Low-Rise Multifamily Prototype Model Validation

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Summary

This technical memorandum describes the methodology used for validation of low-rise multifamily prototype models using data from 2019 Residential Appliance Saturation Survey (RASS)[1]. The California Prototypes Development project, funded by Southern California Edison's (SCE) Codes and Standards Program, aims to establish a unified set of prototype building models representing California's building stock. This initiative enables the California Energy Commission (CEC) and the California Public Utilities Commission (CPUC) to employ consistent underlying assumptions about the building stock when conducting various analyses, including the evaluation of proposed energy code modifications and the assessment of deemed and custom measures for incentive programs. While the development of these prototype models is documented in a separate report[2], this document focuses on the validation process of the developed models. It provides detailed descriptions of model enhancements implemented during validation and presents final comparisons to surveyed data and other relevant data sources.

Introduction

Following the development of the low-rise multifamily prototype models (i.e., the 2-story 8-unit garden style prototype and the 3-story 36-unit loaded corridor prototype), the next step was to validate the models against energy consumption from the building stock. This was done using data from the 2019 RASS for multi-family buildings. RASS data was collected between October 2018 and September 2019. Since appliance consumption in RASS is specified at the building climate zone level, the prototype model consumption was aggregated to the climate zone level (from two prototype models in four vintages in each climate zone) to enable validation. The climate-zone weighted appliance consumption in RASS was derived using statistical methods (i.e., regression models as discussed below) and represents the weighted average energy consumption within the sample, which is expected to align with the 50th percentile (2nd quartile) in a normal distribution. Given the significant variability in consumption patterns across the building stock, and the presence of two prototype models and four vintage bins within each climate zone, it is anticipated that aggregated consumption may deviate from the mean but still be considered valid, if it aligns with weather (i.e., heating degree-days and cooling degree-days) and other consumption trends (for example, low consumption due to seasonal occupancy in certain locations).

Methodology

The validation process involved the following steps:

1. Unit energy consumption (UEC) data from RASS was extracted for multi-family buildings by climate zone and end-use. This involved applying filters to the raw surveyed sample data and extracting and weighting end-use consumption to calculate the UEC.
2. Annual normalized (by square foot) end-use consumption data from prototype models (developed in EnergyPlus) in four vintage bins in every climate zone were aggregated to produce a single value for each end-use within each climate zone (kWh/year for cooling end-use and Therms/year for heating end-use). Then, the results are normalized per floor area, resulting in

[1] https://www.energy.ca.gov/publications/2021/2019-california-residential-appliance-saturation-study-rass

[2] Prototypes Project Documentation 2023-19Dec2023-Residential.docx

annual Therms/square foot (sf) and kWh/sf, for heating and cooling end-uses, respectively. Floor area weighting factors, as provided in Table 11 (Appendix), were applied.

3. The inputs for those end-uses that do not vary and/or that vary to a minor degree across climate zones were adjusted to align with RASS data. These end-uses were:
    a. Water heating: Water heaters were modeled based on climate zone-specific water mains temperatures, which account for slight differences in ground temperatures. A monthly temperature schedule was established for each climate zone to accurately reflect seasonal variations in water mains temperature.
    b. Exterior lighting: not expected to vary by climate zone.
    c. Plug and process loads (washer, dryer, and miscellaneous loads): not expected to vary by climate zone.
4. Cooling and heating end-uses, which do vary by climate zone, were validated against RASS data for each climate zone. Validation involved the adjustment of those model inputs that were assumptions based on industry standards or other sources (i*.e*., not RASS data). For example, thermostat setpoints initially were based on real-world Ecobee setpoints for modeling and they were adjusted during validation.

RASS UEC Calculation Methodology

It is important to understand the procedure used in the RASS analysis to determine the heating and cooling UEC for low-rise multifamily buildings in a climate zone. Specifically, the estimated RASS UECs are determined using a conditional demand analysis (CDA). CDA is a statistical technique used to estimate energy consumption by disaggregating total energy demand into specific end-uses, such as appliances or equipment. This method combines utility billing data, weather information, and customer survey data to produce robust estimates of energy use[3]. The following steps explains the process used in calculating RASS UEC to ensure accurate and consistent results across different climate zones and weather conditions:

1. Data Preparation: This step includes data collection, data cleaning (i.e., eliminating surveys that were determined to have excessive amounts of invalid data, cleaning RASS survey variables, and creating new variables through the cleaning process and the combination of surveyed data), data transformation (*i.e.*, normalization, aggregation, and encoding), data integration, data structuring, and data validation.
2. Normalization of Billing and AMI Data: This normalization process converts the varying number of days in consumption data to a standardized one-year period and allows comparisons across different climate zones by providing annual consumption for long-run normal weather conditions.
3. Degree-Day Models: This step includes utilizing two types of weather files:
    a) Actual year weather data: Separate models for electric and gas consumption are created using actual weather data, including heating degree-days (HDD) and cooling degree-days

[3] https://www.energy.ca.gov/sites/default/files/2021-08/CEC-200-2021-005-MTHLGY.pdf

(CDD) for electricity and primarily HDD for gas. Each model calculates a reference temperature specific to the location of the household.

b) Normal year weather data: The models are then used to calculate normalized annual consumption (NAC) estimates, reflecting estimated energy consumption for a typical (normal) year (based on most recent weather datasets created for the CEC and PG&E by White Box Technologies[4]).

To calculate the RASS UEC accurately, both actual year weather data and normalized weather data were utilized. The methodology for this calculation involves a two-step process, where the first step uses actual weather data to model energy consumption, and the second step applies this model to normalized weather conditions. The detailed procedure for weather normalization, including the Degree-Day Normalization (DDN) model**Error! Bookmark not defined.**, is outlined below.

- Modeling with actual weather data[5]: The actual weather data (October 1, 2018, to September 30, 2019) helps establish a baseline - understanding of how temperature variations impact energy consumption for each household - as well as creating initial degree days models.
- Using normalized weather data to calculate NAC: The normalized weather data (12-year period from 2006 to 2017) is then used to predict what the energy consumption would be in a typical year, adjusting for any gaps present in the actual data.

Furthermore, RASS UEC data is cleaned after being calculated under that normalization process. Specifically, the methodology used in RASS addressed outliers by trimming the data during the regression analysis phase. For datasets where the model's performance was below a threshold ($R^2 < 0.8$), outliers were identified and trimmed to improve model accuracy**Error! Bookmark not defined.**. The trimming of outliers was part of the normalization procedures applied to daily and monthly usage data for both electric and gas consumption.

Also, in order to utilize the UEC data accurately, it first must be weighted to account for varying sampling processes and corresponding weight calculations for each dataset. Specifically, the data needs to be adjusted to a parameter known as sample weight. These sample weights represent the number of households in the broader population that each response corresponds to, rather than just the survey respondents. The steps for calculating sample weights are outlined below**Error! Bookmark not defined.**:

1. Sample stage classification: responses were grouped into different stages based on survey timing and methods (e.g., email-only, early/late responses, nonresponse follow-ups).
2. Solo weight calculation: initial weights were assigned for each stage, representing how many households each response accounted for within the population.
3. Blending fractions: blending fractions were calculated to reflect the share of the population represented by each stage, accounting for varying response rates.
4. Base weight creation: solo weights were multiplied by blending fractions to create base weights, adjusting for different survey stages.

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[4] https://pda.energydataweb.com/api/downloads/2280/Weather%20webinar%20CALEE2018%207-12-2019.pptx.
[5] Actual weather files were developed as part of the CALLEE2018 file development and are posted on CALMAC.org along with the CALEE2018 version of normal year weather data for each specific city: http://www.calmac.org/weather.asp.

5. Calibration (Raking): base weights were fine-tuned using an iterative process to align the weighted data with known population characteristics (e.g., region, dwelling type, income).

Filtering RASS Data

To perform the heating and cooling validation, raw sample data from RASS was used to determine the heating and cooling consumption by climate zone. This data for low-rise multifamily buildings was filtered and combined as indicated below to conduct the cooling and heating consumption.

- Cooling End-Use:
  - Central Air Conditioning Electric UEC
  - Room AC Electric UEC
  - Evaporative Cooler Electric UEC
- Heating End-Use:
  - Primary Heat Gas UEC
  - Auxiliary Heat Gas UEC
  - Conv. Heat Electric UEC
  - Heat Pump Electric UEC
  - Aux. Heat Electric UEC

The following filters were applied:

- Cooling End-Use:
  - Type of building: low-rise multifamily detached
  - Cleaned "Pays for central air conditioning":
    - Yes
    - No, it is part of my rent/condo fee
  - Central Air Conditioning Electric UEC: All non-zero values
- Heating End-Use:
  - Type of building: Low-rise multifamily detached
  - Cleaned "Primary heating fuel": Natural Gas

RASS UEC Results

Following the outlined approach, Table 1**Error! Reference source not found.** and Table 2 display the filtered RASS Unit Energy Consumption (UEC) data for cooling and heating, respectively. Each figure presents three metrics per climate zone, represented by box-and-whisker plots. These tables show the weighted mean, first quartile (Q1), and third quartile (Q3) of the distributed data for each climate zone. The first quartile (Q1) represents the value below which lie 25% of the data points, while the third quartile (Q3) represents the value below which lie 75% of the data points. This spread between Q1 and Q3 is known as the interquartile range (IQR) and is useful for understanding the distribution and variability of the data within each climate zone – where we could identify the range in which the central 50% of energy consumption data points lie. Distribution of this UEC data is presented in **Error! Reference source not found.** and **Error! Reference source not found.**, while cooling and heating data distribution is presented across the 16 climate zones.

Table 1: RASS Cooling normalized end-uses (filtered data for low-rise multifamily dwelling units)

CZT24	RASS Weighted Mean Cooling Consumption (kWh/sf)	Cooling Q1 (kWh/sf)	Cooling Q3 (kWh/sf)	No. of Samples
1	0.71	0.57	1.33	12
2	0.07	0.04	0.12	565
3	0.20	0.08	0.57	671
4	0.24	0.17	0.31	953
5	0.57	0.57	0.57	63
6	0.41	0.20	0.56	1104
7	0.32	0.22	0.42	1078
8	0.48	0.37	0.67	1575
9	0.75	0.49	0.97	2400
10	0.91	0.50	1.03	2314
11	1.59	1.09	3.34	835
12	0.50	0.36	0.78	3955
13	1.83	1.27	2.05	1330
14	1.13	0.52	1.34	627
15	2.32	1.60	3.17	257
16	0.72	0.72	0.76	312

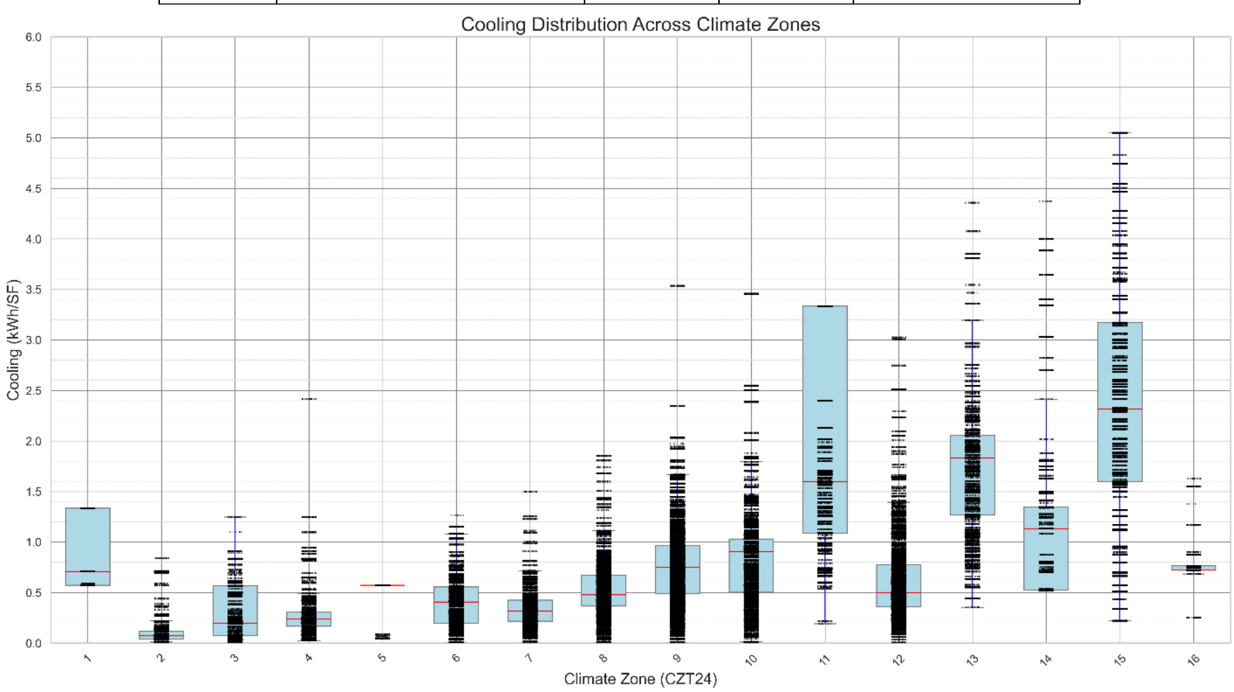

Figure 1: Cooling end-use distribution per climate zone, including median, first quartile, and third quartile of the RASS UEC dataset

Table 2: RASS Heating normalized end-uses (filtered data for low-rise multifamily dwelling units)

CZT24	RASS Weighted Mean Heating Consumption (Therms/sf)	Heating Q1 (Therms /sf)	Heating Q3 (Therms /sf)	No. of Samples
1	0.00	0.00	0.02	19
2	0.03	0.02	0.12	107
3	0.05	0.03	0.08	653
4	0.06	0.05	0.08	156
5	0.10	0.10	0.10	43
6	0.04	0.03	0.06	452
7	0.03	0.02	0.04	304
8	0.03	0.02	0.05	404
9	0.05	0.03	0.06	528
10	0.05	0.02	0.06	212
11	0.05	0.04	0.09	74
12	0.06	0.03	0.07	302
13	0.10	0.07	0.11	157
14	0.05	0.04	0.05	48
15	0.03	0.02	0.03	85
16	0.20	0.06	0.20	17

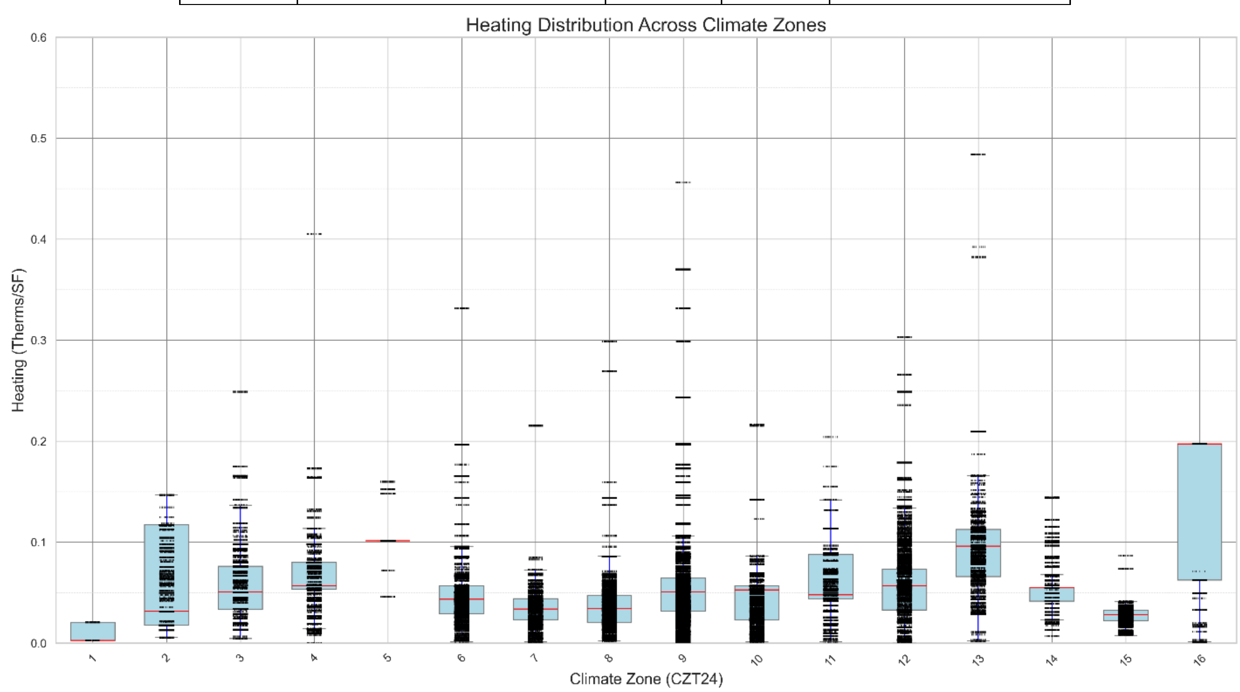

Figure 2: Heating end-use distribution per climate zone, including median, first quartile, and third quartile of the RASS UEC dataset

Model Adjustments

The initial, non-validated (or unadjusted) modeled heating and cooling consumption by climate zone was found to be higher than the UEC from RASS**Error! Bookmark not defined.**. To address this discrepancy, a sequential validation process was implemented to refine cooling and heating energy predictions.

For cooling, the modeled cooling was higher than observed. To lower modeled cooling, a list of those variables that could be adjusted to lower cooling energy was developed. The variables to be adjusted were determined based on whether those variables had model inputs from sources with field or observed data or those inputs that were developed using analysis. For example, the air conditioner efficiency could be lowered to account for in-field degradation. However, this was evaluated during model input development and the COP input was selected based on analysis. Therefore, the air conditioner efficiency was not chosen for adjustment. The first variable to be adjusted was miscellaneous internal loads because they were based on an assumption from PNNL's low-rise multifamily (2006) prototype model[6]. Similarly, the internal lighting power was an assumption from RESNET and not from RASS or other sources with observed data. Next, building envelope improvements were introduced, including reducing the windows' solar heat gain coefficient (SHGC) and incorporating window overhangs and internal window shades to limit solar heat gains. Natural ventilation was then added to simulate occupant behavior, enabling the use of outdoor air to further reduce reliance on air conditioning. Following these measures, infiltration rates were reduced. Finally, the cooling thermostat setpoint temperature was adjusted, with a higher daytime setpoint to lower cooling loads. Each of these adjustments was performed individually, and only after evaluating the results was the next adjustment applied. The model output was compared to RASS-derived UEC data, ensuring the models increasingly aligned with observed energy performance across various climate zones and building characteristics.

For heating, the primary strategy was focused exclusively on reducing infiltration rates to address discrepancies in heating energy predictions. All these inputs were based on assumptions and did not have data in RASS or other sources. The rationale for using these specific inputs instead of others was therefore that there is no basis for the starting values used for these inputs other than industry-standard specifications and engineering judgment.

Existing Input Adjustments

More details on the applied adjustments on the existing inputs are listed below.

- Lighting Power Density (LPD) was set to 0.19 W/ft^{2}all models and vintages for all residential units. For commercial units, LPD is set to 1.1 W/ft^2.
- Plug Loads and Appliances (Equipment Power Density): Plug loads were validated against the 2019 Residential Appliance Saturation Survey (RASS)**Error! Bookmark not defined.** Unit Energy Consumption (UEC) data for low-rise multifamily dwelling units. The adjusted plug load densities are presented in Table 3.

Table 3: Adjusted plug loads

[6] https://www.energycodes.gov/prototype-building-models#Residential

Model	Initial Assumption (W/ft²)	Adjusted (W/ft²)
Garden	5.8	2.4
Corridor	5.8	2.6

- Infiltration: In order to reduce cooling[7] and heating loads, infiltration was reduced by 34% compared to the initial assumption. The adjusted values are presented in Table 4.

Table 4: Infiltration air changes per hour (ACH) adjusted values

Vintage	Initial Assumption	Corridor	Garden (Living Space)	Garden (Attic Space)
Before 1975	1.26	0.42	0.35	0.71
1975-1983	0.99	0.33	0.28	0.56
1984-2005	0.73	0.24	0.20	0.41
2006-2019	0.73	0.24	0.20	0.41

- Window SHGC: Window SHGC was based on estimates from RASS, though there was no direct SHGC data in RASS. SHGC was reduced to 0.40 for all models and vintages. Window visual transmittance (VT) was set to 0.44 to account for the lower SHGC.

Table 5: Windows SHGC adjusted values

Window SHGC	Initial Assumption	Garden - Corridor
All Vintages	0.52 – 0.73	0.40

- Thermostat setpoint: To further reduce cooling loads, the cooling schedule was adjusted by increasing the cooling setpoint to 80 °F throughout the entire day, as shown in **Error! Reference source not found.**. This adjustment accounts for resident behavior, as RASS data indicates that the cooling setpoint is disabled 28% of the time during the cooling season and 25% during the heating season[3]. Additionally, approximately 4.2% of dwelling units were vacant at the time of the 2019 survey[8].

  Compared to DEER prototype models, which use a cooling setpoint range of 78–83 °F varying by climate zone and hour of the day, hourly or climate zone-dependent adjustments were deliberately avoided for simplicity. Instead, a constant cooling setpoint of 80 °F was selected for testing during validation. This choice proved to be a good assumption, as it resulted in validated cooling end-uses that aligned with measured data. Furthermore, the selection of an 80 °F setpoint was supported by an analysis of 2019 RASS data. The data show that the thermostat is off 28% of

[7] https://doi.org/10.1016/j.buildenv.2020.107459
https://doi.org/10.1016/j.buildenv.2022.108848
https://buildings.lbl.gov/publications/estimation-infiltration-leakage-and
[8] https://fred.stlouisfed.org/series/CARVAC

the time during the cooling season, while about 4% of the time the setpoint is above 80 °F, 45% of the time it is between 70–80 °F, and for the remaining 23% it is set to 69 °F or lower. A single setpoint at 80 °F effectively represents an average condition, capturing the variability observed in real-world scenarios and simplifying the model without compromising accuracy in cooling energy predictions.

Table 6: Thermostat setpoint adjustments

Thermostat Setpoint	Initial Assumption	Cooling Setpoint
Cooling (24 hours)	74° F	80 °F

- The initial supply fan power was set to 0.58 W/CFM based on maximum allowed fan power specified in Title 24-2008. Upon further review, the maximum allowed pressure drop by Title 24 was found to be higher than that used in typical fan systems for multifamily dwelling units. The typical fan pressure drop was found to be 2 in. w.c., corresponding to 0.41W/CFM, and this was the value used in the model.

New Model Inputs

Despite the changes listed in the previous section, cooling energy was higher in several climate zones than reported in RASS. To further reduce cooling energy consumption, natural ventilation was incorporated into the model. This change attempts to capture occupant behavior in real multifamily apartments, where occupants open windows to take advantage of cooler outdoor temperatures, thereby minimizing the use of air conditioning and reducing electricity costs. Natural ventilation, corresponding to an air changes per hour (ACH) value, is turned on when the indoor and outdoor conditions are deemed favorable for opening windows. Table 8 shows these thresholds for indoor and outdoor temperatures and Table 9 shows the periods during the year when natural ventilation is allowed in the model. When the indoor and outdoor temperatures at a given hour are within the thresholds, natural ventilation occurs in the model. 7

Table 8: Natural ventilation settings used for validation

Input	Value
ACH	1.5
Minimum Indoor Temperature (F)	75
Maximum Indoor Temperature (F)	80
Minimum Outdoor Temperature (F)	55
Maximum Outdoor Temperature (F)	75

Table 9: Natural ventilation schedules used for validation

Climate zone	Natural Ventilation Allowed	Natural Ventilation Not Allowed

15	All year	Not applicable
All others	May-October	January-April, November-December

Validated Results

Error! Reference source not found. and Figure 3 present the validated modeled energy consumption after applying the adjustments described earlier and after weighting the Garden and Loaded Corridor prototypes across vintages in a given climate zone. The weighting factors have been provided in Table 11 (appendix section). For each climate zone, the weighted heating and cooling end-uses are shown and compared against the RASS UEC values, including the weighted mean, as well as the 25^{th} (quartile 1) and 75^{th} percentile (quartile 3) consumption from the filtered RASS dataset. The validation process aimed to align the results as closely as possible with the weighted mean values. If aligning with the weighted mean was not achievable, the approach was to ensure that the modeled consumption fell within the Q1-Q3 range, which represents the middle 50% of the RASS data.

Figure 5 and Figure 6 present a detailed comparison of the observed trends between the simulation results of the validated models (called as "Modeled") and the RASS UEC data. For both cooling and heating end-uses, the validated results show alignment with the cooling degree days (CDD) and heating degree days (HDD), indicating that the modeled results are capturing the sensitivity of energy use to outdoor temperature variations. The comparison of modeled energy consumption with RASS data exhibits greater variability, and the cooling and heating consumption from RASS does not always correlate with CDD and HDD, and this discrepancy is especially evident in climate zones 1 and 16.

The discrepancies between the RASS UEC data and the modeled results can be attributed to several factors. Firstly, the RASS data has a limited number of respondents in certain climate zones, which can significantly affect the accuracy of the results. For example, in climate zone 1, the sample size is particularly small, with as few as 12 filtered respondents for non-zero cooling UEC and only 19 for heating UEC. Moreover, the modeled prototypes may not fully capture the diversity of occupant behaviors. For instance, some occupants may choose to leave cooling off even when indoor temperatures exceed 80°F, a behavior that would result in lower cooling energy use than what the model predicts. Additionally, there is the possibility that some of the surveyed dwelling units, such as vacation properties or those located in resort areas, are not fully occupied year-round. This seasonal occupancy, along with other external factors like local climate anomalies or socioeconomic conditions, could further distort the energy consumption patterns observed in the RASS data, leading to discrepancies when compared with the more standardized assumptions in the energy model.

The models could have been adjusted further to match the cooling and heating consumption reported by RASS. However, there are limitations to RASS's reported UEC numbers because of the disaggregation and normalization procedures adopted to develop cooling and heating end-use for each sample. In addition, low number of samples in certain climate zones limit the applicability of the predicted consumption. The approach to limit model validation adjustments to rational inputs (as opposed to using a daytime heating setpoint below 70F, for example) was deliberately chosen to avoid overfitting models to the RASS consumption. This approach allows the models to be used more widely and to generate impacts that are more aligned with the broader building stock as opposed to a small sample.

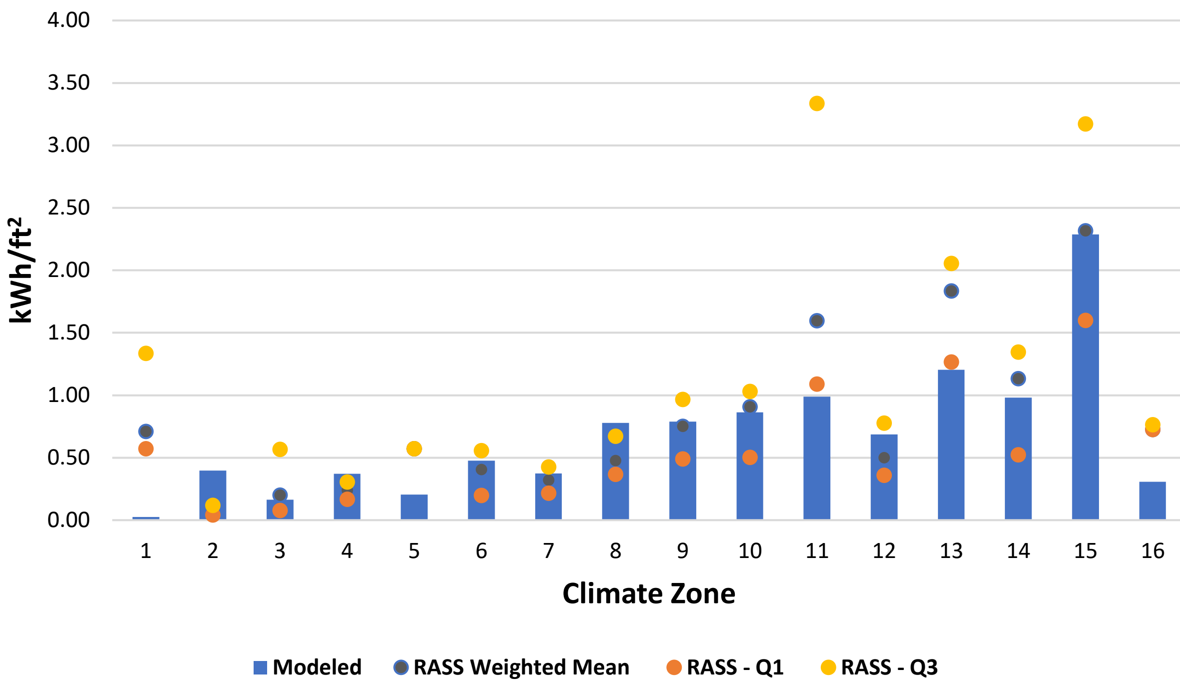

Figure 3: Modeled cooling end-uses compared to RASS 2019

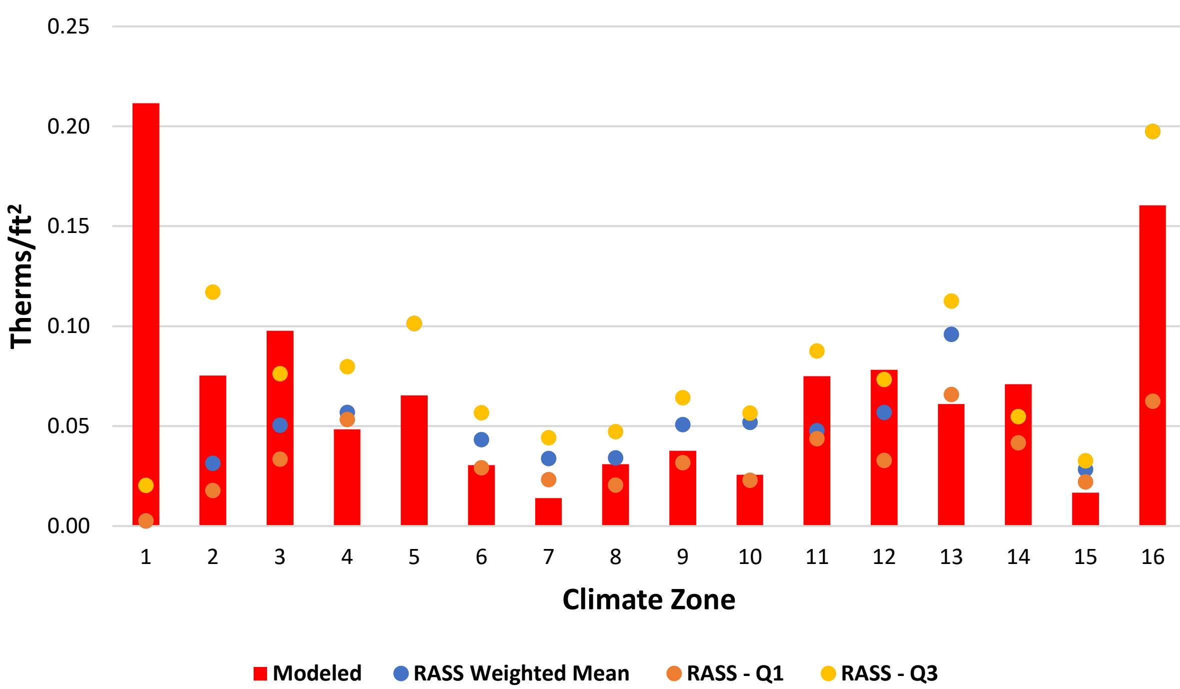

Figure 4: Modeled heating end-uses compared to RASS 2019

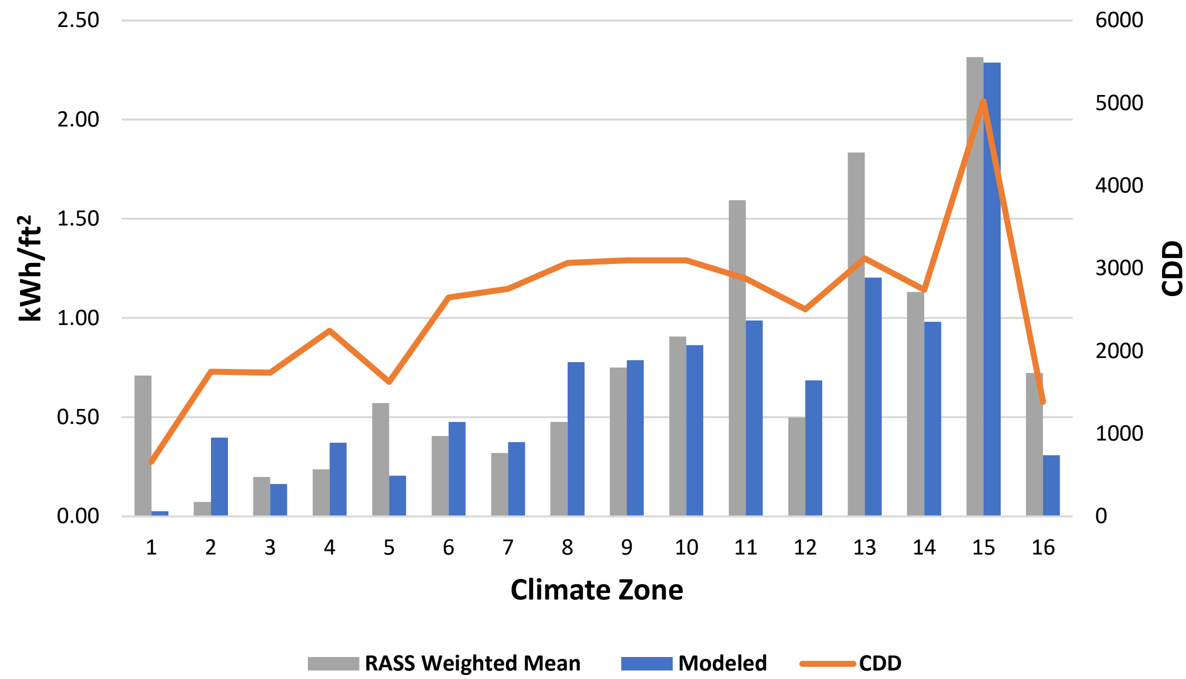

Figure 5: Comparison of cooling end-uses trends from RASS 2019 and modeled consumption

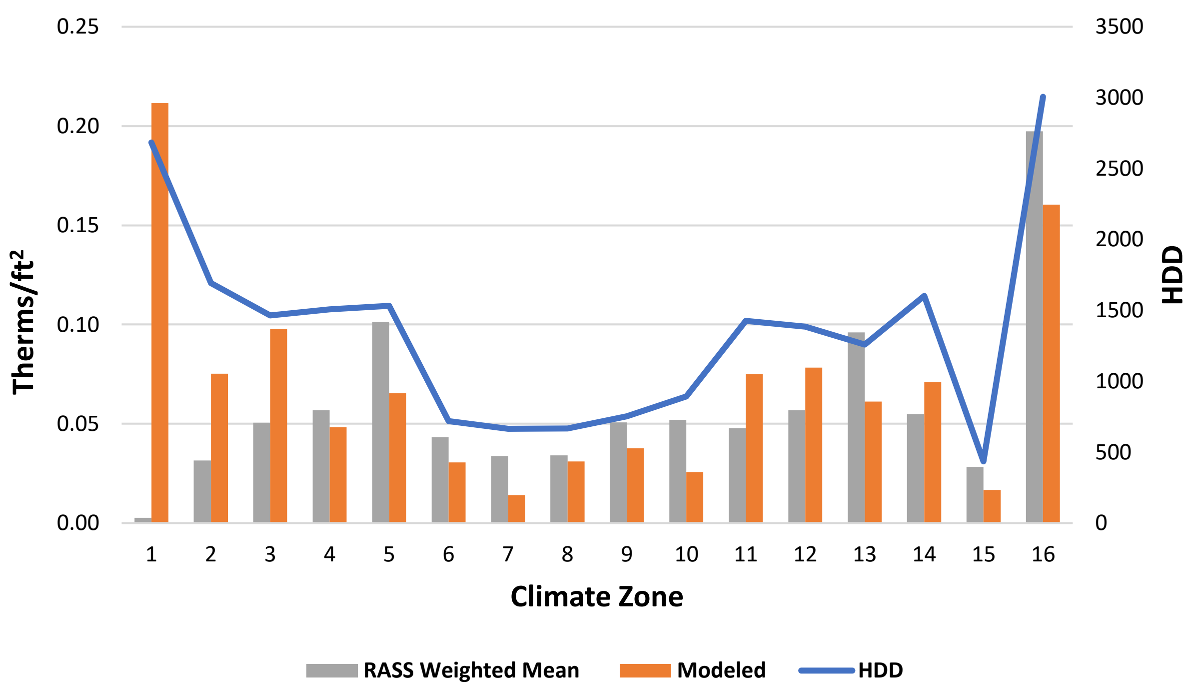

Figure 6: Comparison of heating end-uses trends from RASS 2019 and modeled consumption

Sensitivity of Cooling and Heating End-Uses to Weather

This section evaluates the impact of different weather files on heating and cooling end-uses in the low-rise multifamily prototype models. Specifically, the models were analyzed using two distinct sets of weather files: one set comprises 16 building climate zone weather files used for Title 24 (T24) compliance analysis, which is a subset of the full CZ2022 dataset5; the other set consists of weather station locations utilized by the DEER9 (Database for Energy Efficient Resources) prototype models. The DEER weather stations use a comprehensive array of high-resolution, localized weather data from numerous actual weather station locations across California, while T24 CZ2022 incorporates the most recent weather data, including satellite-derived solar radiation, to accurately reflect current climate trends and variability[10].

Table 10**Error! Reference source not found.** shows the weather stations and representative cities for both the Title 24 and DEER weather data sets used in CEC and CPUC analysis. In several climate zones, the CEC and DEER weather data is identical. However, in some climate zones, for example, in climate zone 16, the cooling degree days (CDD) in the selected DEER weather station are more than twice that of the T24 weather station.

Table 10: Title 24 and DEER Representative Weather Cities and Corresponding Weather Stations

CZ	T24 Rep. City	T24 Weather Station Name	T24 WMO Station Number	DEER Rep. City	DEER Weather Station Name	DEER WMO Station Number
1	Arcata	ARCATA-AP	725945	Eureka	EUREKA	725940
2	Santa Rosa	SANTA-ROSA(AWOS)	724957	Napa	NAPA-CO	724955
3	Oakland	OAKLAND-METRO-AP	724930	Oakland	OAKLAND-METRO-AP	724930
4	San Jose-Reid	SAN-JOSE-IAP	724945	San Jose-Reid	SAN-JOSE-IAP	724945
5	Santa Maria	SANTA-MARIA-PUBLIC-AP	723940	Santa Maria	SANTA-MARIA-PUBLIC-AP	723940
6	Torrance	TORRANCE-MUNI-AP	722955	Los Angeles	LOS-ANGELES-IAP	722950
7	San Diego Lindbergh	SAN-DIEGO-LINDBERGH-FIELD	722900	San Diego Lindbergh	SAN-DIEGO-LINDBERGH-FIELD	722900

[9] https://github.com/sound-data/DEER-Prototypes-EnergyPlus/tree/main/weather

[10] https://www.calmac.org/publications/Update_of_CA_Weather_Files_for_Energy_Efficiency_and_Building_Energy_Compliance_CALMAC_ID_PGE0450.pdf

CZ	T24 Rep. City	T24 Weather Station Name	T24 WMO Station Number	DEER Rep. City	DEER Weather Station Name	DEER WMO Station Number
8	Fullerton	FULLERTON-MUNI-AP	722976	Long Beach	LONG-BEACH-DAUGHTERTY-FLD	722970
9	Burbank - Glendale	BURBANK-GLNDLE-PASAD-AP	722880	Los Angeles Downtown	LOS-ANGELES-DOWNTOWN-USC	722874
10	Riverside	RIVERSIDE-MUNI	722869	Riverside	RIVERSIDE-MUNI	722869
11	Red Bluff	RED-BLUFF-MUNI-AP	725910	Red Bluff	RED-BLUFF-MUNI-AP	725910
12	Sacramento	SACRAMENTO-EXECUTIVE-AP	724830	Stockton	STOCKTON-METRO-AP	724920
13	Fresno	FRESNO-YOSEMITE-IAP	723890	Fresno	FRESNO-YOSEMITE-IAP	723890
14	Palmdale	PALMDALE-AP	723820	Daggett	DAGGETT-BARSTOW-AP	723815
15	Palm Springs-Intl	PALM-SPRINGS-THERMAL-AP	747187	El Centro	EL-CENTRO-NAF	722810
16	Blue Canyon	BLUE-CANYON-AP	725845	Bishop	BISHOP-AP	724800

The two sets of weather data result in different heating and cooling consumption in each climate zone as shown in **Error! Reference source not found.**. This shows that the energy models are responsive to changes in heating and cooling demand coming from the weather data. In climate zone 16, the modeled results using DEER weather files predict a higher cooling energy use per floor area, as shown in **Error! Reference source not found.**. This outcome is consistent with the higher CDD associated with the DEER weather files for that climate zone, as illustrated in **Error! Reference source not found.**.

Similar trends are observed for heating end-uses. In climate zone 16, the use of DEER weather files results in higher predicted heating energy use per floor area, as depicted in **Error! Reference source not found.**. This finding is aligned with the higher HDD values associated with the DEER weather files, as shown in **Error! Reference source not found.**. The comparison between the two sets of weather files highlights how even small differences in climatic data can lead to meaningful variations in the modeled energy use.

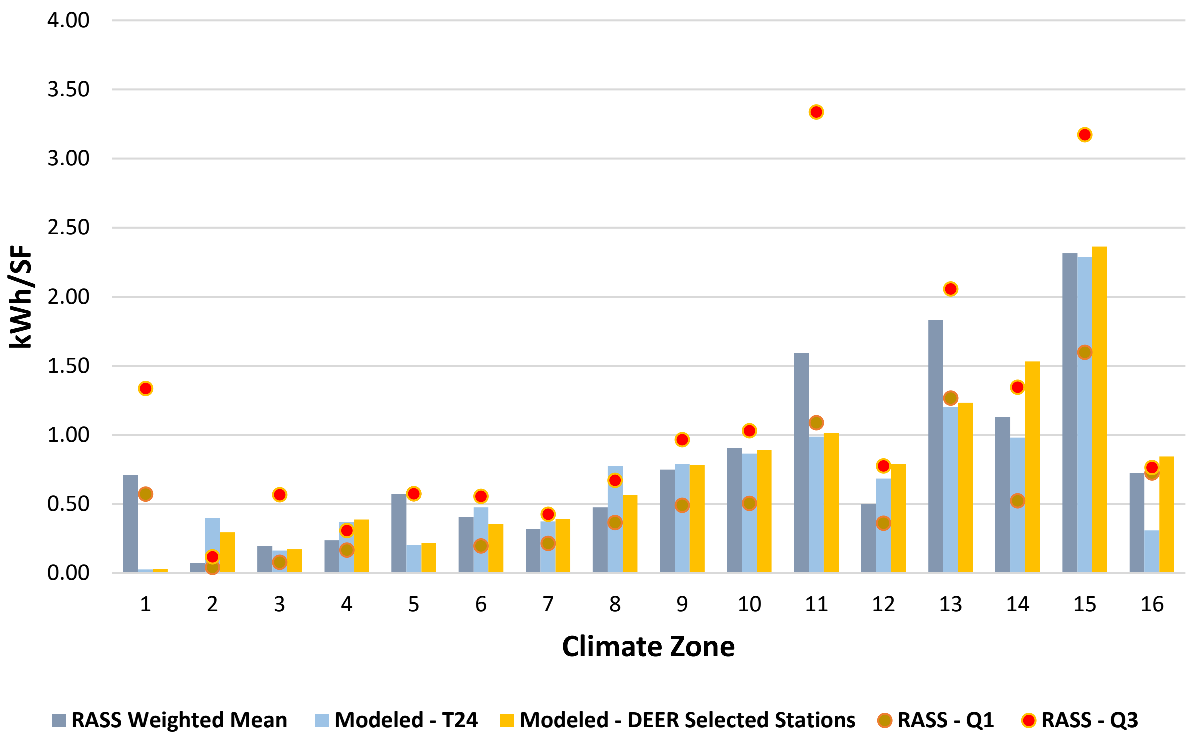

Figure 7: Comparison of cooling end-uses between RASS 2019 and modeled consumption using T24 and DEER weather files

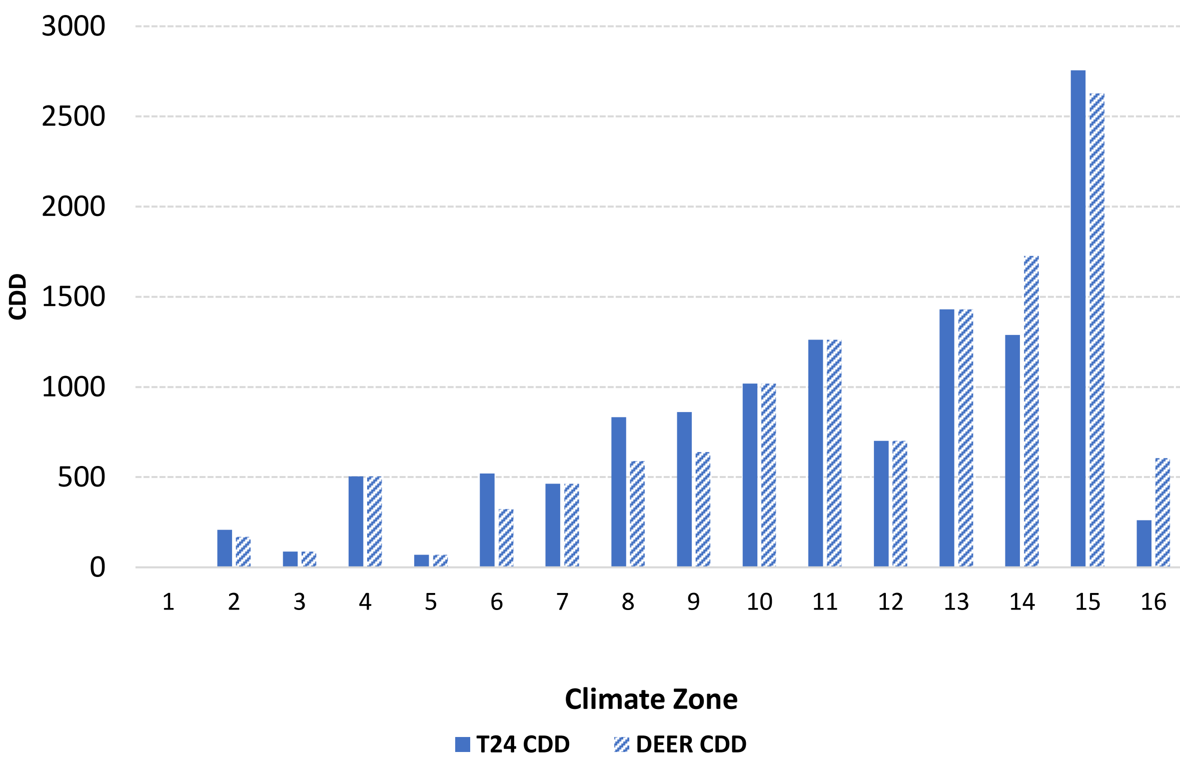

Figure 8: CDD comparison between T24 and DEER weather files

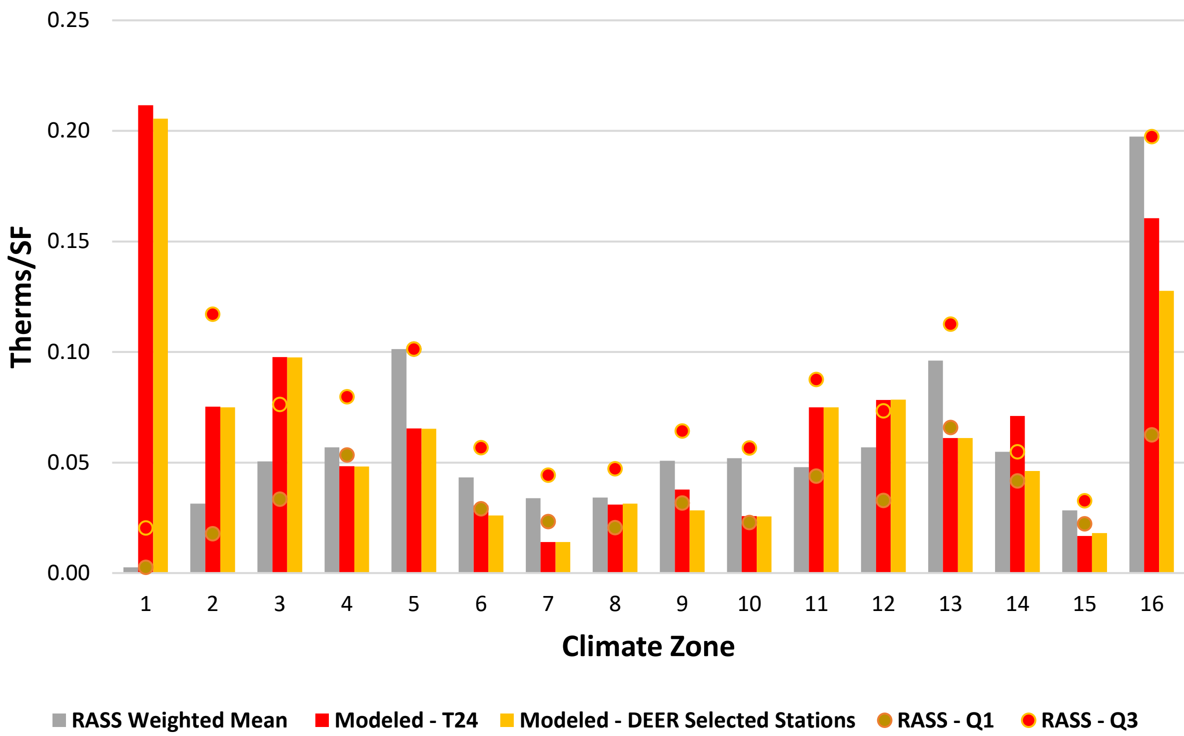

Figure 9: Comparison of heating end-uses between RASS 2019 and modeled consumption using T24 and DEER weather files

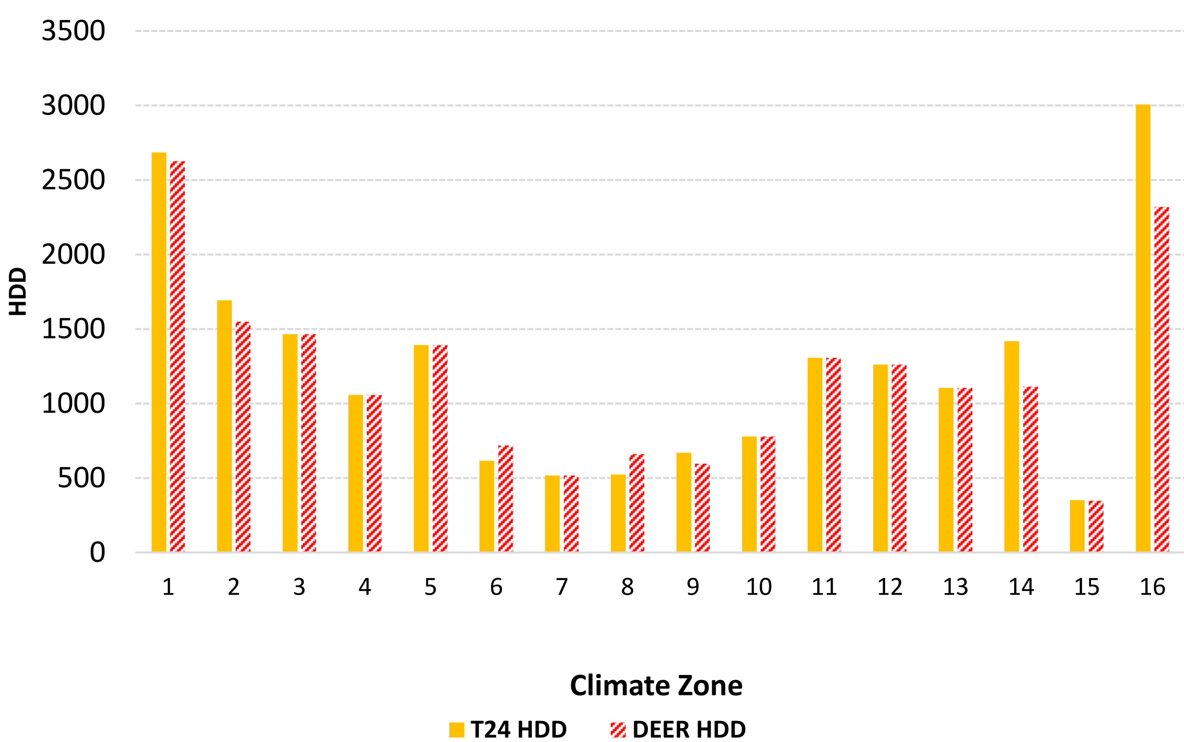

Figure 10: HDD comparison between T24 and DEER weather files

Conclusion

This memo describes the validation process employed for the low-rise multifamily prototype models to align the simulated energy consumption with the RASS UEC data. Model inputs that did not have a direct source of data were considered candidates for adjusting the modeled consumption. Infiltration, fenestration SHGC, interior lighting power, and the thermostat setpoint were adjusted during the validation process. In addition to these inputs, new inputs were added, such as natural ventilation to bring the modeled consumption within range. The results indicate that for most climate zones, the modeled heating and cooling energy consumption aligns with the weighted mean UEC values from RASS. When achieving a close match with the weighted mean was not feasible, the models were adjusted to ensure the results fell within the interquartile range (Q1-Q3) of the RASS dataset.

In some climate zones, the modeled consumption was outside the expected range (Q1-Q3), and this departure is especially evident in climate zones 1 and 16. This variability was attributed to the limited sample size in the RASS dataset and the fact that dwelling units in these climate zones are subject to seasonal occupancy patterns or non-standard thermostat operation. The models could have been adjusted further, for example, by setting the thermostat to off, but the approach taken was to not aggressively attempt to adjust model inputs to RASS data in certain climate zones when observed consumption trends in RASS did not align with HDD/CDD trends.

Additionally, a sensitivity analysis was performed to test how the models respond to changes in cooling and heating demand by using two sets of weather data, one from Title 24 and another from DEER. Even within the same climate zone, using a different weather station with different CDD and HDD resulted in a proportional change to the cooling and heating consumption. This confirms that the models respond appropriately to changes in cooling and heating demand.

Attachment

The attached report details the progress achieved from 2021 to 2023 on the residential segment of the Prototypes project, including building stock assessment, model input development, and model construction.

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Appendix: Low-Rise Multifamily Construction Weighting Factors

Table 11: Low-rise multifamily prototypes weighting factors

Vintage	Prototype	Climate Zone															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Pre-1975	MF-Garden	0.1212	0.0301	0.2906	0.0327	0.0071	0.0175	0.0127	0.0602	0.0693	0.0013	0.0699	0.0207	0.0630	0.0590	0.0123	0.0009
	MF-Corridor	0.7647	0.0119	0.3573	0.0416	0.0095	0.4833	0.0805	0.3495	0.3608	0.0220	0.0593	0.1920	0.0536	0.0044	0.0147	0.0269
1975-1983	MF-Garden	0.0148	0.0259	0.0154	0.1692	0.1892	0.0191	0.0747	0.0247	0.0292	0.0175	0.0345	0.1078	0.1152	0.0133	0.1835	0.0494
	MF-Corridor	0.0271	0.3182	0.0519	0.1548	0.6234	0.2066	0.2563	0.2322	0.1017	0.0513	0.1530	0.1719	0.2181	0.3675	0.1300	0.7392
1984-2005	MF-Garden	0.0342	0.0684	0.0284	0.0389	0.0146	0.0520	0.1040	0.0236	0.0297	0.1329	0.1777	0.0611	0.0452	0.1480	0.3818	0.0452
	MF-Corridor	0.0057	0.5064	0.1584	0.3165	0.0847	0.1966	0.3906	0.2364	0.3400	0.7194	0.2388	0.3600	0.3534	0.3344	0.2694	0.1370
2006-2019	MF-Garden	0.0017	0.0028	0.0025	0.0186	0.0151	0.0029	0.0010	0.0181	0.0069	0.0041	0.0008	0.0035	0.0741	0.0255	0.0029	0.0000
	MF-Corridor	0.0307	0.0363	0.0955	0.2277	0.0564	0.0219	0.0802	0.0554	0.0623	0.0515	0.2660	0.0828	0.0773	0.0479	0.0054	0.0014