CASE STUDY

Automating the Measurement & Verification of Energy Efficiency

SMART BUILDINGS CENTER
A project of NEEC

Summary

Energy efficiency is a fast-growing priority for building owners in the Pacific Northwest, set against a backdrop of rising energy costs and an increasingly competitive rental market. One of the main barriers to more widespread investment and implementation of energy efficiency upgrades is the difficulty owners experience in tracking the return on investment (ROI) given the many variables associated with buildings. This case study discusses two low-cost methods available to building owners to improve the tracking of ROI from energy efficiency efforts.

Business Challenges: Tricky and Costly to Isolate Savings from Energy Efficiency Investments

As with any investment, building ownersand property managers want to see the expected savings from their energy efficiency investments to verify return on investment (ROI). If buildings were a static asset, a simple calculation could highlight these savings. But shifting weather patterns, changes in occupancy, different occupant behaviors and operator practices, and varying equipment lifespans are just some of the common fluctuating factors that can significantly impact energy consumption. This dynamic reality makes it difficult to attribute savings to any single efficiency retrofit or operational change.

Traditional methods of verifying actual savings achieved by energy efficiency measures can be complicated and pricey. In the most comprehensive approach, owners hire an energy engineer to create a predictive thermodynamic energy model of the building that calculates the baseline energy use prior to the installation of energy efficiency measures, using hourly simulation software such as the U.S. Department of Energy's eQUEST (see Image 1). The engineer then conducts an intensive data collection process to develop an intimate understanding of the building's operation schedules, usage patterns, and operational and capital improvements that have been implemented in the building.

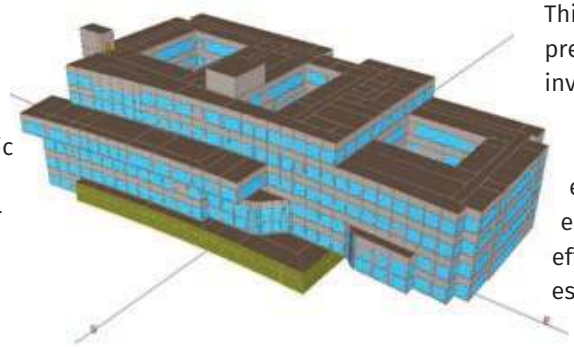


Image 1: Thermodynamic Energy model (eQUEST energy modeling software); source: Google Images

With this information, the engineer calibrates the model to match the building performance and estimates two baseline data points: the monthly/annual energy use the building would have consumed in the absence of the installed energy conservation measures and the estimated monthly/annual energy savings from the installed energy conservation measures. Standards from the International Performance Measurement & Verification Protocol (IPMVP),[1] are used for verification, especially when associated with a utility program. Based on the experience of the authors (Paladino and Company), the price tag for this comprehensive modeling and analysis process is typically $0.10/sq ft (for large buildings) to $0.50/sq ft (for smaller buildings). For a 300,000 sq ft high-rise office building, the costs would be on the lower end due to economies of scale (around $30,000). Costs for calibration, analysis, and publishing of updated reports would add another $5,000-$8,000 per year. It is worth noting that another prevalent method of savings verification relies on "deemed" savings quantity for distinct energy conservation measures, sometimes corroborated by short-term monitoring. This method is inexpensive and generally preferred if it is available for all measures involved in a particular energy project.

While energy model calibration is an effective approach to retroactively estimating savings achieved from energy efficiency installations (Image 2 estimates energy use by end-use categories), it has limited capability for tracking ongoing performance that would highlight failures or below-average performance of energy efficiency measures, thereby lacking the ability to facilitate course corrections.

[1] Efficiency Valuation Organization (2012). "IPMVP Public Library of Documents," http://w.evo-world.org/index.php?option=com_content&view=article&id=272&Itemid=379&lang=en

Building owners interested in tracking the impact of individual energy conservation measures over time must install additional sub-meters at the building panel boards. The cost for sub-metering is typically in the range of $2,500 per metering location. This can become cost-prohibitive in multi-tenant buildings where different energy conservation measures are installed on multiple floors.

Potential Solutions: Low-Cost Automated M&V Technologies

The proliferation of "big data"[2] and the increasing number of technologies that can harness and make sense of it have created an opportunity for building owners to verify energy efficiency savings in a different way. In buildings, big data entails numerous variables that fluctuate to impact energy use. New products bring computing power, powerful algorithms, customized hardware, and the capability to plug into existing systems to help building operators better understand the performance of potential energy efficiency upgrades. These automated measurement and verification (M&V) tools are alternatives to the traditional modeling and tracking methods described above and purport to be less labor-intensive and more cost-effective.

To better understand the emerging role of automated, low-cost M&V software and hardware products in today's market, the Smart Buildings Center (SBC) in partnership with the Northwest Energy Efficiency Alliance (NEEA) initiated a short-term pilot demonstration of products that tackle big data in their own ways to verify savings. Paladino and Company selected two of these products—DeltaMeter and Verdigris—based on product capabilities, spearheaded the execution of the pilot, and conducted a joint evaluation.

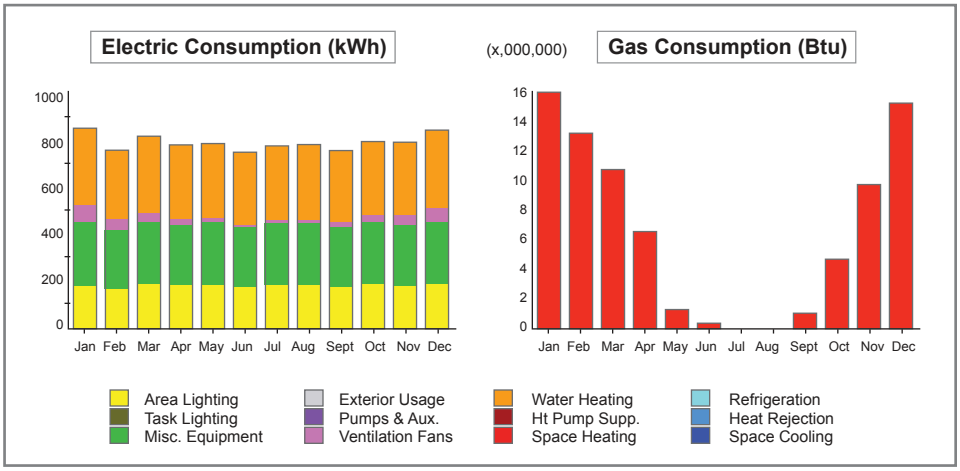


Image 2: Energy by end-use results from energy modeling software; source: Google Images

DeltaMeter

DeltaMeter®, developed by Portland, Oregon-based EnergyRM, is a software platform that features a set of virtual M&V tools that run via the cloud and, thus, do not require physical deployment at a building. Using patented algorithms in combination with monthly energy bills, DeltaMeter creates a thermodynamic model at the end-use level that can estimate the baseline energy use the building would have had in absence of the energy efficiency measures. It then tracks and compares that "virtual baseline" against the actual building performance to reveal the delta of savings achieved.

While the DeltaMeter does not require hourly interval data to model the building, 15 minute or hourly interval data greatly assist in the specific diagnosis of a variance from the norm, whether positive and negative. DeltaMeter can provide diagnostic analysis, savings potential/energy efficiency recommendations, metered performance verification and ongoing M&V crosschecks to ensure persistence and continuity for a building or a portfolio. The product is also set up to calculate the energy yield from efficiency for Metered Energy Efficiency Transaction Structure (MEETS) purposes.[3] This is an innovative contracting approach to considering energy efficiency savings as a transactable resource that can reliably pay back third-party investors in building retrofits.

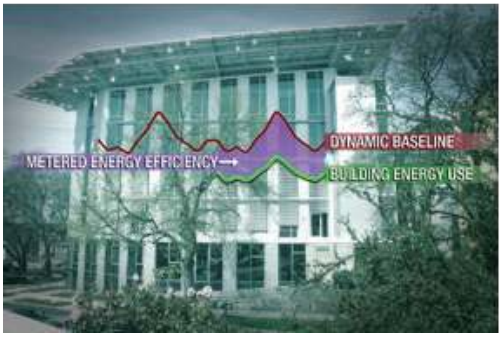
Current single building product pricing is approximately $300-$500 per month plus minimal setup costs, making it a low-cost M&V option compared to traditional comprehensive energy modeling, sub-metering, and calibration. With larger portfolios of buildings, the price can drop to below $100/building. It remains to be seen over time how this purportedly lower cost option compares on an accuracy and precision vector with the traditional comprehensive energy modeling. Those questions are being currently examined by NREL in a comprehensive study of the DeltaMeter's accuracy and end-use disaggregation, which is expected to be completed in fall 2015.

Verdigris

Northern California-based Verdigris offers advanced analytics with an in-house M&V technology solution services overlay. This energy monitoring system offers deep insight into energy savings opportunities by analyzing high-resolution electricity consumption data from buildings' circuits mapped against utility data.

[2] Big data is a broad term for data sets so large or complex that traditional data processing applications are inadequate. Challenges include analysis, capture, data curation, search, sharing, storage, transfer, visualization, and information privacy. The term often refers simply to the use of predictive analytics or other certain advanced methods to extract value from data and seldom to a particular size of data set. Accuracy in big data may lead to more confident decision making from building owners and better decisions can mean greater operational efficiency, cost reduction, and reduced risk.

[3] http://www.meetscoalition.org/how-meets-works/



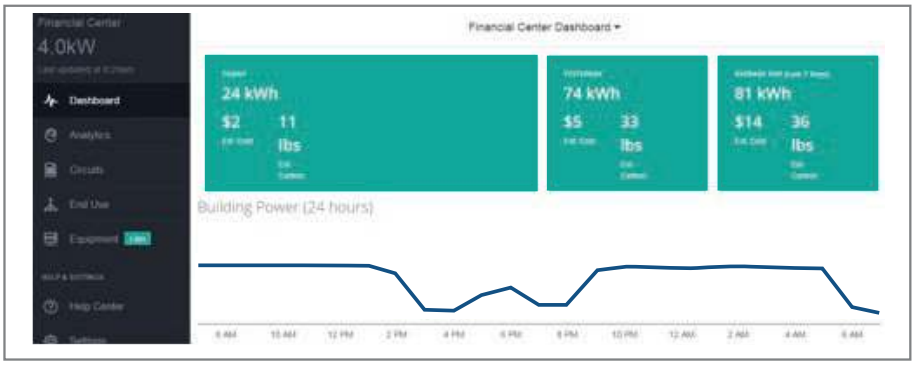


Image 3: (Left) DeltaMeter's concept, (Right) Verdigris Dashboard for Financial Center Building

Verdigris uses energy bills and measured data obtained from patented current transducer (CT) hardware installed at selected building panel boards, as well as custom machine learning algorithms, to predict a baseline. This baseline accounts for dynamic building and environmental factors and disaggregates energy by end use. Through data analysis, Verdigris engineers generate custom monthly and annual M&V reports to help measure performance against the baseline and identify areas for energy improvement as part of the proprietary software package. Verdigris offers 4G LTE and Wi-Fi options to transmit the data collected by their CT hardware to the cloud.

A customizable dashboard interface, accessible online and through a mobile-friendly platform, shows a real-time data stream of metered energy use at up to one-minute intervals, offering a granular approach to tracking energy goals. The Verdigris platform also provides energy efficiency recommendations, peak demand analysis, anomaly detection, automatic notifications, and equipment-level monitoring.

The technology cost, including the back-end analytical support, is approximately $1,500 per building (assuming 8-10 panels with detailed monitoring installed) and is a low-cost M&V option when compared to traditional comprehensive energy modeling, sub-metering, and calibration.

Pilot Project Methodology

As part of the Accelerated Technology Deployments (ATD) program, the SBC commissioned Paladino and Company to deploy the two technologies at eight high-profile commercial buildings in Seattle. Unico Properties, a real estate investor and full-service operator of office and multifamily buildings in the western United States, provided the host buildings for the study. Unico's portfolio offered a unique opportunity to include a range of buildings' areas, ages, number of floors, and other factors in the demonstration.

Both technologies used data from monthly energy bills, details on building characteristics and use patterns as reported in ENERGY STAR Portfolio Manager®, and information about installed energy conservation measures to establish a 2013 baseline period. This baseline was then used to predict energy use for the 2014 reporting period. The evaluation team compared the predicted 2014 energy use with data from 2014 monthly energy bills to verify accuracy. The technologies also predicted a disaggregation of energy end use for the reporting period. Where possible, the team compared the predicted disaggregation using data from any sub-meters installed in buildings.

As part of the installations and data analysis, the team tracked information on M&V accuracy, ease of installation, scalability, and training time for operations staff as well as any disruptions to building/tenant for installation.

Image 4: (L to R) 51 University, Financial Center, Stone 34; Source: Unico Properties

Results: Benefits & Challenges of Automated M&V

The hands-on experience deploying Verdigris and DeltaMeter at multiple Class-A office buildings demonstrated that both technologies provide ongoing low-cost options for evaluation, measurement and verification (EM&V), in addition to the traditional energy modeling and calibration process, although tradeoffs in accuracy and installation challenges may exist as these technologies are still relatively new. In addition, owners looking to isolate the savings from each energy efficiency measure installed in the project will likely continue to use the traditional energy calibration method since these approaches can more precisely isolate savings associated with each end use. However, the traditional approach becomes more challenging and costly when one tries to isolate the savings from measures within the same end use category—an example of this situation is lighting energy end-use savings from light fixture replacements and from daylight sensor installation—or where multiple measures are highly interactive.

Persistence Tracking for Energy Savings

Both products tested generated regular monthly reports during the demonstration period, showing energy use and savings against a baseline throughout the year. The building managers as well as the evaluation team saw great value in this regular access to performance and savings information, particularly when compared to their previous access to episodic reports generated by engineers engaged to calibrate the building model, typically on a one to three year cycle. The monthly reports and the dashboard (in Verdigris' case) allow Unico to track whether energy efficiency measures are operating as anticipated and to undertake maintenance efforts as required to implement performance-driven course corrections.

Accuracy within Acceptable Limits

Following a very brief, one month, demonstration period, a comparison of the two products was made. The comparison included an estimation of 2014 energy use from data on monthly energy bills. This showed that the predictions were within +/- 0-10% of actual monthly energy use and within 5% of actual annual energy use for 6 of the 8 buildings in which DeltaMeter was installed and 2 of the 3 buildings in which Verdigris was installed. According to IPMVP, this degree of deviation that is in line with the level of uncertainty of +/-20% of monthly energy use using monthly energy data and +/- 5% of monthly energy use using hourly calibration. It is of note that for Verdigris, despite hourly calibration, the measurement period for this study was only one month. It is also noteworthy that the DeltaMeter is constrained to use only revenue certified measurements because its savings estimates are intended to be used for revenue purposes.

Achieving a high level of accuracy in traditional energy modeling has always been a balancing act between cost and addressing uncertainty. Four of the 8 buildings encountered by DeltaMeter in this study required non-traditional modeling because of significant occupancy variations. For one of the two buildings that fell outside the 5% annual energy use accuracy range, the evaluation team learned that anchor tenants had added an unidentified (i.e., confidential) amount of data center load and changed the HVAC schedules. The second building had recently completed tenant improvements and was in the process of completing further improvements during the pilot. Further study and analysis of these two buildings is recommended to pinpoint whether the available data on tenant usage patterns is the reason for such a large margin of error.

It is important to note that all the test buildings are located in Seattle, which has a mild climate and fairly discrete cooling and heating months. Further study and analysis is recommended to ensure that the same level of accuracy is achievable in other climates with larger seasonal swings. It is also worth mentioning that each of the demonstration buildings had automation systems that had outdated trend logs, resulting in sparse sub-metered data that hindered the ability to back-check the end-use disaggregation predictions. Incomplete trend log data is not uncommon in commercial buildings as it was a feature not always configured in older building automation systems (BAS), and in case of newer BAS, typically there are site specific data storage limit and archival issues. The lack of standard trend log elements, local data storage limits, and archival planning result in expensive, and in most cases, impossible data re-construction of past system and energy performance. Paladino had requested that Unico initiate new trend logs towards the end of the demonstration, and at the time this case study was published substantive trend log data was not available. When further trend log data is available, however, back-checks can be performed.

Observations of the Evaluators

Further improving the accuracy of the predictions may require different efforts for the two products. For Verdigris, the accuracy of energy prediction at the whole building level can be improved as the percentage of the building covered by

Verdigris' tenant-level hardware installation increases (i.e., installed at more electricity panels). Accuracy can be further improved by incorporating whole-building data, either from a Verdigris deployment at the building mains, or by integrating smart meter utility data through Green Button or another data API, if available.

For DeltaMeter, using hourly information will (1) improve the diagnostic function by pinpointing equipment issues and (2) allow for demand monitoring versus time as well. The DeltaMeter will accommodate hourly modeling, but interval data is not required for a Delta Meter. An hourly data feed would have to be obtained from the utility (possible upgrade in meter), from using a sub-metering technology or through trend logs from a BAS. Given the challenges with limited onsite data storage, a cloud-based sub-metering technology could be a solution to provide reliable hourly data to DeltaMeter.

Ease of Installation and Scalability

One significant difference between the two technologies is that Verdigris requires physical deployment of hardware at the building site, whereas DeltaMeter does not.

DeltaMeter's deployment proved to be primarily a straightforward data gathering exercise. The team first obtained monthly energy use data associated with all main building meters, details on building area and space types, and information about changes in building occupancy over the evaluation period. This required a low level of effort for the test portfolio, mainly because all buildings were already uploaded in ENERGY STAR's Portfolio Manager,[4] including detailed notes on occupancy changes, building space type, and square-footage. The Unico team also provided Paladino with written clarifications on several anomalies and unexpected variances at each building discovered during the EnergyRM engineers' review of monthly energy use data. EnergyRM published its M&V report for all eight buildings in the demonstration project within one week, a relatively short turnaround compared to traditional reporting timeframes.

Verdigris hardware consists of a daisy chain of 42 snap-on current transducers (CT) connected to a hardware bud. The snap-on CTs are non-intrusive and do not require any additional wiring. Verdigris recommends that a licensed electrician perform the installation. The deployment team explored three hardware installation configurations, but decided to install at the building sub-panels since other options would have required custom CTs, longer lead times to ship installation hardware, and/or building power shutdown for about 30 minutes (although a non-power shutdown option is possible with a wiring-hot methodology at a higher installation cost). The team verified availability of either Wi-Fi access points or 4G LTE signal at the sub-panels prior to installation. For buildings using Wi-Fi access, IT departments typically require security permissions before Verdigris hardware can send metered data readings to the cloud.

While the installation process requires coordination and planning, once the Verdigris hardware was installed, per-minute interval data from each circuit at the sub-panel became available immediately on the Verdigris dashboard for tracking and monitoring purposes. The Verdigris system also measures at sub-minute intervals for more detailed analysis, although this data was not used for the purposes of this study. At the end of each month, Verdigris publishes monthly reports using this data. The installation process involves sending Verdigris photographs of the physical electric panels and panel schedules, which are programmed into a web-based App. Verdigris then configures the CTs and ships the hardware for installation. Verdigris technical help is available over phone and by email to help guide the installation process.

Low, Ongoing Technology Costs Appealing for Many

Both technologies operate on a software-as-a-service (SAAS) model, and charge a low monthly subscription fee for providing monthly, real-time reports on performance and deviation from the calculated baseline. This pay-as-you-use model removes the high first costs associated with traditional M&V solutions. Verdigris pricing model is $200 per panel per month to provide real-time performance data and monthly M&V reports, and DeltaMeter provides monthly snapshots on building performance and M&V tracking on a sliding scale from approximately $500 per month for a single building to $100 per building in a large portfolio. According to Unico's director of sustainability, Brett Phillips, "The pricing model for this new class of technologies is attractive and reduces barriers to entry, compared to traditional methods."

Ready for MEETS Transactions

MEETS is a new transaction structure that provides a quantifiable, contracted cash flow for energy efficiency project investments, representing a potential alternative model for widespread adoption by utilities, building owners, and third-party investors. It is currently under pilot by Seattle City Light at the Bullitt Center, with much discussion about future expansion. Both products evaluated in this pilot have the capability to provide the information required for validating MEETS transaction energy reduction goals "contracted" for the building. While DeltaMeter reports are readily set up to generate data for MEETS validation purposes, Verdigris provides this information on an as-needed basis by completing further analysis on the metered data transmitted by Verdigris hardware.

[4] http://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager

Conclusion: Ongoing, Low-Cost Tracking for Energy Savings is Here... Almost

The ATD demonstration project highlighted how both Verdigris and DeltaMeter can offer a potentially cost-effective approach to energy modeling and sub-metering processes, yet careful attention to data collection, to user/occupant patterns, and meter reading accuracy is important for the results to be valuable. Additional improvements in accuracy should be pursued and post-M&V report discussion meetings will likely illuminate other ways to boost the potential value of these products to building owners and operators.

Feature	Verdigris	DeltaMeter
Accuracy	●●●	●●◖
Cost	●●●	●●●
Ease of installation	●●	●●●
Flexibility for future application such as MEET*	●●	●●●
Real-time monitoring and feedback	●●●	●●

** Noting that EnergyRM staff members helped develop the MEETS model*

The regularity of reports and granular real-time interval data have the potential to add value to owners who are typically limited to an annual picture of performance if the owners have the resources to respond to the trends identified by the reports and abundant data. Furthermore, the recommended use of cloud storage alleviates the burden of increasing on site data storage for traditional sub-metering efforts. While the installation or setup process proved to be time-consuming for Verdigris, Unico's Phillips recognized that "the ongoing, persistent benefits of smart building solutions are often worth front-end investments in capital and time."

The stage is set for owners to achieve close monitoring, control, and course correction of the performance of their energy efficiency investments using automated M&V tools such as DeltaMeter and Verdigris. If granular real-time monitoring, monthly M&V reports, and equipment-level monitoring/alerts is required, Verdigris is probably the better option. For owners looking for M&V monthly snapshots to back-check performance as well as forward-looking recommendations on energy efficiency measure recommendations, then DeltaMeter should fit better.

About the Smart Buildings Center

The Smart Buildings Center (SBC) is a project of the Northwest Energy Efficiency Council (NEEC), which is a non-profit industry association of the energy efficiency industry. The SBC supports growth and innovation in the Pacific Northwest's energy efficiency industry, serving as a hub for industry activities and raising the visibility of energy efficiency companies and projects.

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