Connecticut Advanced M&V Pilot

Advanced measurement & verification (M&V) for energy efficiency projects shows great promise as a means to provide near real-time feedback on project savings and support new program approaches, but there are many challenges to be overcome in developing new M&V methodologies. A commercial M&V 2.0 pilot was initiated in 2017 that included a diverse group of project partners, and results from this pilot provide valuable insights into the process of conducting M&V 2.0. Through the pilot advanced M&V was applied to utility-sponsored retrofit projects, and project savings were monitored for 12 months.

What is M&V 2.0?

M&V 2.0 (sometimes called automated M&V or advanced M&V), is characterized by (1) Increased data availability, primarily in terms of finer time scales or higher volume and (2) enabling the processing of large volumes of data at high speed via automated analytics, to give near real-time savings estimates. These approaches are intended to be conducted more quickly, more accurately, and potentially at lower cost than non-automated methods

Pilot site selection

The advanced M&V pilot targeted projects with expected whole building electric savings of at least 5% (if savings are too low they cannot be distinguished from noise in the data). Thirty-four pilot projects were identified by utility partners that fit this savings criteria, based on upfront engineering calculation estimates. To confirm selection for the pilot, a baseline hourly energy model was created for each project site, and the quality of that model was assessed using three model fitness metrics:

- R^2, target >0.7
- CV(RMSE), target <25%
- NMBE target within -0.5% to +0.5% range

28 of the 34 candidate sites passed the fitness screening criteria outlined above and were included in the pilot (Figure 1 shows an example baseline model plot). The majority of the efficiency measures that were installed at the pilot sites were lighting projects (upgrades or controls), followed by upgrades to the heating and cooling system motors. Grocery stores were the most common building type in the pilot (n = 9), followed by office buildings (n = 6).

Ongoing savings tracking

After pilot site selection the partner utilities provided Berkeley Lab with information on the measure installation dates and updated electric interval data for pilot sites every quarter. The interval data was loaded into Berkeley Lab's open source advanced M&V tool ("RM&V 2.0") to determine the savings to date, and analysis charts were reviewed to see if the savings were accumulating as expected. If advanced M&V analysis uncovered any anomalies in the savings profile, the utility investigated possible causes and reached out to the customer for more information if needed.

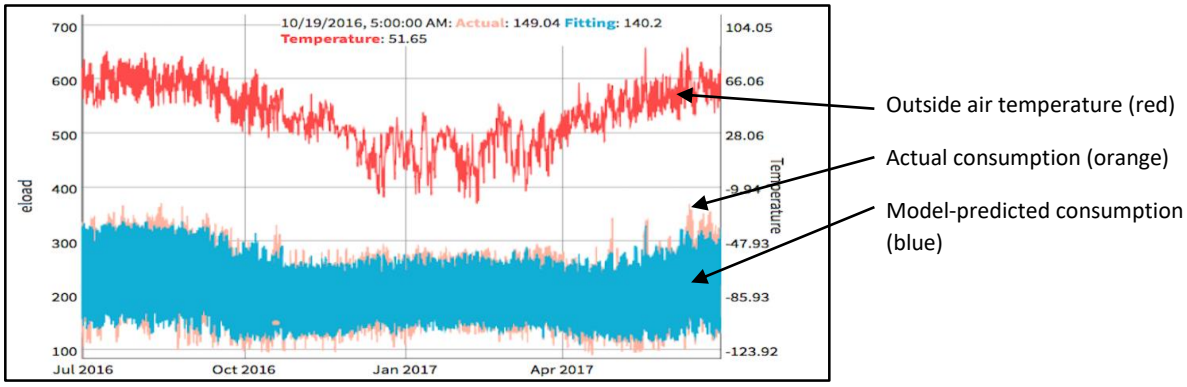

Figure 1: Example baseline model plot. Actual and predicted consumption closely overlaps, providing a visual complement to model fitness metrics.

Pilot savings analysis and reporting

After at least nine months of post installation data was received, savings totals and charts were reviewed and documented. A time period of two months prior to measure implementation, also known as the 'project blackout period', was removed from the dataset for all sites to allow for any discrepancy between reported and actual implementation dates.

Two types of chart were used for savings analysis under this pilot: time-series charts and cumulative sum of savings (CUSUM) charts (Example in Figure 2). CUSUM charts track the cumulative sum of the difference between actual energy consumption and model-predicted consumption (with predictions derived from the baseline model). CUSUM charts were reviewed for each pilot site to monitor for any anomalies and to compare kilowatt-hour (kWh) savings from M&V 2.0 with the upfront engineering savings estimates provided by the utility.

Savings estimates went through a 3-step review sequence, that addressed the following questions:

- Are the expected savings (based on utility estimates) 5% or greater?
- Is the CUSUM chart profile relatively 'clean,' i.e. relatively straight and without major inflections that might suggest non-routine events or atypical operating schedules?
- Is there significant difference between the advanced M&V savings estimate and the utility savings estimate? Does it merit further investigation?

This process allowed for both quantitative and qualitative review of savings.

Based on the 3-step review sequence, the savings results from 26 pilot sites (measure installation at 2 sites did not proceed) could be grouped into four categories:

- **Category 1:** Sites with a clean savings profile (i.e., a relatively straight CUSUM) and difference between advanced M&V and utility estimate within 20% (6 projects). Example in Figure 2.
- **Category 2:** Sites with a clean savings profile, and advanced M&V results consistently much lower than the utility savings estimate (a deviation of 35% or greater) (5 projects).
- **Category 3:** Sites with an irregular savings profile that could indicate the presence of non-routine events (NREs) or atypical building use or scheduling (9 projects). Example in Figure 3.
- **Category 4:** Sites with low expected savings (<5%), where advanced M&V savings estimate is considered unreliable. These sites were initially expected to install more measures and have greater savings than were actually installed during implementation (6 projects).

As illustrated in these examples, advanced M&V enables qualitative review of actual impacts at the meter, in addition to quantifying total savings. This can provide valuable additional feedback to utilities and to building owners. Interval data analysis can also be used to quantify impacts for specific periods of day and/or year, which is becoming increasingly important (this was not within the scope of this pilot). As adoption of advanced M&V grows, implementers will need to decide what level of anomalous savings profile or total savings deviation will merit further investigation.

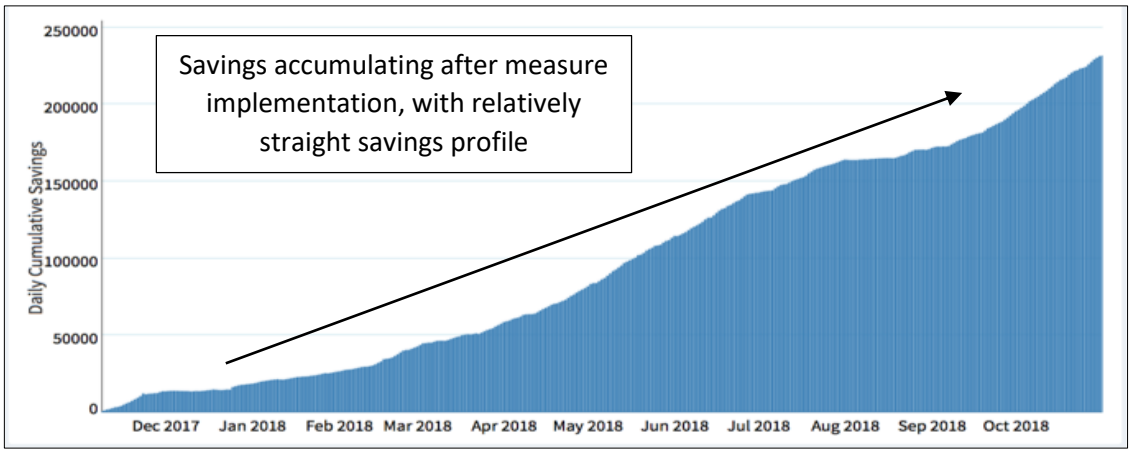

Figure 2: Daily CUSUM chart indicates relatively consistent savings accumulating over the performance period

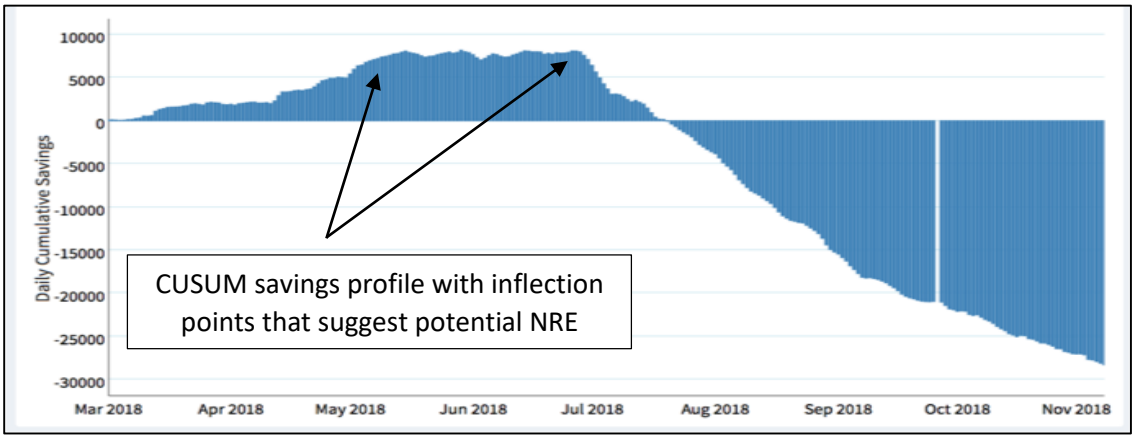

Figure 3: CUSUM chart for grocery store, indicating possible NREs in May and/or July

Aggregated Savings Analysis

Given the variation in savings present at individual sites, savings were aggregated into a cohort total. As a summed total, advanced M&V savings estimates were 57% of the utility program estimates. This simple aggregated total is of interest but doesn't tell the full story. Looking at totals by project category (Table 1), a utility can make better decisions on where follow up action is merited, based on savings characteristics.

Table 1: Utility and Advanced M&V Savings Estimates

Project Savings Characteristics	Utility Savings Estimate (kWh)	Advanced M&V Savings Estimate (kWh)
Category 1 (6 projects)	3,236,100	2,728,540
Category 2 (5 projects)	2,799,540	1,537,768
Category 3 (9 projects)	3,626,699	188,963
Category 4 (6 projects)	652,515	1,503,350

For example, projects in category 2 may require review of the utility's calculation assumptions, and projects in category 3 may warrant investigation to understand potential non-routine changes or measure failures.

Key Takeaways

The Connecticut Advanced M&V pilot provided valuable insights for the implementation of advanced M&V, as summarized below:

- Pilot demonstrated a practical approach to classifying projects based on quantity of savings and qualitative aspects of the savings profile
- Advanced M&V provided value through early feedback into achieved savings, *as they accrued*
- Non-routine events were detected in a timely manner at sites, allowing utilities to observe how non-program-related events affect building consumption
- Users of Advanced M&V will need some time, guidance, and experience to review results and determine whether further investigation is needed

Advanced M&V, as applied through this pilot, is not proposed as a direct replacement for a comprehensive Evaluation, Measurement and Verification (EM&V) process. However, it can offer valuable benefits as an element of EM&V, in supporting pay-for performance programs, or as a means for utilities to get an early indication of energy impacts for their programs.

Partnering for Success in Advanced M&V

The Connecticut advanced M&V pilot is a collaborative effort by Connecticut Department of Energy and Environmental Protection, Berkeley Lab, Eversource, United Illuminating, and the Northeast Energy Efficiency Partnerships (NEEP). Pilot funding is provided by the U.S. Department of Energy. The pilot complements other areas of Berkeley Lab research into advanced M&V. More information on these efforts can be found at: https://buildings.lbl.gov/emis/assessment-automated-mv-methods