Getting Everyone to "Yes": Putting Efficiency Into Efficiency Programs by Standardizing Meter Data Analysis

Ethan Goldman, Vermont Energy Investment Corporation, Burlington, VT

ABSTRACT

Now that advanced metering infrastructure (AMI) is commonplace, how can sub-metering apply to energy efficiency and renewable energy programs' other critical uses? A statewide energy efficiency utility has begun to standardize metering procedures and documentation to streamline analyses and reduce the incidence of data irregularities in its EM&V analyses.

Faster feedback from reduced time for data scrubbing can enable corrections and the integration of inputs with project-level savings estimates. The efficiency utility has begun looking at (1) actual pre- and post-retrofit power levels of equipment, (2) equipment run hours from power metering and proxy measurements like AMI (whole-building) data analysis, and (3) normalization factors (weather and production levels). The efficiency utility hypothesized that measure types would be represented in its customer information tracking system of the program portfolio, well beyond "quantity x savings per customer = total." The model actually allows calculations from metered data to override assumed values in deemed savings estimates. The results will provide updated savings estimates, and actual uncertainty bounds that can indicate inputs that are worth updating with metered values.

This model will help improve accuracy and credibility of savings estimates for large energy users with many projects and a broad range of performance characteristics. Now that affordable, communicating meters and sensors have lowered the "cost" of data for analysis, data availability is no longer limited to large projects. This paper examines how the efficiency utility has applied the model, and offers early results from its application to smaller customers, EM&V, and program design.

Estimating Savings with Data: More is Better

Advanced Metering Infrastructure (AMI) or "smart" meters are becoming more prevalent, comprising nearly one-third of utility meters in the United States. (FERC 2014). Although they can help measure savings for some kinds of projects, they have limits. AMI data improve the quality of regression models for weather-driven change, because daily energy use can be compared to daily weather (in heating and cooling degree-days). This approach allows many more data points for a given period. This might be adequate for measuring a large retrofit project with 10 to 20 percent electrical savings in a building with fairly consistent use (such as an office building). However, the model contains some uncertainty on non-weather-related change, which could obscure the savings of smaller projects. In addition, energy savings in new construction or "market opportunity" projects cannot be compared to pre-installation energy use, so AMI data are of little use in such cases.

For measuring changes that might be obscured by larger whole-building variations in energy use, or where the baseline energy use must be estimated from measurements of contingent variables, sub-metering can greatly reduce the uncertainty of the savings estimate. Sub-metering isolates the system by measuring energy use at the appropriate point in a building's electrical distribution system, typically within a breaker, control, or service panel on a circuit serving only the load or loads of interest. Sub-metering can also involve measuring parameters such as temperature, flow, pressure, or indoor or outdoor environmental factors that could drive variation in energy use. The sub-metering data might be used to “directly” measure energy savings using an IPMVP Option “B” (isolation sub-metering) approach. Alternately, proxy variables can be sub-metered and an engineering model used to calculate savings.

How Is Sub-metering Used?

Energy savings estimates for deemed measures often rely on statistically rigorous field studies to either measure savings through pre / post or control / treatment methods. Such studies can also be used to establish operating hours or average power consumption inputs for engineering model-based savings calculations. Under current practice, conducting these studies often involves sub-metering tens or hundreds of sites, and can cost thousands of dollars per site.

Sub-metering is also used to determine energy savings estimates for “custom” projects involving energy conservation measures (ECMs) that do not have established savings estimates because they are too variable (or simply too new or unusual) for the type of study described above. Such custom savings estimates are typically undertaken only for the largest projects. They involve significant time and expense to design the data collection and analysis plan, then to deploy and commission the sub-metering equipment, and finally to conduct the analysis and report the estimated savings.

An Increasing Number of Projects Are Getting Metered

The statewide efficiency program (Efficiency Vermont) has, in the past several years, been increasingly metering projects to estimate energy savings for both installed and proposed ECMs. This does not suggest that the savings are directly attributable to the metering, but it does suggest that the use of metering is becoming more widespread. Figure 1 shows the claimed electric savings for all custom projects for which sub-metering data were included in the project documentation files. The total savings for 2013 is equal to approximately one quarter of total electric savings for that program year.

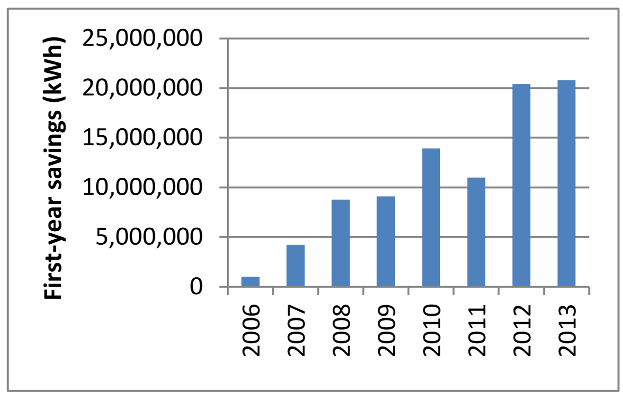

Figure 1. Increasing Amount of Metered Savings on Efficiency Vermont Custom Projects

Savings verification. The first major driver behind the increase in metering for 2007 and 2008 projects was prompted by a requirement from the regional transmission organization (ISO New England), which has a Forward Capacity Market (FCM) into which Efficiency Vermont energy savings are bid as demand resources to the grid. ISO New England required that a portion of custom projects be metered, to meet specific statistical confidence and precision metrics (ISO New England 2010). For a more detailed discussion of that evaluation process see Parlin and Chiodo 2011.

Proactive metering. Although the sampling strategy for meeting FCM statistical requirements involves metering all projects over a certain size, efficiency program implementation staff are increasingly choosing to meter when they must estimate savings for large ECMs. This is particularly the case if there is a need to assure decision-makers that the savings are accurate. When savings estimates are based on objective sub-meter data, the dynamic of the conversation with a customer often changes from a sales negotiation to shared problem-solving.

New or variable ECMs. As Efficiency Vermont staff have become more familiar with sub-metering, they have used it to calculate savings for custom projects involving new technologies that do not have well-established energy savings estimation approaches. Those custom projects might also employ technologies that have widely variable savings, depending on the exact operating conditions of a particular application. Sub-metering cannot eliminate all sources of uncertainty, but in many cases it can provide a much more reliable investment decision for both the customer and efficiency program.

Customer-installed meters. Many building operators are investing in building energy management systems (BEMS) and other types of building monitoring and controls systems. These offer better management of building operations. With the growing prevalence of "smart" devices and equipment, many observers expect these built-in sources of building data will become more prevalent.

If Sub-metering Were Easy, Everyone Would Do It

With so many benefits from sub-metering, why doesn't every efficiency project rely on measured data? Under the best conditions, sub-metering projects are typically time-consuming custom technical studies, requiring multiple experts and expensive equipment. Not infrequently, something does not go as planned, causing costs to rise and potentially impacting the quality of the resulting savings calculation. The main steps in the process and interactions with various data management systems and documents are shown in Figure 2

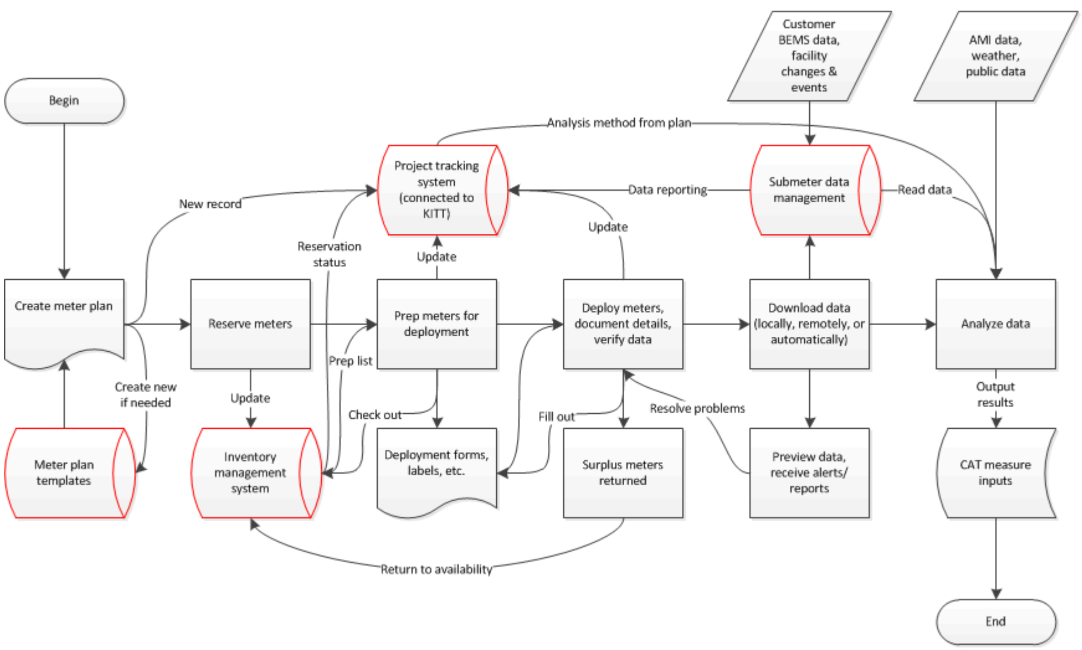

Figure 2. Standard Sub-metering Process Flow Diagram for a Custom Energy Efficiency Project

Not only is this a complicated process to navigate, there are challenges at each step. Creating a meter plan requires not only understanding the building science behind energy calculations, but also how to design an experiment. Developing metering plans is often time-consuming. If the plans are flawed, the metering exercise will not yield valid results. Specifying hardware to measure the necessary parameters requires not only knowledge of sensors, data-loggers, and networking, but also information about the physical conditions of the site (for example, pipe size and thread pitch for pressure transducers). This information must be determined through site visits or communication with facility staff. Successful meter deployments depend on connecting sensors to building equipment, then configuring meters and local or internet-based data-loggers. Mistakes can go undetected until it is too late to remedy them. Or it might even be unclear if the data are providing a surprising (but valid) answer or whether they are reflecting an error in deployment. Both troubleshooting and analysis depend on detailed and unambiguous documentation. Details that might seem obvious in the field can cause confusion and errors later on if they are not recorded. These deployment logs, along with photos and spot-metering results, must be organized and related to the actual meter data files. Finally, the analysis must be conducted and the validity of the results assessed to determine if the accuracy and uncertainty meet the original objectives.

The cost of all this labor can currently surpass $2,500 for projects of only modest complexity. Therefore, this approach is limited to custom projects with significant savings potential.

Case study: Compressed Air System Pay-for-Performance

In 2014, Efficiency Vermont launched an initiative that targeted inefficient compressed-air systems (CAS). It was based on a pay-for-performance model. The initiative had a straightforward methodology: (1) Efficiency Vermont metered a customer's CAS to measure both energy use and air flow rates; and (2) by analyzing the resulting data, efficiency utility staff could tell customers how much energy might save if were to upgrade to more efficient equipment. (4) The customer then would hire a contractor who paid all project costs. (5) Upon completion of the project and inspection by Efficiency Vermont, the efficiency utility confirmed the energy savings from the data obtained by the equipment meters and sent the contractor a check. The customer had lower energy costs with zero capital investment; the contractor had profitable work; and the electricity system eliminated unnecessary demand on the grid.

The benefits were substantial, and offered up promising replication for other similar types of efficiency program design and service delivery. Projects were enrolled more quickly, because they were not dependent on customers' budgets or internal capital spending approval processes. Projects also had built-in quality controls: Efficiency Vermont paid contractors on the performance of the specified equipment they installed or improved, ensuring that the incentive was delivering the expected savings.

However, this initiative also struggled with some of the current challenges with sub-metering. Some projects did not have enough of the key parameters metered to conduct analyses conclusively. Meters were sometimes not installed correctly or documented with adequate detail to validate the accuracy of the data. The cost of metering equipment meant that they were only available to each site for limited time periods, and the missing data sometimes led to ambiguity when analysts tried to interpret of the data. Finally, the analysis results were not always conducted consistently by CAS contractors and program staff, leading to confusion and unmet expectations, not to mention redundant effort. The proposed sub-metering system is intended to address these challenges and provide a streamlined and consistent approach that will be capable of delivering on the potential of this sort of pay-for-performance initiative.

Mass-customized Sub-metering

To reduce the cost of metering projects while also improving their quality, it is necessary to standardize and automate much of the time-consuming labor that is not adding value to the result. However, because buildings are not mass-produced, each metering project must be customizable to reflect the differences of individual buildings and ECMs. Decisions on how to adapt to variations in buildings must still be handled by humans, while software streamlines or fully automates most of the data management and analysis work. Efficiency calculations are specific to individual buildings, but are structured so as to allow further analysis on data across multiple similar projects.

Reducing Errors and Excess Time

Inherent to reducing the time required to plan and install a metering project is the need to reduce errors in the planning and installation process. The work of catching and troubleshooting those errors takes considerable time, and the further that error-detection is removed in time and space from the original source of the error, the harder to fix. In the worst case, errors that are unresolved at the time of analysis can even render that analysis invalid and impossible to complete successfully. Even a single missing measurement point can invalidate the whole analysis, requiring the whole metering project to start from the beginning.

In 2012, Efficiency Vermont undertook a "Value Stream Mapping" exercise to better understand how the different aspects of metering fit together, and where there were opportunities for improvement. This process identified a number of different sources for errors and delays, including:

- Unclear process and roles for program staff
- Unexpected challenges during meter deployments cause errors
- Customers are not satisfied by intrusive process and lack of feedback
- Inability to develop broadly applicable results from multiple similar custom projects
- Lack of clear guidance about which projects are cost-effective to meter

Through improvements in training, documentation, standardization of equipment labeling and preparation, and increased support from specialized support staff, the error rate has fallen from 8% in 2013 to 3% in 2014. Another target for improvement was the long lead time between the initiation of a custom metering project and the completion of that project, which can stretch out over several months. The major steps and estimated time for each are listed in Table 1.

Table 1. Time Estimates for Meter Plan Development and Execution

Step	Active work time (hours)	Elapsed time (days)
Develop plan	1 – 20	1 – 60
Schedule meters	0.25 – 8	1 – 4
Deploy meters	5 – 13	1 – 2
Collect data	0	7 – 60
Retreive & download data	1 – 5	1 – 2
Analyze data	1 – 25	1 – 14
TOTAL	**8 – 71 hours of work**	**12 – 142 days elapsed**

Standard Templates for Common Efficiency Measures

Planning a metering project requires a specific set of skills regarding metering hardware and time-series data analysis as well as detailed knowledge about the building in question. Currently, developing metering projects typically involves the dedicated effort of both a metering specialist as well as the energy consultant who has been working with the building owner or manager on the proposed ECM. Establishing the goals of the study, the required data and metering hardware which will collect it, and documenting these plans adequately typically takes about 10 hours. More problematic is the time elapsed during the development of a metering plan, while all the participants iterate on collecting information, evaluating options, revising the plan, collecting more information, etc. This process still takes far more than the goal of 30 days, though it has fallen below the prior average of more than 100 days.

In order to streamline the development of metering plans, the old Excel-based system has been converted to a web application that includes standard templates for common types of metering projects. In addition to providing a more robust, intuitive interface, information about all metering projects is now stored in a central database, allowing for better search and reporting capabilities. The same sort of usability improvements that have made a variety of data-input systems faster and more reliable, such as drop-down value pickers, auto-complete fields, and dynamic validation, can help users to complete meter plans faster and with fewer mistakes. Ultimately, this interface will be able to help users to better understand the key decision points required to design a metering study that accurately records the key parameters needed to calculate energy savings for their project. The aspects that distinguish each building can be translated into a customized metering plan, while the best practices for measuring a particular ECM can be replicated across all projects.

Deployment Preparation and Field Kits

Setting up a deployment of sensors and meters requires the assembly of multiple components under time pressure, since the process often requires the interruption of normal operations for a commercial or industrial customer. Preparation can not only save time, it can also ensure that everything is installed, documented and tested properly. Since many meter installations are performed by energy consultants who are experts in efficiency, not metering, and involve local or electricians who may or may not have installed power meters before, it is imperative that the installation process be intuitive and not require long, detailed instruction manuals. Over time, the metering team has developed systems for labeling equipment, color coding components, checking the condition of equipment, and packaging loggers & supplies so that everything is organized and easy to install correctly in the field.

Planning for a successful meter deployment is critical, but it’s impossible to anticipate all the variations that can be encountered in the field. Every meter project is sent out with tool kits for troubleshooting physical issues, including not only basic tools but also tape, zip ties, and other materials to ensure that sensors can be successfully positioned in the appropriate location for the desired measurement. The metering kit also contains spares of critical loggers, and a variety of sensor sizes and ranges so that installers can make adjustments in the field if physical constraints or observed measurements indicate that the “best-laid plans” will not be enough to capture the required data. Finally, the documentation provided to field techs and electricians should guide them through the key steps in the process, and should include install guides, check lists, a place to provide guided and unguided feedback, and contact info for the program’s metering specialist and metering equipment manufacturers if all else fails.

Real-time Error Checking

Even when all the cables appear to be connected correctly and the checklists are carefully followed, there are still opportunities for bad data due to failed sensors, loose connections, misconfiguration, and a variety of other causes. Waiting until the end of an intended metering deployment to collect data and check for errors not only delays the project, it also increases labor and travel costs. In order to troubleshoot the full metering installation by checking the validity of the data, the installer should have guidance about expected ranges for each measurement, which should be specified when developing the plan. In addition to specific ranges of expected values for a particular measurement, there are often readings for a general type of measurement that are suspect, such as negative power measurements, that should always be flagged for further investigation. Besides the expected range of an individual measurement, there is often an expected range for the performance calculation that a group of measurements will be used for. An example here is the efficiency of a chiller that is calculated as the ratio of delivered energy to consumed energy. If the result is greater than 100%, it would suggest that one or more of the measurements are invalid.

While it is possible to perform these accuracy tests manually during the course of the installation, in practice this step is often neglected due to time constraints and errors are only discovered much later. By documenting the meter plan in a structured fashion, the system that can convert the equipment rating and sensor range values into standard tests. Further, if the metering hardware can support remote data access, the system can also query live data from the meters as they are installed, compare those values to the test conditions, and flag any anomalies for review by the installers in real-time. To ensure that the final analysis can be conducted with confidence, the system can prompt the installers to document the results of any independent verification performed on site, such as checking that a low power factor is due to a lightly-loaded motor and not the mismatched phase of voltage and current sensor.

Automatically Generating Analysis as Data Accumulate

In addition to helping to identify errors early in the metering process, linking networked meter data collection to analysis algorithms can inform other decisions about the quality of the metering results. One key parameter to the design of a metering study is how long to collect data in order to achieve a statistically valid result. There are some guidelines, such as metering a non-variable load for at least two weeks (ISO New England 2010) but in many cases it is impossible to know how long it will take to measure the equipment over a representative range of conditions and to gather enough samples to achieve the desired precision. Rather than manually calculating these stats after manually downloading data and performing the efficiency calculations, it is possible to define the relevant statistical tests from the outset and monitor the results until the desired level of accuracy is achieved. Unexpected results or data quality problems can spur troubleshooting early in the process, before time is up, weather/test conditions are no longer favorable, or the customer's patience has expired. In addition, having access to ongoing calculation of the performance metrics of interest allows the energy analyst and customer to collaborate on iterative testing of controls and operation changes.

By contrast, one study that used conventional data-loggers was supposed to compare energy use between a period of time when the automated power saving mode of a new control system was enabled and a period when it was disabled. Once the data-loggers were retrieved and the data analyzed, it was discovered that no difference could be detected. One hypothesis for this unexpected outcome was that the building operators had forgotten to disable the energy-saving mode during the "baseline" period. But by the time the problem was discovered weeks later, there was no way to determine for sure whether the test was faulty or if the technology was not actually saving energy.

Taking Advantage of Cheap, Connected Metering Hardware

Mass production of the microprocessors, network cards, and other electronics that are used to build meters are driving down the cost of metering hardware. For example, while the industry-standard meter from a few years ago costs roughly $2,000 for a four-channel networked data-logging power meter, new, comparable quality models with 12 channels now cost around $500. DOE recently sponsored a low-cost wireless meter challenge with a target price of $100 for a 3-phase power meter. As sensors and meters become integrated with the self-monitoring and control circuitry hardware in building systems such as lighting, HVAC, and manufacturing systems, most metering hardware will add only $1-10 per measurement point. However, communicating with such integrated hardware and correctly interpreting data from those sources will require robust metadata standards, such as are being developed by Project Haystack (www.project-haystack.org).

Tools for Rapid Analysis

Ultimately, the purpose of metering is to analyze the data and produce a savings estimate. To that end, there are many opportunities for improvement for standardizing and automating the analysis process to make it faster and less error-prone.

Standardizing Data Management

The first step in standardizing data analysis is to standardize the storage and management of meter data from a range of sources. Multiple "adaptors" ingest data from networked meters as well as files uploaded from dataloggers and other sources of data such as Building Energy Management Systems (BEMS). Each adaptor parses file contents automatically so that all timestamps are stored consistently, measurement units are standardized, and separate columns are parsed from multi-sensor sources (e.g. combined temperature and humidity monitors). Once data are stored in a standard structure, analysis algorithms can work consistently with data from different sources.

In order to calculate energy savings estimates from these streams of data, each must be clearly identified as a specific parameter: the measurement of a particular aspect of some physical system, such as the power supplied to a fan motor or the temperature of a room. All the parameters required to calculate savings for the energy conservation measures (ECMs) are defined in the metering plan. The plan for each metering project can include one or more objectives which group similar ECMs by end use such as lighting or HVAC to the extent that those ECMs will share similar analysis calculations. The metering plan is designed to articulate what meters will be deployed in order to collect the parameters needed to perform the analysis calculations. The relationships of the entities defined by a metering plan are shown in Figure 3.

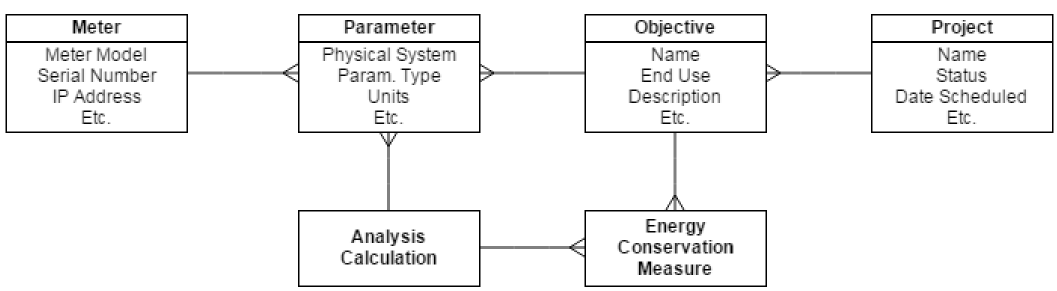

Figure 3. Meter Plan Entity Diagram

Although the meter plan allows an analyst to request a complete list of meters and describe how they relate to the savings calculations for particular ECMs, the relationship of parameters to analysis calculations also benefits from standardization. For example, if a standard savings calculation for an HVAC Roof-Top Unit (RTU) is being applied to a project with temperature data from supply and return ducts as well as a power meter on the RTU (Figure 4), there should be an unambiguous way of labeling the different parameters so that the savings calculation can be validated. Project Haystack is an open-source semantic modeling solution for building equipment systems that was developed for this purpose.

Project Haystack uses "tags" (name-value pairs) to associate standard models of building systems with the entities in our meter plans.

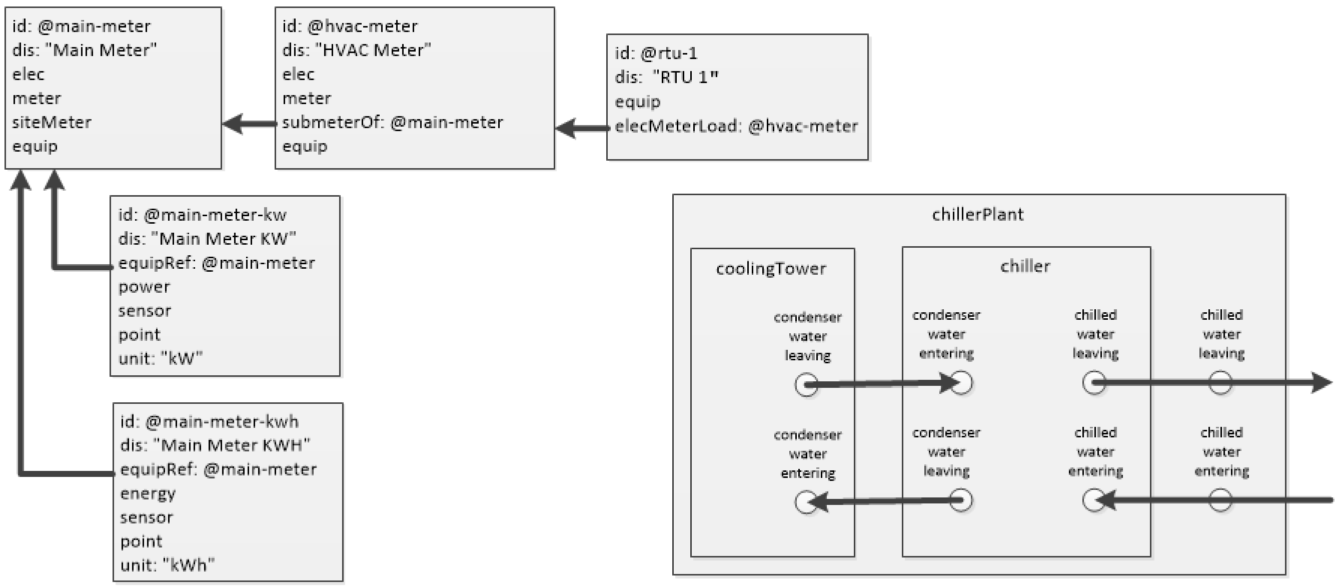

Figure 4. Tag Model for Relating an RTU to a Sub-meter and Main Meter (Left); Standard Points Defined for Chiller Equipment (Right)

Analysis Example: Light Logger Run-time Analysis

One frequent type of metering project involves using light-level loggers to determine run-time of particular lighting fixtures. Rather than using lighting on/off data-loggers with internal threshold detectors that must be configured by turning lights on and off (which is difficult to do for many applications) and which cannot be validated independently, light-level data-loggers produce a time-series of sensor readings that must be converted to run-time by applying an appropriate threshold and then calculating the average on/off duty cycle during weekday, weekend, on- and off-peak periods, and finally projecting the average annual use for each type of period. In some circumstances, the combination of daylight and light from the fixture in question can be difficult to distinguish when casually inspecting the data file, but when shown on a time-series plot and histogram in Figure 5, the user can clearly see the different light levels of each mode and use the slider (indicated by the red arrow) to input the appropriate threshold. The user can also crop the beginning and end of the data if the logger recorded data before or after it was deployed in the correct location. The application then rapidly computes the duty cycle for each hour of each day in the monitoring period (shown at lower left) and the coincidence factors and projected annual operating hours. In this way, the software lets the human apply judgment where needed, and automates the rest of the data analysis (results shown at lower right). Providing meaningful visualizations of the data inputs and the calculated results allows the user to look for subtle errors (such as a discontinuity mid-way through the metering period that might indicate that the sensor was disturbed) which would be difficult to detect automatically.

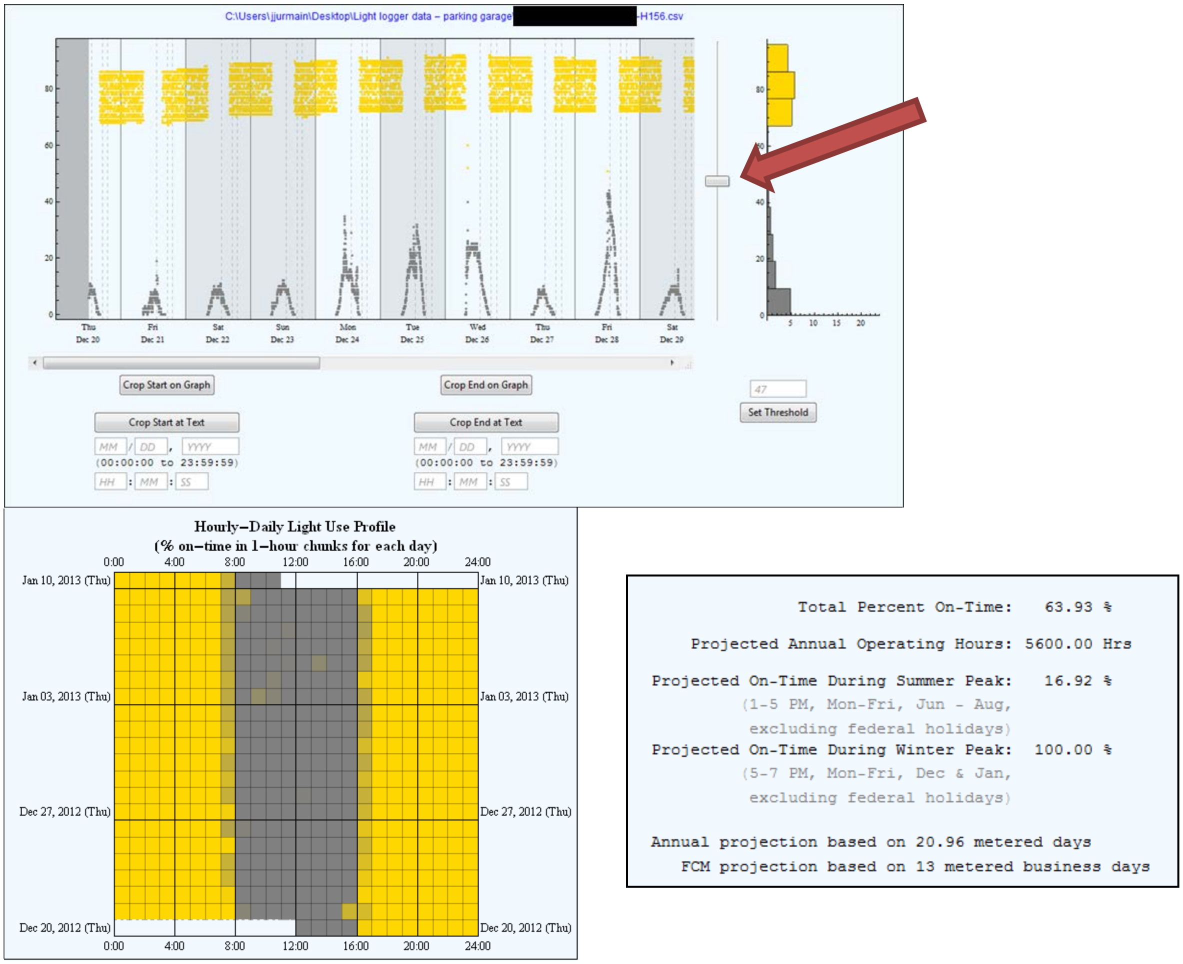

Figure 5. Light-logger Data Analysis Software

Benefits: Saving Time and Improving Results

A typical lighting project that requires metering for savings verification would deploy 6 – 12 light loggers to develop load profiles for a random sample of fixtures. Cleaning and analyzing the data for summer/winter peak periods and annual run hours, generating charts and other documentation would typically take around 20 minutes per logger for a trained and experienced analyst. Using the automated analysis software shown here, each logger's analysis takes an entry-level analyst around five minutes to complete (a four-fold reduction in labor, saving 1.5 – 3 hours per project), and generates consistent, thorough reports for each logger. It also greatly reduces the chances of errors due to manual alignment of holidays (for peak-period calculations), daylight savings time changes, and other subtle errors that can easily avoid detection, even on review. In fact, we found one error in a previously-reviewed excel-based analysis after replicating the analysis in the tool: the table of weekday/weekend/holiday calculations had been copied from an earlier analysis and erroneously categorized one day in a two-week sampling period as a holiday.

Automated analysis of structured data also facilitates uncertainty and sensitivity analysis, which is often neglected due to time constraints. Meta-analysis of custom projects across a market for a particular technology, such as lighting in secondary schools, could lead to improvement in the prescriptive load-shapes used to estimate savings. However, past experience with such meta-analysis revealed that variations in the analysis process and documentation made it impossible to reliably identify intermediate results such as peak coincidence factors without extensive re-work of each analysis. When all data sets are identified with semantic tags from Project Haystack and linked to automated analysis software, querying such factors across tens or hundreds of historical projects should be fast and reliable.

We are even able to identify significant savings from aspects of the system that seem relatively mundane: preparing data for analysis. One of the first steps needed to prepare data for analysis is to align all the data sets on a common time series so that calculations across all the parameters at each point in time can reference the appropriate measurement for each parameter. In the simplest case, this requires down-sampling (by summing or averaging as appropriate) or interpolating some parameters to match the frequency of others. In more complicated cases, this requires identifying and filling gaps, or creating time-series data with regular intervals from event-driven logger data that only record a value when it changes. Manually performing this step for a whole project's data takes about four hours, but an automated time-series aligner tool we developed cuts that down to around one hour. Once data collection is integrated into a standard storage system, this step will essentially disappear.

Conclusions

Efficiency service providers can benefit from using the most relevant and cost-effective data and analysis techniques available. While AMI data represents an improvement over monthly billing data, sub-metering holds even more promise. Large custom projects and emerging technology studies have successfully used sub-metering to estimate savings for years. However, even with current industry best practices, sub-metering is costly, time-consuming, and prone to error. After identifying the root causes of these challenges and describing the key attributes of a system that would overcome them, we began building a sub-metering support system designed for efficiency program providers.

The improved metering system is intended to support planning, deployment, and analysis tasks. Improvements to the planning phase include standardized documentation of the intended parameters to be metered and templates that allow well-developed approaches to be replicated. During deployment, documentation and field kits support users in the process of physically installing meters, while automated error-detection will address more subtle configuration issues. In the analysis phase, structured data management and automated calculation interfaces allow computers to speed through number-crunching while the analysts focus on interpreting the results. Trying to systematize this complex process has made it clear that expert users employ a range of problem-solving techniques to adapt to variations in different building systems, but many aspects can still benefit from standardization.

While the integrated sub-metering and analysis system is not yet completely built and deployed, early results from individual aspects have been promising. Standardized planning and documentation produces organized, complete data sets that support better analysis results. When installers are provided with tools and techniques for troubleshooting installations, it results in fewer errors during data collection. Structured data management allows program managers to learn from patterns across projects. And automated analysis tools produce more consistent, reliable results in far less time. We expect that the final system will provide even more benefit as these components mature and become linked to each other and to real-time data from networked meters.

Making energy investment decisions relies on timely and actionable data. As sub-metering equipment gets cheaper and better integrated with efficiency analysis, those decisions can be made with more customer-specific data. "Getting everyone to yes" means not only convincing building owners that investing in efficiency is a good decision for them, but also allowing program implementers and evaluators to support a wider range of cost-effective ECMs. Someday it could also mean providing a path for investors to support efficiency through a market that values efficiency by measuring its output.

References

Federal Energy Regulatory Commission (FERC). 2014. *Assessment of Demand Response and Advanced Metering*. https://www.ferc.gov/legal/staff-reports/2014/demand-response.pdf

ISO New England. 2010. *Manual for Measurement and Verification of Demand Reduction Value from Demand Resources Manual M-MVDR, Revision 2*.

Parlin, Kathryn, and Jennifer Chiodo. 2011. "Demand Reduction in the Forward Capacity Market: Expectations & Reality," 2011 International Energy Program Evaluation Conference: Impact Through Evaluation, http://www.iepec.org/conf-docs/papers/2011PapersTOC/papers/078.pdf. Madison, Wisc.: IEPEC.