# Impact of AMI on Load Research and Forecasting

*J. Stuart McMenamin, Ph.D*
*Managing Director, Itron Forecasting*

## Introduction

The purpose of this paper is to discuss the impact of advanced metering infrastructure (AMI) on the business processes involved in load research and forecasting. It starts with a short overview of current load research and forecasting processes. Definitions and an overview of AMI technologies are provided next. Then, the discussion proceeds to summarize the things that do and do not change because of AMI. Finally, these changes are translated into impacts on forecasting and load research business processes. Also, some conclusions are provided about the impact of these process changes for and meter data management (MDM) and data analysis systems.

## Discussion of Current Load Research Processes

The core function of load research is to collect and analyze interval data for a statistical sample of customers of a particular type. Samples are usually designed on a rate class basis. For example, for the residential class, a typical sample might involve about 250 interval meters collecting 15-minute data. The goal is to use the sample to estimate interval load shapes or profiles for the class.

The estimation process is called sample expansion, and the standard formulas provide estimates of typical customer loads, the total class profile, and measures of the uncertainty of these estimates (standard errors). To be cost effective, samples are usually stratified, and sample expansion is then based on stratified mean-per-unit (MPU) or ratio methods. Samples are typically designed to generate 90% confidence bands that identify population peak loads within ±10%. For industrial and large-user classes, interval data are often collected for billing purposes, and for these census classes, profiles can be computed exactly by adding the loads for each interval across customers.

While validation, editing, and estimation (VEE) for the large customers is usually performed by the billing group, VEE for customers in the statistical sample is usually performed by the load research group. Validated data are then used to support expansion calculations, which may be performed on a monthly or annual basis. In some cases, these calculations are performed on a daily basis, typically to support market operations in open markets.

At the end of each year, the load research group publishes the official class profiles for the year. These profiles may come directly from the sample expansion process or they may go through minor modifications to calibrate the sum of the classes (plus estimated losses) to hourly system loads.

The main uses of load research data are:

- **Cost Allocation.** Class profiles provide the basis for cost allocation in rate cases.
- **Rate Analysis.** Rate analysts use class profiles to calculation revenue impacts from alternative rate structures, such as time-of-use rates.
- **Forecasting Models.** Forecasting groups can use class profiles to understand usage patterns and weather response, which helps build stronger models and stronger weather normalization processes.
- **Finance – Booked Sales.** Forecasting and Accounting can use profiles or profile models to help understand the relationship between billing cycle energy use and calendar month energy use at the class level.
- **Finance – Unbilled Sales.** Models of profile data can be used to help estimate unbilled energy usage based on weather over the unbilled days in each cycle.
- **Operations – Facility Loads.** Based on connectivity data that link customers to distribution facilities (e.g., transformers), it is possible to use load research profile data to estimate the loading of individual facilities, a key input to distribution facility optimization.

- **Settlements.** In competitive retail markets, profiles are used to support hourly or sub-hourly settlement calculations for mass market customers that do not have interval meters.
- **Program Planning and Evaluation.** Programs promoting energy efficiency and demand response require profile data to estimate the impact and cost effectiveness of programs.
- **Marketing.** Marketing groups use class profiles and special studies for other market segments to understand how and when different types of customers use energy.

In addition to these main uses, load research groups often end up being the keepers of all interval data. This role emerges naturally because they have the most experience managing and handling interval data and interval databases. In this role, they function as an internal service group supporting billing, rates, jurisdictional settlements, customer relations, forecasting, program planning, and marketing groups.

## Discussion of Current Forecasting Processes

Electricity delivery companies perform three main types of forecasting: operational, financial, and planning.

- Operational forecasting supports short-run system operation and is practiced by ISO's and utility system operators as well as generators, traders, and retail suppliers. This type of forecasting is usually high frequency (updates every day or every hour), it uses high frequency system load data (e.g., 5 minute, 15 minute, or hourly), and it has a relatively short focus (the rest of today, tomorrow, the next week).
- Financial forecasting is oriented around budgeting and monthly reporting processes. Activity cycles in this area are annual and monthly and the focus is medium term with most emphasis on the coming year.
- Planning involves longer time horizons and supports facility investment decisions, such as generation and transmission system planning and substation planning. This is typically an annual activity and time horizons are long (e.g., 10 to 15 years or more).

The focus of the following discussion is on financial forecasting processes.

Financial forecasting processes center on an annual budget forecast. Typically, these forecasts are based on statistical models of customer growth, monthly sales and revenues. These models are estimated using billing cycle data, and they relate sales volumes to weather variables, economic conditions, energy prices, and other factors that impact the saturation, efficiency, and usage of energy using equipment.

Sales forecasting models are estimated using the actual weather and economic conditions that occurred over the historical sales period. Budget forecasts are then generated based on "normal" weather and expected economic conditions. Although the models are estimated with cycle-based data, the forecasts are often generated on a calendar month basis. Monthly forecasts are often disaggregated to the daily and hourly levels.

As the year proceeds, the models and model parameters are used for a variety of backward-looking activities. These include:

- **Weather Normalization.** Actual sales reflect the actual weather that occurred over the days in the billing cycles or in the calendar month. Weather normalization is the process of adjusting the actual results to the values that would have occurred had weather been normal.
- **Calendar Month Sales Estimation.** Actual sales for a revenue month accrue from energy usage over the billing cycles that are included in the revenue month. For financial reporting purposes, it is necessary to

estimate sales volumes for the calendar month. This translation can be based on backcasting calculations using forecasting models.

- **Unbilled Sales Estimation.** Unbilled sales represents customer usage between the end of each billing cycle and the end of the calendar month. This energy has been delivered to the customer but not yet billed, and appears as an asset on the balance sheet at the end of each month. This estimation process can be based on backcasting calculations using forecasting models that account for the number of unbilled days and weather that occurred over those days.

- **Variance Analysis.** After the results for a month are finalized, the goal of variance analysis is to understand the difference between the actual results and the budget forecast. Sources of variance are isolated and quantified, including deviations in customer growth from the expected levels, weather deviations from normal, and unexpected economic developments.

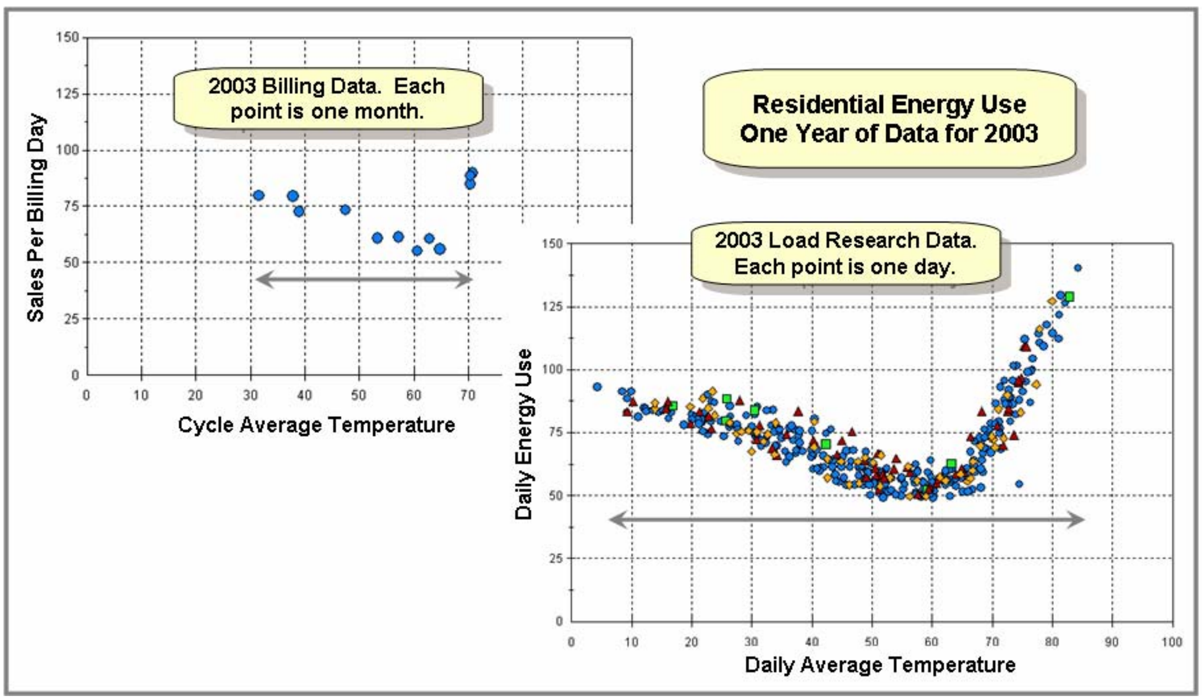
## Interactions Between Forecasting and Load Research

As shown in the example in Figure 1, class-level profile data from load research can be used to strengthen the forecasting process. This figure shows billing data and load research data for the residential class for one year. The billing data is converted to average daily use by dividing by the average number of days in the billing cycles in each month. These data are plotted against the average temperature for the days in the corresponding cycles.

The plot for the load research data is on the same scale and shows the estimated daily energy computed from the hourly profile for the residential class. The value for each day is plotted against the average temperature for that day, and the points are color coded by day type.

As is evident from the plot, the load research data provides a much more complete picture of how weather works. It provides 365 observations for the year and each point can be cleanly matched with corresponding weather and calendar conditions. In contrast, the monthly data provides only 12 points, and the match with weather is complicated because of the staggered billing cycles.

***Figure 1: Example of Billing Data and Load Research Data for One Year***



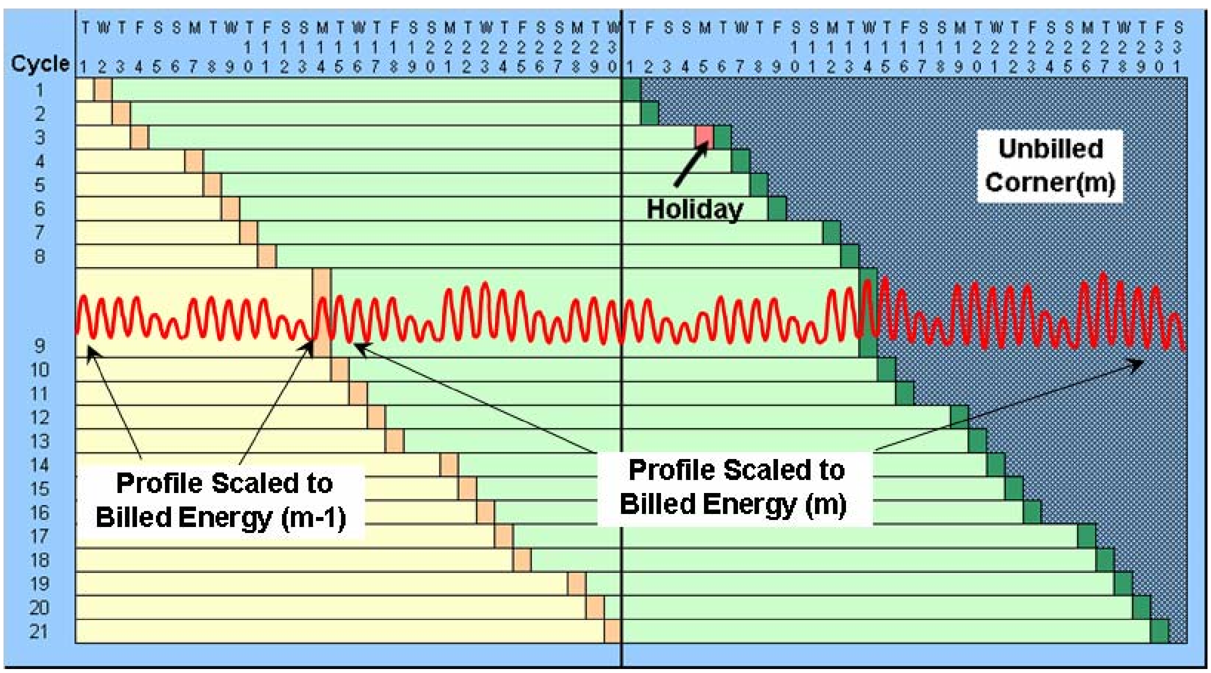

 

In addition to providing 30 times the number of data points, the daily load research data span an 80 degree range on the X-axis. In contrast, the range of average temperatures in the monthly plot is about 40 degrees. This is because the billing month weather is averaged and weighted over the roughly 60 calendar days that impact sales in each revenue month. Note that the variation is also reduced on the Y-axis.

The point is that the load research data provides a clear picture of how weather impacts sales for a rate class. There is greater variation in both directions, and the data shows a clear stable relationship. It shows where apparent heating loads and cooling loads begin, and it shows the relative strength of early degrees versus later degrees. The rich relationship evident in the load research data can be estimated, and once captured, these coefficients can be imposed in the construction of multi-part monthly variables to be used in the forecasting models. The result is models that provide a stronger explanation of historical variations in monthly sales and that provide stronger capabilities for weather normalization, calendar month calculations, and unbilled sales calculations.

The other place where profile data from load research are highly useful is in financial closing calculations. This is illustrated in Figure 2, which shows a two month period and the geometry of billing cycles over this period. The figure covers the calendar months of June and July, and the green horizontal bars represent the days covered by each of 21 cycles in the July revenue month (month m). Each bar ends on a read day, represented by a dark green shade. The yellow bars to the left of the green bars represent the last part of the cycles for the prior month (m-1).

***Figure 2: Use of Profile Data in Financial Closing***




On the bar for cycle 9, profile data are shown covering the billing periods and also extended to the end of the calendar month. These values may be direct load research calculations or they may be predicted values from models of the profile data, computed with actual weather for each day. Billing data (monthly kWh) for a cycle can be used to scale the profile to represent the customers on that cycle. Then calculated totals can be used to understand the relationship between energy used over the cycle days (June 15 to July 14 in the example for cycle 9) and the days in the calendar month (July 1 to July 31). They can also be used to calculate totals over the unbilled days (July 15 to July 31).

By applying this type of logic, it is possible to estimate with strong accuracy calendar month energy (booked sales) as well as unbilled energy, based on the geometry of the billing calendar and the evolution of weather patterns over the month.

There are other important interactions between load research and forecasting that are not discussed here. The purpose of highlighting the specific areas discussed above is to lay the foundation for the discussion of how things change when AMI data become available.

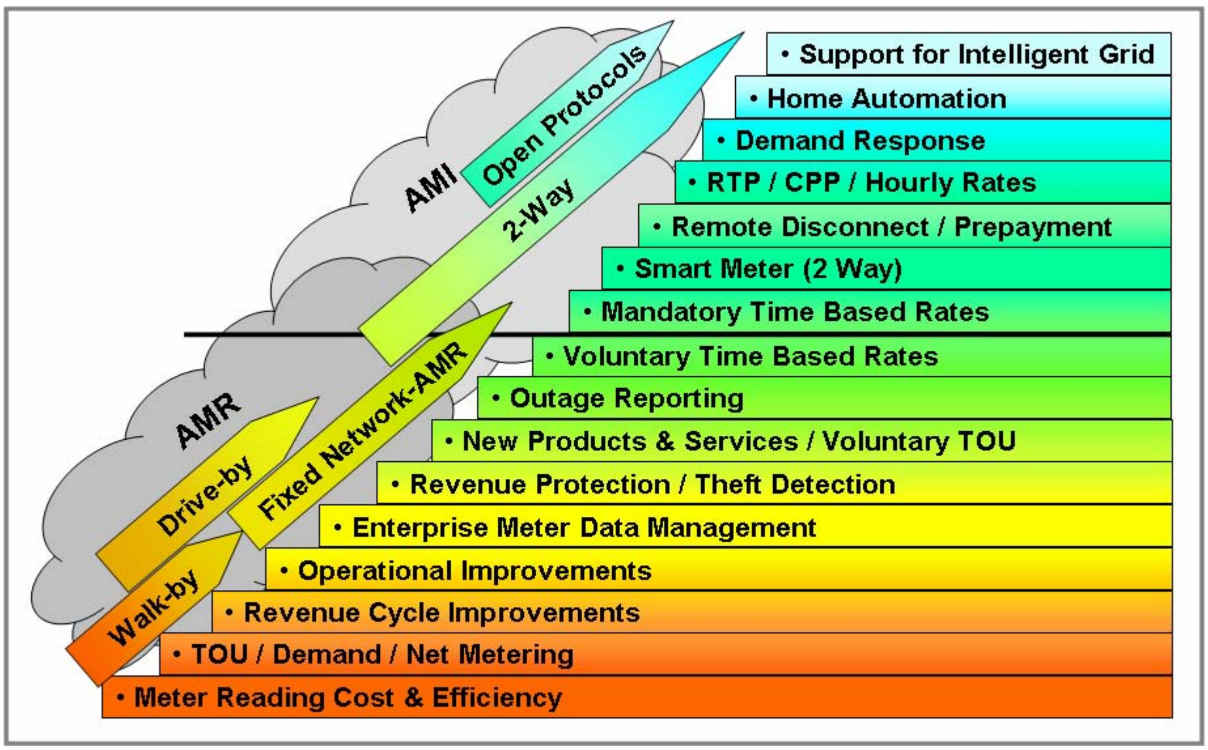
## AMI Technologies and Functionality

AMI involves the use of meters with two-way communication technologies that allow utilities to:

- Meet business and operational needs for meter data collection on a near real-time basis.
- Empower customers to participate in demand response programs.
- Meet the meter-based requirements for moving toward a smart grid.

Figure 3 provides a depiction of the types of functionality enabled by AMI. The functionality stack starts with capabilities enabled by automated meter reading (AMR) technologies. These early items do not require high frequency (interval) data, real-time connections, or 2-way capabilities. As you move up the stack, real-time connections become important for functionality like theft detection, outage reporting, and critical peak pricing programs. Interval data is required for time-based rates, real-time pricing, and demand response programs. And 2-way communications come into play for remote disconnects, demand response communications, and home automation.

***Figure 3: AMR vs. AMI Functionality***

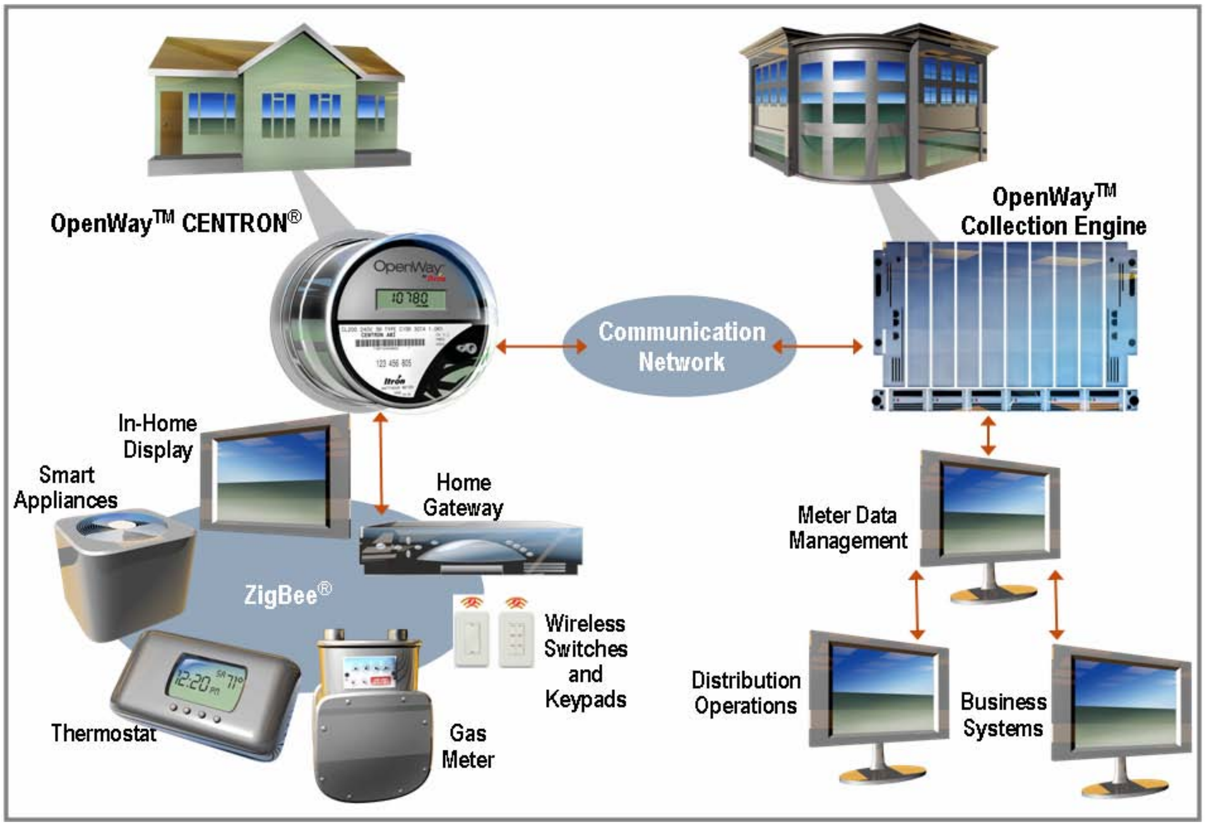



From our perspective, the critical element with respect to forecasting and load research is the timely collection of interval data. While AMI systems enable the capture of interval data for all customers, it is an open issue whether AMI systems will be configured to gather and store interval data on a universal basis. From a long-run perspective, we believe that this will be the case. This means that systems will need to be sized and configured to collect and store interval data at a frequency of hourly or higher for all customers.

The components of an AMI system are illustrated in Figure 4. On the left hand side is the AMI meter, represented here by the Itron Openway Centron meter. This meter has two way communications through a communication network. On the customer side, communications from the meter go out to other devices through a home area network or directly using Zigbee protocols. This allows communications through the meter to send information to displays in the home, communicate with thermostats and switches in the home, and gather information from other meters (gas and water).

On the utility side, data and communications pass through the network to the collection engine. The collection engine passes data through to the MDM system. From this point, data is delivered out to operational systems and to business systems. Our interest is on the business systems side, which is where the forecasting and load research functions reside.

***Figure 4: Depiction of AMI System Components***




## Things That Do Not Change

Although the introduction of AMI is an important step in the evolution of utilities, the core functionality of the business does not change. Things that remain the same include:

- Energy still needs to be produced/generated and delivered to the customer.
- It still takes wires and pipes to deliver energy.

- Environmental concerns remain important.
- Bills are still calculated and delivered to customers on a cycle basis.
- Hourly load profiles continue to be used in rate cases, forecasting, and planning.
- Forecasting is still about the future. This remains an analysis task because you can't meter the future.
- Weather normalization and variance analysis remain as counterfactual analysis tasks that are required to understand recent measured results.

Although we believe that interval data will be collected for all customers, we also expect that billing cycles will continue to be used. This is necessary to smooth the workload in the billing process and at the call center. These are the same reasons that credit card and phone companies work on a billing cycle basis. Note that the cycles won't necessarily be route based in the long run, since cycles for an individual customer can be modified in an AMI system without concern for the physical location of the customer. The key point here is that as long as cycles are used, the financial closing process will continue to require calculation of calendar month sales and unbilled sales.

From a forecasting perspective, the core forecasting tasks, which include budget forecasting, weather normalization, and variance analysis remain unchanged. As discussed in the next section, the data used in these calculations may change, but the basic analysis requirements will remain the same.

## Things That Do Change

Related to forecasting and load research, the main thing that changes with AMI is the availability of interval data for all customers. Before AMI, interval data were available for large customers with interval data recorders and for the statistical sample of load research customers. With AMI, we believe that interval data will be collected for all customers.

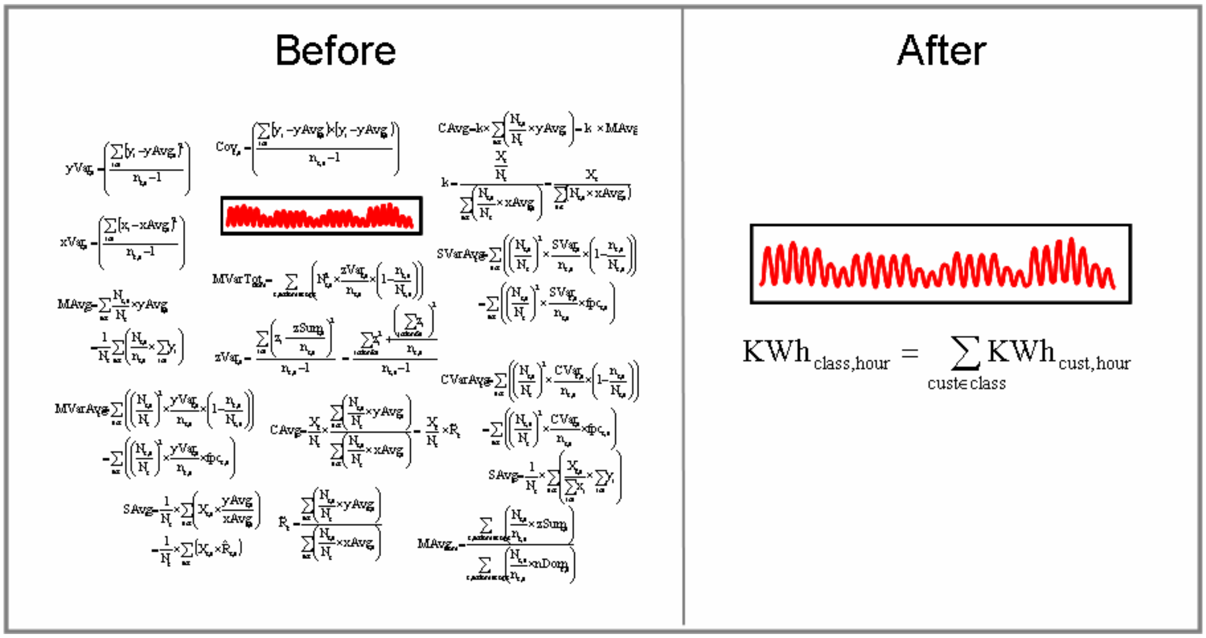
Also, the data will be collected on a near real-time basis. Currently, interval data is collected once a day or sometimes on a monthly basis. With AMI, data collection is a continuous process, and interval data for all customers will be flowing through the data collection system with minimal lag time. For most customers, data generated on one day will be available in MDM on the following day.

### Class Profiles

This has significant implications for load research. Once AMI meters and systems are fully deployed, there will be no need for the complex statistical processes for estimation of class load profiles. Instead of strategic sample design and sample expansion calculations, class profiles will be calculated as a massive add up across the interval data for customers in the class. This is depicted in Figure 5.

There are some challenges to work through before this conclusion holds. For example, because of the volume of data, validation processes will need to be automated, with visual inspection reserved for a small subset of extreme cases. Also, although it is expected that data collection success rates will be close to 100%, there will still be a need to adjust upward by some small amount to account for missing data. New business applications will need to be built and configured to perform the add-up calculations and adjustments. Finally, MDM systems will need to be configured to provide interval data to the add-up applications on a daily basis.

***Figure 5: Class Profile Calculations Before and After AMI***




## Facility Load Estimation

One of the things that becomes available with universal interval data is the capability to aggregate customer loads at the distribution facility level. At the lowest level, customer loads can be aggregated by transformer, then feeder, then substation. In the end, they can be aggregated to the system level.

Currently, these types of calculations are supported through estimation. The estimation process combines connectivity data (the mapping of customers to transformers, transformers to feeders, etc.), customer bills, and load research data to estimate facility level loads. This estimation is usually done with a significant lag (e.g., estimates for the prior year).

With universal interval data, load research data is no longer required for this calculation. Facility loads can be computed directly by adding up the individual customer data. This will give a much clearer picture of actual facility loading patterns. It will require new business applications to configure and execute the facility load calculations, and MDM systems will need to be configured to provide interval data to these applications.

## Calendar Month Use by Class

As discussed above, estimation of calendar month energy use by class is currently an analysis task performed by forecasting and finance groups as part of the monthly closing process. Utilities usually know how much energy was produced and delivered during the month, but they currently do not know who it went to until the meters are read. And since the reads are on a cycle basis, it is still a challenge to map measured usage to days in the calendar month.

With universal interval data, this becomes a massive add up. Interval data can be aggregated to the days in the calendar month and added across the customers in a rate class. Over time, there will be a growing database of actual monthly consumption data by class, and at some point, it will be possible to use this regular monthly data rather than irregular billing cycle data to estimate forecasting models.

## Unbilled Energy

As discussed above, estimation of unbilled energy is currently an analysis task performed by forecasting and finance groups as part of the monthly closing process. A variety of methods are used for this task, and this calculation is often a source of confusion and consternation to management.

With universal interval data, this becomes a massive add up. At the end of a month, it is possible to look at each customer, identify the most recent billing date for that customer and add the intervals between the billing date and the end of the calendar month. This can then be aggregated by rate class, and converted to a dollar value (unbilled revenue) that is placed on the balance sheet. On the income statement, revenue for the month is then computed as billed revenue plus the change in unbilled revenue.

Because unbilled energy can be calculated directly for each customer, all confusion about unbilled energy will disappear. Current indirect estimation methods used by many utilities (based on billing data and prior months' unbilled estimates) will be replaced by direct estimation of unbilled energy each month. AMI data and analysis systems to process these data are expected to provide improved clarity for this task.

## Energy Losses

Losses between the generator and the customer are typically estimated using engineering calculations or loss formulas. Some utilities will compute overall losses as the difference between net generation for system load and customer bills using something like a 24 month rolling calculation. Although it is expected that losses vary significantly throughout the year, constant loss factors are normally used because exact values are not available.

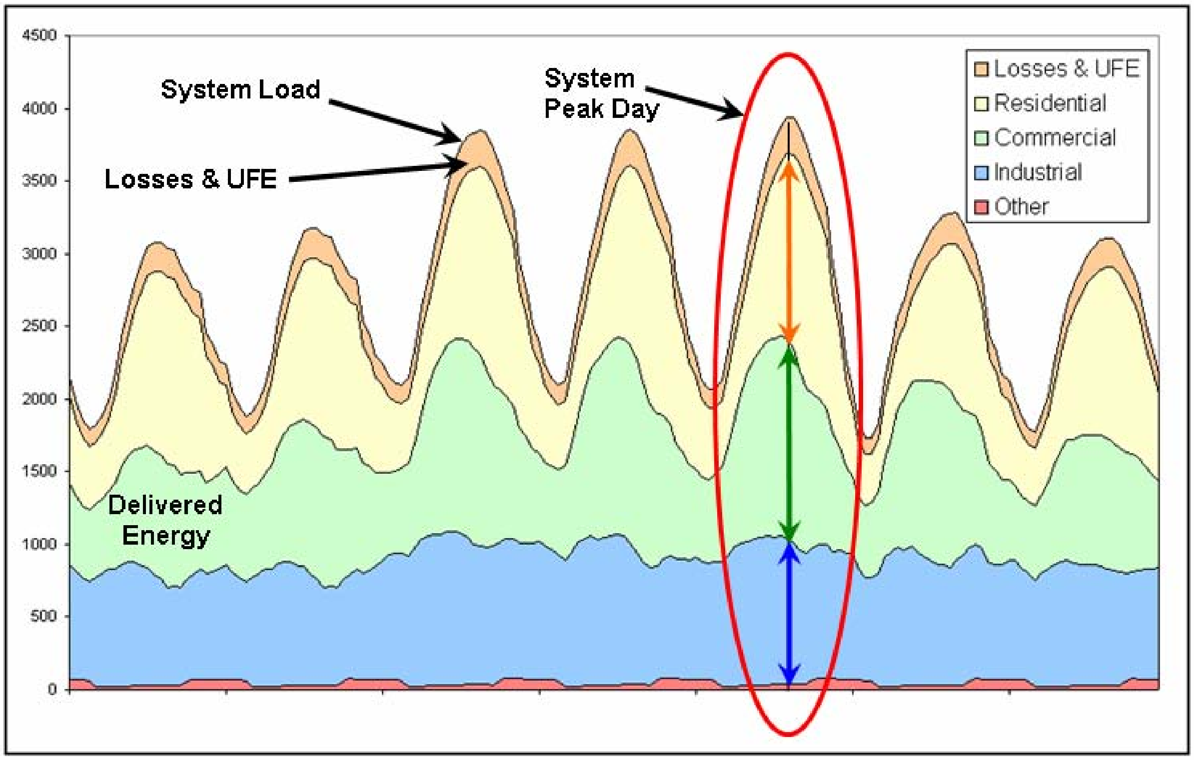
With AMI, losses can be calculated directly at the interval level as net generation for load minus delivered energy. This is depicted in Figure 6, which shows hourly system loads for the week of the system peak. The top line is the hourly system load, which is measured directly through SCADA systems. The figure also shows a bottom-up total for each of the major rate classes, with industrial loads at the bottom, followed by commercial, followed by residential. The gap between the bottom-up total and the system load is losses and unaccounted for energy (UFE).

The values in this picture can currently be estimated using profiles from load research data. However, because the statistical uncertainty is typically in the 5% to 10% range for each class, estimates from load research do not help clarify the level and pattern of hourly losses. With AMI systems, the pattern of hourly losses becomes clear.

## Financial Clarity

The previous three items (calculating monthly energy by class, calculating unbilled energy, and calculating hourly losses) all point to one of the subtle benefits of AMI – financial clarity. AMI data, properly analyzed and aggregated provides a clear picture of how customers use energy on an hour by hour basis. When the books are closed for a month, they can be closed with high confidence.

*Figure 6: AMI Data provides Clarity about the Composition of System Load*




## What This Means for Load Research

The above conclusions do not have immediate implications for load research. For the next five to ten years, load research studies will continue using current methods in most utilities. There will be transitional issues as AMI systems are deployed.

- As AMI meters are installed, existing load research meters will be displaced (unless load research groups insist on keeping these meters in place). Load research groups will need to be involved in the deployment process if they want to track existing sample meters and switch the data feed from existing collection systems to the AMI collection system.
- As AMI meters are deployed, there will be the opportunity to include additional sample points in load research studies at little additional cost. Load research groups will need to decide if they want to tap into additional meters, but this will require dynamic thinking about sample designs.

For load research groups, the big changes come after the AMI deployment is complete.

- Once AMI meters are in place and interval data collection processes are running smoothly, MDM system will be the central database for collection and distribution of interval data. Calculation of class profiles will be one of many functions supported by interval data provided by MDM.
- Once add-up processes are implemented, there will be no need for the class samples and the sample expansion processes and systems.

- Special studies (e.g., end-use metering, program design, and program evaluation) will continue to require sampling processes and expansion calculations.
- In competitive markets, there will be no need for profiling samples and profile backcasting systems, since all customers will have interval data for settlements calculations.
- Load research departments will change into data analysis and special study departments. The load research group will no longer be at the center of interval data collection.

Note that these conclusions are based on the assumption of interval data collection for all meters. Although we believe this will be the case, AMI systems will also support collection of low frequency data (such as daily consumption). In cases where AMI systems are not configured to collect interval data on a universal basis, existing statistical processes can continue to be used with samples implemented in the AMI framework.

In any case, load research groups need to be heavily involved in the AMI deployment process. This will be necessary to keep load research functionality intact through the transition. Once AMI is complete, there will still be a need for Dynamic Profiling applications that calculate class profiles based on interval data provided by MDM. The load research group (or its successor) will be responsible for these calculations and for maintenance of aggregate class profiles. Also, there will be an ongoing need for analysts and analysis applications that support special studies based on interval data.

## What This Means for Forecasting

The fundamental role of the forecasting group will not be impacted heavily by AMI. The main changes will relate to the financial closing process.

- **Calendarization.** The role of forecasting in estimation of calendar month energy by class will go away. Calendar month energy use by class will be calculated as a direct add-up of customer interval data.
- **Unbilled Energy.** The role of forecasting in estimation of unbilled energy by class will go away. Unbilled energy by class will be calculated as a direct add-up of customer interval data. This will provide improved financial clarity relative to current processes.
- **Budget Forecasting.** Budget forecasting needs will remain the same, but the models will eventually be estimated using calendar month data instead of cycle data. With these data, it will be possible to forecast and track daily energy by class as well as monthly energy.
- **Weather Normalization.** Weather normalization processes will continue. With AMI data, it will be possible to apply normalization and tracking processes at the daily level (tracking weather normalized daily energy by class against budget forecasts), providing improved clarity and visibility.
- **Variance Analysis.** Monthly variance analysis processes will continue. For the first time, analysts will have access to actual calendar month loads by class, and this will clarify the comparison of actual results against budget forecasts.

## Challenges for IT and the Role of MDM

Information technology (IT )systems will need to be scaled for high volumes of data. Hourly interval data for a population of 1 million customers will generate 24 million observations per day. MDM systems will need to be configured to validate and store these data and to deliver validated interval data for individual customers to a variety of business systems in a variety of formats.

- **Billing Determinants.** Interval data or billing determinants by customer will be required by the billing system. Billing determinant calculations will be made on a billing cycle basis and may be made by MDM or by a downstream application.
- **Hourly Profiles.** Interval data by customer will be required to compute aggregated profiles each day at the rate or rate class level. The dynamic profiling application will aggregate interval data by class and in other dimensions of interest.
- **Monthly Energy and Unbilled Energy by Rate.** Daily data by customer will be required to compute aggregated daily and monthly usage at the class level. At the end of the month, it will be necessary to compute unbilled energy by customer, allowing these numbers to be aggregated to the class level.
- **Facility Loads.** Interval data by customer will be required by facility load estimation systems to support distribution system operations.

In addition to these business systems, data will be delivered to a variety of operational systems, such as customer care applications, connect/disconnect operations, demand response programs, outage detection applications, and revenue assurance applications to name a few. Because this functionality will require significant investments in IT systems and hardware, it seems likely that the role and influence of IT groups will expand with AMI.

## Itron Inc.

Itron Inc. is a leading technology provider to the global energy and water industries. Itron Inc. consists of Itron in North America and Actaris outside of North America. Our company is the world's leading provider of metering, data collection and utility software solutions, with nearly 8,000 utilities worldwide relying on our technology to optimize the delivery and use of energy and water. Our products include electricity, gas and water meters, data collection and communication systems, including automated meter reading (AMR) and advanced metering infrastructure (AMI); meter data management and related software applications; as well as project management, installation, and consulting services.

To know more, start here: www.itron.com

**Itron Inc.**
**Corporate Headquarters**
2111 North Molter Road
Liberty Lake, Washington 99019
U.S.A.
Tel.: 1.800.635.5461
Fax: 1.509.891.3355

**Itron Inc.**
**Energy Forecasting - West**
11236 El Camino Real
San Diego, California 92130-2650
Phone: 1.858-724-2620
Toll Free: 1.800.755.9585
Fax: 1.858.724.2690
Email: forecasting@itron.com
www.itron.com/forecasting



Publication 100910WP-01
10/08