter and two way communication infrastructure and Meter data Management Systems (MDMS) have created a daunting challenge for utilities to store, organize and manage massive volumes of meter data. In its August 2009 report, Federal Energy Regulatory Commission (FERC) reported an estimated deployment of 140 million smart meters by the year 2019.[10] If that is 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 utilize such gigantic volumes of meter data and translate it 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 be spent on the smart grid over the next several years.[11]

To understand the enormity of this challenge, consider the example of Austin Energy's Smart grid roll-out. In its first phase of deployment, Austin Energy installed 500,000 meters that were configured to collect 15-minute interval energy data. This activity generated 180 terabytes (TB) of data including data collected and stored for disaster recovery redundancy (1 TB is equal to 1024 gigabyte (GB)). Based on this example, one smart meter can produce 400 megabytes (MB) of data per year. The amount of data collected depends of course, on the sampling frequency, the upload frequency and the number of variables (or channels) being collected. Some utilities such as Pacific Gas and Electric (PG&E) are reported to have employed a low upload frequency of two uploads per day per meter on their fleet of 700,000 meters. This activity results in about 1.2 petabytes (PB) of data, or over 170 MB per meter per year (1 PB is equal to 1024 TB). Furthermore, smart grid functionality may require shorter

[10] 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

11 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

sampling frequencies (such as 5-minute, or 10-minute) and additional information such as amps, volts, watts, vars, total harmonic distortion etc. which will result in even larger volumes of data.[12] Though 400 MB is less than an average CD worth of data, millions of smart meters installed across each utility is a very large amount of data that creates a huge data conundrum for the utilities in terms of storage and processing. According to SAS, a leading provider of business analytics software and services, the scale of the data is not unique to the electric utility industry. Other industries have faced similar challenges in the relatively recent past. For example when credit and debit cards were first introduced, the financial services sector suddenly had a mass of information about how their customers were spending their money.

In the retail sector, the shift came when shops introduced electronic point of sale (EPOS[13]) systems, and then loyalty cards – both of which enabled retailers to gather detailed information about customer buying behavior. More recently still, mobile phone companies have been able to capitalize on a surge of data about calling habits and text messaging. More than the technological challenge of dealing with the "data deluge" facing the industry today, the utility industry has an ideological challenge of how to turn this mass of data into useful insights.[14]

Though managing the tremendous amounts of data seems highly challenging, utilities can approach this data challenge as a new business opportunity. Granular data 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 smart grid. 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 smart grid 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 AMI.

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[12] Danahy. J , Bochman.A (2009, October) "The Coming Smart Grid Data Surge", SmartGridNews.com
Available: http://www.smartgridnews.com/artman/publish/News_Blogs_News/The-Coming-Smart-Grid-Data-Surge-1247.html

13 Electronic point of sale (EPOS) is self-contained, computerized equipment that performs all tasks of a store checkout counter. It allows payments by bank or credit cards, verifies transactions, provides sales reports, coordinates inventory data, and performs several other services normally provided by employees. http://www.businessdictionary.com/definition/electronic-point-of-sale-EPOS.html

14 SAS White Paper, "From smart metering to smart marketing – How SAS can help utility companies take advantage of the data explosion".

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.[15]

This chapter provides an overview of data analytics functionalities that can be implemented for extracting useful information from meter data. Key applications supported by MDMS which can be used for system operation and customer benefit are discussed.

Customer Data Analytics and AMI

Figure 4-1 shows a typical AMI model along with two additional system components – customer data analytics and customer information. Recently, AMI systems and technologies have been the focus of rapid advancement and significant investment by both vendors and utilities. Though not widely implemented yet, AMI is revolutionizing utility operations by bringing near real-time data into the enterprise and unleashing integrations with other utility information technology (IT) systems.

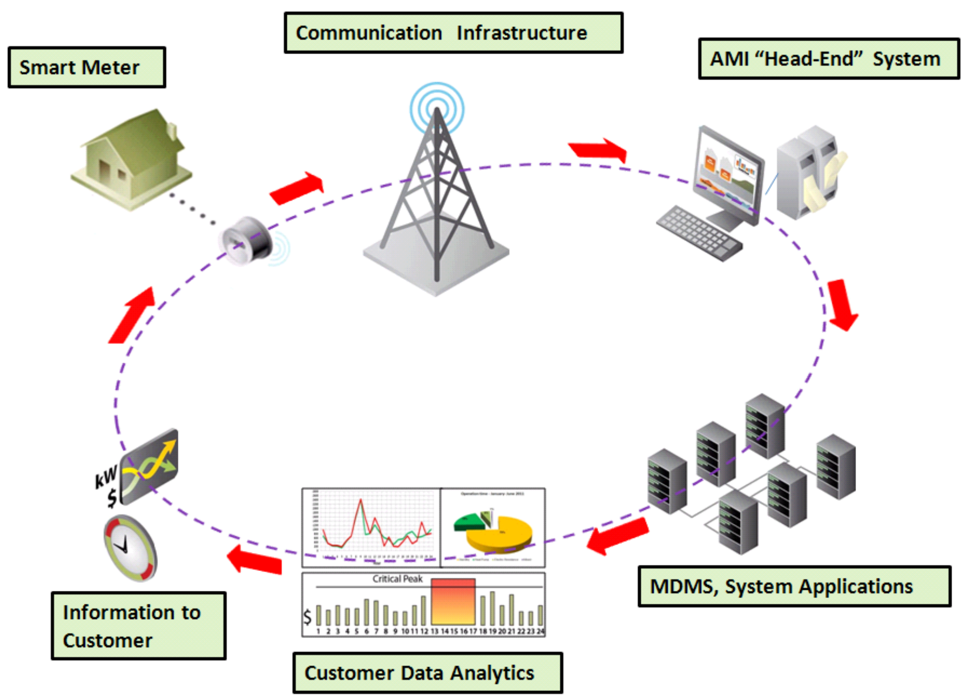

Figure 4-1
An Illustration of Customer Data Analytics and the AMI Framework

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

The typical AMI system components illustrated in **Error! Reference source not found.** are

- Smart Meter - An electronic meter that collects energy usage data in discrete time intervals and reports back to the utility.
- Communication Infrastructure – This includes hardware and software communication equipment employed for two-way transfer of data and control/monitoring signals. The communication network carries mainly energy consumption data from the smart meter to the utility and control and command information from the utility to the smart meter. The infrastructure encompasses communication technologies such as Radio Frequency (RF) links, Optical Fiber lines, Power Line Carrier (PLC) technology, telephone systems, cellular technologies and broadband technologies. Additional hardware such as communication towers, repeaters etc. form an integral part of the communication system.
- AMI "Head-End" System - This system is typically a software system hosted on servers at a central location to collect and maintain raw meter data received from individual meters. "Head-end" systems are also tasked to manage critical IT functions such as network management, monitoring and control of meter hardware and backup support for disaster recovery and restoration purposes.
- Meter Data Management System (MDMS) – Meter data management is a software system that provides a platform for managing data from multiple metering systems and make the data available for other applications internal or external to the utility. Legacy MDMS were typically designed to import raw meter data from the "head-end" system and conduct data validation, editing and estimation tasks on the raw data. The validated data was then used by billing analysis systems. MDMS today are capable of providing application programming interfaces (APIs) and data interfaces between MDMS located at multiple destinations, to customer information systems (CIS) and to operational systems such as outage management system (OMS), workforce management system, distribution management system (DMS), GIS (Geographic Information System) and asset management systems. Besides this functionality, an advanced MDMS may support remote connect/disconnect of meters , power status verification\power restoration verification and on-demand read of remote meters.[16]
- System Applications – This is a generic term used for hardware and software that can be an integral part of the MDMS or can exist as a separate entity. This system acts like a centralized "staging area" for creating, storing and reporting data required by databases and tools used in other departments/groups across the utility, such as load and demand forecasting, business and marketing, management reporting, finance and customer service.

[16] Advanced Metering Infrastructure Technology: Limiting Non-Technical Distribution Losses In the Future. EPRI, Palo Alto, CA: 2008. 1016049.

- Customer Data Analytics – refers to the hardware, software, methods and processes used to derive useful customer information from interval meter data. Additional data such as weather, customer surveys and pricing information are used to develop regional, demographic and customer-specific data that can be used by the utility to understand customer needs. Some of the applications of customer data analytics include diversified load shapes by customer class, diversified end-use load profiles using accurate disaggregation techniques, assessment of historic meter data to predict system peaks and distribution equipment failures on peak days, pinpoint usage patterns of individual customers to indicate meter defect, meter tampering, or theft of service[17], customer information portals, energy use and billing data presented in user-friendly formats such as charts, graphs etc.
- Information to customer – refers to specific information and feedback sent by the utility for various customer application programs such as alternative pricing options, conservation awareness and energy-saving tips, demand response triggers, real-time prices etc.

AMI System Components: Stakeholders and Benefits of the Data

Because of the potential volume of data from smart metering systems it is important to understand the value of data generated or processed at each AMI system component. Such understanding may assist in planning data management resources before smart metering is implemented. To understand the nature of data being generated within AMI systems five distinct data classes are created as described below.[18]

- Meter – includes energy usage and demand values such as average, peak and time of day
- System operations – includes electrical variables that in one way or the other represent the behavior of the grid
- Asset condition – includes data that represents the condition, health and behavior of the assets
- Event message – represents information that is exchanged between AMI components to represent event detection, e.g., theft and meter tampering detection events, outage event flags etc.
- Metadata – represents all the other data and information that is needed to organize and interpret the data classes

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[17] Pierzga.M.A , Lead Business Systems Analyst, PPL Services Corporation, "Using Meter Data from AMI with Meter Data Management Software to Identify Theft and Equipment Issues, September 7, 2008

18 Hoss. F (2010, June) "Smart Grid Data Management : 7 tips from the trenches", SmartGridNews.com
Available:

Additionally data characterizations can be made to answer questions critical to the implementation of data management and data organization systems within an AMI system –

- What type of data (based on the data class described above) is being generated and processed at each AMI component?
- Where is the data (physical location such as utility headquarters, third party hosted etc.) being generated or processed within the AMI system?
- How widely (or rarely) is the data generated or processed at each AMI component used in utility customer applications?

Utility AMI architectures should take into consideration the data storage, data management and analytical strategies which allow effective processing of data with the required levels of accuracy, security and speed. Right now, that is a challenge. Lessons learned from AMI system installations[19] to date and the current data challenges encountered due to smart meter deployment will potentially help utilities design the "second-wave" of AMI systems with optimally-designed hardware and software components for better data management, customer data analytics and quick delivery of information that can be analyzed and used by system operators to respond to dynamic system behavior. For instance, if smart meter voltage reads are being used as input for the utility's Outage Management System (OMS), a major storm resulting in thousands of customers being without power, will result in neither the OMS nor operators/dispatchers being able to process the large amount of data without the right analytics and/or the tools that allow data visualization capabilities.

Utilities are assessing high performance data communication systems and other technologies to improve the performance of data-driven applications for high-value utility applications. For example, some utilities are looking into building their own private communication networks such as wireless broadband field area networks (FAN) which can provide dedicated high-performance communication for transmission of AMI backhaul data and directly connected smart meters. FANs can play a critical role in transmitting information and results from data analytics applications for dynamic/granular situational awareness and for supporting a host of other high volume, data-driven applications. EPRI's smart grid demonstration projects being hosted at American Electric Power, Sacramento Municipal Utility District (SMUD) and ESB Networks Ltd., Ireland are testing dynamic control of distribution feeders using smart grid data analysis and processing data "on the fly" in real-time. The information is used to automatically and instantaneously reconfigure systems including volt, volt-amp reactive (VAR) and watt optimization on feeders for efficient and reliable system operation.[20] However, it may take at least four to five years more before these technologies can come into play and become an integral part of AMI, because of

[19] Smart Metering: Lessons Learned. EPRI, Palo Alto, CA: 2010. 1021627

20 Harrison. L (2011, November) "What makes the Smart Grid "Smart"? –Bringing together sensing, communications and control for high-value utility benefits", *Transmission and Distribution world magazine*

two key challenges. Firstly, new smart grid/AMI technologies need to be tested and evaluated at multiple utility sites and under multiple operating conditions for assessing reliability and security. This can be time consuming, before the technologies are verified and tested for actual installs. Secondly, utilities are faced with cost-recovery and regulatory pressures such as whether to fund these new systems as CAPEX (capital expenditures) or OPEX (operational expenditures) and how the public utility commission will view these costs and allow capital cost-recovery. It may take a while before regulatory uncertainties are resolved and a clear picture emerges.

Table 4-1 illustrates the relationship between AMI system components, data functions, class of data and the beneficiaries of data emanating from each AMI system component. The benefits of the data at the component-level are specified.

Table 4-1
AMI system components, data classes and benefits

AMI System Component	Data-related Functions	Data Class	Beneficiary	Benefits
Smart Meter	Collect interval energy usage data Collect additional variables such as volts, amps, var, power factor etc.	Meter , System operations	Utility, Customer	Reduced cost of meter reading Billing Understanding of customer usage and behavior Allows access to usage data via informational portals Alternate rate and pricing offerings
Communication Infrastructure	Conduit for data and information flow	Meter, system operations, asset condition, event messages, metadata	Utility, Customer	Communication of meter data to the utility Customer receives information such as pricing signals, demand response control and event information
AMI head-end system	Collection of meter data, repository of data for utility MDM, network management and some data management functions	Meter , system operations	Utility	Collection and management of raw meter data Meter data redundancy Manage AMI network

Table 4-1 (continued)
AMI system components, data classes and benefits

AMI System Component	Data-related Functions	Data Class	Beneficiary	Benefits
Meter Data Management System (MDMS)	Validation, editing and estimation of meter data for billing, aggregation and totalization, reporting and analysis	Meter	Utility Customer	Billing, Customer Information System Improved outage detection and restoration Theft detection GIS mapping and integration Distribution planning
Customer Data Analytics	Customer data analysis, data warehousing, load profiling, intelligence useful to understand customers	Meter	Customer Utility	Analysis and reporting Statistical analysis Load/demand forecasts Load research Usage information of customers

Sample Customer Data Analytics Solutions

DataRaker Inc.[21]

A key challenge in implementing smart metering infrastructure is extracting information from the terabytes of interval metering data. DataRaker Inc. provides a hosted solution using a software as a service business model. According to the vendor, little additional IT hardware and no extra personnel are needed on the utility side to begin analysis of stored smart meter data. The meter data is integrated with Customer Information System (CIS), GIS, and third-party facility and customer data to provide any number of analysis options for utilities. This solution may replace a legacy MDMS or just augment existing systems. Measurable results are delivered within 30 to 60 days from initiation of the solution.

A library of algorithms is available to customers and customers can work with the vendor solution to develop new models for custom analysis. Standard functions include evaluating meter data on a regular basis to identify malfunctions and errors in data reporting. This extends to identifying service bypass and meter tampering, with the ability to estimate lost energy and revenue. The available data is processed continuously to identify significant patterns and events, and can be used in myriad ways throughout a utility.

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[21] http://www.dataraker.com/

The solution implements a web-based interface which allows utility employees to easily access customer data to assist in call center applications. Applications also exist in load research and distribution planning, leveraging the combination of demographic and weather data. The DataRaker solution can be used in energy efficiency and demand response program design and evaluation. As a start the system can aid in customer segmentation and recruitment, baseline development and determination of appropriate incentive payments.

Several utilities are employing DataRaker to increase the value of their advanced metering infrastructure (AMI) and smart meter deployments. Kansas City Power and Light (KCP&L) is using DataRaker in their Smart grid demonstration. With the DataRaker solution KCP&L is able to look at usage at a circuit level which has allowed them to better leverage programs within the distribution system. Efficiency and demand response programs can be marketed around key circuits.

DataRaker has been used by Philadelphia Electric Company (PECO) and Pennsylvania Power and Light (PPL) to detect energy theft. It is also used by We Energies, and provided data to pilot studies 22 to aid in validation of energy savings from efficiency investments in homes in Milwaukee, WI. The data provided by the DataRaker solution included monthly electricity and gas usage and characteristics of homes.

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[22] Eileen Hannigan, "Milwaukee Pilot Program Results," Focus on Energy, Middleton, WI, Mar. 2011.

Section 5: Next Steps

What Do Customers Value?

According to a recent EPRI report[23] the benefits of the smart grid include:

- Allows Direct Participation by Consumers. The smart grid consumer is informed, modifying the way they use and purchase electricity. They have choices, incentives, and disincentives.
- Accommodates all Generation and Storage Options. The smart grid accommodates all generation and storage options.
- Enables New Products, Services, and Markets. The smart grid enables a market system that provides cost-benefit tradeoffs to consumers by creating opportunities to bid for competing services.
- Provides Power Quality for the Digital Economy. The smart grid provides reliable power that is relatively interruption-free.
- Optimizes Asset Utilization and Operational Efficiently. The smart grid optimizes assets and operates efficiently.
- Anticipates and Responds to System Disturbances (Self-heal). The smart grid independently identifies and reacts to system disturbances and performs mitigation efforts to correct them.
- Operates Resiliently against Attack and Natural Disaster. The smart grid resists attacks on both the physical infrastructure (substations, poles, transformers, etc.) and the cyber-structure (markets, systems, software, communications).

What do customers value? This is an important question, 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 collapse of the structured wholesale markets in 2002 and 2003 did not help support the case for lower prices as competitive choice and 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 or their inertia does not seem to be enough to motivate them.

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

Do they want load data from their smart meter? Do they want load data for their appliances? Do they want to know if those appliances are efficient and if they will break down? The answers seem to be an intuitive yes but how much are they willing to pay to achieve those services? There are no answers to these questions today. This is an area for further research for EPRI in the coming years.

Utility Value

The same EPRI study, cited above, estimates the net benefits from smart grid savings at $1.3 to $2.2 trillion over a twenty year period. This represents a 2.8 to 6.0 benefit cost ratio. These benefits are net of financing and rate of return costs. The implication is that industry rates will decline by that amount of costs savings as the smart grid savings accumulate.

However, the electric utility industry continues to be largely regulated. This means that in order for utilities to earn a return on those investments they must be either recovered through rates or customers must be 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 these customer data analytics investments may not produce shareholder returns. This may be a significant issue as utilities struggle with the huge capital outlays required to invest in the smart grid and are loathe to making further investments in customer data analytics without some assurance of cost recovery. This is a significant increase in business risk for utilities.

These are the same issues that were faced by utilities engaged in energy efficiency in the early 1990's. 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 smart grid area are to render bills and modify their AMI systems 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 report 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 Table 5-1.

Table 5-1
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.

Appendix A: Select AMI and Smart Meter Data Implementations

This section describes AMI and smart meter data implementations conducted by two utilities.

UTILITY A

Meter System Status:

3.7 million smart meters installed to date. All the installed meters are two-way communication enabled and are connected through a wide-area communication network to the utility office.

Rationale:

Smart meter deployment was driven primarily by the cost savings associated with monthly meter reading and off-cycle readings. Detailed customer energy usage information (for both the utility and customers) available from smart meters provides the ability to design and offer more sophisticated rate options as well as meter-based products and/or services in the future.

Smart Meter Data Uses:

The utility is working to derive additional benefits from the AMI system, having completed the integration of their new AMI system with their outage management systems.

Approach

The approach for coming up with data uses was through intra-organizational inquiries to all departments for potential applications. Based on the responses, the utility and its affiliates are in the process of identifying high-value uses and benefits of smart meter data.

System Components and Functions

The AMI smart meter system currently installed includes the components as shown in Table A- 1.

Table A-1
AMI System Components and Functions

Component	Vendor	Function	Comment
Smart Meter	Itron	Meters energy usage	Installed meter currently read usage in one-hour intervals. In the future, the utility plans to configure about 10-15% of its installed smart meter base at 15-minute resolution to allow detailed data collection for load research purposes and potential new rate plans.
FlexNet™ AMI system	Sensus	Remotely read, collect and manage data	
MDM system	Itron, Inc.	Operational system such as SCADA. Fully focused on validation, verification and estimation of meter data.	Different utilities define the functional role of MDM system differently, but the utility chose to use it for billing focus only.
AMI data warehouse or a centralized Staging area for MDM verified data	Under evaluation	Store, manage and analyze data for use in other databases and programs	Utility is currently working to evaluate and implement this component in the future.

Current Activities

Following are a list of activities currently conducted by Utility A to foster development of meter data uses –

1. Small pilots such as the EPRI Green Circuits project, to evaluate uses of data
2. AMI data management efforts to define and recommend the appropriate technologies to provide smart meter and MDM verified data to subsystems such as databases, programs etc. for use in applications such as load research, forecasting, planning, distribution management system, outage management system etc.
3. Definition and implementation of a governance process for smart meter data.

UTILITY B

Meter System Status:

More than 650,000 automatic meter reading systems (AMR) installed by 2010. The AMR system can only read energy-only (KWH only) meters. Those meters that record time of use (TOU) or demand measurements, or interval data still have to be read by hand. SmartSynch AMI solution installed and currently operating.

System Architecture

A schematic of the AMI system is shown in Figure A-1. The system consists of three components – Smart meter, head-end software and existing public wireless cellular network. The head-end software is TMS (Transaction Management System) which manages meter communication (meters send data on a schedule), collects & stores the data, exports to an MDM system.

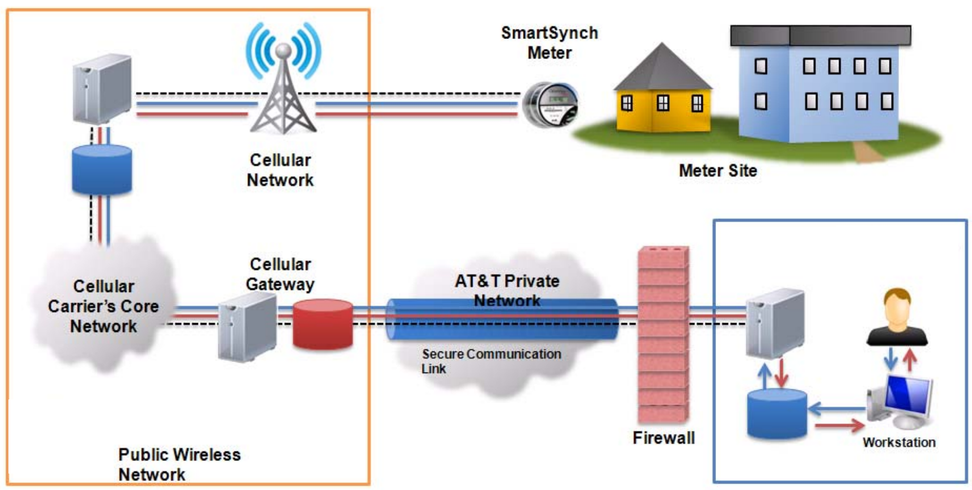

Figure A-1
A Schematic of AMI SmartSynch System

AMI SmartSynch and Meter Data Management (MDM) System Capabilities

Some of the key AMI and MDM system capabilities are shown in Table A-2.

Table A-2
Current and Future Capabilities of AMI SmartSynch System

AMI System Capabilities	MDM System Capabilities
Load profile data collection	Store and analyze large amounts of interval Data
Automated meter reading	Central storage for all interval data
Real-time meter event Notification	Billing determinant calculations
Power outage detection and restoration	Verification, editing and estimation of meter data
Remote meter diagnostics	Billing
Remote meter tamper detection	Data feed to customer webportal
Remote meter configuration	

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