



COMMERCIAL WHOLE BUILDING DEMONSTRATION

Joint Study Report

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Executive Summary

1. Introduction

In 2012, the California Public Utilities Commission (CPUC) requested its regulated investor-owned utilities (IOUs) to develop energy efficiency (EE) programs that focus on interventions that leverage comprehensive approaches to achieving deep savings in commercial buildings (Decision 12-05-015, 2012). In response to this request, Pacific Gas and Electric Company (PG&E) developed and launched the Commercial Whole Building Demonstration (CWBD) in 2014.

Several factors were considered in the development and launch of the CWBD. These included:

- California's IOUs including PG&E had substantially completed installation of advanced metering infrastructure (AMI) to customer buildings, which provided electric and natural gas energy use data in short time intervals. These data enable relatively fast feedback on a building's energy use patterns and day-to-day performance.
- To date commercial energy efficiency (EE) programs have not widely leveraged the availability of AMI data, nor the new analysis tools and techniques. Recent years have produced research on the accuracy and technical merits of M&V based on AMI data; however, evaluation protocols have not yet been updated to address the use of AMI data. This is due in part to the established measure-based regulatory framework and partly due to unfamiliarity with the more advanced analytical methods used to model energy use patterns in existing buildings based on AMI data among industry practitioners.
- Development and widespread use of energy management and information systems (EMIS) have helped building operators identify and address building performance issues and quantify avoided costs of installed energy efficiency measures.
- In 2015, the California Governor signed into law Assembly Bill 802 (AB 802, Williams, 2015) that directed the CPUC to allow IOU savings claims based on reductions in energy usage observed at the meter, normalized for factors that typically influence energy consumption. This methodology is known as normalized meter-based energy consumption ("NMEC"). This has provided the EE industry with new methods to estimate savings and track performance for multi-measure, deep savings commercial buildings projects and elevated the need to better understand 'meter-based' methods and their role in EE programs. Throughout this document, we refer to meter-based programs as those that provide this site-level NMEC measurement approach to quantifying savings.

While whole building M&V methods have existed for many years, California IOUs have not implemented commercial programs to achieve deep savings in existing buildings at scale. Consequently, there is a need to create a formal process (the Joint Study Process) involving multiple stakeholders to subject the methods to rigorous testing and to memorialize the results in a thorough report. The CWBD is a 12-building demonstration program ("Demo") designed to implement and evaluate multi-measure, deep savings projects and to pay incentives based on savings achieved over the year after implementation. Two whole-building M&V methods, IPMVP's Option C and Option D were used to quantify savings. Two EMIS vendors were engaged to provide Option C M&V and one technical consultant provided Option C analysis using two public domain models. CWBD Implementers provided the Option D analysis. Participation in the CWBD was invitation-only and was based on the customer's business sector, premise characteristics, and past energy usage.

PG&E and the CPUC initiated a Joint Study Process of five participants early in the program as customers were recruited and continued well past payment of the final incentives. Examination of the CWBD's program design, implementation processes and requirements, savings analysis, and results provided an opportunity to inform a framework for program design and evaluation moving forward. A limited sample of five of the twelve program projects were selected for the Joint Study; the remaining projects were part of a separate study undertaken by SBW Consulting. The Joint Study team is comprised of PG&E CWBD program administration staff, CPUC staff, technical consultants, and evaluators.

PG&E offered participants incentives based on savings determined by Option C methods. In all cases PG&E used savings estimated using the Option D method as the basis for the program's regulatory savings claims. Regulatory savings were claimed based on the measure-by-measure savings estimates from Option D since the CWBD was developed and implemented prior to passage of AB 802. Option D was added to the Joint Study after its launch after CPUC clarified that a savings claim resulting from the CWBD must be made according to regulatory rules. A back-casting approach was used in Option D in which simulations were calibrated to post-installation data.

This Demo provided a unique opportunity to compare results from each of these unique M&V methods, one essentially a whole-building "top-down" approach using statistical methods (Option C) and the other a measure-focused "bottom-up" approach using engineering simulations (Option D).

2. Study Objectives

The objectives for the Joint Study were narrowed to the four described below.

- 1. Comparison of whole building program savings estimates between Option C and D approaches.**
How do the savings estimates compare between the two methods and what are the major risks to whole building programs that each method addresses? What trade-offs are made when using one methodology over the other?
- 2. Improvements to key program technical requirements and documentation.**
What worked well and what needed improvement regarding the CWBD's technical and documentation requirements that are useful for future program designs and evaluation? What specific improvements are needed for successful implementation of Option C and Option D methods moving forward?
- 3. Factors informing the design of future meter-based whole building performance programs.**
What policies and procedures are required from both a regulatory and a program administrative perspective? What data and information are needed to support evaluation of a program using IPMVP Option C to determine savings in the California regulatory context?
- 4. Addressing the emerging technical and regulatory questions necessary to scale such programs and support evaluation.**
What changes to the existing California evaluation frameworks are appropriate for whole building programs? How can NMEC-based programs be designed to facilitate evaluation? What data are critical for IOUs to collect that will facilitate timely evaluation?

3. Results

3.1. Comparison of Savings Resulting from Option C and Option D

Figure 1 shows the comparison of the electric savings for each of the five study sites as estimated from Option D and Option C analyses. Option C results are based on the open source time of week and temperature (TOWT) modeling algorithm developed by Lawrence Berkeley National Labs. The figure compares both the weather-normalized and the actual savings estimates for the two methodologies. Similarly, Figure 2 shows the comparison of the natural gas savings estimates for the study sites as estimated from Option D and Option C TOWT analyses.

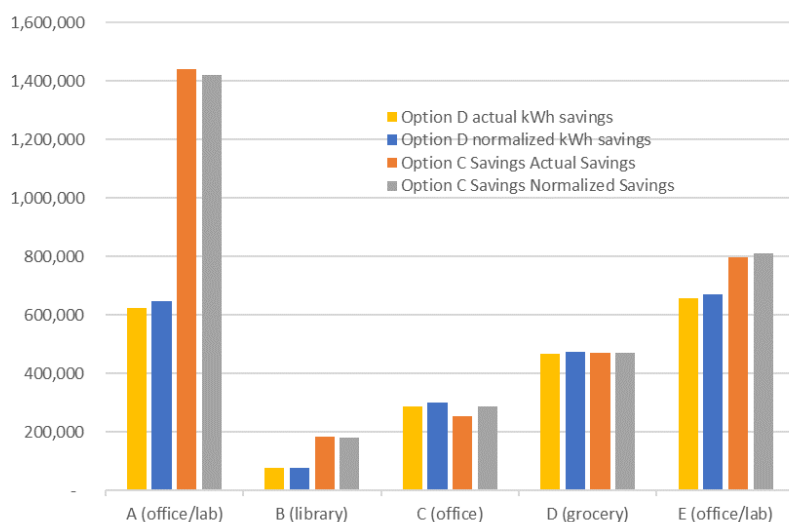


Figure 1: Comparison of Option C and Option D Electric Savings Estimate of 5 Study Sites

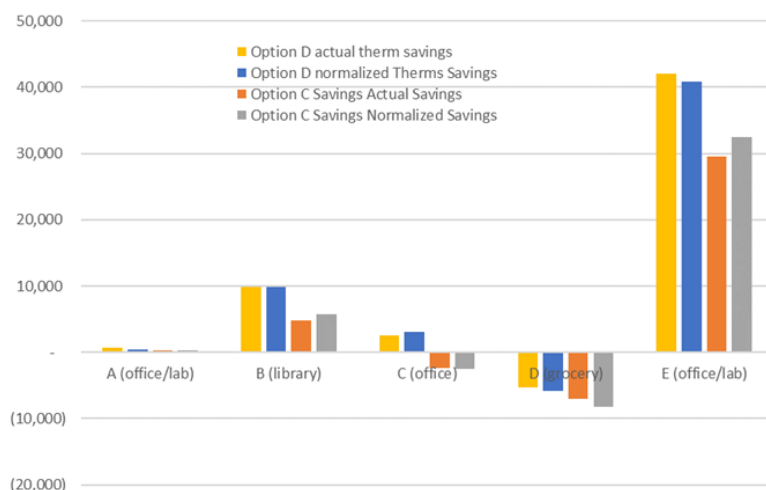


Figure 2: Comparison of Option C and Option D Natural Gas Savings Estimate of 5 Study Sites

From the two figures above, it is evident that overall the savings estimates for the five study sites didn't change significantly with the change of weather data from actual to normalized conditions. However, significant differences were observed between the Option C and Option D savings results. In three cases, the Option C electric savings estimates were higher than the Option D estimates. Overall, the Option D savings estimates were higher than the Option C estimates for gas savings.

The Option D simulations and Option C models provided kWh savings estimates that were comparable (within 5%) in two of the five buildings (Sites C and D) whereas there were large differences between the kWh savings estimates for the other three buildings. The key factors driving these differences in savings estimates between the Option C and D estimates were identified as non-routine events (NREs) confirmed for sites A and E, and possibly occurring at site B. The known NREs at sites A and E were simulated in the Option D method.

The Option C analysts (PG&E technical consultant and EMIS vendors) did not conduct site visits. They were provided the energy use data by PG&E to run their M&V analyses, but they did not collect data on building operation schedules, special events, or NREs. Thus, the analysts had no ability to adjust their models or check the accuracy of their estimates after having adjusted for these events.

The Option C and D methods did not produce similar estimates of natural gas savings for any of the five study sites. In three of the five sites, the Option C modeling algorithms could not reproduce the baseline gas usage patterns, resulting in poor goodness-of-fit (GOF) metrics. NREs were suspected as the cause of the differences with Option D in the two of the sites. Some of the Option D simulations did not calibrate well to gas usage. For these sites, the equipment was not defined appropriately in the simulations due to lack of equipment specifications and operational data having been incorporated into the models.

4. Discussion and Recommendations

4.1. Comparison of Option C and D Approaches to Whole Building Program Design

Option C and Option D represent fundamentally different approaches to estimating savings resulting from energy efficiency interventions. Both estimation approaches have advantages and disadvantages depending on the application. Some of these are discussed below.

- The Option C approach is generally lower cost because it bases savings estimates on the totality of energy savings by observing the changes in energy use before and after EE measures are installed. This meter-based approach works best for projects where savings are expected to be large as compared to the total energy consumed at the premise. A key challenge for Option C is when significant NREs occur at a facility during the reporting period, adding cost and uncertainty to the savings estimate.
- The Option D approach is more labor intensive—and therefore costlier—given its use of simulation software that requires considerable training to use, the level of effort and time to collect input data and information, and the iterative runs required to reach calibration and estimate savings for each EE measure. A key advantage is its ability to isolate savings estimates for individual measures and estimate interactive effects between measures.

Shortcomings of each approach, along with tradeoffs to consider when selecting an approach are summarized in Table E-1.

Table E-1. IPMVP Whole Building Option Selection

Shortcomings of Option C	Shortcomings of Option D	Tradeoffs Between Option C and D Methods
• Option C models have a risk that results do not reflect the actual savings achieved by the project – mainly due to NREs. • Models that don't meet goodness of fit criteria. • Projects that don't generate savings "above the noise."	• Ignoring or mischaracterizing behavioral (and operational) issues in whole building simulations • Simulation errors due to inaccurate or insufficient inputs • Simulation errors due to simulation engine limitations • Simulator's experience • Simulation calibration cost	• Data requirements • Non-program-related changes to buildings that confound the analysis • NRE adjustments

4.2. Recommendations to Improve Program Technical Requirements and Documentation

The CWBD was ambitious. It was developed to test many aspects of achieving comprehensive deep savings in participating buildings. The Demo employed unique entities to perform different activities. The administrator developed infrastructure to provide data to software vendors, technical consultants, and implementers. The CWBD began in 2013 and its final participant's incentive was paid in 2018. The Joint Study identified several elements that worked well and several areas that could be improved.

- Option C analysis by remote parties. While the electric energy models performed well based on goodness-of-fit metrics, the models did not account for building operation schedules that could have improved the models, nor for NREs that created biased estimates.
- Building pre-screening. Poor model goodness-of-fit metrics were obtained for natural gas models for four of the five study sites. Building pre-screening, whereby one year of historical meter and weather data would inform which buildings and energy sources are good candidates for Option C analysis, should be required for improved modeling outcomes.
- Use of performance period monitoring for NRE detection. Option C analysts should periodically download and analyze whole building meter data throughout the performance period to track whether the expected savings are materializing and assess whether NREs have occurred during the performance period.
- Level of detail "sweet spot" for Option D simulations. While it is generally time consuming to create fully geometric representation of buildings with all HVAC zones included, a "sweet spot" must be found that allows for an accurate representation of building characteristics, operations and loads presented to the HVAC systems affected by the measures but does not take an inordinate amount of time to create.
- Improve Option D calibration requirements. The CWBD procedures manual required verification report simulations to be calibrated with monthly data only. Building simulations can be improved

through calibration to hourly data to true up daily building operating schedules, identify daytypes, and unanticipated building shutdowns.

Specific technical improvements were identified that may improve the success of future whole building Programs:

- Development and standardization of NRE identification and impact quantification methods. NREs occurred in a significant number of the joint study sites. Given their uncertain characteristics, multiple methods should be used to identify and quantify NREs, including through analysis of AMI data, ongoing contact with building operators, through adjustments in whole building simulations, and through modifications to engineering calculations based on building data collected separately. More development work is needed in this area.
- Improve methods for estimating savings uncertainty for Option C methods. Further work is needed to develop an industry-accessible methodology to estimate savings uncertainty using advanced data models and short time interval data.
- Improve methods for estimating savings uncertainty for Option D methods. The estimation of saving uncertainty in Option D models has received less attention than Option C methods. Research has brought some statistical rigor to the estimation of savings uncertainty, but more work is needed.
- Industry standard calibrated simulation procedures for existing buildings. The CWBD's procedures for calibrating simulations fell short of simulating the study site buildings accurately. A search of building energy simulation industry organizations did not reveal an industry-consensus procedure for calibrating simulations of existing buildings. An industry-standard procedures document for Option D methods would greatly benefit the industry.

4.3. Design of Future Whole Building Performance Programs

Further development work is needed so that California will have the tools in place to administer and evaluate these types of programs. Several recommendations are offered to improve program management and improving program designs. Some of these elements that were identified are discussed below.

Program Management

- The greenfield subject matter of whole-building meter-based methods made it difficult for those without a statistics background to navigate. Recommendations for improved program management include:
 - Development of a matrixed approach to project management should be considered whereby representatives from multiple organizations having roles managing specific program functions are involved in program planning, including: customer targeting and outreach, field engineering, project implementation, data science, project technical review, evaluation, policy, regulatory reporting, and regulatory oversight.
 - Formal project planning tools and ongoing revisions to their outputs are essential for communication, recordkeeping, management and evaluability.
 - A "living" policy and procedures manual that details program requirements and processes that accommodates frequent updates.
 - A "data and file specifications and workflow requirements" document to facilitate program processes as customers are recruited, their energy use patterns are analyzed, baselines are

established, measures are identified, savings are quantified, and the program is evaluated. Key files include interval-level energy usage data, premise characteristics, key weather data, project data, and tracking and adjustments for NREs.

- Embedded M&V. In addition to an in-house evaluator on the team to represent the program administrator, third-party evaluators should be included at the planning stage to inform data collection requirements and procedures to ensure evaluability and conformance to regulatory requirements.
- Single repository of record for project files and a manageable directory structure.
- Weather data. The utility should be the sole source for weather data used in the analyses, including the mapping of treated premises to the appropriate weather stations.

Program Design Elements and Requirements for Success

Some of the most important design elements are:

- Program implementation plan incorporating embedded M&V. Having a program implementation plan (PIP) that explicitly identifies the points in the program where key information and data will be provided to regulatory staff and evaluation consultants is critical.
- Customer targeting, including use of an invitation only approach, pre-screening customers, and recommending program alternatives for unsuitable projects.
- Documenting program influence. Guiding principles for program design should be focused on effectively influencing potential participants to develop and implement multi-measure deep savings efficiency plans in their buildings.
- Documenting existing conditions prior to project acceptance. Proper documentation of existing conditions ensures that the baseline established routine operating conditions and is not artificially depressed from non-working equipment or artificially inflated from poorly maintained equipment.
- Need for a "Plan B" analysis plan. An alternate analysis strategy will need to be in place to meet customer needs when the Option C analysis is inconclusive or cannot be completed.
- Documentation of energy efficiency measures. Because the demo evolved to be a comparison between Options C and D, detailed information about measure-level savings estimates and expected useful life was captured. Moving forward with a meter-based program, capturing measure-level detail will be just as critical.
- Post-installation inspections. Given their reliance on post-installation data to populate their models, it is critical that on-site, post-installation inspections are built into the program design. These inspections should go beyond a simple physical inspection since proper operation of the measures can be difficult to verify without performing functional performance testing.
- Planning to address non-routine events (NREs). Two primary means to address NREs include: Ongoing structured interviews with building operators and software detection of NREs.
- Incorporate performance monitoring of energy use throughout the implementation and performance periods. Performance monitoring may be implemented in different ways, but it is essentially a comparison of actual energy performance to expected energy performance.

4.4. Addressing Emerging Technical and Regulatory Questions to Scale Programs and Support Evaluation

The site-specific Option C methodology of the CWBD was a direct response to the CPUC's call to IOUs in 2012 to develop a comprehensive approach to accomplish deep savings in commercial buildings. At that time—and until the passage of AB 802 in 2015—there was no methodology approved by the CPUC to use utility meters as a basis to determine energy and demand savings in commercial buildings.

There are two documents governing evaluation methods in the State of California: the California Evaluation Framework (2004) and the California Evaluator's Protocols (2006). Neither document provides a methodology for using data from utility meters to determine energy and demand savings for a specific premise whereby adjustments must be made for non-routine events. There is a recognition among evaluation professionals that the California Evaluation Framework needs a major update. A needs assessment in 2007 outlines a set of recommendations that include the addition of methodologies for NMEC analyses. Until the time that such an update is available, Southern California Edison has completed a first-generation NMEC Savings Procedures Manual for implementers that addresses much of the site-level analysis requirements. The Efficiency Valuation Organization, publishers of the IPMVP Protocols, has elected to develop its Advanced M&V guide based on this manual.

Several recommendations were made to improve program design to facilitate evaluation and increase the scale of efficiency through programs.

- Develop a standard set of procedures and requirements for the development and application of advanced M&V, including validating meter data, preparing data sets, matching weather data files to premises, selecting appropriate modeling algorithms, reporting model goodness-of-fit metrics and uncertainties, and reporting savings.
- Increase transparency and replicability to facilitate evaluation by use of well documented open source modeling algorithms. Use validation methods and standards such as those developed at LBNL when proprietary modeling algorithms are used.
- Resolve uncertainty estimation methods for hourly models and use savings uncertainty as a criterion in place of rules-of-thumb at both a project-level and a portfolio level, enabling projects with poor model fit but high savings as well as projects with good model fit but low savings to participate in meter-based programs.
- Always strive for deep savings, greater than the 15% targeted in CWBD, and allow inclusion of capital projects and BRO measures.
- Programs delivered using ratepayer funds under the jurisdiction of the CPUC must meet regulatory cost effectiveness criteria. Cost effectiveness calculations require a consistent set of metrics, including gross savings, project costs and net-to-gross ratios consistent with gross savings baseline assumption. The effective useful life of a multi-measure project is based on estimated savings-weighted EUL of the measures installed. Measure-level engineering estimates will be necessary to estimate project EUL and savings calculations done during project development will likely suffice for this purpose.
- Embedding M&V into the design and operation of a meter-based program facilitates the evaluation process by ensuring that programs are evaluable. Meter-based programs are data driven, and by their nature require data collection on the part of the program implementers to a level of quality required by evaluators. Given the time required for projects to complete the performance period

and enter the savings claim process, the ex-post evaluators will need to maintain contact with implementers throughout the project lifecycle. Data gathering, documentation of processes, and data analyses should be responsibilities that are shared between program implementers and evaluators.

5. Conclusion

5.1. Comparison of whole building program savings estimates between Option C and D approaches.

The predominant risk in whole building programs is the occurrence of NREs and their impacts on the energy savings, whether estimated through Option C or Option D. In this study, the team could estimate NRE impacts after it collected information from the site that enabled it to be simulated in the Option D model. The Option C analysts did not go on site and therefore were blind to any occurrences of NREs. A proactive approach to identify, document, and quantify non-routine events is critical for estimating site by site savings. All models, regardless of the GOF statistics, will converge on the wrong savings if NRE adjustments are not included.

The CWBD encountered issues with both Option C and Option D analysis. Programs should avoid a focus on a single analysis method and recognize the need for ‘backup’ analysis methodologies to meet the needs of individual projects and regulatory requirements.

5.2. Improvements to key program technical requirements and documentation.

Although there was significant development of the program policies and procedures manual, data specification documents, reporting templates, and other resources, the study team found weaknesses in their content, and lack of enforcement of their use.

It was also noted that there are several areas where consensus industry standards would be helpful: establishing a framework and methodology for identifying and quantifying NREs, improving uncertainty estimation methodologies for both Option C and D M&V methods, and developing an industry standard methodology for calibrating Option D simulations and estimating individual measure and well as whole building savings.

5.3. Factors informing the design of future meter-based whole building performance programs.

Deep savings whole building savings programs are long engagements with their participants, the CWBD engaged with its customers for up to five years. Consistent project management, reporting, and data archiving is critically important, as is maintaining consistency of procedures and technical review. Embedded EM&V concepts should be explored and included in program design to assure evaluators will have the information needed for their tasks.

The CWBD illuminated several best practices: identifying potential participants through analysis of usage data, pre-screening program participant to assure baseline model goodness of fit and accuracy, assuring participants willingness to invest in deep savings and await incentive payments based on performance, providing consistent energy data and weather files, providing good documentation of baseline conditions, documenting program influence, and establishing specific procedures for NREs.

5.4. Addressing the emerging technical and regulatory questions necessary to scale such programs and support evaluation.

There is a lack of an accepted evaluation methodology to use utility meters as a basis to determine energy and demand savings in commercial buildings. Neither of the two main evaluation guidance documents, the Evaluator's Framework and the Evaluator's Protocols, provides a methodology for using data from utility meters to determine energy and demand savings for a specific premise whereby adjustments must be made for non-routine events. In addition, reporting structures for meter-based programs don't fit well in deemed or custom reporting structures.

Several other considerations should be addressed to facilitate evaluation of meter-based projects and programs:

- Education and training on advanced M&V methods to reduce confusion and leverage its benefits appropriately.
- Open source advanced M&V models will be preferred, but methods to validate proprietary models should be adopted to increase the number of market actors.
- Research should be pursued in needed areas, such as developing savings uncertainty algorithms for M&V methods employing advanced modeling algorithms.
- Cost-effectiveness and useful life metrics should be broadened to evaluate the combined packages of deep saving measures installed in meter-based projects.

Finally, as meter-based projects have a long duration, successful and informed evaluation will only result when evaluation data and information requirements are embedded in program design. Embedded EM&V will be critically important to gain rapid feedback on program operation and effectiveness.

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B.1 Study Process Activities 50