Performing High-Rigor Impact Evaluations Cost-Effectively in the COVID-19 Era

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ABSTRACT

Impact evaluations are an important part of regulatory requirements and cannot be abandoned, even during a pandemic. This paper examines the successes and lessons learned from an impact evaluation designed to replace traditional evaluation, measurement, and verification (EM&V) with virtual alternatives. The authors of this paper evaluated a statewide program administered by two investor-owned utilities (IOUs) that incentivized the installation of controls on hotel guest room HVAC equipment. The magnitude of savings achieved by the measure depends heavily on parameters that traditionally require field visit(s) and M&V to verify. In lieu of traditional on-site data collection, evaluators conducted "virtual site visits" with customers to verify measure installation and key operating parameters and fielded remote surveys to characterize the energy consumption in guest rooms and the facility as a whole. Simultaneously, evaluators obtained pre- and post-installation, facility-level utility consumption data from the IOUs and trended HVAC performance data from energy management systems (EMS) ensuring all key data points were comparable to traditional data collection methods.

These virtual site visits, combined with a templated "semi-custom" modeling approach, reduced the costs typically associated with modeling-based commercial and industrial evaluation using site-specific simulation models by approximately 30%, without compromising evaluation rigor. The cost-effective solutions for data collection and analysis developed for this project are applicable to HVAC systems for other sectors such as schools, multifamily, and healthcare, even after the pandemic.

Introduction

EM&V has been used as a primary tool by regulators to determine whether energy efficiency programs are achieving policy goals. EM&V methods have been refined and improved over time as energy efficiency program strategies evolved (US EPA 2019). Traditional high-rigor data collection for EM&V in accordance with the current International Performance Measurement and Verification Protocol (IPMVP) usually requires selection of sites suitable for end-use measurement, temporary equipment decommissioning to provide safe installation of data logging devices, their subsequent removal, followed by data processing and analysis. Needless to say, these methods are expensive and time-consuming and can be inconvenient for program participants at times.

Traditional in-person data collection supporting EM&V has been difficult to conduct post March 2020, as governing bodies issued lock-down or shelter-in-place orders due to the emergence of the COVID-19 pandemic. This paper examines a creative and cost-effective alternative to traditional data collection: "virtual site visits" that use technology to collect performance data for high-rigor assessment. Virtual site visits and remote data requests led to fast, cost-effective data collection that focused on key savings parameters, which in turn allowed evaluators to streamline the templated "semi-custom" analysis approach. Through this approach, evaluators focused on updating the parameters of greatest engineering uncertainty that impact savings to calculate the gross measure impacts for 85 sampled projects. The baseline eQUEST models were calibrated to the pre-installation monthly billing data, enhancing confidence in the achieved results from the "semi-custom" modeling approach.

Studied Technology

DNV evaluators worked together with staff from the California Public Utilities Commission (CPUC) to conduct an impact evaluation of commercial heating, ventilation, and air conditioning (HVAC) equipment installed as part of Investor-Owned Utility (IOU) energy efficiency programs in program year (PY) 2019[1]. Among the technologies selected for this evaluation effort were retrofit add-on controls to packaged terminal air conditioners (PTAC) and packaged terminal heat pumps (PTHP) installed in lodging guest rooms. Two IOUs in California, Pacific Gas and Electric Company (PG&E) and San Diego Gas & Electric Company (SDG&E) filed savings claims under this measure group. The control measures claimed by PG&E modulate temperature setpoints of the guest room PTAC/PTHP unit when controls sense the room is unoccupied, whereas the control measure claimed by SDG&E varies the PTAC/PTHP unit's supply fan speed to optimize the efficiency of the system's cooling and heating system.

The PTAC/PTHP controls measure group contained 192 sites that claimed savings during PY 2019. About 84% of the sites (162 sites) participated under PG&E's program and 16% (30 sites) took part in the program under SDG&E's program. The magnitude of savings achieved by the measure depends heavily on the actual occupancy schedules of the guest rooms, override status of the control box, affected guest room area, HVAC equipment efficiencies, and achieved run time reductions. Therefore, it was critical for the evaluators to obtain these site-specific post-installation parameters (operating conditions) to perform accurate energy savings calculations.

Technology Evaluation – Approach and Methodology

To estimate the electric energy savings from the PTAC/PTHP controls measure group, the evaluators designed the sample to achieve ±10% relative precision at the 90% confidence level. In order to achieve this relative precision with an assumed error ratio[2] of 0.80, a total of 85 sample sites were required. Table 1 shows the planned and achieved sample sizes for the PTAC/PTHP controls measure group by IOU.

Table 1. Sample Counts by IOU

IOU	Population Size	Planned Sample Size	Completed Sample Size
PG&E	162	70	74
SDG&E	30	15	13
Total	**192**	**85**	**87**

Phase One: Virtual Site Visits.

After the sample was designed, the evaluation commenced with the first phase which involved comprehensive data collection and "virtual site visits." This was accomplished through a combination of

[1] The full evaluation report is available here: https://pda.energydataweb.com/api/view/2510/CPUC%20Group%20A%20Commercial%20HVAC%20Impact%20Evaluation%20Report%20PY2019%20Final.pdf

[2] The error ratio is the ratio-based equivalent of a coefficient of variation (CV). The CV measures the variability (standard deviation or root-mean-square difference) of individual evaluated values around their mean value, as a fraction of that mean value. Similarly, the error ratio measures the variability (root-mean-square difference) of individual evaluated values from the ratio line, 'Evaluated savings = Ratio multiplied by Reported savings', as a fraction of the mean evaluated value.

videoconferences, telephone calls, emails, and photograph exchanges with the building staff. The virtual site visits were performed to accomplish the following tasks:

- Verify measure installation and installation rate
- Obtain inventory of equipment affected by the measure
- Verify key project details in program tracking data
- Determine measure operational parameters
- Determine facility operational parameters

The videoconferences, telephone calls and emails allowed remote verification of measure installation and data collection on the impacted equipment and facility, despite the ongoing COVID-19 pandemic. An assigned engineer conducted a virtual site visit with knowledgeable facility staff by first confirming key project tracking details listed below:

- Project location, to identify the appropriate California climate zone
- Facility type
- Quantity of installed guest room HVAC controls
- Overall facility area, in sq. ft.
- Number of floors in the building
- Average guest room size, in sq. ft.

The engineer then asked the facility staff to lead them to specific guests rooms so that the engineer could perform a remote visual inspection of the installed controls and affected PTACs or PTHPs within a selection of guest rooms determined by the engineer based on guest room area and location. The rooms were selected to have sufficient representation of all the various room types within the building, and at different locations as well (core vs. perimeter). Evaluation engineers remotely inspected systems via live video feed (e.g., FaceTime, Zoom, and Microsoft Teams) on the PTAC/PTHP unit and the controls that were installed as part of the measures. In cases where facility staff were unable to accommodate video, engineers directed them while they collected the necessary data from specific guest rooms during which they answered questions about the controls and impacted equipment and described what they observed to the engineer, such as the make/model of the PTAC/PTHP units and the control panel on the thermostats. For all methods of virtual M&V conducted, the engineer requested that the building staff take photographs of the impacted PTAC and PTHP unit nameplates and provide them to the evaluator by email. These photographs were subsequently verified by the engineer so that the efficiency of the installed equipment could be incorporated in the site-specific energy savings analysis models. DNV evaluators ended up completing 87 remote site visits out of a target sample of 85.

Following the verification of videos and photos resulting from the remote inspections, the engineers asked a battery of questions to the facility staff to collect information about both the installed and preexisting guest room HVAC controls along with details about the facility and its general operation to inform the building simulation models. The survey battery included the topics listed below:

- Make and model of installed controls
- Make and model number of all impacted PTAC or PTHP units
- Preexisting control types, setpoints, and usage patterns
- Post-project control schemes including typical occupied and unoccupied setpoints, and override patterns
- Pre- and post-project occupancy along with any notable changes to the facility's operations or energy consumption, including seasonality
- Common area information including HVAC and lighting inventories along with other energy-intensive end-uses (e.g., elevators, swimming pools, fitness centers, etc.)

To encourage participation in virtual site visits and remote data collection, the facility contacts were offered a $150 gift card incentive or a donation of the same amount to the CA United Way COVID-19 Relief Fund. In most cases, the virtual site visits and site contact interviews were completed within an hour. In a few instances, the DNV engineer needed to follow up with the facility contact to gather supplemental information that was not available during the initial virtual site visit. Some of the recurring challenges that came from using this data collection methodology included struggling to identify the most appropriate contact at the facility who can assist with virtual site visits, in addition to requesting an hour of their time for the evaluation in the middle of a pandemic while the industry was heavily understaffed. However, evaluators worked through these challenges by patiently requesting the facilities management to get to the right person to participate in the virtual site visits, and by accommodating various times of the day for the individual to collect the data necessary for a high-rigor evaluation.

Table 2 shows the tasks accomplished in Phase 1, and a comparison of how those tasks would have been performed absent the pandemic.

Table 2. Phase 1 tasks vs. pre-pandemic evaluation practices

Evaluation task	**Virtual site visit**	**On-sites (Pre-pandemic)**	**Evaluator assessment of virtual site visit activity**
Verify measure installation and installation rate	Video inspections and installation records (e.g., invoices) provided by site staff	Manual inspection and quantification of installed controls by engineer	The number of controls to be inspected was restricted for the virtual site visits by the amount of time available for the site staff for the video call.
Obtain inventory of equipment affected by the measure	Collect data over video call with site staff. Alternatively, site staff also sent pictures of equipment nameplates.	Manually record the equipment nameplate data on-site.	Completing this task virtually required additional follow-ups with the site staff and resulted in data collection delays.
Verify key project details in program tracking data	Interview with site staff over video call	Site walkthroughs, supplemented by an interview with the site staff during a site visit	The evaluators were able to accomplish these tasks using a virtual site visit significantly faster than through an on-site visit. While there were gaps within the data collected over a phone interview, it was not large enough to affect the evaluation rigor.
Determine measure operational parameters			
Determine facility operational parameters			

Phase Two: Remote Data Collection and Analysis

The second phase of the virtual M&V process included data collection from the HVAC controls manufacturer affiliated with PG&E's programs. During the evaluation, DNV's engineers learned that each guest room's control was transmitting cooling and heating temperature setpoints, room temperature, humidity, occupancy status, compressor status, heater status, and fan status at five-minute intervals to the facility's central energy management system (EMS). If the participant had given permission, this data was being uploaded to the HVAC control manufacturer's cloud-based servers. The evaluators requested

and collected cloud-based temperature and occupancy trend data directly from the HVAC controls manufacturer.

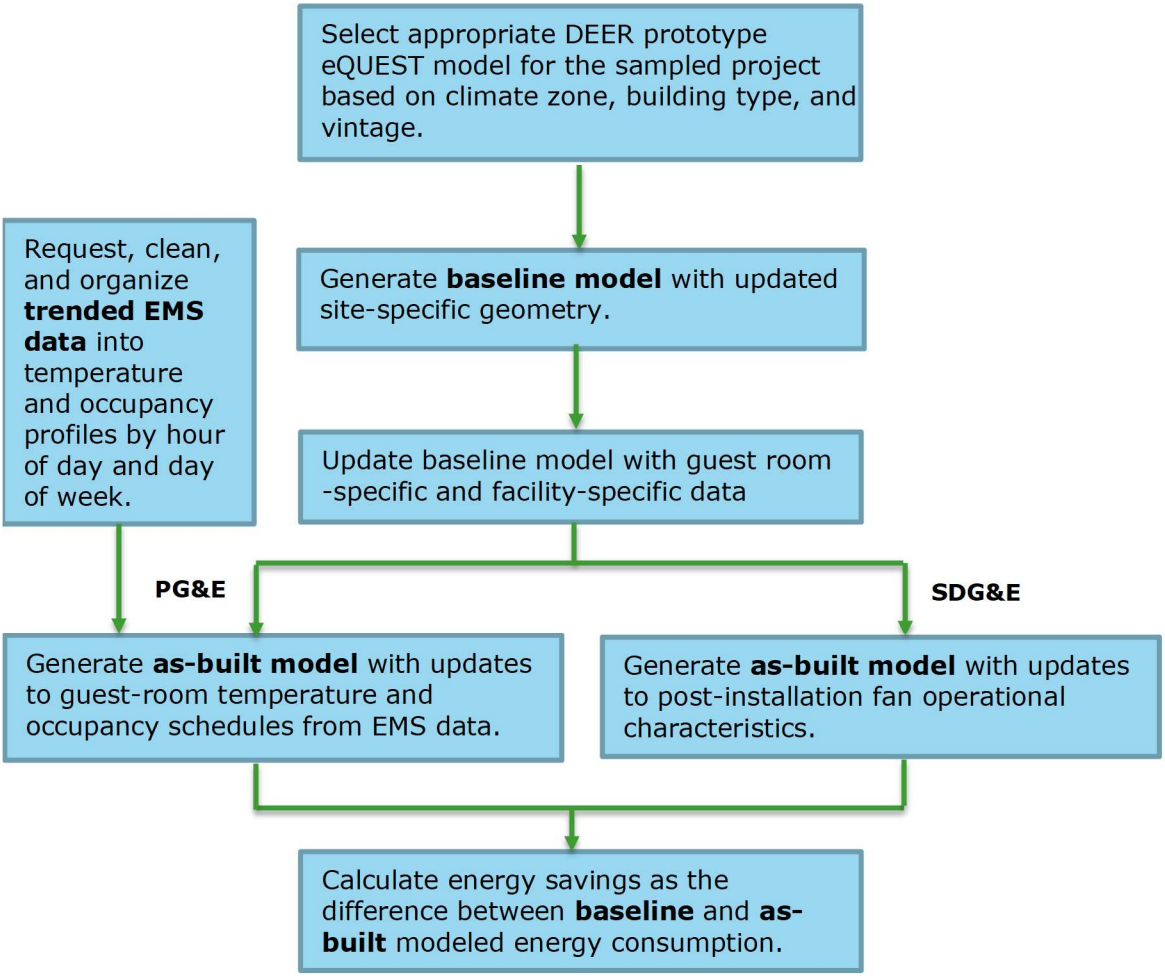
The evaluated measure impacts are heavily coincident with changes in building occupancy, and COVID-19 lockdowns affected the hospitality industry operations significantly. Therefore, the objective of the evaluation was to obtain pre-pandemic data on how the measure was performing (runtime reductions of the PTAC/PTHP units) and estimate energy savings associated with measure installations absent the pandemic. The trend data obtained by the evaluators covered as many pre-pandemic months in 2019 and 2020 as were available among 50 participating facilities. Site-specific data was not available for 37 sample points since the facility's central EMS was not permitted to transfer data to the cloud-based server by the participant.

DNV evaluators processed and parsed the available data by key segments (e.g., hotel/motel, assisted living) to be as representative of PY2019 participants as possible. This trend data from HVAC controls manufacturer provided evaluation-grade performance data as robust as would have been obtained if field M&V were possible, as it included approximately 10 months of hourly data from all guest room controls that were installed as part of the measure at 50 locations. Additionally, evaluators also requested and received monthly billing and Advanced Metering Infrastructure (AMI) hourly electric consumption data from the IOUs for all sampled facilities to calibrate simulated facility base energy usage.

Data Processing, Analysis, and QA/QC

An enhanced rigor approach was used to evaluate the savings of the PTAC/PTHP Controls measure group. Instead of developing site-specific building simulation models from scratch, we used a "semi-custom" modeling approach as depicted in Figure 1 below.

Figure 1. PTAC/PTHP controls measure group analysis process flow.



Developing the baseline model. The CPUC and California Energy Commission (CEC) developed Database for Energy Efficiency Resources (DEER) prototype building models to allow a comprehensive assessment of building energy performance for 23 distinct building types assumed to be representative of California's non-residential building stock. The prototype building models encompass six vintage tiers and 16 California climate zones. The DEER prototype models are in eQUEST format. Each building prototype file describes a single site configuration with either one building or multiple buildings served by one or multiple HVAC system types.

The PTAC/PTHP controls measures' ex-ante unit energy savings (UES) for both PG&E and SDG&E were estimated from DEER prototype baseline models. Based on our remote data collection efforts for this measure group, evaluators determined that PTAC/PTHP controls measures were implemented in hotels, motels, and senior living facilities in 2019. The evaluators selected the most appropriate DEER prototype building model for each of those classifications to develop the site-specific baseline model for evaluation. In the case of senior living facilities, the evaluators determined that the nursing home prototype would be most appropriate based on facility and occupant characteristics.

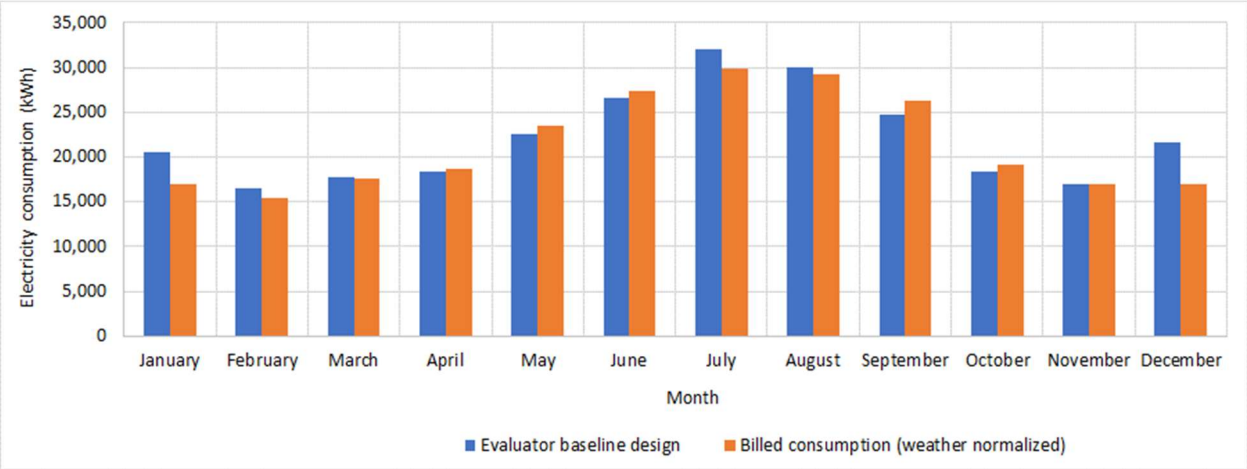
Each of the DEER prototype models has assumptions built into it in the form of overall facility area, number of floors, typical activity area type contributions, envelope characteristics, thermal zoning characteristics, lighting and HVAC systems characteristics, plug load characteristics, and annual schedules

for occupancy, lighting, cooling/heating temperature setpoints, and equipment. To develop the site-specific baseline model, evaluators updated the DEER prototype model's library files to reflect real-world data collected during virtual site visits. DNV evaluators developed "semi-custom" templatized forms which were used in the analysis of all 87 sampled sites to assist in updating the DEER prototype model with site-specific parameters. The templatized forms identified parameters within the DEER prototype model's library input files that needed an update and generated outputs that could be pasted into the library files to make them site-specific. For example, building geometries were updated to reflect actual facility area (in square feet) and percentage area contributions from each space type (e.g., guest rooms vs. common areas).

Then, evaluators generated the appropriate baseline model for each sampled project based on building type, building vintage, and climate zone using a simulation generator software called MASControl3. MASControl is CPUC's model-based measure analysis software, created to generate DEER prototypical buildings and to estimate impacts from pre-developed DEER measures. MASControl uses the DOE2/eQUEST library to develop DEER database values. In the baseline eQUEST model that was developed, evaluators adjusted critical input parameters that represent how the guest rooms' and facility's energy-consuming systems operated in the pre-installation scenario, including HVAC, lighting, and plug loads. DNV evaluators also updated the baseline model's guest room cooling setpoints and schedules, heating setpoints and schedules, and occupancy schedules as determined from trend (time-series) data provided directly by the HVAC controls manufacturer. The trended data represented only the post-installation period. Therefore, the guest room baseline cooling and heating setpoints were assumed to be equal to the average post-installation setpoints during occupied periods.

As a final step in baseline model development, evaluators compared the baseline model to the weather-normalized, pre-installation monthly electric billing data as provided by the IOUs and attempted to calibrate the models to be within 10% of monthly consumption data. This comparison with billed electric consumption data generally instilled confidence in baseline model accuracy and, in some cases, led us to refine inputs to better reflect real-world operating conditions (e.g., common area plug loads and senior living patient room equipment power densities). An example of a baseline model calibrated to facility consumption for a sampled site is illustrated in Figure 2.

Figure 2. Example of a site-specific baseline model calibrated to facility consumption.

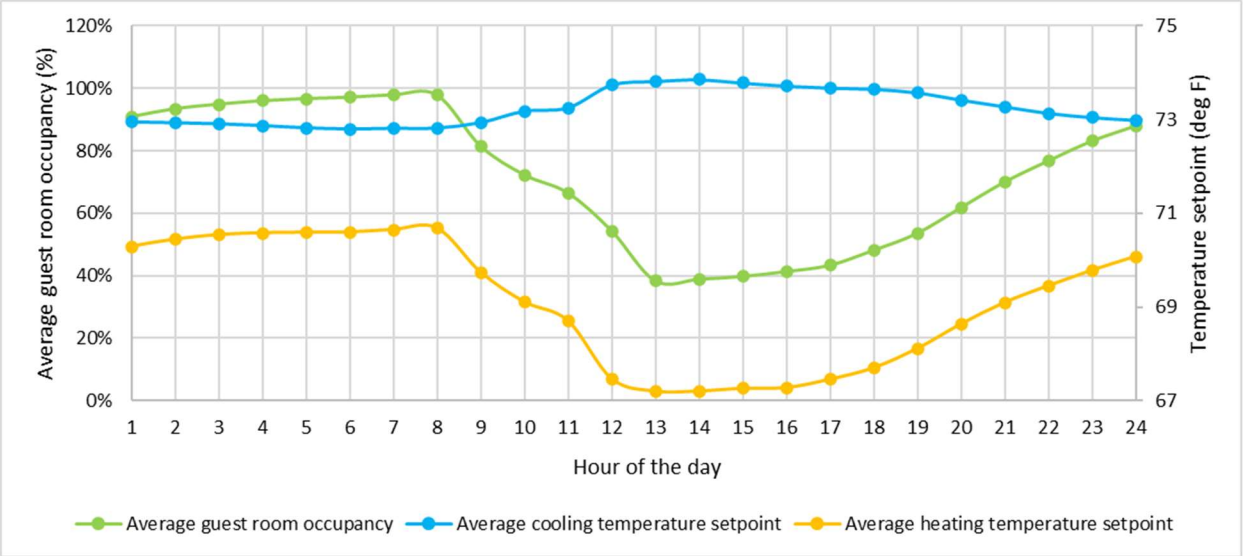


The development of "semi-custom" templatized forms to make DEER prototypical models site-specific greatly reduced the evaluators' burden of developing site-specific models from scratch. There were challenges associated with calibrating the models to weather-normalized facility billing data accurately, given the "semi-custom" approach. In many cases, this required the engineers making follow-up calls to the facility staff to clarify and obtain additional information from the facility and guest rooms to update the baseline model.

Manufacturer EMS data processing. DNV evaluators requested hourly data for guest room cooling temperature setpoints, heating temperature setpoints, and occupancy rates from the HVAC controls manufacturer for all 162 projects incented by the PG&E programs offering the PTAC/PTHP controls measure in PY2019. The controls manufacturer provided cloud-based data trends for 50 PY2019 projects. Each project's data included hourly average readings of temperature setpoints, the occupancy status for individual guest rooms, and covered approximately 10 months in the post-installation period on average.

DNV evaluators reviewed the data trends in depth to parse out any erroneous values prior to utilizing them in the analysis. The data set was cleaned, processed, and filtered to include only periods that were not affected by COVID-19 (prior to March 2020). Next, the data at the project level was aggregated to estimate daily profiles for cooling temperature setpoints, heating temperature setpoints, and occupancy rates for both rented and non-rented rooms. An example of such daily profiles generated for a rented room at a sampled site is illustrated in Figure 3. For sampled projects for which data was not provided by the HVAC controls manufacturer, data from similar projects with available data were aggregated and averaged to estimate daily profiles for use in the analysis.

Figure 3. Example of daily average profiles generated for a rented room at a sampled site.



Developing the as-built model – PG&E measure group. Once an appropriate baseline model was developed for each sampled project, a similar site-specific, post-installation (i.e., "as-built") model was developed using the "parametric runs"[3] feature in eQUEST. This was done by modifying independent variables such as post-installation guest room cooling, heating set point schedules (keywords in eQUEST - COOL_TEMP_SCH and HEAT_TEMP_SCH), and occupancy schedules (PEOPLE_SCHEDULE) based on the trend data described previously.

Developing the as-built model – SDG&E measure group. Using the "parametric runs" feature in eQUEST, the post-installation PTAC/PTHP supply fan operational characteristics (keyword in FAN_CONTROL) was updated based on the control module's operation as described by the manufacturer. The model was modified to reflect "continuous" fan operation instead of "intermittent" in the baseline model, resulting in fan savings intended from the measure.

Evaluated savings calculation. The baseline and as-built models formed the basis of the evaluated savings for the PTAC/PTHP controls measure group. For each project in the sample, site-specific models were generated to produce annual energy consumption totals and peak demand estimates for baseline and as-built conditions. The differences in energy consumption and peak demand between the two models defined the modeled evaluated savings. The modeled evaluated unit energy savings (UES) was calculated as the quotient of modeled evaluated savings and the number of modeled guest rooms.

Results

Figure 4 illustrates average evaluated UES (annual kWh and peak kW) by facility type, for the PG&E and SDG&E PTAC/PTHP measure groups. For the PG&E measure group, PTAC/PTHP control measures installed in nursing homes resulted in significantly lesser savings than hotels or motels. This can be attributed to patient rooms in nursing homes being occupied for longer durations of the day compared to a hotel/motel guest room, and the measure primarily saving energy during unoccupied hours. It is also important to note that the SDG&E PTAC/PTHP controls measure group resulted in significantly less savings

[3] The parametric runs capability of eQUEST provides a means to define and simulate multiple, alternative simulation cases, where each new case is a parametric variation of the base case.

than the PG&E counterpart. The difference lies in the measure technology – the control measure claimed by SDG&E varies the PTAC/PTHP unit's supply fan speed to optimize the efficiency of the system's cooling and heating, whereas the PG&E measure group reduces compressor and supply fan runtime of the guest room PTAC/PTHP unit when the room is unoccupied. DNV evaluators determined that the SDG&E measure group achieved marginal reductions on the PTAC/PTHP fan's energy consumption, but not significantly on the compressors. It was also estimated that for the PG&E sample on an average, the measure group saved 19% of baseline guest room HVAC usage in hotels, 18% of baseline guest room HVAC usage in motels, and 5% of baseline patient room HVAC usage in nursing homes. For the SDG&E sample on an average, the measure group saved 3% of baseline guest room HVAC usage in hotels and motels.

Figure 4. Evaluated UES by facility type – Annual kWh and Peak Demand kW.

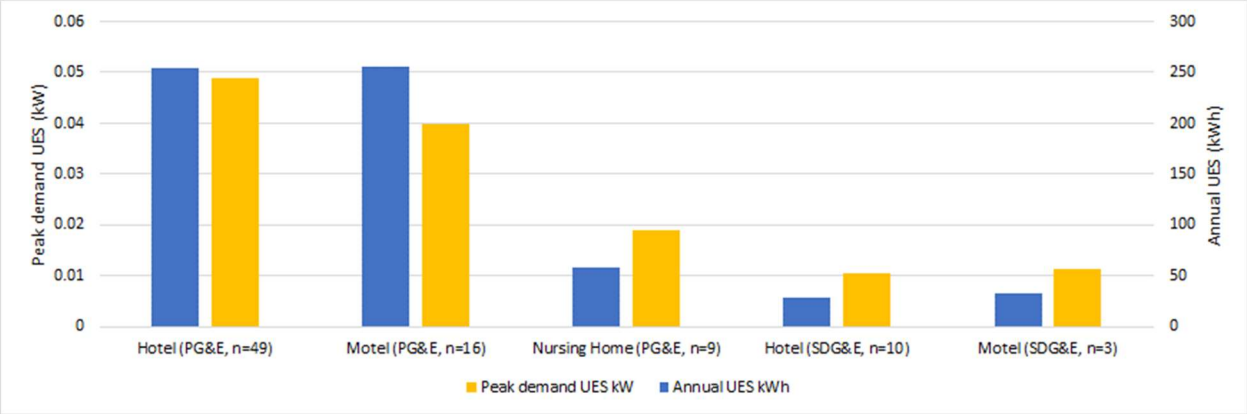
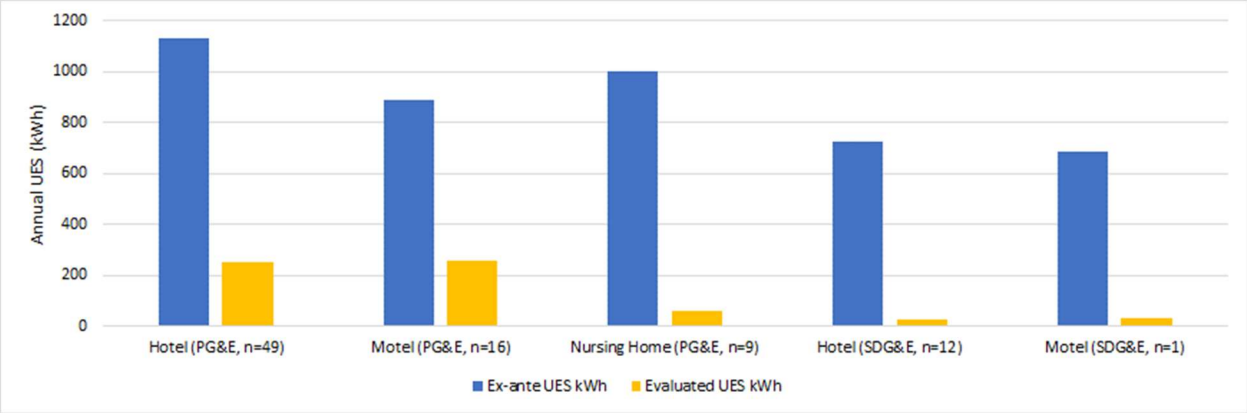


Figure 5 illustrates average ex-ante and evaluated annual UES kWh by facility type, for the PG&E and SDG&E PTAC/PTHP measure groups. DNV evaluators identified primarily through virtual site visits, drivers other than site-specific measure operation that impacted evaluated energy savings from the studied technologies and resulting in a significant difference between ex-ante and evaluated UES as seen in Figure 5. California Title 24 2013, which went into effect on July 1, 2014, requires that PTACs within hotel/motel guest rooms "shall have captive card key controls, occupancy sensing controls, or automatic controls built-in such that, no longer than 30 minutes after the guest room has been vacated, setpoints are setup at least +5°F (+3°C) in heating mode. Engineers found that 31 facilities were either constructed, majorly renovated, or had all guest room HVAC systems replaced after July 2014, invoking Title 24 2013 and invalidating the claimed measure savings for those incented units. Based on a review of the PTAC/PTHP unit nameplates at these facilities, it was understood that the units have built-in HVAC controls. Additionally, evaluators also found that the facility staff had removed or overridden installed controls at 12 facilities due to customer complaints, resulting in invalidation of claimed savings for those incented units. Findings from the study indicate that it was possible to conduct a thorough and robust evaluation of the measure despite the pandemic. Virtual data collection facilitated this process.

Figure 5. Annual UES (kWh) by facility type – Ex-ante and Evaluated.



Conclusions

This study has illustrated how evaluators can leverage existing characteristics of HVAC control measures and utilize novel data collection methodologies—such as substituting in-person site visits with virtual site visits—to perform a high-rigor evaluation at reduced costs. By developing templatized "semi-custom" forms to make DEER prototypical models site-specific and then calibrating the baseline models to facility consumption data, the evaluators were able to achieve high-rigor results at a significantly lower cost than traditional evaluations. The virtual site visits performed through videoconferencing also ensured the collection of every critical parameter for the evaluation in a way similar to in-person visits. The lessons learned from this evaluation can be applied to similar HVAC control measures installed at various other sectors, such as schools, multifamily, and healthcare, which use prototypical models as a starting point for analysis. This evaluation was performed during a pandemic, but the virtual M&V methods adopted in this study can be applied in future evaluations even after COVID-19 lockdowns are lifted and it is safe to perform site visits. The authors have summarized the advantages and disadvantages of specific data collection and analysis methods used in the evaluation albeit the advantages clearly outweigh the disadvantages.

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References

U.S. Environmental Protection Agency (EPA) 2019 (June). Guidebook for Energy Efficiency Evaluation, Measurement, and Verification. https://www.epa.gov/sites/default/files/2019-06/documents/guidebook_for_energy_efficiency_evaluation_measurement_verification.pdf

Commercial HVAC Sector PY 2019 Impact Evaluation Report for California Public Utilities Commission (CPUC). May 2021. https://pda.energydataweb.com/api/view/2510/CPUC%20Group%20A%20Commercial%20HVAC%20Impact%20Evaluation%20Report%20PY2019%20Final.pdf