Building Energy Modeling for Zero Net Energy Design

Using California's Compliance Software - CBECC and EnergyPro: Better Ways to Assess Site Energy Usage

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This document is intended for building designers, building energy modelers, model and compliance code developers, and anyone interested in Zero Net Energy design. This paper draws from the findings of the EPIC research project (EPC 15-097) optimizing domestic hot water in four multifamily affordable all-electric new construction projects in California. The research focused on the evaluation of domestic hot water heat pump systems in four multifamily affordable all-electric new construction projects in California. Final Report: Getting to All-Electric Multifamily ZNE Construction Publication Number: CEC-500-202X-XXX.

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Background

Building energy modeling is conducted for several reasons: to iterate on design strategies, to estimate consumption in order to size solar PV array that will successfully offset a building's energy use, to assess a building's compliance with building code, and to determine the utility costs to residents, amongst others. The modeling software discussed is the California Energy Commission (CEC)-approved software for building compliance, both for residential buildings (EnergyPro and CBECC-Res) and for nonresidential buildings (EnergyPro and CBECC-Com). This software was used to estimate the building's energy use at three multifamily properties (Calistoga, Cloverdale and Atascadero) predicting zero net energy (ZNE) performance, to demonstrate compliance with California's Title 24 Building Energy Efficiency Standards, to secure funding through various affordable housing funding sources (one through the United States Department of Agriculture), and eventually compare to actual energy usage to evaluate building performance. Several design meetings were conducted, and models built in coordination with the client to determine the best design, based on whichever metric is most important to the client (lowest first cost, lowest operational costs, best for the environment, etc.). When the final design is determined, the solar PV array is then sized. The main design goal this modeling supported was to achieve ZNE operationally over the course of the year. The following technical brief delves further into how building energy models can be used in the ZNE design process.

Problem Statement

The CEC approved modeling software estimates a building's energy use; however, not all end uses are modeled in the software and some end uses are based on older algorithms, or do not capture the entirety of an end use. As a disclaimer, there are considerations when comparing modeled estimates to actual, measured energy usage. One important consideration is that models present an average outcome, based on average behavior, occupancy, and weather. Actual energy usage results from very specific (and real) behavior, occupancy, and weather that can differ greatly from a multi-year and cross-societal average. Although there are changes from year to year (in occupancy, weather, etc.) for a building, our modeling software should still be accurate enough to properly size a ZNE solar array.

For ZNE design, the solar energy production should equal the energy consumption of the building on an annual basis, thereby fully offsetting the building's energy load. If these do not match, then utility bill cost may end up being higher than expected for building owners and residents alike, and the ROI of the ZNE design will not be realized. However, based on the value of PV and rate design, a building may be net zero in cost (zero net energy utility bills), but may not actually be net zero in energy. Falling short of ZNE design goals can reflect poorly on the designers and consultants from the funding agencies that require ZNE targets; however, buildings are not typically monitored to assess actual ZNE performance (although some building owners will be motivated to verify and improve upon their designs). In general, the goal of ZNE design is to reduce the impact a building will have on the electricity grid, utility bill costs, and the environment. The aim of this technical brief is to offer guidance to consultants and designers in considering a building's full energy use in designing for ZNE.

Modeling Strategy

The modeling strategy listed below was used for three of the demonstration properties in this study: Calistoga, Cloverdale and Atascadero, each of which targeted 100% ZNE property wide.

1. **Estimate primary residential loads:** HVAC and DHW. This was done using EnergyPro modeling software.
2. **Estimate secondary residential loads:** cooking, lighting and plug loads. For these projects the CUAC calculator was used because the CUAC has algorithms for high occupancy housing typically seen in affordable housing projects.
3. **Estimate primary non-residential loads:** community rooms, mechanical rooms, stairways, hallways, etc. This was done using EnergyPro.
4. **Estimate additional non-residential loads:** site lighting, central laundry, elevator(s), and miscellaneous electric loads. These calculations were done outside of EnergyPro.
    - **Site lighting:** this includes parking lots and walkways, which are currently not included in the software.
    - **Central Laundry:** the method used to estimate laundry use was based on three leading field studies done on high efficiency laundry equipment and multifamily energy use (NEEA 2013, Cadmus Group 2010, and National Research Center 2002). The current model in the software also estimates the laundry energy use as if it were in-unit, but from research and field observation central laundry uses roughly half that of in-unit laundry.
    - **Elevator(s):** the software does not estimate the yearly energy use of this load, but it can document their presence for compliance purposes. The elevator energy estimates for these projects were based on metered utility data from various projects.
    - **Miscellaneous Electrical Loads:** the software does include "plug loads" and "appliances/ancillary" energy uses, but observations from several projects indicate that this does not encompass all miscellaneous loads observed in the field. To compensate for this, an average yearly miscellaneous load per building is added to the whole building estimate, which is determined using utility metered data that was specifically metered to capture the miscellaneous loads per building.
5. **Finalize the whole site energy use estimate:** by adding together the estimates from steps 1-4.
6. **Design the solar PV array to offset the building's energy use:** the size of the solar array, or amount of offset, is determined by the funding commitments and these three projects had the commitment of being zero net energy, so their solar arrays were sized to match the load of the building. For these projects, the solar arrays were oversized slightly to encompass any discrepancies between the modeling and actual energy use. Even though net energy metering agreements require that the solar array not be oversized, a slight oversize within reasonable limits is deemed acceptable. The solar contractor will use a different modeling tool to define the final solar array size to meet the targeted production. For these projects, the CEC PV Calculator was used. There can be a 2-5% difference in what the solar contractor will specify and what the

original solar production target was. This difference can be attributed to using a different type of software.

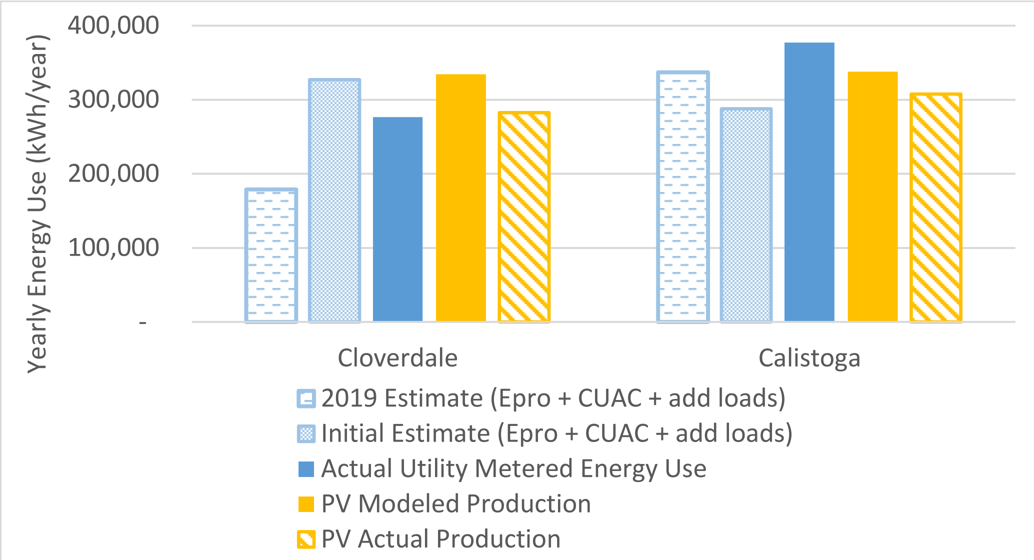
Whole-Site Modeled vs. Utility Metered Energy Use

The result of the method described is shown in the figures below along with the actual energy used for the three projects. There are two estimates for comparison – one using the 2019 software and the second using the software at the time of the final design of each project. Calistoga and Cloverdale were permitted under 2008 software and Atascadero was approved under 2013, however the estimate shown below uses the 2016 version of the software. Solar production was 10-15% less than what was predicted at each project. (To read more on solar design discrepancies in ZNE design, read the Project Team's other technical brief on this topic: Solar Photovoltaics Technology Brief)

For Calistoga and Cloverdale, the modeled usage estimated in the 2019 software was less than the actual usage represented in the utility monitored data. This is mostly due to the 2019 software not being able to model the Aermec large central combined heating, cooling and domestic hot water system installed at each project. Modeling workarounds are common for systems like these –a project must get an alternate system approved in the model from the CEC to show code compliance. The work around used in the 2019 estimate was individual HVAC systems and HPWH tanks for each apartment. The Aermec system uses roughly double the energy use compared to this work around estimate.

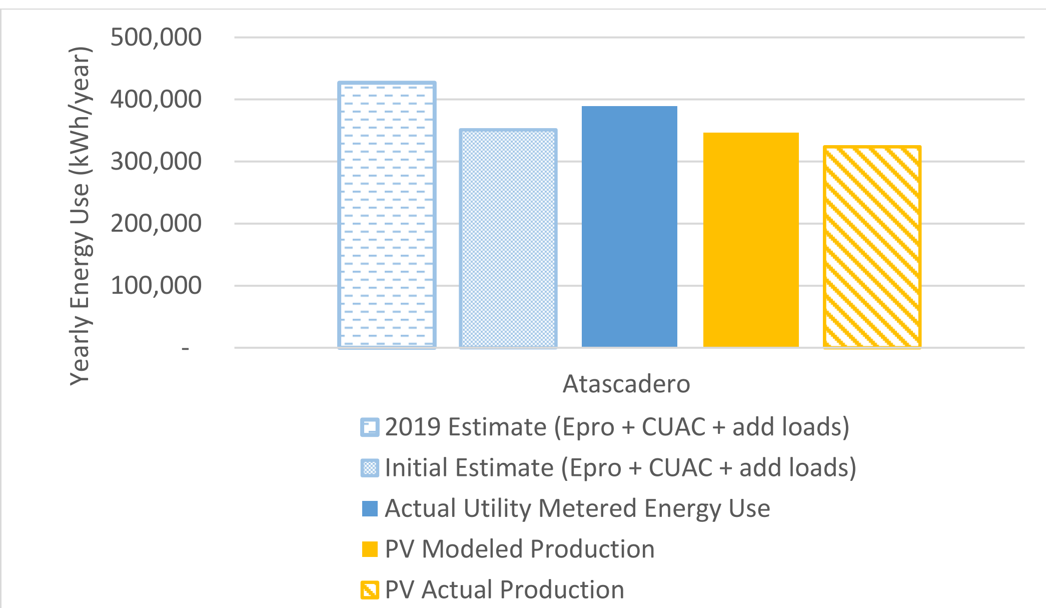
The initial estimate for Cloverdale went beyond the process described above. The monitored data collected from Calistoga (which was built first) was used to inform Cloverdale's ZNE estimate. Calistoga's Aermec system used much more energy than originally estimated; this information influenced the sizing of the solar PV system at Cloverdale, which was designed with a 130% offset. Cloverdale met its ZNE target, partially due to sizing the PV to align with revised energy consumption using Calistoga data, and partially because the Aermec's performance was better than the Aermec's at Calistoga. Read more on the performance of the central Aermec systems in the Project Team's CEC EPIC Final report.

Figure 1: Calistoga and Cloverdale modeled whole site energy use and solar PV production compared to 2019 actual utility-monitored energy use.



The initial estimate at Atascadero resulted in estimated energy usage that was lower than was observed from the utility data. Since this estimate was made, the method for determining additional loads was improved. The improved modeled usage using the 2019 software was greater than the actual utility data usage by about 9%. Despite overestimating usage, the modeled usage tracked closer to the actual usage as compared to the two other demonstration sites. This project had individual split HVAC heat pumps and heat pump water heaters for each unit, both of which can be modeled in the software.

Figure 2: Atascadero whole site modeled energy use and solar PV production compared to 2019 actual utility-monitored energy use.



Although the method presented in this technical brief is not perfect, its aim is to account for additional energy uses that may be present at a zero net energy building site. Including additional loads, using calculators that reflect the occupants at the building, and incorporating field-collected data can improve a zero net energy estimate. Generally speaking, it is best to slightly overestimate a building's energy use and solar array, since both energy consumption and solar production can vary in a given year depending on a range of factors.

Recommendations

- Supplement modeled data with real data when possible, to estimate building loads (data from previous projects, etc.) (Example: using Calistoga's monitored data to inform Cloverdale's estimated building loads).
- Supplement the modeled loads with "additional" loads at the building using the most accurate data possible, preferably field-monitored data. This requires a clear understanding of how loads are modeled in the software and what loads are excluded from the modeling software. The "additional" loads included in the estimates above were site lighting (like parking lots and walkways), elevators, central laundromats, and miscellaneous building loads. Make sure data used is relevant to your project type (for example, multifamily and affordable).
- Design a right-sized solar array to fully offset all the energy uses of the building. Talk with the solar contractor about assumptions in the solar models (like degradation overtime) to ensure a solar array is right-sized. In general, it is reasonable to slightly oversize system, up to 10%, to account for annual variations.
- Use tools that are applicable to your design based on the building, and its location and occupants. (For example, using the CUAC calculator for multifamily low-income housing vs. using CBECC or EnergyPlus out-of-the-box for market rate housing).

Learn More

This report and project were funded under the CEC's EPIC grant EPC 15-097 "Optimizing Water Heating Performance for Multifamily ZNE". Read more about these projects in the Team's CEC EPIC final report, case studies, and technical briefs. This project was also discussed in three ACEEE papers, which are available online.[1]

[1] Energy Usage Patterns in All-Electric Multifamily Buildings in California https://aceee2020.conferencespot.org/event-data/pdf/catalyst_activity_10622/catalyst_activity_paper_20200812131016556_76f5f9fc_35ec_4986_8f67_db5de0ccdf75
Multifamily ZNE Water and Energy Monitored Data https://aceee2020.conferencespot.org/event-data/pdf/catalyst_activity_10629/catalyst_activity_paper_20200812131018908_09bc0fe7_c730_4bec_85c1_f74117bd0dac
Hitting the Duck with Heat Pump: Thermal Storage Load Shifting Optimization in All-Electric Multifamily DHW https://aceee2020.conferencespot.org/event-data/video/catalyst_activity_10606/catalyst_activity_video_20200725023657813_bc593bbe_9007_47c1_858b_0eebfb20c639

Resources

The Cadmus Group, Inc. (2010). Do the Savings Come Out in the Wash? A Large Scale Study of In-Situ Residential Laundry Systems. ACEE Summer Study on Energy Efficiency in Buildings.

NEEA (2013). Residential Building Stock Assessment: Multifamily Characteristics and Energy Use. Northwest Energy Efficiency Alliance.

National Research Center (2002). A National Study of Water and Energy Consumption in Multifamily Housing.

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