Measurement & Verification Guide

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The long-term success of any comprehensive energy efficiency program depends on the development of an accurate, successful Measurement & Verification (M&V) plan. The main objective is to define the processes that will be used to verify the performance results of the energy improvement measures. There are industry standard M&V protocols that have been developed for reliable and consistent measurement practices. The most prevalent standard for M&V is:

- U.S. Department of Energy, 2012, *International Performance Measurement & Verification Protocol (IPMVP)*

The M&V guidelines described here are based in part on the International Performance Measurement and Verification Protocol and contain excerpts taken from that document.

The benefits of the protocol as defined by IPMVP are:

1. Defining the role of verification in energy contracts and implementation.
2. Discussing procedures, with varying levels of accuracy and cost, for verifying:
   - Baseline and project installation conditions, and
   - Long-term energy savings performance.
3. Providing techniques for calculating “whole-facility” savings, individual technology savings, and stipulated savings.
4. Providing procedures that are consistent, industry accepted, impartial, and reliable.
5. Providing procedures for the investigation and resolution of disagreements related to performance issues.

The IPMVP protocol should be used as a guide to calculate the kWh (and kW) savings of project-related and non-project related conservation measures. The energy savings can be converted to cost savings ($) using the related facility’s utility rates, including demand charges and time-of-use charges.

Measurement and Verification Options

IPMVP defines four M&V options (Options A through D) that meet the needs of a wide range of performance contracts and that provide suggested procedures for baseline development and post-retrofit verification. The options are summarized in the following table.

Option C is used for retro commissioning efforts that include the implementation of multiple low / no cost measures impacting multiple systems, and may even have an effect on systems that have not been modified. For example, a change in set points or schedules may impact electrical cooling energy used by a roof top packaged unit and the gas energy of a boiler.

Option C requires data for a 12-month base year and then measurements in the post retrofit period. Historic 12-month energy utility data for commercial buildings that are utility metered is typically from the utility available upon request and can be used as a base year for M&V calculations.

M&V Option	How Savings Are Calculated	Typical Applications
Option A: Partially Measured Retrofit Isolation		
Savings are determined by partial field measurement of the energy use of the system(s) to which an ECM was applied, separate from the energy use of the rest of the facility. Measurements may be either short-term or continuous. Partial measurement means that some but not all parameter(s) may be stipulated, if the total impact of possible stipulation error(s) is not significant to the resultant savings. Careful review of ECM design and installation will ensure that stipulated values fairly represent the probable actual value. Stipulations should be shown in the M&V Plan along with analysis of the significance of the error they may introduce.	Engineering calculations using short term or continuous post-retrofit measurements and stipulations.	Lighting retrofit where power draw is measured periodically. Operating hours of the lights are assumed to be one half hour per day longer than store open hours.
Option B: Retrofit Isolation		
Savings are determined by field measurement of the energy use of the systems to which the ECM was applied, separate from the energy use of the rest of the facility. Short-term or continuous measurements are taken throughout the post-retrofit period.	Engineering calculations using short term or continuous measurements	Application of controls to vary the load on a constant speed pump using a variable speed drive. Electricity use is measured by a kWh meter installed on the electrical supply to the pump motor. In the base year this meter is in place for a week to verify constant loading. The meter is in place throughout the post-retrofit period to track variations in energy use.
Option C: Whole Facility (Bill Comparison)		
Savings are determined by measuring energy use at the whole facility level. Short-term or continuous measurements are taken throughout the post-retrofit period.	Analysis of whole facility utility meter or sub-meter data using techniques from simple comparison to regression analysis.	Multifaceted energy management program affecting many systems in a building. Energy use is measured by the gas and electric utility meters for a twelve month base year period and throughout the post-retrofit period.

Figure 1. Table of 3 Measurement & Verification options proposed to be used in this project as defined by the IPMVP international standard. *Source: IPMVP publication*

Adjusting for non-Project Related Savings

If multiple projects are conducted at the same time, using Option C for the collective impact of the projects is the simplest approach. However, if the effects of a project need to be isolated from those of non-project retrofits, the following guidelines can be followed.

The non-project retrofits can be classified into 2 categories:

i) Non-Project related retrofits whose benefit can be isolated and calculated using Option A or Option B, e.g. lighting retrofits or installation of Variable Speed Drives.

For such retrofits, the cost savings of the individual retrofit for the applicable post period can be calculated using Option A or B and the result subtracted from the whole building savings calculated using Option C. If needed, the savings calculations for the post period can be broken up into different date ranges to accommodate implementation dates of different non-project related measures.

For example, if a lighting retrofit is undertaken at a specific facility and the savings calculated to be 200 kWh during a specific month, whereas the whole-facility savings from for that month are calculated using Option C to be 450 kWh, then 250 kWh will be attributed to the project's conservation measures and 200 kWh to the lighting retrofit. The kWh savings calculated using each option should be converted to cost ($) using the facility's rate schedule, including any time-of-use charges and demand charges.

ii) Non-Project related retrofits whose benefits must be calculated using Option C, e.g. replacement of energy management system, other retro commissioning projects

In cases where the non-project related measures impact multiple systems in a building, the disaggregation of savings between overlapping non-project and project-related measures will require more attention. One possible method is to allow for at least 3 months separation period between the start of the non-project related and the project related measures. During the separation period, Option C can be used to calculate the savings for the first measure to be implemented. After the second measure is implemented, the whole-facility savings calculated using Option C would represent the total savings resulting from the first and second measure. The savings attributed to the second measure can be calculated by subtracting the % savings of the first measure from the savings of both measures combined. For example, if a project-related measure is implemented that resulted in 6% whole-facility energy savings, and after an interim period a non-project related measure was implemented and the new savings are calculated to be 9% then the savings attributed to the second measures are 3%. Other methods may be available and can be determined on a case-by-case basis or in the M&V plan.

Fluctuations in Energy Prices

The savings are typically reported in energy units (BTU, kWh, therms, water gallons, cubic feet) and in cost savings ($). Fluctuations in energy prices will change the cost impact of any energy savings. When the prices increase, the dollar value of the savings increase although the energy savings may not have increased. When the prices decrease, the dollar value of the savings decrease even though the energy savings may not have decreased.

To maintain an accurate representation of cost savings, energy savings can be converted to cost savings using any of two methods:

i) Based on the energy rates (blended or actual) of the base year, and

ii) Based on the energy rates (blended or actual) of the current year.

The customer can evaluate the performance of the measures using the 2 metrics. The base year rates are the most 'fair' rates to use to estimate the cost impact based on energy savings alone, whereas the savings based on the current rates reflect the combined effect of of price fluctuations and energy savings.

Changes to Site Real Estate Infrastructure and Occupancy Levels

Other factors that will affect the energy usage of a facility include changes to the facility square footage and changes to the occupancy levels of the facility. Changes to occupancy may not be a large issue for buildings with relatively steady seasonal or annual occupancy levels. Changes in site real estate infrastructure are more noticeable and should be accounted for. When additions to a site are expected, it will be encouraged that the additions be sub-metered to account for the energy usage of the additions. If sub-metering the additions is not possible, then the energy model approach can be used. For example, if a project related measure has been implemented and 15 months later a site expansion was made. Then the 15 months of post measure will be used to generate a model for the facility's post-measure energy usage. Post the expansion, that model can be used to calculate the post-measure energy usage of the original facility and the regular process can then be used to calculate savings. A third method would be to estimate the energy increase due to the site expansion, with estimates of duty cycle on equipment, lighting capacity, plug load estimates, etc., and subtract the estimated additional energy from the expanded facility's measured energy.

Phases of Measurement and Verification

1. **Preparation.** Base year data for all energy meters (electricity, water, gas, sewer) is obtained, performance metrics specified, M&V plan is finalized, any additional needed instrumentation / metering is installed and commissioned.

2. **Base Period Analysis.** The baseline energy models are created for all buildings and systems as needed based on a pre-implementation period of time year. Wherever possible, a period of 1 year should be used to build the energy baseline models. Models can be developed for all energy types (electric, water, gas, sewer) and should be based on non-energy independent variables including time of day, day of year, ambient weather conditions, weather trends, other seasonal environmental factors, etc.

3. **Post-Measure Verification.** In the post-measure period, the baseline model for each building and each energy type is used to calculate the savings of the implemented measure for the M&V reports.

Measurement and Verification Accuracy

The level of measurement and verification accuracy is a function of how well the building energy data can be modeled for the base year. The accuracy of any model developed to be used for M&V purposes needs to be verified. Verification is typically done by randomly splitting the available historic data into two sets, a set used to develop the model and a second set used to test the model. Model accuracy is measured by statistical methods.

Case Study of MelRok's Energy Baseline Model

A case study is presented here of an energy model generated using the MelRok Energy Platform. The MelRok multi-variable regression models are automatically generated using a random selection of base year data points, equivalent to 70% of the total base year data. Once the model is built, the remaining 30% of the data that has not been used to generate the model is used to test the validity of the model. The predicted vs. measured values for the 30% test data are compared and the resulting model accuracy calculated. MelRok's multi-variable non-linear regression models have demonstrated accuracies in excess of 98% for the base year.

Figure **2** is a sample result of a model created for electric energy usage of a facility. It includes 4 charts:

1. Timeline of predicted vs measured Hourly Demand for the Training Sample. The Training Sample represents a random selection of 70% of FY 2018 Hourly Demand data.
2. Scatter plot and linear curve fit of predicted vs measured Hourly Demand for the Training Sample.
3. Timeline of the predicted vs measured Hourly Demand for the Test Sample. The Test Sample represents a random selection of 30% of FY 2018 Hourly Demand data.
4. Scatter plot and linear curve fit of predicted vs measured Hourly Demand for the Test Sample.

The MelRok models have demonstrated error margin of less than 1% on annual energy calculations (2018 ACCO BEMS Pre-Optimization Analysis Report to the California Energy Commission).

The hourly/daily/monthly energy savings calculated using the energy baseline model can be used to track daily performance throughout post-effort period and observe the savings as modifications are being made.

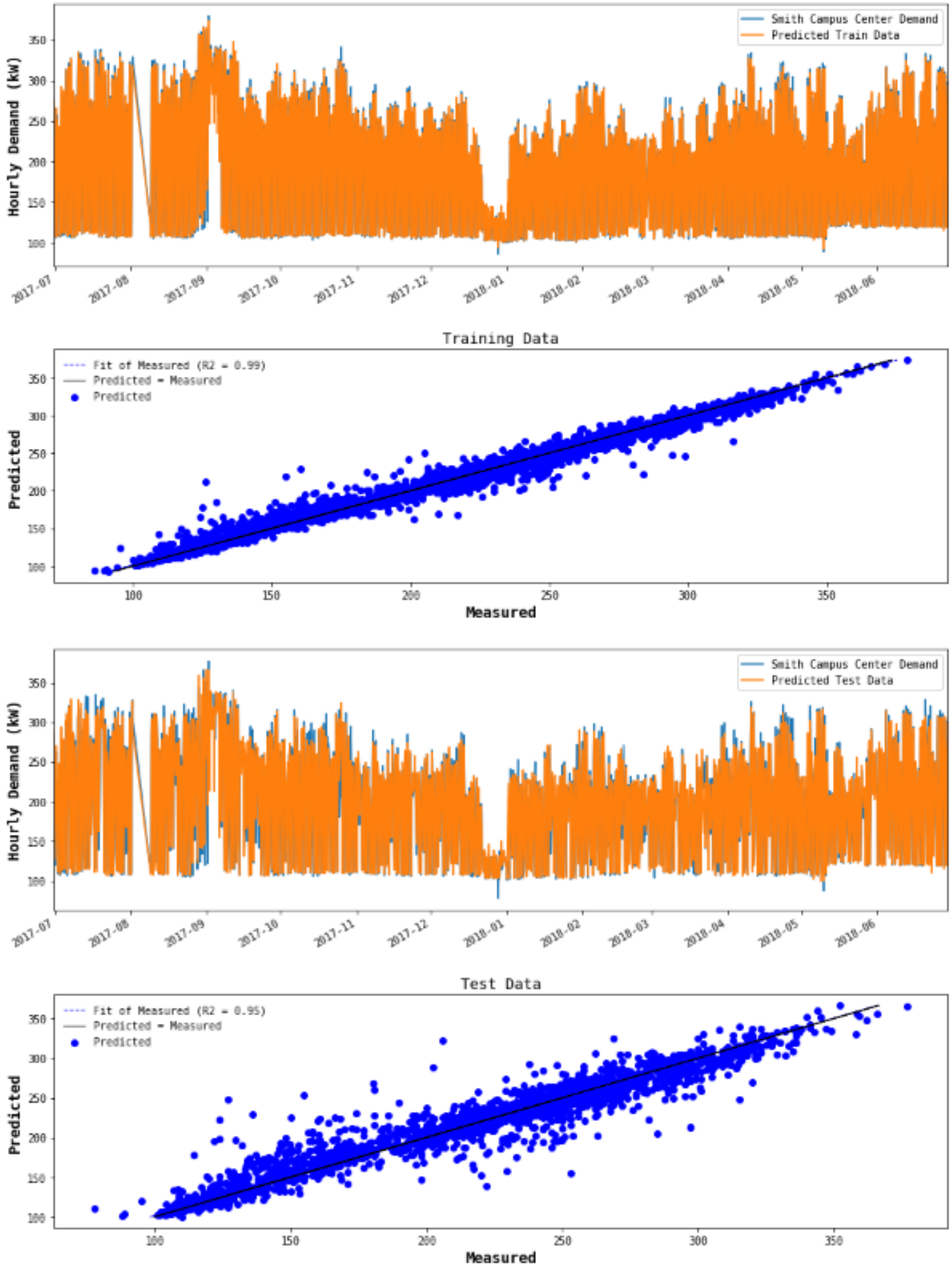

Figure 2. Timeline and correlation charts of sample energy model for training (top) and test data for electric energy (demand) of a facility. The training data was used to develop the model and the test data was used to test the accuracy of the model in predicting measured vales. The training data has a correlation coefficient of 0.99, meaning that 99% of the behavior of the data is explained by the model. The test data has a correlation of 0.95, meaning that 95% of the behavior of the test data is predicted by the model.

Tracking Performance vs MelRok Model

The MelRok platform allows for the predicted energy consumption calculated by an energy model to be plotted as an overlay to the measured energy consumption of the current year. This allows the users and the commissioning team to visualize the results in a time resolved matter to detect periods of good performance and any periods of poor performance, in addition to aggregated savings.

Time resolved charts available on the MelRok portal are shown in Figure **3**. The solid line is the 15-minute demand measured in the current year (May 2019) and the dashed line is the predicted energy demand using a model of the energy consumption for 2017, the base year. Time resolved comparison of modeled vs. actual energy allows for the confirmation of the nature of the reductions, whether they are attributed to schedule trimming (later starts, earlier stops), schedule changes (weekends and holidays), set point changes (cooling thresholds), and optimized speed (smoother ramp up and down of air handlers, pumps and fans).

The same data can be visualized at different resolutions, including hourly and daily. Figure **4** is the same data presented in Figure **3** but aggregated daily.

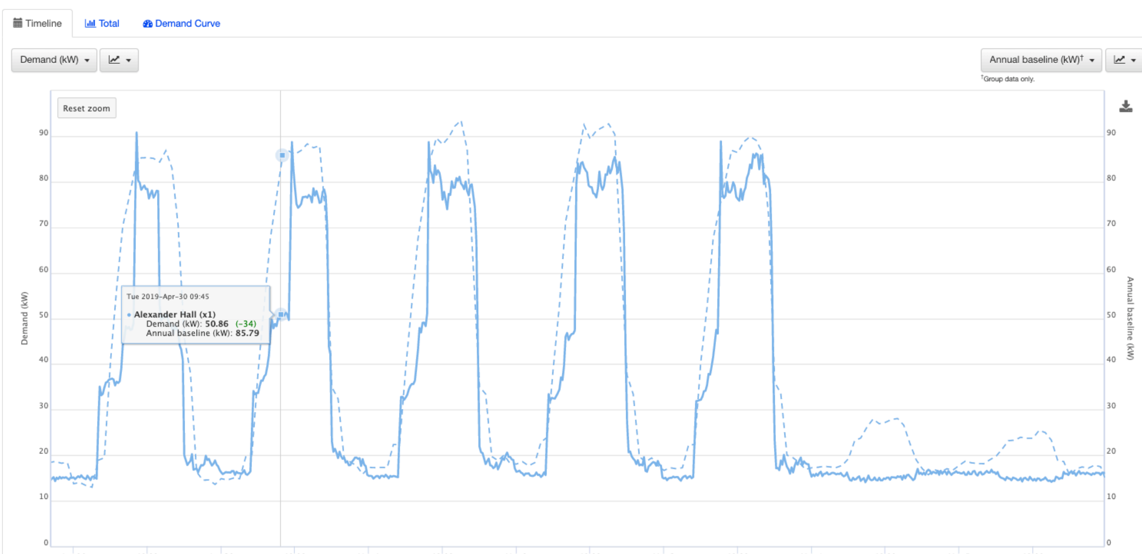

Figure 3. Comparison of energy predicted using an energy model for a base year and energy measured in current year. The solid line represents the measured energy in 2019 and the dashed line represents the predicted energy usage using a model of the building's energy consumption in 2017. The reduction in energy usage due to schedule and set point changes are visible. The tool tip highlights the reduction in energy at each specific time stamp.

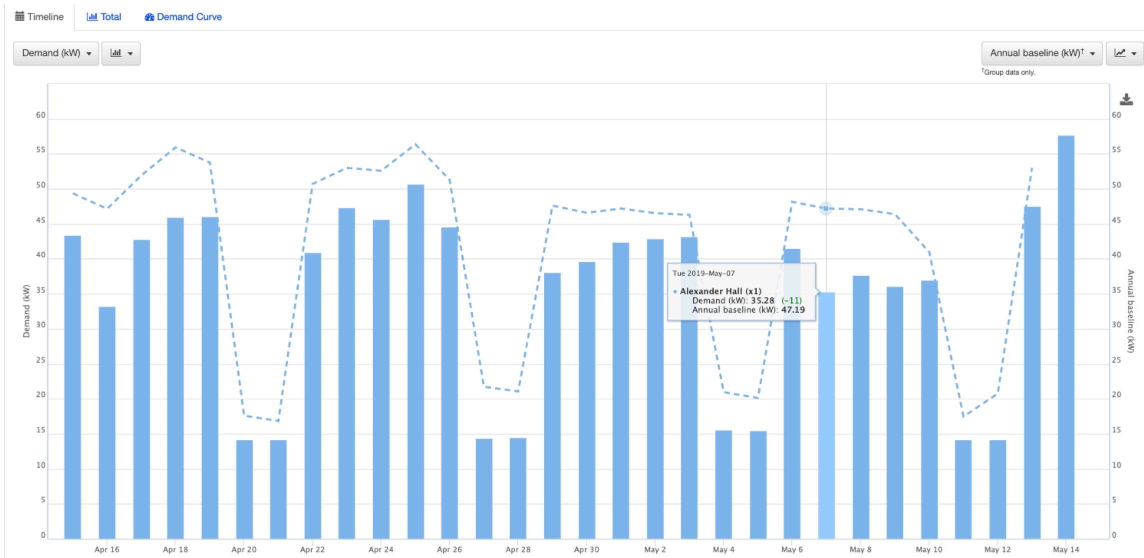

Figure 4. Comparison of daily energy predicted using an energy model for a base year (dashed line) and daily energy measured in current year (solid bars).

Reports can be generated to compare measured energy usage to the predicted energy usage for a given period and base year.

About MelRok

MelRok is an energy technology and services company that developed and delivers a turn key, automated, scalable and low cost energy optimization platform. MelRok's Self-Driving Buildings™ platform leverages existing metering, building automation systems (BAS), and other energy infrastructure assets to simplify energy management in buildings and eliminate the 20% of energy that is typically wasted in US commercial buildings.

MelRok's energy optimization platform leverages existing and new energy metering assets to offer the ultimate in energy metering benefits and maximize the returns from investments in energy metering. MelRok's platform allows for the real time collection of energy data from multiple sources, including energy meters and building automation systems, multiple vendors, and multiple buildings onto one platform. The data is stored, analyzed in real time, and made available to authorized users via a web-based portal or APIs. Built-in and turnkey analytics, using artificial intelligence and physics-based rules, eliminate the need for expensive energy consultants and data scientists to process the energy data for cost-saving findings and reporting. MelRok's platform is OpenADR 2.0b certified and establishes two-way communication with buildings allowing for the automated and continuous cloud-optimization of building automation systems.

MelRok engineers are experts in the design and implementation of energy metering platforms and assist customers throughout all phases of meter deployment and BAS optimization projects. For more information, please visit www.melrok.com or send an email to info@melrok.com.

About the Author

Dr. Kamel co-founded MelRok and managed its growth to a recognized leader in energy optimization and real time demand management systems. Dr. Kamel led the design and development of a universal Energy IoT gateway, and a cloud-based platform for real time energy analytics, fault detection and control of building energy management systems. Michel was principal investigator in several projects, including a $2.5M California Energy Commission grant for the demonstration of an automated continuous cloud-based energy optimization platform for buildings. He has authored 6 US patents in energy management and optimization, 2 US Patents in aerospace, and 3 international patents in Energy. Dr. Kamel presented his work at dozens of national and international conferences, has served on several technology Boards and currently serves on University of California Irvine's Dean of Engineering Leadership Council.

Dr. Kamel has a Ph.D. in Mechanical Engineering from Stanford University.