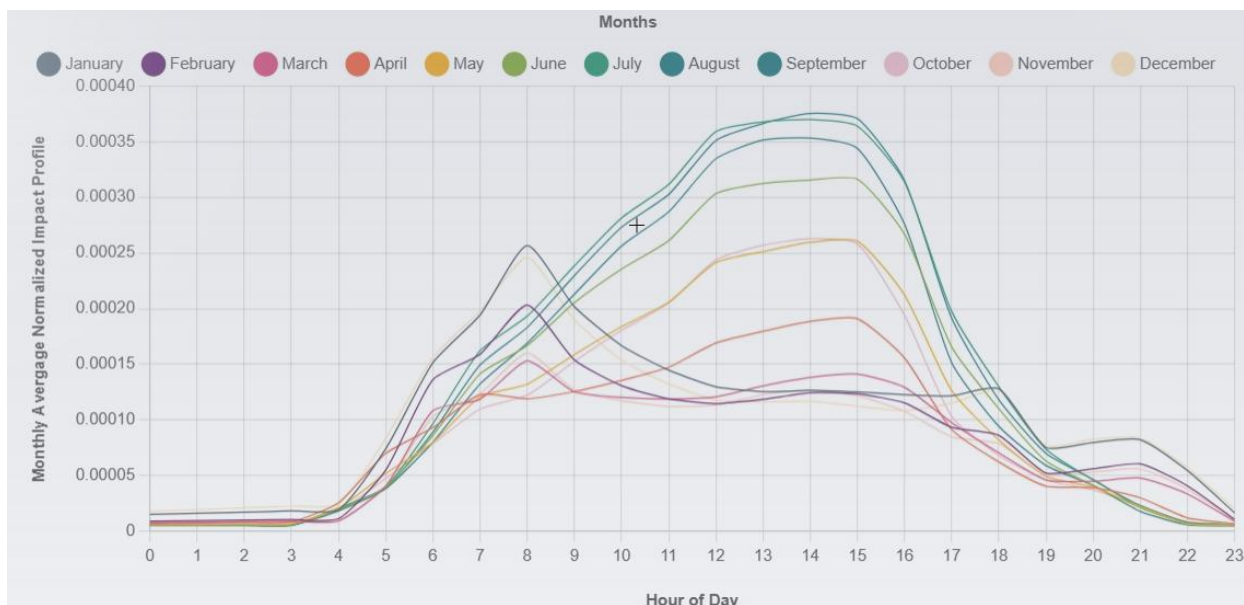




Load Shape Planning for Tool Development

Final Report

ET25SWE0041



Prepared by:

Ayad Al-Shaikh Second Hand Energy

Mostafa Tahmasebi TRC

Lake Casco TRC

Afshin Faramarzi TRC

Jake Schefrin TRC

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Disclaimer

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Executive Summary

California's transition from legacy impact profiles to consumption load shapes (CLS) is a critical step in improving the valuation of deemed energy efficiency measures for the 2028 program cycle. This transition comes at a time when avoided costs are increasingly time dependent and when load flexibility and load-shifting measures are becoming more important to portfolio performance. In that context, this project studied how new electric consumption load shapes should be developed and what level of granularity is justified when representing those shapes in statewide tools and downstream systems. The work focused on five major load shape categories within the deemed portfolio—cooling only, heating and cooling, fuel substitution, water heating, and continuous loads—and considered how building location, building type, base case variation, and measure case variation influence the value of energy over time.

To support this objective, the project team developed a framework for creating, analyzing, and comparing consumption load shapes across a representative set of 10 measure packages spanning the five load shape categories. The work included stakeholder outreach, measure package selection, consumption load shape creation, avoided cost integration, and a consolidating framework intended to support future measure development activity. The team prioritized modeled measure packages because they produce parameter-specific results and align well with the objective of establishing a repeatable process for grouping and consolidating large numbers of load shapes. We also considered non-modeled measures using available data sources and prior studies where appropriate.

The analysis shows that the value of a load shape is highly sensitive to when energy is consumed or saved, particularly because avoided generation and transmission and distribution costs are concentrated in a relatively small number of high-value hours. This shows the importance of representing load shape differences in a way that captures meaningful variation without creating an unmanageable number of permutations. Across the evaluated measure packages, the project team found that substantial reductions in the number of CLS are possible while maintaining relatively low variation in unitized electric benefit. For some large modeled heating, ventilation, and air conditioning (HVAC) measure packages, the number of possible CLS can be reduced from several thousand to a much lower number by combining building type and building location—in some cases, from approximately 18,000 individual curves to 357—and then further reduced to 16 grouped curves through broader building and location groupings, with only a modest increase in average standard deviation.

The results also show that the appropriate degree of consolidating depends on measure type. Residential HVAC measures showed strong correlation when grouped by building location and HVAC type, although some higher variation remains in specific cases. Water heating measures showed strong correlation across the full measure package; commercial refrigeration measures were highly correlated primarily by building location, and food service measures were more responsive to schedule variation than to weather-related factors.

Overall, this project demonstrates that consumption load shape coalescing can be conducted in a structured way that balances analytical value with implementation practicality. The findings support

the development of an optimized set of load shapes that improves the valuation of electric benefits while staying compatible with downstream systems, such as the California Electronic Technical Reference Manual, Cost-Effectiveness Tool, California Energy Data and Reporting System, and related program data platforms. A recommendation from this study is that prototype start days should be aligned directly with avoided cost documentation during the energy modeling process to reduce post processing complexity and avoid misalignment issues. The work also identified several next steps, including further evaluation of HVAC type definitions in commercial HVAC measure packages, improved understanding of the relationship between CLS error and impact load shape error, additional review of facility-level versus end-use data and associated interactive effects, and continued refinement of schedule-driven and location-based groupings.

At-a-Glance Summary

- The analyzed measure packages can reduce the number of CLS by orders of magnitude, while only increasing average standard deviation to about 6 percent. Consolidating CLS can lead to significant simplification of measure package data with minimal impact on the precision of final cost effectiveness outputs.
- Commercial HVAC measure packages are most highly correlated when considering the two parameters of building type and building location, resulting in 90 percent reduction in CLS and less than 1 percent average standard deviation.
- Residential HVAC measure packages are most highly correlated when considering the two parameters of building location and HVAC type, resulting in almost 90 percent reduction in CLS and less than 6 percent average standard deviation.
- Water heating measure packages have significant correlation across the entire measure package, with a total standard deviation across measure case CLS of less than 5 percent.
- The commercial refrigeration measure package the team analyzed was very highly correlated when maintaining building location only. The result here mimics the commercial HVAC recommendation of preserving building type and building location, except that only one building type exists for these measure packages.
- Groupings of building types and building locations can further reduce the number of CLS.
- Several report recommendations support creating quality CLS and establishing a coalesced CLS, but the team recommends additional work in this area.

			Number of Consumption Load Shapes (CLS)		
Measure Type	Measure Package ID	Measure Name Full	Original CLS	Coalesced CLS	Average Std Dev
Cooling Only	SWHC013	Unitary Air-Cooled Air Conditioner, Over 65 kBtu/hr, Commercial	~18,000	336*	0.7%
	SWHC043	Multiple Capacity Unitary Air-Cooled Com AC Between 65 and 240 kBtu/hr	~4,000	336*	0.8%
Heating and Cooling	SWHC046	Packaged Heat Pump Air Conditioner Commercial, Fuel Substitution	~7,600	336*	0.7%
	SWHC045	Heat Pump HVAC, Residential, Fuel Substitution	640	86	5.4%
	SWSV001	Duct Seal, Residential	612	52	4.6%
Water Heating	SWWH025	Heat Pump Water Heater, Residential, Fuel Substitution	~3,000	1	4.3%
	SWWH014	Heat Pump Water Heater, Residential	~3,000	1	4.3%
	SWWH001	Faucet Aerator, Residential	~3,000	1	4.3%
Continuous	SWCR001	Anti-Sweat Heater Controls	52	16	0.3%
	SWFS021	Fryer, Commercial, Fuel Substitution	14	7	5.3%

* Measure could be coalesced to 16 CLS with an average SD of <~3% with a grouping methodology.

Table 1: Summary of measure package CLS results.

Abbreviations and Acronyms

Acronym	Meaning
ACC	Avoided Cost Calculator
Cal TF	California Technical Forum
CEDARS	California Energy Data and Reporting System
CET	Cost-Effectiveness Tool
CLS	Consumption load shapes
CPUC	California Public Utilities Commission
DEER	Database for Energy Efficiency Resources
DS-Type	Demand savings type
EUL	Effective useful life
eTRM	Electronic Technical Reference Manual
HP	Heat pump
HVAC	Heating, ventilation, and air conditioning
IOU	Investor-owned utility
kBtu	One thousand British thermal units
kWh	Kilowatt-hour
MP	Measure package
PA	Program administrator
PG&E	Pacific Gas & Electric Company
REN	Regional Energy Networks

Acronym	Meaning
SCE	Southern California Edison
SD	Standard deviation
SDG&E	San Diego Gas & Electric
TRC	Total Resource Cost
TSB	Total System Benefit
TD	Transmission and distribution
UEC	Unit energy consumption

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Introduction

The creation of new consumption load shapes is scheduled for completion by program administrators (PAs) before the next California program cycle, as outlined in the most recent Database for Energy Efficiency Resources (DEER) resolution, E-5350. The intensive development phase for the 2028 cycle must conclude—including planning, measure package (MP) updates, and MP approvals—by July 31, 2026. This project will define load shapes for various usage types and determine the optimal level of data granularity required for integration into DEER 2028 updates. The most recent guidance has been to include separate consumption load shapes for each modeled base and measure case.

This long-awaited work is critical because load shapes significantly influence cost-effectiveness and Total System Benefit (TSB), and their importance continues to increase as the energy market evolves. Two examples highlighting this growing relevance:

- Cost-avoidance values are becoming increasingly time-dependent, making the relationship between energy consumption and time of day more influential on Total Resource Cost (TRC) and TSB.
- Load flexibility and load-shifting measures are expanding, relying on the value of energy consumption during specific time periods. This consumption load shape effort is aligning with MP development for the upcoming program cycle, beginning with a PA development plan that was submitted to the California Public Utilities Commission (CPUC) in August 2025.

This CalNEXT project analyzed five electric load shape categories within the deemed measure portfolio—cooling only, heating and cooling, fuel substitution, water heating, and continuous loads—and evaluated their sensitivity to TRC and TSB relative to other key parameters, such as kilowatt-hour (kWh), therms, effective useful life (EUL), and net-to-gross ratio. The project addressed a critical question that is easily overlooked in the development process: What level of granularity should apply when creating new consumption load shapes? The project team assessed whether and when load shapes should be consolidated or segmented based on parameters such as:

- Building location
- Building type
- Base case variation
- Measure case variation

Adding new consumption load shapes for each permutation could significantly enhance cost-effectiveness results, but the implementation burden may strain existing systems, including the Electronic Technical Reference Manual (eTRM) and California Energy Data and Reporting System (CEDARS) storage, Cost-Effectiveness Tool (CET) processing, and PA or implementer data platforms. Identifying when additional detail provides meaningful value enables (1) the creation of an optimized set of load shapes that remain compatible with downstream systems, and (2) a scalable foundation for future load flexibility and load-shifting measure development.

Background

The role of load shapes in energy efficiency is to link energy savings to their corresponding avoided costs throughout the calendar year. Historically in California, the CPUC developed and maintained savings load shapes, also called impact profiles, with the last update occurring in 2011. The 21 existing load shapes from that update—differentiated by program administrator and climate zone—remain the sole reference for deemed measure packages today. In contrast, the Avoided Cost Calculator (ACC), established in 2005, is updated biennially to enhance the accuracy of demand-side resource benefit calculations (California Public Utilities Commission (CPUC) n.d.). Following this two-year cycle, a quarterly avoided-cost table is updated to quantify the value of savings for each impact profile over a 31-year horizon. Using this table, the CET calculates the benefits of demand-side resources based on avoided transmission, distribution, and generation costs. In recent updates, the CET has expanded to include additional benefits from water pumping and refrigerant impacts in the overall cost-effectiveness calculation.

Through the most recent DEER resolutions, the CPUC has initiated an update to California's load shapes. As part of this update, the state of California will transition from impact profiles to consumption load shapes (CLS), which enable improved quantification of load-shifting value. The timing of this transition is critical because the past two years have marked a major shift from the eQUEST modeling platform to EnergyPlus. After one year of commercial prototype use and two years of residential prototype use, stakeholders and the CPUC have resolved many technical issues related to the prototypes, establishing a stable foundation for developing new CLS during the next measure development cycle for Program Year 2028, which is scheduled for Quarter 1 to Quarter 2 of 2026.

Several parallel efforts are in progress to ensure system readiness:

- The eTRM will support load shape references through TechIDs, EnergyPlus data files, and associated consumption load shape data.
- CEDARS will store consumption load shapes, integrate access to these new files, and manage the transition from impact profiles to consumption load shapes.

When this work is completed, a more accurate valuation of energy benefits will be realized for deemed measure packages.

Objectives

This project established a data-driven framework for developing and comparing energy CLS across multiple end uses and measure types in California's deemed measure portfolio. By examining a representative group of ten measures across five distinct consumption shape categories, the project created the foundation for a standardized and transparent methodology that can be applied portfolio wide.

The primary objective of this effort was to translate measure characteristics into consistent modeling parameters that capture the diversity of real-world applications. This includes defining how factors such as offering type, building type, building location, and HVAC configuration influence load shape

patterns. Through this process, the project will identify key parameters and modeling combinations that can represent the broader population of measures within each load shape category.

Another objective was to generate and analyze CLS for both baseline and measure cases at a detailed, permutation level. Using methods consistent with existing deemed measure protocols, these load shapes will provide high-resolution insights into typical energy use patterns and their relationship to avoided costs. This comparison across parameters will highlight which measure types drive the greatest cost-effectiveness differences and which factors contribute most to load shape variability.

One goal of the study was to develop recommendations for a coalescing tool that allows efficient comparison, grouping, and visualization of load shapes. These methods will be designed for repeatability and scalability, enabling their integration into future measure development and planning activities across the California deemed portfolio.

Finally, because this work forms the analytical foundation for how deemed measures will represent energy use over time, a key objective is to facilitate collaboration and technology transfer across the statewide program. The project team engaged closely with IOUs, measure developers, California Technical Forum (Cal TF) staff, and former Ex Ante consultants to ensure alignment in methodologies and create a clear pathway for adoption. This engagement helped position the final findings as a shared resource for the development, review, and coalescence of load shapes across California's energy efficiency programs.

Methodology and Approach

The project team followed a plan that included:

Stakeholder feedback: We contacted external stakeholders to inform them of the project scope and gauge interest for various future steps, then established smaller groups to support various parts of the project.

Measure package (MP) selection: This project proposed to examine a group of 10 deemed MPs that span a group of five different CLS types. The team assembled an initial, larger set of MPs from recent claims, program planning data, and programmatic experience, which we used along with key stakeholder input to make a final selection.

Consumption load shape creation: Electric consumption load shapes will be created at the permutation level using a methodology consistent with MP development (i.e., derived from EnergyPlus or consistent with calculated assumptions). Standardizing the methodology for the creation of the CLS allows stakeholders greater visibility to comment on the approach.

Data analysis: The team completed an analysis comparing electric CLS, using scripting in R and Python. Integrating avoided cost emphasizes or deemphasizes curve features to ensure that the comparison is better aligned with how energy is valued throughout the day.

General load shape coalescing framework: We developed a framework for extending the project results to additional MPs and collected recommendations for coalescing electric CLS, which we

made available to key stakeholders for feedback. Special consideration was taken to ensure that recommendations can be readily integrated into a coalescing tool to facilitate tech transfer.

Findings

Stakeholder Feedback

The team contacted key stakeholders throughout the project in four phases to ensure that we could produce results that are used and useful to the broadest group possible. This outreach included the following phases: (1) educating stakeholders about the project goals, (2) soliciting input to refine the measure list, and (3) sharing results and findings to collect feedback. These phases touched various stakeholder groups, as shown in Table 2 below.

Table 2: Stakeholder feedback chart.

Stakeholder Group	Phase 1: Educate	Phase 2: Measure List	Phase 3: Results/Feedback
Program Administrators' (PA) and Regional Energy Networks' (REN) Deemed Teams	X	X	X
Implementers' Program Teams	X		X
Deemed Ex Ante Team/Deemed Lead Regulator	X	X	X
Measure Developers	X		X
Cal TF Staff	X		X

Stakeholder groups are defined as:

Program administrators' (PAs) and Regional Energy Networks' (RENs) deemed teams, such as Southern California Edison (SCE), Pacific Gas and Electric Company (PG&E), San Diego Gas and Electric (SDG&E), SoCalREN, and BayREN. PAs and RENs provided important input on both initial measure selection and results from the project. In all cases, a PA will lead the development and updates of MPs, which drives their desire for quality data. In addition, managing the costs and benefits of coalescing load shapes considers issues such as portfolio risk, data and system maintenance costs, and transparency.

Implementers' program teams, such as Willdan, Energy Solutions, Synergy Companies, TRC Companies, ICF, and CLEAResult. Implementers provided feedback on the implications of coalescing curves and the cost of not-coalescing curves.

Deemed Ex Ante team and deemed lead regulator, such as the Ex Ante deemed team, DNV-GL, and CPUC staff. Ex Ante consultants provided prospective on their expectations for new CLS to promote the best available data. In addition, CPUC systems will need to be updated to use the new data that is planned for the summer of 2026; ensuring a clear alignment of needs and capabilities between systems will help ensure successful implementation for Program Year 2028 updates.

Measure developers' deemed team leads, such as Solaris, Energy Solutions, RMS, and TRC. Measure developers provided feedback on the selected MPs, as well as the recommendations for coalescing CLS, which may vary by end use, building type, and other key parameters.

Cal TF staff: Cal TF staff plays a key role in standardizing statewide methodologies that can cleanly fold into statewide tools, like the eTRM. Sharing progress with this team ensured that results can be transferred quickly into practice where applicable.

The project team onboarded stakeholders by sharing an overview presentation with each individual or group so that they had a basic understanding of the project goals. We completed Phase 1 of the project by sharing a summary presentation—including as [Appendix A](#)—to stakeholders that included:

- Project goals and values
- How to get involved
- Expected outcomes and timeline

The Stakeholder Feedback section of the project is in the “Results” portion of Phase 3, as shown in [Table 3](#) below.

Table 3: Stakeholder feedback status.

Stakeholder Group	Phase 1: Educate	Phase 2: Measure List	Phase 3: Results/Feedback
PAs and RENs Deemed Teams	X	X	X
PG&E	Complete	Complete	Complete
SCE	Complete	Complete	Complete
SDG&E	Complete	Complete	Complete
Implementers' Program Teams	X		X
TRC Companies	Complete		Complete
Energy Solutions – FS	Complete		Complete

Stakeholder Group	Phase 1: Educate	Phase 2: Measure List	Phase 3: Results/Feedback
Energy Solutions - HVAC	Complete		
ICF	Complete		
Synergy Companies	Complete		
Willdan	Complete		
Deemed Evaluators/ Deemed Lead Regulator	X	X	X
DNV-GL	Complete	Complete	Complete
Peter Biermayer and Ex Ante Consultant	Complete	Complete	Complete
Measure Developer Deemed Leads	X		X
RMS Energy Company	Complete		
Solaris	Complete		Complete
TRC Companies	Complete		Complete
Cal TF Staff	X		X
Cal TF Staff	Complete		Complete

Measure Package Selection

The measure selection process for the load shape coalescing analysis project includes 10 MPs representing a wide range of load shape types, including:

- Cooling only
- Heating/cooling
- Fuel substitution
- Water heating
- Continuous loads

The objective in selecting these MPs was to balance the inclusion of high-impact measures with broad representation of consumption load shape patterns. This approach aims to ensure immediate applicability to current claims and enhances the ability to generalize findings across a larger set of MPs. Accordingly, the following criteria guided the initial selection of MPs:

- **Fuel substitution/electrification MPs:** Included due to their high portfolio value and the distinct analytical methods required when transitioning from gas baseline to electric measure cases. These MPs have been intentionally prioritized.
- **Claims data from 2021/Q1 through 2024/Q4 (kWh and TSB):** These MPs with higher benefits were inherently more valuable to portfolios. Claims prior to 2021 were excluded due to limited comparability, as Measure Detail IDs were not yet included in claim records.
- **Variety in building type and sector:** Measures that span multiple building types and sectors were prioritized to differentiate value across these combinations. Because avoided-cost data fluctuates significantly by hour, the approved operating hours for a given building type can strongly influence the value of a unit of energy saved.
- **Variety in building location:** Measures that spanned all building locations were prioritized to determine whether certain zones could be consolidated. This zone aggregation may be more appropriate for some load shape types than others.
- **EnergyPlus-modeled MPs:** These measures were prioritized because they produced well-defined consumption load shapes and inherently generated numerous permutations. Developing new load shapes is outside the project's scope, so the team did not pursue MPs lacking a clear path to load shape identification unless there was a strong justification.

Special cases have been included as time permits, such as:

- Additional control strategies for high-value heat pump (HP), fuel substitution, or HVAC measure packages.
- Food service measures with extended or late operating schedules.

Measures excluded: Sunsetting MPs were excluded unless stakeholder input indicated that revised load shapes could improve cost effectiveness. MPs that provided only gas-related benefits—excluding fuel substitution measures—were also removed from consideration.

The team compiled the initial group of MPs, presented in [Appendix B-1](#), through stakeholder discussions. We shared the list, which continued to expand, with PA deemed and implementer

program teams during the Phase 1 stakeholder outreach effort; we also actively solicited feedback from these teams to identify MPs that would benefit most from this analysis.

From this initial group, the key project contributors (TRC and Second Hand Energy) completed the final MP selection, which is provided in [Appendix B-2](#) and shown in [Table 4](#) below. Selection rationales are also documented in [Appendix B-2](#) in alignment with the stated criteria to ensure transparency and support extrapolation of results.

Table 4: Measure package section list.

Load Group	Fuel Sub	Measure ID	Measure Description
Continuous	No	SWCR001	Anti-Sweat Heater Controls
	Yes	SWFS021	Fryer, Commercial, Fuel Substitution
Cooling Only	No	SWHC013	Unitary Air-Cooled AC, Over 65 kBtu/hr, Commercial
	No	SWHC043	Multiple Capacity Unitary Air-Cooled Commercial AC (65–240 kBtu/hr)
Heating and Cooling	Yes	SWHC045	Heat Pump HVAC, Residential, Fuel Substitution
	Yes	SWHC046	Packaged Heat Pump AC, Commercial, Fuel Substitution
	No	SWSV001	Duct Seal, Residential
Water Heating	No	SWWH001	Faucet Aerator, Residential (<i>electric offerings</i>)
	No	SWWH014	Heat Pump Water Heater, Residential
	Yes	SWWH025	Heat Pump Water Heater, Residential, Fuel Substitution

Consumption Load Shape Creation

The team used two primary calculation approaches to construct consumption load shapes:

- Modeled measure packages (e.g., EnergyPlus)
- Non-modeled measure packages (e.g., supported by evaluation, measurement, and verification data; studies; or other accepted documentation of a measure’s consumption)

As previously described, this project primarily focused on modeled measure packages for two main reasons. First, modeled results produce parameter-specific outputs, reflecting the multiple factors that influence results—such as building type, building location, vintage, HVAC type, and efficiency

level. Additional consumption load shapes can be developed for both base and measure cases, although many of these will exhibit similar characteristics. Second, the objective of this project is not to create new load shapes, but rather to develop a framework that enables measure developers to generate and consolidate load shapes consistently, particularly during periods of high development activity. To most effectively support this objective, the team simulated measures that were already modeled. We recognize that several of the most significant measure packages in the portfolio—including HVAC, water heating, and fuel substitution—align directly with this modeled-measure approach.

Table 5: Measure package modeling type.

Calculation Approach	Measure ID	Measure Description
Modeled		
	SWCR001	Anti-Sweat Heater Controls
	SWHC013	Unitary Air-Cooled AC, Over 65 kBtu/hr, Commercial
	SWHC046	Packaged Heat Pump AC, Commercial, Fuel Substitution
	SWSV001	Duct Seal, Residential
	SWHC045	Heat Pump HVAC, Residential, Fuel Substitution
	SWWH014	Heat Pump Water Heater, Residential
	SWWH025	Heat Pump Water Heater, Residential, Fuel Substitution
	SWHC043	Multiple Capacity Unitary Air-Cooled Commercial AC (65–240 kBtu/hr)
Non-Modeled		
	SWFS021	Fryer, Commercial, Fuel Substitution
	SWWH001	Faucet Aerator, Residential (<i>electric offerings</i>)

Modeled Measure Package Approach

The simulation approach for modeled MPs is documented in more detail in [Appendix C](#), which clarifies which MPs were modeled. Some of the most important parameters that were maintained include:

Weather Data: CZ2022 EnergyPlus.

The correct weather stations can be found through this CPUC link:

<https://cedars.cpuc.ca.gov/deer-resources/tools/energy-plus/file/2890/download/>
(California Public Utilities Commission (CPUC)).

Simulations should match the weather characteristics of the avoided cost data. The 2024 ACC documentation (CPUC / E3 n.d.), which is the latest version used for Program Year 2026 claims, documents the use of CZ2022 weather data.

Calendar Year Start Day: Res prototypes = Thursday; Non-Res prototypes = Sunday.

This start day of the week corresponds to January 1, which is simulated in the model. For the CPUC prototypes, this start day differs between the residential and non-residential prototypes but can be validated in EnergyPlus, as shown in [Figure 1](#) below.

The screenshot shows the EnergyPlus software interface. On the left, the 'Class List' pane displays a hierarchy of objects. The 'RunPeriod' object is selected. On the right, the 'Field' pane shows the parameters for the 'RunPeriod' object. The 'Day of Week for Start Day' field is highlighted with a red box, and its value is 'Sunday'. Other fields include 'Begin Month' (1), 'Begin Day of Month' (1), 'Begin Year' (1), 'End Month' (12), 'End Day of Month' (31), 'End Year' (1), 'Use Weather File Holidays and Special Days' (No), 'Use Weather File Daylight Saving Period' (No), and 'Apply Weekend Holiday Rule' (No).

Field	Units	Obj1
Name		Annual
Begin Month		1
Begin Day of Month		1
Begin Year		1
End Month		12
End Day of Month		31
End Year		1
Day of Week for Start Day		Sunday
Use Weather File Holidays and Special Days		No
Use Weather File Daylight Saving Period		No
Apply Weekend Holiday Rule		No

Figure 1: Screenshot from EnergyPlus for a non-residential prototype.

The alignment of the day of the week—i.e., weekdays and weekends—from the simulation with the same day of the week from the avoided cost data is critical. The 2024 ACC documentation states that a 2018 calendar year was used for that calculation, which requires a start day on Monday.

Therefore, since all CPUC prototypes start on either a Sunday or Thursday, the simulated data had to be shifted to be in alignment.

The team strongly recommends prototypes be changed to align with avoided costs documentation. Shifting days to maintain day of the week alignment is not difficult, but aligning days will have the

consequences of misaligning temperature and holidays. Aligning start days directly in the energy modeling process avoids the need to do additional post-processing to align the start days.

The documentation in [Appendix B](#) also shares:

- The MPs' version number that most closely matches the model.
- The source of the prototype files, which are typically stored on GitHub.
- The MP measure developer who initially created the simulation.
- The parameters that combine to define the different simulations created, which constitute the variation this is seen between the models.
- The energy consumptions values that were saved hourly for each simulation. End-use data was specifically needed for these simulations to ensure that consumption load shapes were comparable across building types.

A new, valuable resource to understand these prototype models is the CPUC Scorecard, which documents each prototype. These scorecards were created by TRC, supported by SCE, and requested by the CPUC and measure developers to support measure review and development. These files are available in a draft state for review [here](#). This tool makes model features—such as operating schedules and holiday calendars—available and transparent.

The output files include the hourly energy (i.e., kWh) for both select end use and the building-level use. The unit energy consumption (UEC) value can be extracted from this table of 8,760 values as the sum of the values, which would then need to be normalized for that particular MP. For example, the residential water heater MP uses a normalizing unit of one water heater, while the commercial refrigeration anti-sweat heater MP uses a normalizing unit of linear foot for low-temperature refrigerated cases, which models 269 units.

Non-Modeled Measure Package Approach

Non-modeled measures are typically characterized by fewer permutations. This limited variability occurs because, unlike modeled measures that depend on factors such as weather and building type, non-modeled measures maintain consistent conditions across applications. The analysis of non-modeled measures can leverage existing data from other projects, such as:

- National Laboratory of the Rockies
- Electric Power Research Institute
- Commercial Building Energy Consumption Survey
- Residential Appliance Saturation Survey
- Prior CalNEXT/emerging technology studies

This data can help develop consumption load shapes or draw from studies on usage patterns and can also determine the appropriate level of evaluation for consumption load shapes. However, in this context, additional segmentation may provide further analytical value.

Data Analysis

Figure 2 shows how raw data from 8,760 hourly energy files and avoided costs has been used and combined into quarterized avoided costs that can be used for calculating electric benefits.

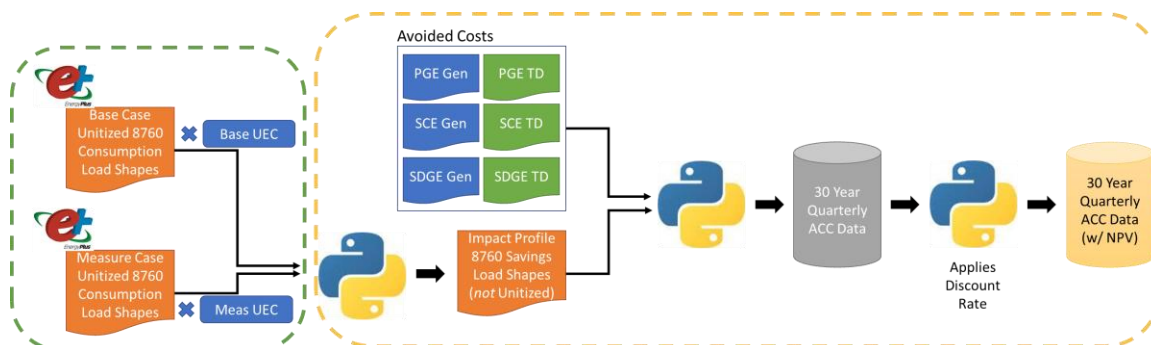


Figure 2: Data flow to combine ACC data and load shape data (if data comes from EnergyPlus).

Accessing and Understanding Avoided Cost Data

Avoided cost data establishes the cost framework for demand-side resources. The approved data are available through the [DER Cost-Effectiveness](#) website (California Public Utilities Commission (CPUC)). This tool enables users to access and visualize both the generation and transmission/distribution datasets; the most recent data set available will be used for this analysis, which corresponds to the 2024 ACC, as shown in Figure 3 below.

Claim Program Year	Filing Program Year	CET Avoided Cost Version	Avoided Cost Calculator Vintage
2020	2020	2020	2019/E-5014
2021-2023	2021-2023	2021	2020/E-5077
	2024-2031 Application	2022	2021/E-5150
2024-2025	2024-2027 True-Up	2024	2022/E-5228
2026-2027	2026-2027 Mid-Cycle and 2028-2035 Application	2026	2024/E-5328

Figure 3: CEDARS screenshot.

Source: [CET - CEDARS](#) (California Public Utilities Commission (CPUC))

For this report, the team provided generation avoided cost data for each IOU. The following methodology, which replicates the approach used in the eTRM, associates each building location with a specific IOU (PG&E, SCE, or SDG&E). When multiple IOUs served the same building location, the IOU with the largest territorial coverage was selected, as summarized in [Table 6](#). The one

exception is from building location 5, where only PG&E transmission and distribution (TD) data was directly available.

Table 6: Designation of the IOU used for each building location for generation and transmission and distribution avoided costs.

Building Location	Primary IOU
1	PG&E
2	PG&E
3	PG&E
4	PG&E
5	PG&E
6	SCE
7	SDG&E
8	SCE
9	SCE
10	SCE
11	PG&E
12	PG&E
13	SCE
14	SCE
15	SCE
16	SCE

The following sections provide some perspective and insight into the generation, as well as TD data used to quantify benefits. Understanding the variation in cost that makes some hours high or low in value can provide insights into what types of differences ultimately impact cost effectiveness.

Generation avoided cost data (labeled in [Figure 4](#) below as “PGE Gen,” “SCE Gen,” and “SDGE Gen”) are provided for a 31-year period and generally increase year-over-year, as illustrated in [Figure 5](#) below. Data sets for the three IOUs do vary, but the shapes remain similar between all three—e.g., peaks occur during the same hours of the year and the trend over 31 years is similar. This data does not vary by building location.

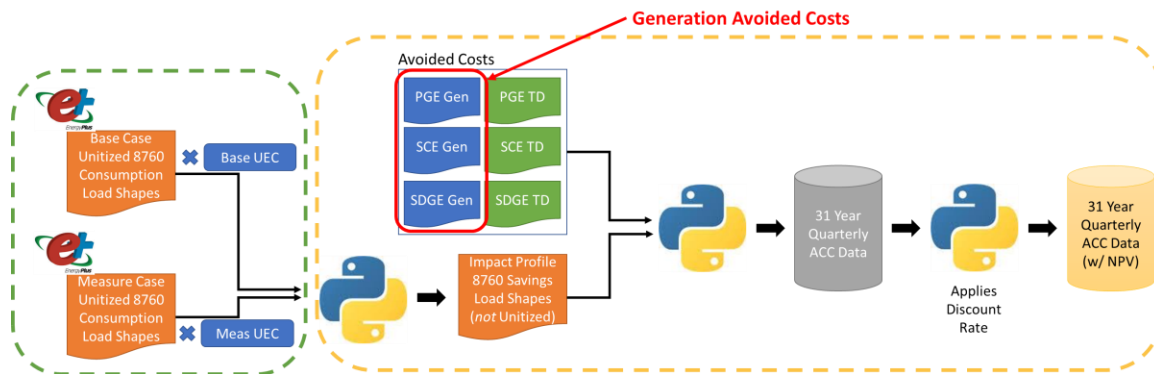


Figure 4: Generation avoided cost data outlined in red.

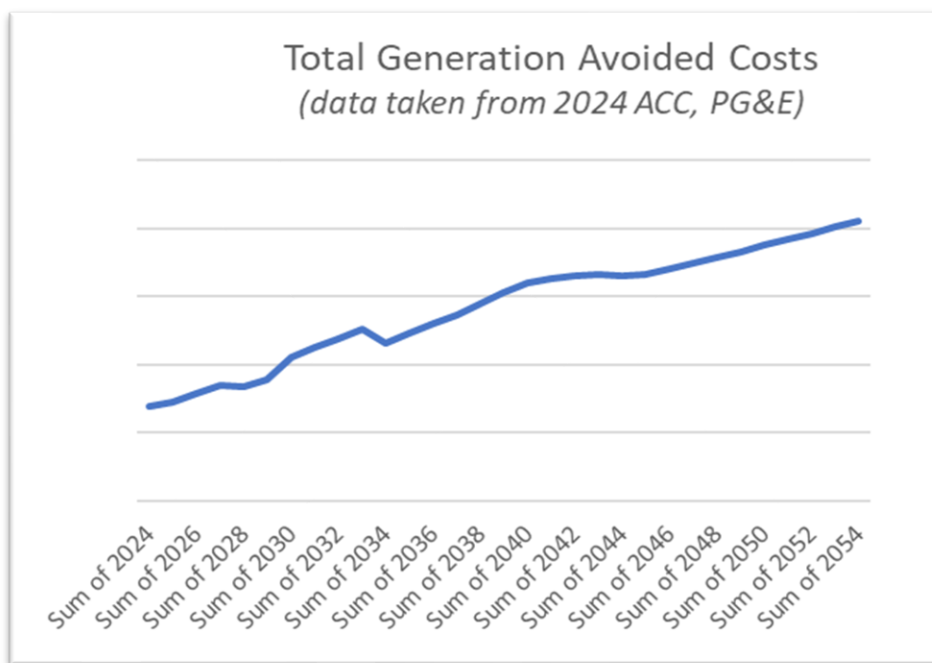


Figure 5: Annual generation avoided cost pattern spanning 31 years.

Within a single year, generation avoided cost follows the trend shown in the [Figure 6](#) below.

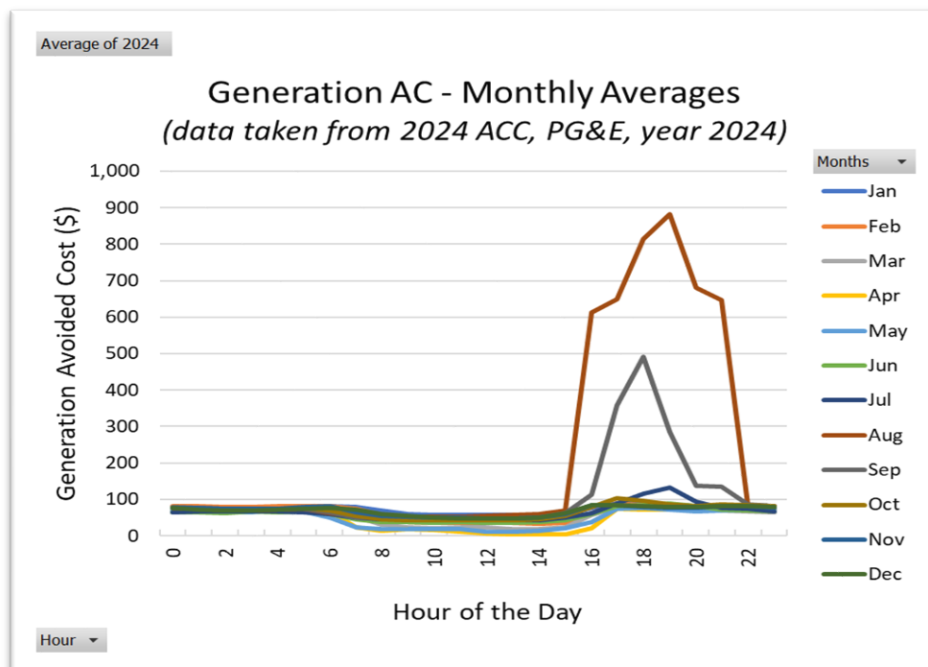


Figure 6: Typical average monthly patterns for generation avoided costs.

The monthly view of generation avoided costs shows an average day that is relatively flat across most months, with varying dips due to solar production and extreme peaks in very specific summer months and days.

This histogram of generation avoided cost data in [Figure 7](#)—which shows the number of hours in each bin of cost data (e.g., there are 752 hours per year that have less than \$10 per hour of generation value)—provides more insight into two notable deviations. First, a decline in avoided generation costs occurs during daylight hours (roughly 8:00 a.m. to 4:00 p.m.) due to increased solar production; this decline is more prolonged and pronounced during the summer months. These hours are represented by the lower range of the histogram. In this section of the curve, 11 percent of the hours represents less than 1 percent of the total annual generation avoided cost value. Second, sharp peaks emerge in certain summer months—for example, August and September in building location 1.

These peaks occur over only a few days each month, typically between about 4:00 p.m. and 9:00 p.m. These hours are represented by the upper range of the histogram and are described in more detail in [Table 7](#) below. Viewing a monthly average, as shown in [Figure 6](#), demonstrates a pattern but masks the scale of the peak, since the peaks only occur in a small number of days (i.e., not uniformly throughout the month). The spikes are shown in [Figure 8](#) when hourly data is plotted. In this upper tail of the histogram, about 2 percent of the hours represents about 25 percent of the total annual generation avoided cost value.

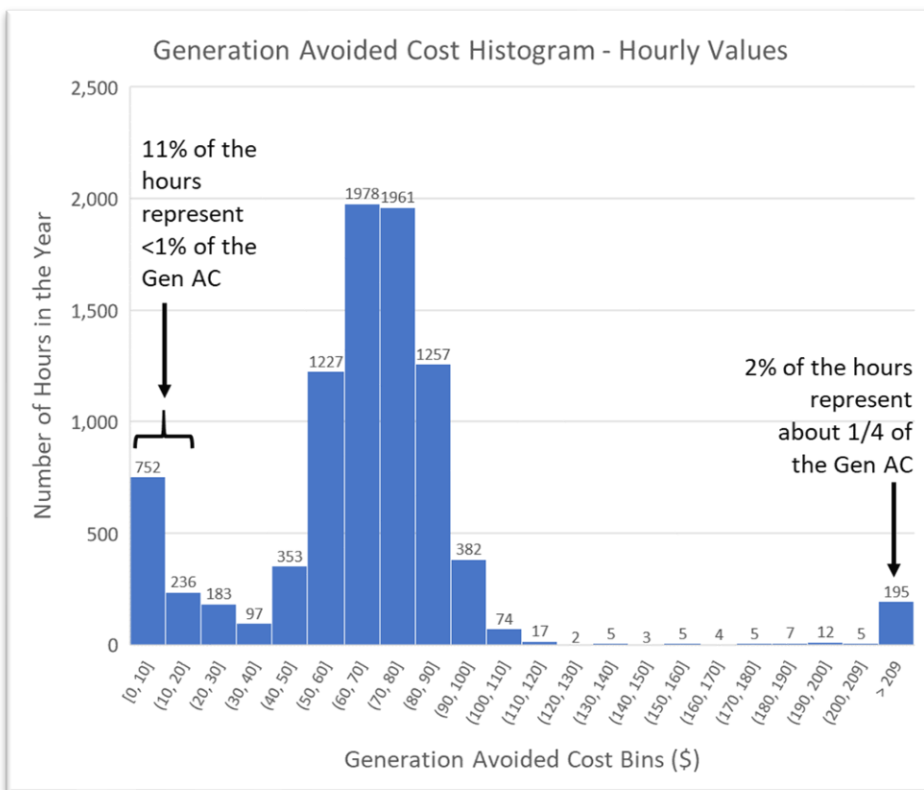


Figure 7: Histogram of generation avoided costs showing the significance of the high and low extremes.

Table 7: Documentation of the hours when generation avoided cost is greater than \$210.

Month	Hours/Month	Start Time	End Time
June	2	7:00 PM	7:00 PM
July	7	6:00 PM	8:00 PM
August	136	4:00 PM	9:00 PM
September	47	5:00 PM	9:00 PM
October	2	5:00 PM	6:00 PM

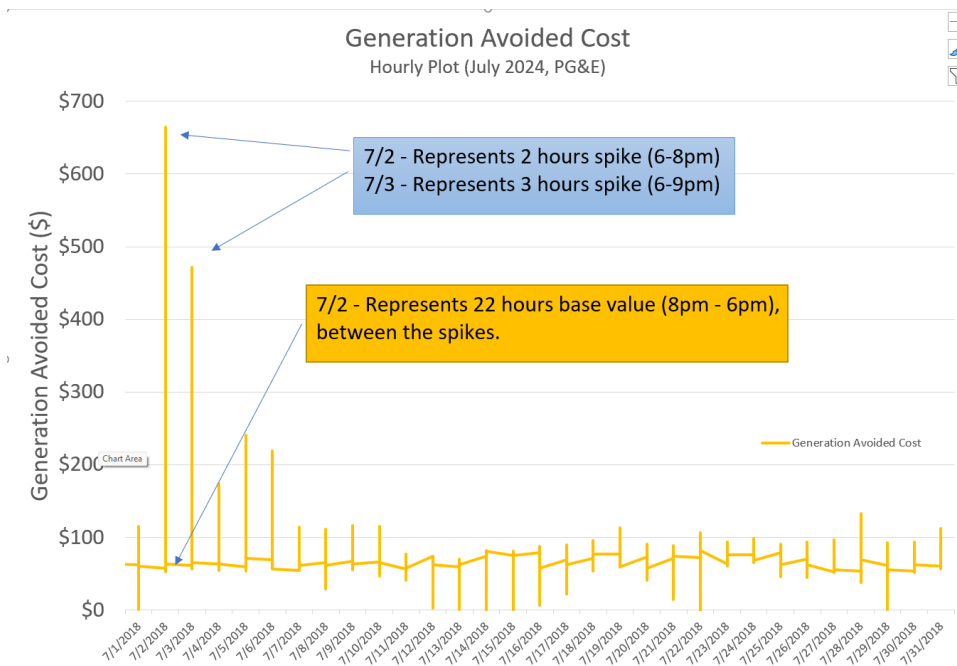


Figure 8: Hourly graph of avoided costs for PG&E, July 2024.

TD avoided cost data (labeled in [Figure 9](#) below as “PGE TD,” “SCE TD,” and “SDGE TD”) varies by both IOU and building location. Total annual costs generally increase year-over-year, as illustrated in [Figure 10](#) and [Figure 11](#) below.

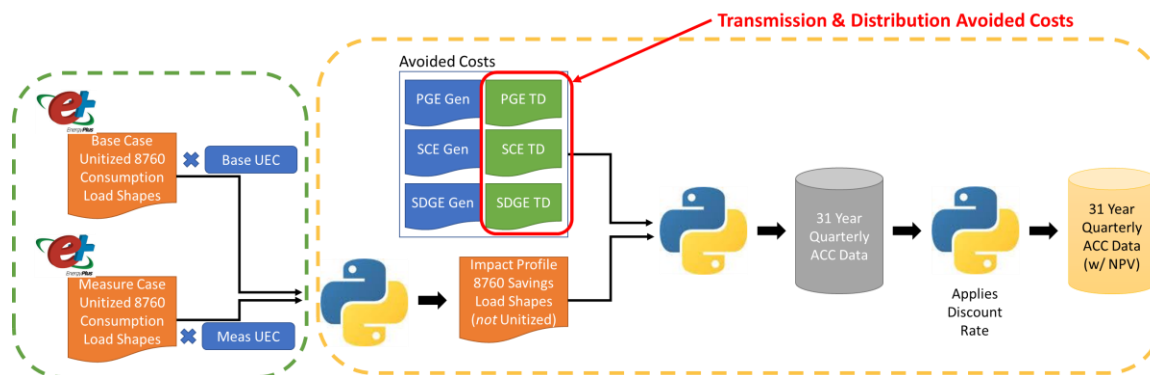


Figure 9: TD avoided cost data outlined in red.

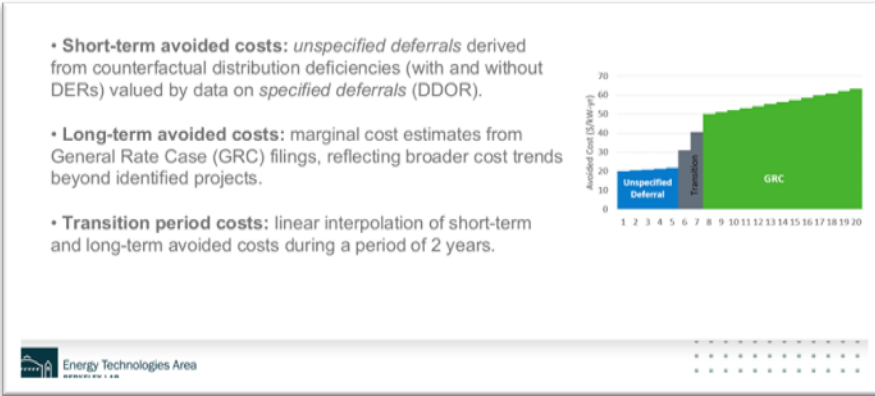


Figure 10: Transmission avoided cost zones.

Source: Berkeley Lab presentation, Avoided Distribution Cost Research Plan, Energy Technologies Area, Berkeley Lab, August 2025 (Heleno 2025).

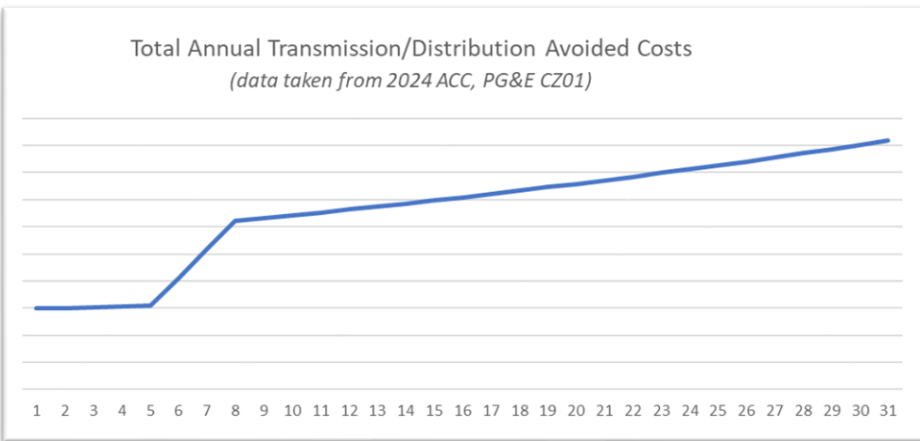


Figure 11: Annual TD avoided cost pattern spanning 31 years.

When examined at a more granular level, the avoided TD costs are concentrated within a few summer months, as illustrated by PG&E data for building location 1 in [Figure 12](#).

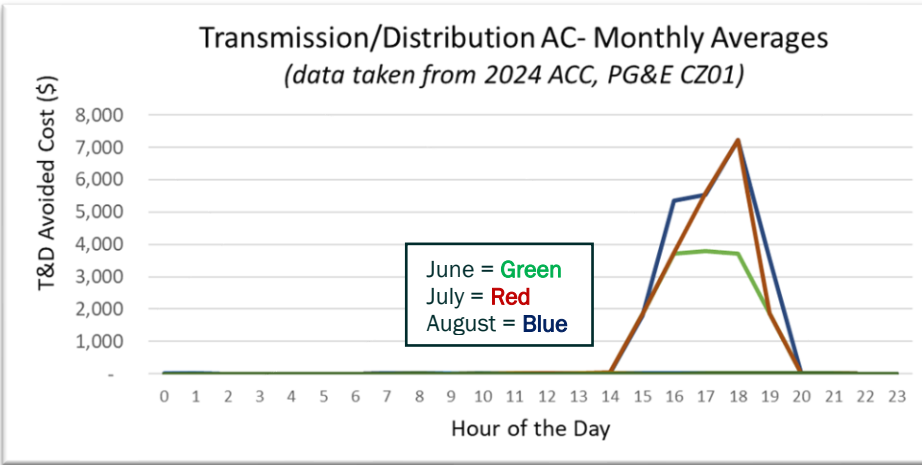


Figure 12: Typical average monthly patterns for TD avoided costs.

More specifically, [Table 8](#) below shows the number of hours per day in each building location during which TD costs are significantly higher than baseline levels. All other hours are orders of magnitude smaller than these spikes in cost.

Table 8: 2024 TD cost avoidance data showing the number of high-cost hours per building location for each applicable IOU.

Date/Time	PG&E (CZ: 1, 2, 3a, 3b, 4, 11, 12)	SCE (CZ: 5, 6, 8, 9, 10, 13, 14, 15, 16)	SDG&E (CZ: 7)
6/11/2018	3	0	0
6/12/2018	5	0	0
7/2/2018	5	0	3
7/3/2018	3	3	3
7/4/2018	0	5	0
7/5/2018	0	3	0
7/6/2018	0	1	0
7/9/2018	0	6	0

7/10/2018	3	6	2
7/11/2018	2	4	2
8/7/2018	0	4	0
8/8/2018	0	3	0
8/9/2018	0	1	0
8/10/2018	4	3	0
8/14/2018	0	2	0
8/16/2018	0	2	0
8/17/2018	0	5	0
8/18/2018	0	1	0
8/21/2018	0	3	1
8/24/2018	0	3	0
8/28/2018	0	3	0
8/29/2018	1	3	0
8/31/2018	7	0	0
9/3/2018	2	3	0
9/8/2018	0	2	0
10/18/2018	1	1	0

Using Avoided Cost Data with Consumption Load Shapes

Figure 13 below shows how data are combined to create the quarterly ACC data, as well as the single electric benefit value for each consumption load shape.

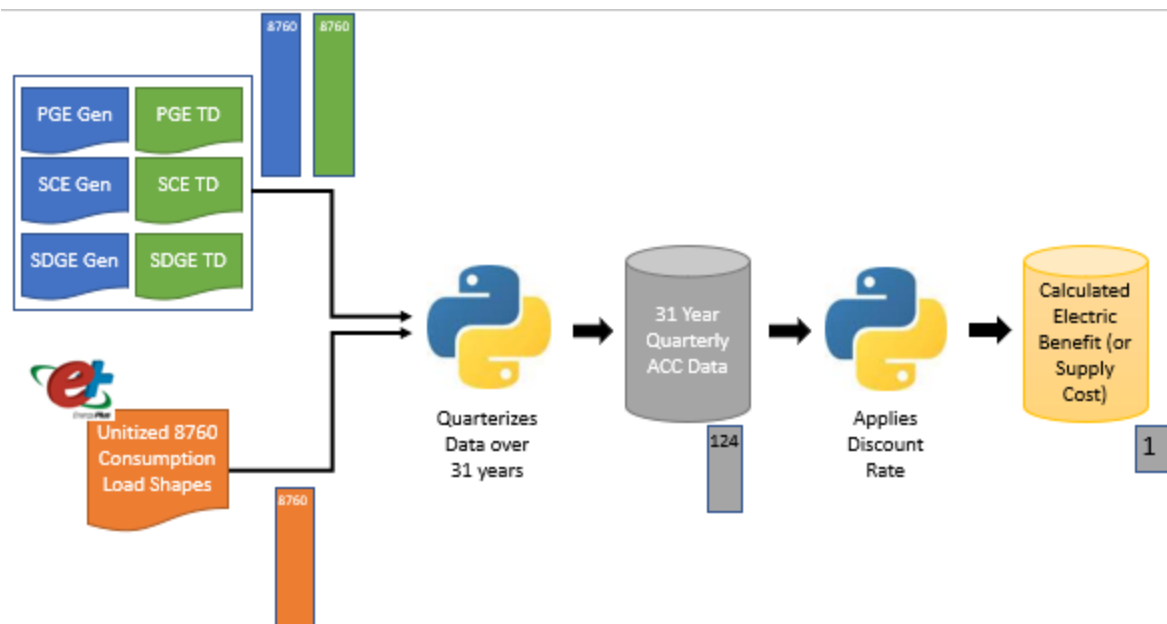


Figure 13: Quartered avoided costs and final electric benefit calculated.

Through this flow, the unitized load shape consumption data is translated into one set of quarterized avoided cost data (i.e., four quarterly values for each year from 2024 through 2054).

The final step translates the quarterized data to a single value, called unitized electric benefit (UEC), shown in dollars per kWh in today's dollars, based upon the start year of the program and the actual quarter of the claims using the discount rate associated with the appropriate IOU. For this project, we considered the start year of 2026 and claim quarter of Quarter 3. This choice of quarter mimics the approach PAs use in the eTRM. In this way, we calculated unitized electric benefit by summing enough quarterized values to match the effective useful life (EUL) of the measure.

These are the same electric benefits used to evaluate TRC and TSB through the CET after multiplying by UEC.

Establishing a Threshold of Error

When determining appropriate error bands for the analysis, the team used the CET Calculator to quantify the impact of key parameters in the cost-effectiveness analysis. In [Figure 14](#) below, we ran the CET using the following inputs:

- First Year: 2026
- Avoided Cost Year: 2026
- Market Effects: 0 percent

In each case, all parameters in a representative claim were held constant, while only one parameter was systematically varied. Each parameter value was adjusted in 20 percent increments in both positive and negative directions; the team applied this approach to kW, kWh, therms, cost, and incentive. We included two additional key parameters—EUL and building location—that could not be modified as uniformly. For EUL, the value was adjusted using typical lifetimes, resulting in irregular

percentage increments. Similarly, the building location parameter¹ varied across all 16 climate zones while maintaining all other parameters as constant values.

The CET results were then normalized for TRC ratio, TSB gross, and ElecBens. The outcomes were consistent across all three metrics, with the expected exception that cost-related parameters (cost and incentive) did not affect TSB or electric benefit results. The output is plotted in [Figure 14](#), which shows the relationships between TRC and various parameters.

From these results, a few observations result in some key energy inputs. Both kWh and therms vary linearly with TRC and benefits, due to the way they are multiplied by avoided cost curves. Meanwhile, kW has no impact on TRC and benefits because of the way that all DEER deemed impact shapes are categorized—e.g., by demand savings type (DS-Type).² The relationship between TRC ratio and other parameters can be quantitatively observed, allowing a reasonable range of variation to be established, as shown in [Table 9](#) below. Specifically:

- Incentives exhibited a weak correlation, where ± 20 percent changes in incentives altered the TRC ratio by only ± 4 percent.
- kWh demonstrated a strong correlation, where ± 20 percent changes in kWh altered the TRC ratio by ± 11 percent.
- Cost and EUL showed the strongest correlation, where ± 20 percent changes altered the TRC ratio by ± 20 percent.

Table 9: TRC ratio variation due to a change in a parameter of ± 20 percent.

Variation of Parameter	kWh	Cost	EUL	Incentive
-20%	-11%	20%	-14%	4%
20%	11%	-14%	19%	-3%

¹ Building Location is plotted within Figure 14 to visualize the impact of Building Location that changes due to TD avoided costs and discount rate. Note that it does not align with the align with the x-axis values that drive percent variation in parameters.

² This demand savings type, DS-Type, determines how transmission and distribution avoided costs are used within the CPUC's Cost Effectiveness Tool (CET)

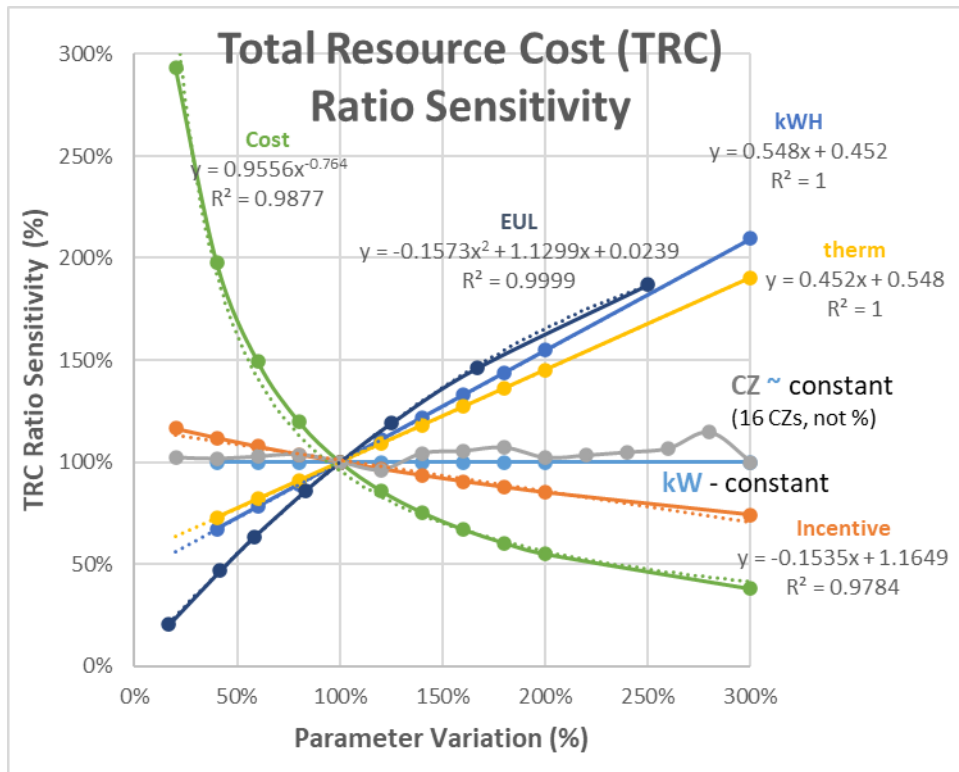


Figure 14: TRC ratio sensitivity to variation of input parameters.

As a guidepost for error, it is not unreasonable to believe that the measure cost or EUL used in a measure package could be ± 20 percent, which results in an acceptable error in TRC, TSB, or electric benefits. Therefore, lacking any official CPUC documentation on the acceptable error, the deviation of somewhere between ± 10 and 20 percent for acceptable error was assumed to be reasonable for this project.

Measure Package Consumption Load Shape Analysis

The team analyzed the MPs in [Table 10](#) by separating the parameters that described each model and linking these with the unitized electric benefit values (\$/kWh), which were calculated via the CET analysis described above. In this way, we used a cluster analysis to consider groups of data at several levels:

- Parameters (e.g., building type, capacity, etc.)
- Groups of parameters (e.g., building type and building location)
- Subsets of parameters (e.g., cold climate, hot climate, etc.)

Table 10: MP list.

Load Group	Fuel Sub	Measure ID	Measure Description
Continuous	No	SWCR001	Anti-Sweat Heater Controls
	Yes	SWFS021	Fryer, Commercial, Fuel Substitution
Cooling Only	No	SWHC013	Unitary Air-Cooled AC, Over 65 kBtu/hr, Commercial
	No	SWHC043	Multiple Capacity Unitary Air-Cooled Commercial AC (65–240 kBtu/hr)
Heating and Cooling	Yes	SWHC045	Heat Pump HVAC, Residential, Fuel Substitution
	Yes	SWHC046	Packaged Heat Pump AC, Commercial, Fuel Substitution
	No	SWSV001	Duct Seal, Residential
Water Heating	No	SWWH001	Faucet Aerator, Residential (<i>electric offerings</i>)
	No	SWWH014	Heat Pump Water Heater, Residential
	Yes	SWWH025	Heat Pump Water Heater, Residential, Fuel Substitution

For each MP, the analysis included:

- Summary table of the variation by parameter
- Interpretation of this table with key findings
- Visual graphics to help understand the variation by parameter

The team created visuals of the data to understand the analysis. Each figure has very similar features, as shown in the example in [Figure 15](#). A more detailed and visual graphics explanation is provided in [Appendix C](#) to understand the link between each summary table and the visual graphics.

- Each point represents a single CLS that has been translated into a unit electric benefit number (\$/kWh) to facilitate comparison. The decision to use end-use data rather than facility data also stems from the need to compare values across different building types.
- Unit electric benefits (\$/kWh) represent the vertical axis, where electric benefits for a base or measure case can be calculated as the unit electric consumption (kWh/norm unit) * unit electric benefits (\$/kWh). Note that the CET outputs electric benefits that are associated with savings. The relationship between these values is given by:

$$\text{Electric Benefits (\$)} = \text{UEC}(\text{base}) * \text{Unit Electric Benefits}(\text{base}) - \text{UEC}(\text{meas}) * \text{Unit Electric Benefits}(\text{meas})$$
- Points are colored to align with building location.

- The mean unit electric benefit value is plotted as a solid horizontal line.
- The +/-10 percent error bars from the mean unit electric benefit are plotted as dotted horizontal lines.
- We provided bar and whisker plots to show the spread of data, but jitter plots include every point so that the shape of the data is also visible. This shape can be valuable for understanding additional grouping and outliers.
- The horizontal axis displays groups for each chart. In this case, PA is included in this one example to clearly show the data broken down by building location. Typical categories include building type, building location, equipment type, equipment efficiency, capacity range, vintage, measure case, voltage, and electric resistance. All figures are available in [Appendix D](#), but only representative figures are shown here to share results more clearly.
- Some graphs show the breakdown between measure and standard cases when the group name in the horizontal axis begins with “Msr” or “Std,” as in [Figure 15](#).

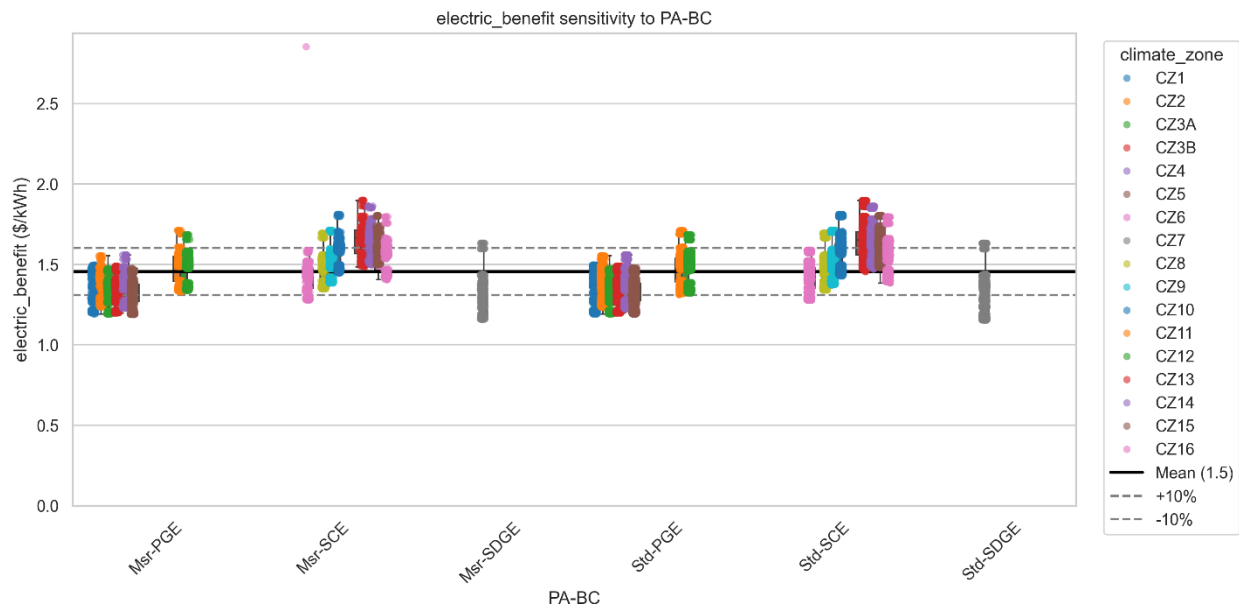


Figure 15: Sample graphic for SWHC013 of unit electric benefits versus building location and IOU.

We used end-use data specific to each measure package for this analysis to facilitate comparisons between building types. If facility data was used, comparisons of impact data would be valid, but comparisons of consumption data would be building-type specific. [Table 11](#) explains which end-use data we used to construct consumption load shapes for specific types of MPs.

Table 11: End use data for consumption load shape.

Measure Type	Heating Electricity	Cooling Electricity	Fan Electricity	Water Heating Electricity	Refrigeration Electricity ³
HVAC	X	X	X		
Water Heating				X	
Commercial Refrigeration	X	X	X		X

³ Refrigeration Electricity is composed of several items: compressor, refrigeration case, evaporator fan, and case lighting electricity. For the Anti-Sweat Heater MP, this energy was also subdivided by low- and medium-temperature refrigeration.

SWHC013, UNITARY AIR-COOLED AC, OVER 65 KBTU/HR, COMMERCIAL

The measure case in this MP was defined as an air-cooled air conditioner or heat pump with a cooling capacity greater than or equal to 65 thousand British thermal units per hour (kBtu/hr), installed in a non-residential building. Historically, this MP has been valuable to the portfolio, although has dropped in benefits in recent years. The HVAC modeled MP serves all commercial building types and building locations that have prototypes available in EnergyPlus for new and existing vintages.

Recommendation: The recommendation for this MP suggests coalescing with a combination of building type and building location. This simplification can be accomplished either directly with explicit parameters (e.g., Asm&CZ01) or with grouped parameters (e.g., BT1&Loc1), which matches the other commercial HVAC load types.

Table 12: SWHC013 parameter results.

Parameter Name	CLS	Max SD ⁴ of (\$/kWh)	Avg SD of (\$/kWh)	Parameters
Whole Model	~18000		10%	
Building Type	21	9.9%	7.9%	Asm, ECC, EPr, ERC, ESe, EUn, Gro, Hsp, Htl, MBT, MLI, Mtl, Nrs, OfL, OfS, RFF, RSD, Rt3, RtL, RtS, SCn
Building Location	16	9%	6%	CZ01, CZ02, CZ03, CZ04, CZ05, CZ06, CZ07, CZ08, CZ09, CZ10, CZ11, CZ12, CZ13, CZ14, CZ15, CZ16
Equipment Type	2	9.9%	5.0%	Packaged AC, Packaged HP
Equipment Efficiency	14	10%	10%	9.7, 10, 10.2, 10.8, 11, 11.2, 11.5, 12, 12.5, 13
Capacity Range	4	9.9%	9.9%	135 - 239, 240 - 759, 65 - 134, > 760
Vintage	2	10%	10%	Ex, New
BT&CZ	357	3.9%	0.7%	Asm&CZ01, Asm&CZ02, ..., SCn&CZ15, SCn&CZ16
BT2&Loc2 ⁵	16	5.0%	2.8%	BT1&Loc1, BT1&Loc2, ..., BT4&Loc3, BT4&Loc4

The data in [Table 12](#) can be interpreted in the following way:

- This MP included about 18,000 individual CLS. If all CLS were combined to one representative curve, the result would show a standard deviation of about 10 percent, as illustrated in [Figure 16](#).

⁴ Standard deviation (SD) measures the dispersion of the data set, or how much individual data points vary from the sample mean and is calculated as: $SD = \sqrt{\sum(x - \bar{x})^2 / (n - 1)}$.

⁵ This row is highlighted as it represents the recommendation for this grouping and shows a dramatic improvement in simplicity (i.e., decrease from 18,000 to 16 CLS) with a small error (i.e., average SD < 5%).

- [Figure 16](#) also shows the relationship and similarity between standard and measure case models. The similarity persists when showing grouping by other parameters, such as building type, equipment type, equipment efficiency, capacity range, and vintage. These additional graphics are available in [Appendix D](#).
- The remaining rows show how clusters of different types improved (i.e., lowered this standard deviation); note that the deviation should never be higher than the case when all CLS are grouped together. For example, the building type row suggests that 21 CLS would be required to have a separate CLS for each building type. This increase to 21 CLS would decrease the standard deviation to an average of 7.9 percent across all building types. The maximum standard deviation is 9.9 percent, which happened to occur in the conditioned storage building type.
- In this HVAC measure package, no single parameter decreased the average and maximum standard deviation dramatically (i.e., below SD of 5 percent, which is at the lower end of the variation seen in other parameters that impact benefits, as shown in [Table 9](#)).
- When building type and building location were combined as a parameter, the number of combinations still decreased substantially from 18,000 to 357 combinations—such as Asm&CZ01, Asm&CZ01, SCn&CZ16—in this row. This improved relationship becomes visually apparent when data is plotted for just one building type, as shown in [Figure 17](#). A tighter spread of the jitter plot shows an average standard deviation of 0.7 percent and a maximum standard deviation of 3.9 percent.
- The final row of BT2&Loc2 represents groups of parameters from the building type and building location parameter lists. Instead of including 21 building types, we established four groups of buildings that show similar results. In the same way, instead of including 17 building locations, we established four groups of weather zones that show similar results. More information about how the team established these groups is included in [Appendix E](#).⁶ The combination of building and location groups decreased the number of CLS from 357 to 16, which produced a marginal impact to the jitter plot, showing an average standard deviation of 3 percent and a maximum standard deviation of 5 percent, as illustrated in [Figure 18](#).

⁶ The team acknowledges that this concept is not new—PAs have shared in previous discussions about groupings that creating a layer of groupings includes additional work their systems do not include today.

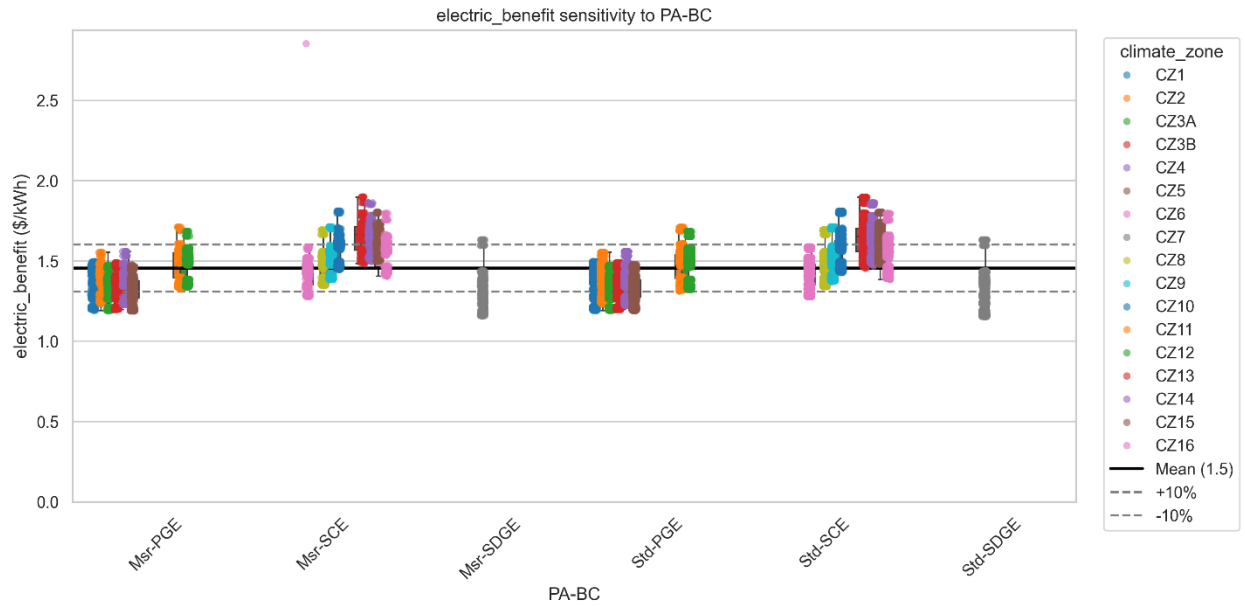


Figure 16: Unit electric benefits vs. building location and IOU and base case.

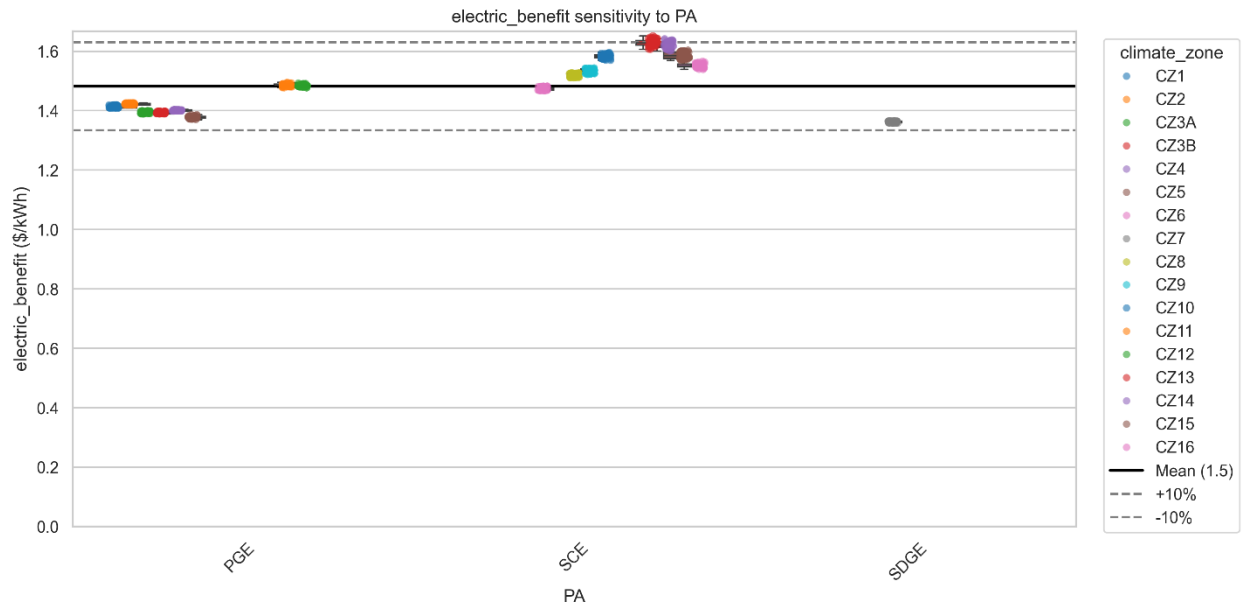


Figure 17: Unit electric benefits vs. building location and IOU for large offices.

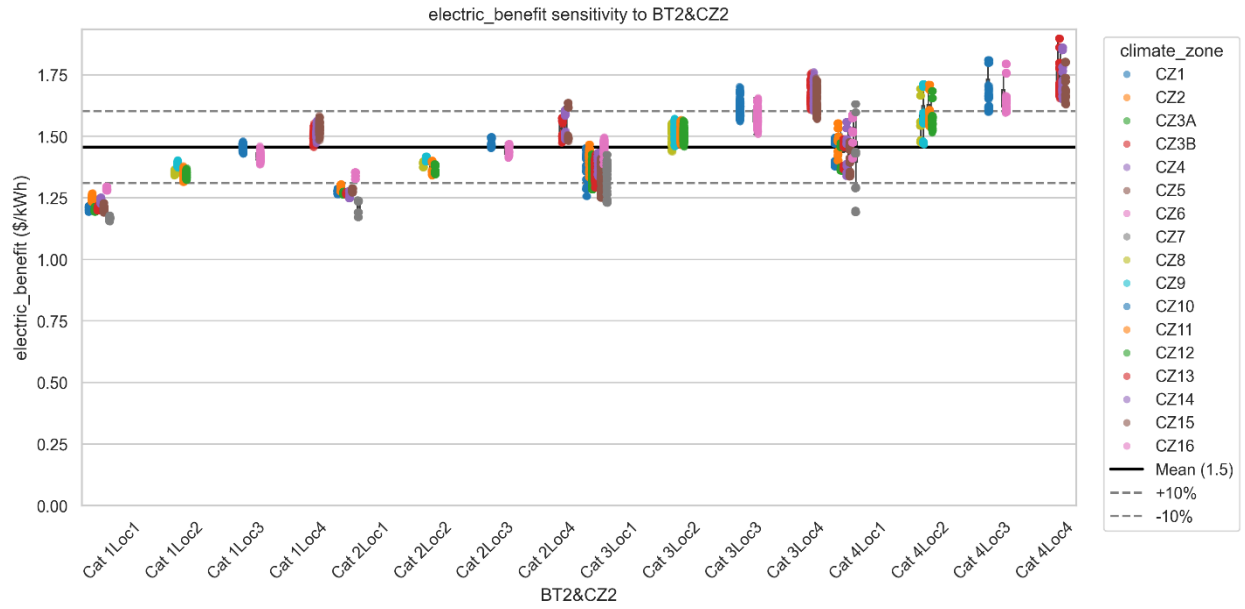


Figure 18: Unit electric benefits with groupings for building type and building location.

SWHC043, MULTIPLE CAPACITY UNITARY AIR-COOLED COMMERCIAL AC (65–240 KBTU/HR)

The measure case in this cooling-only MP was defined as a unitary air-cooled air conditioning unit with a multispeed indoor fan and a compressor with either (1) variable speed compressor(s), (2) multiple-step compressor(s), or (3) multiple compressors operating on a single refrigeration circuit (tandem compressors). Portfolio savings for this MP have been strong but have slightly decreased over the last several years. The HVAC modeled MP serves all commercial building types and building locations that have prototypes available in EnergyPlus for new and existing vintages.

Recommendation: The recommendation for this MP suggests coalescing with a combination of building type and building location. This simplification can be accomplished either directly with explicit parameters (e.g., Asm&CZ01) or with grouped parameters (e.g., BT1&Loc1), which matches the other commercial HVAC load types.

Table 13: SWHC043 parameter results.

Parameter Name	CLS	Max SD of (\$/kWh)	Avg SD of (\$/kWh)	Parameters
Whole Model	~4,000		10%	
Building Type	21	9.8%	7.5%	Asm, ECC, EPr, ERC, ESe, EUn, Gro, Hsp, Htl, MBT, MLI, Mtl, Nrs, OfL, OfS, RFF, RSD, Rt3, RtL, RtS, SCn
Building Location	16	8%	6%	CZ01, CZ02, CZ03, CZ04, CZ05, CZ06, CZ07, CZ08, CZ09, CZ10, CZ11, CZ12, CZ13, CZ14, CZ15, CZ16
Equipment Efficiency	5	10%	9.9%	10.8, 11, 12, 12.5, 13
Capacity Range	2	10%	10%	135 - 239, 65 - 134
Vintage	2	10%	9.9%	Ex, New
BT&CZ	357	4.1%	0.8%	Asm&CZ01, Asm&CZ02, ..., SCn&CZ15, SCn&CZ16
BT2&CZ2	16	4.7%	3.0%	BT1&Loc1, BT1&Loc2, ..., BT4&Loc3, BT4&Loc4

The data in [Table 13](#) can be interpreted in the following way:

- This MP included about 4,000 individual CLS. If all CLS were combined to one representative curve, the result would show a standard deviation of about 10 percent, as shown in [Figure 19](#).
- [Figure 19](#) also shows the relationship and similarity between standard and measure case models—a similarity that persists when showing grouping by other parameters, such as building type, equipment type, equipment efficiency, capacity range, and vintage. These additional graphics are available in [Appendix D](#).
- The remaining rows show how clusters of different types improved (i.e., lowered this standard deviation); note that the deviation should never be higher than the case when all CLS were grouped together. Many of the individual parameters remained close to the 10

percent average standard deviation. In this HVAC measure package, no single parameter decreased the average and maximum standard deviation dramatically.

- When building type and building location were combined as a parameter, the number of combinations still decreased substantially from 4,000 to 357 combinations—such as Asm&CZ01, Asm&CZ01, SCn&CZ16—in this row. This improved relationship became apparent when the team plotted data for just one building type, as shown in [Figure 20](#). A tighter spread of the jitter plot showed an average standard deviation of 0.8 percent and a maximum standard deviation of 4.1 percent.
- Note that the same favorable relationship was found in the previous commercial HVAC example.
- The final row of BT2&Loc2 represents groups of parameters from the building type and building location parameter lists. The combination of building and location groups decreased the number of CLS from 357 to 16, which had a marginal impact on the jitter plot, showing an average standard deviation of 3.0 percent and a maximum standard deviation of 4.7 percent.

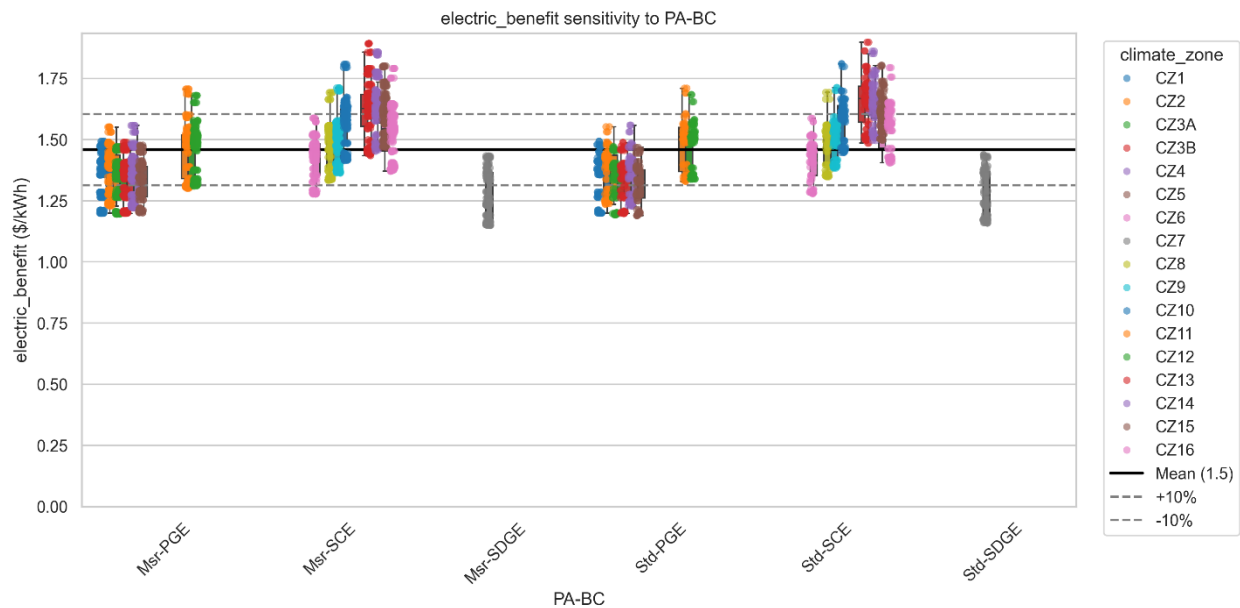


Figure 19: Unit electric benefits vs. building location and IOU.

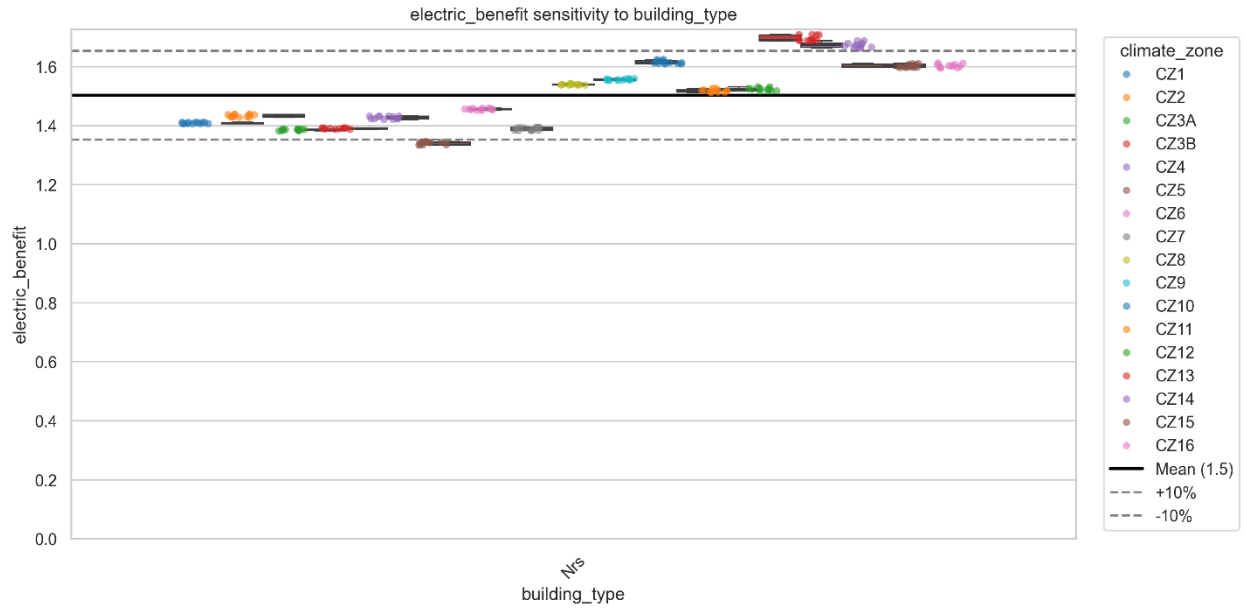


Figure 20: Unit electric benefits vs. building location and IOU for nursing home.

SWHC046, PACKAGED HEAT PUMP AC, COMMERCIAL, FUEL SUBSTITUTION

The measure case in this heating-and-cooling MP was an electric air-source heat pump that uses auxiliary heat—also known as electric resistance heating—when additional heating is required. The base case in this fuel substitution MP was a commercial packaged (or split-system) unit with electric direct expansion cooling and gas heating. This HVAC MP offers moderate savings, and the HVAC modeled MP serves all commercial building types and building locations that have prototypes available in EnergyPlus for existing vintages. Note that for fuel substitution MPs, the electric benefit is actually negative; it is called the electric supply cost, and it impacts total TSB differently for fuel substitution and energy efficiency MPs.

Recommendation: The recommendation for this MP suggests coalescing with a combination of building type and building location. This simplification can be accomplished either directly with explicit parameters (e.g., Asm&CZ01) or with grouped parameters (e.g., BT1&Loc1), which matches the other commercial HVAC load types.

Table 14: SWHC046 parameter results.

Parameter Name	CLS	Max SD of (\$/kWh)	Avg SD of (\$/kWh)	Parameters
Whole Model	~7,500		12%	
Building Type	21	13%	11%	Asm, ECC, EPr, ERC, ESe, EUn, Gro, Hsp, Htl, MBT, MLI, Mtl, Nrs, OfL, OfS, RFF, RSD, Rt3, RtL, RtS, SCn
Building Location	16	8%	5%	CZ01, CZ02, CZ03, CZ04, CZ05, CZ06, CZ07, CZ08, CZ09, CZ10, CZ11, CZ12, CZ13, CZ14, CZ15, CZ16
Equipment Type	5	12%	12%	IEER-rated Package Heat Pump, SEER2-rated Package Heat Pump, SEER2-rated Package Heat Pump 1 Stage, SEER2-rated Package Heat Pump 2 Stage, SEER2-rated Split Heat Pump
Equipment Efficiency	18	13%	12%	11.4, 12.2, 12.35, 12.7, 13.2, 13.4, 13.5, 14, 14.2, 14.4, 14.5, 14.8, 15, 15.4, 15.5, 16, 16.3, 17.3
BT&CZ	357	2.7%	0.7%	Asm&CZ01, Asm&CZ02, ..., SCn&CZ15, SCn&CZ16
BT2&CZ2	16	5.3%	2.7%	BT1&Loc1, BT1&Loc2, ..., BT4&Loc3, BT4&Loc4

The data in [Table 14](#) can be interpreted in the following way:

- This MP included about 7,500 individual CLS. If all CLS were combined to one representative curve, the result would show a standard deviation of about 12 percent, as shown in [Figure 21](#).

- [Figure 21](#) also shows the relationship and similarity between standard and measure case models. The similarity persists when showing grouping by other parameters, such as building type, equipment type, equipment efficiency, capacity range and vintage. These additional graphics are available in [Appendix D](#).
- The remaining rows show how clusters of different types improved (i.e., lowered this standard deviation); note that the deviation should never be higher than the case when all CLS are grouped together, and many of the individual parameters remained close to the 12 percent average standard deviation. In this HVAC measure package, building location decreased average standard deviation, but maximum standard deviation remained higher.
- Note again that parameters like equipment type, equipment efficiency, and vintage did not drive statistical differences in the load shape.
- When building type and building location were combined as a parameter, the number of combinations still decreased substantially from 7,500 to 357 combinations—such as Asm&CZ01, Asm&CZ01, SCn&CZ16—in this row. This improved relationship became apparent when the team plotted data for just one building location, as shown in [Figure 22](#). A tighter spread of the jitter plot showed an average standard deviation of 0.7 percent and a maximum standard deviation of 2.7 percent.
- The final row of BT2&Loc2 represents groups of parameters from the building type and building location parameter lists. The combination of building and location groups decreased the number of CLS from 357 to 16, which had a marginal impact on the jitter plot, showing an average standard deviation of 5.3 percent and a maximum standard deviation of 2.7 percent.

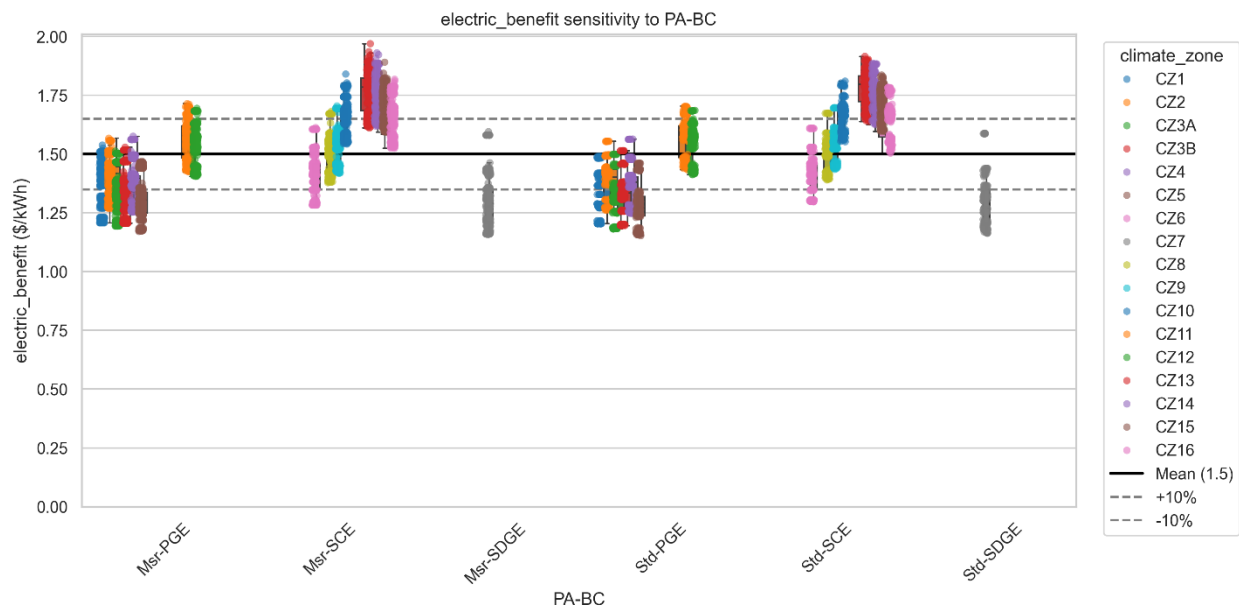


Figure 21: Unit electric benefits vs. building location and IOU.

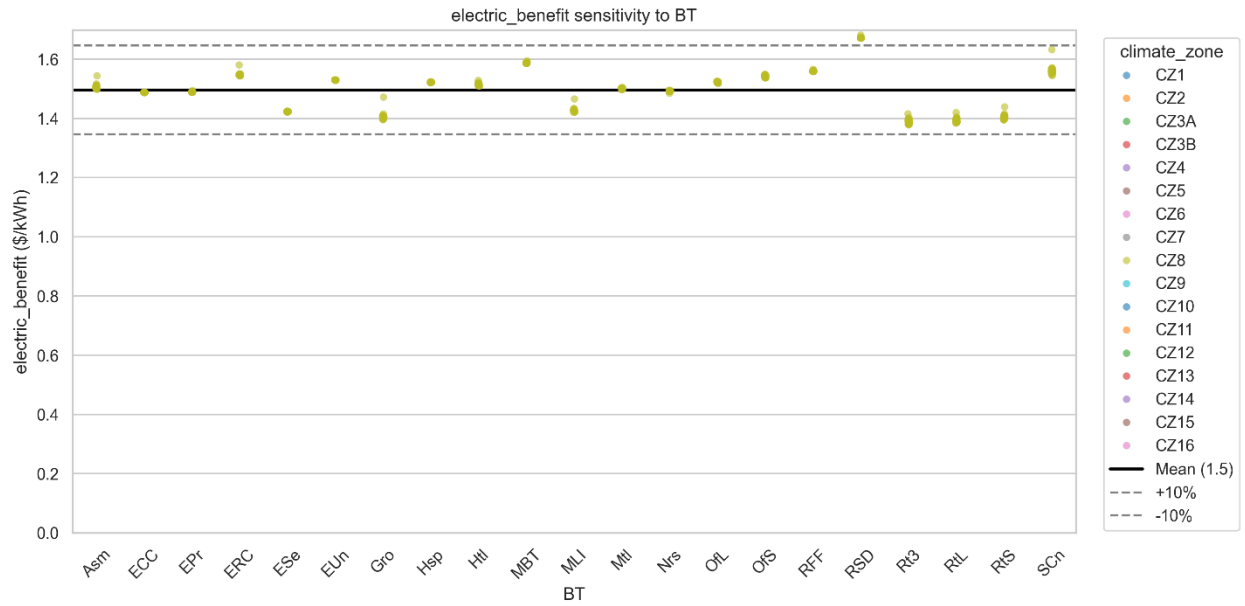


Figure 22: Unit electric benefits for building location 8 only.

SWHC045, HEAT PUMP HVAC, RESIDENTIAL, FUEL SUBSTITUTION

The measure case in this heating-and-cooling MP is an electric central air-source heat pump that utilizes auxiliary heat, also known as electric resistance heating, when additional heating is required. The base case for this fuel substitution MP was defined as a residential central air conditioning unit (direct-expansion type) for cooling and a gas furnace or a hot water boiler connected to either a fan coil unit or radiator system for space heating. This high-value MP ranks amongst the most valuable in terms of TSB within the portfolios. The HVAC modeled MP serves all residential building types and building locations that have prototypes available in EnergyPlus for existing vintages.

Recommendation: The recommendation for this MP uses a combination of HVAC type and building location, which matches the other residential HVAC load types.

Table 15: SWHC045 parameter results.

Parameter Name	CLS	Max SD of (\$/kWh)	Avg SD of (\$/kWh)	Parameters
Total Models	640		18%	
Building Type	3	20%	17%	DMo, MFm, SFm
Building Location	16	22%	14%	CZ01, CZ02, CZ03, CZ04, CZ05, CZ06, CZ07, CZ08, CZ09, CZ10, CZ11, CZ12, CZ13, CZ14, CZ15, CZ16
Equipment Type	5	17%	13%	DXGF, DXHP, DXHW, NCGF, NCOH
Equipment Efficiency	9	16%	14%	12.4, 14.3, 15.2, 16, 16.9, 17.8 18.7, 19.6, No Cooling
HVAC&CZ	86	21%	5.4%	DXGF&CZ01, DXGF&CZ01, ..., NCOH&CZ15, NCOH&CZ16
HVAC&CZ2	20	25%	18%	DXGF&Loc1, DXGF&Loc2, ..., NCOH&Loc3, NCOH&Loc4

The data in [Table 15](#) can be interpreted in the following way:

- This MP included about 640 individual CLS. If all CLS were combined to one representative curve, the result would show a standard deviation of about 18 percent, as shown in [Figure 23](#).
- [Figure 24](#) shows the same data as [Figure 23](#), except that measure and standard cases were differentiated on the same graphic. In this case, the difference was significant, which stems from the different HVAC cases between measure case (e.g., heat pumps) and standard case (e.g., no cooling with gas furnace, direct expansion with gas furnace, direct expansion with hot water heat, or no cooling with other heat). In these instances, the team recommends coalescing the base and measure cases separately.
- The remaining rows show how clusters of different types improved (i.e., lowered this standard deviation), but they do not make a dramatic improvement. Many of the individual parameters remained close to an 18 percent average standard deviation. In this HVAC measure package, individual parameters showed local improvements, but key outliers kept the maximum deviation high. Two examples of outlier impact within a parameter

include no cooling in the NCGF and NCOH HVAC types and hydronic heating in the multifamily buildings.

- When HVAC type and building location were combined as a parameter, the number of combinations—such as DXGF&CZ01, DSGF&CZ01, and NCOH&CZ16—decreased from 640 to 86. This improved relationship became apparent when the team plotted data for just one building location, as shown in [Figure 25](#). A tighter spread of the jitter plot showed an average standard deviation of 5.4 percent, but the maximum standard deviation still spiked to 21 percent, partially due to hydronic details and building type.
- In this case, HVAC type could be improved by breaking out systems into different names if they performed significantly differently. DXHW could include options for fan coils or radiators, should these differences be modeled.

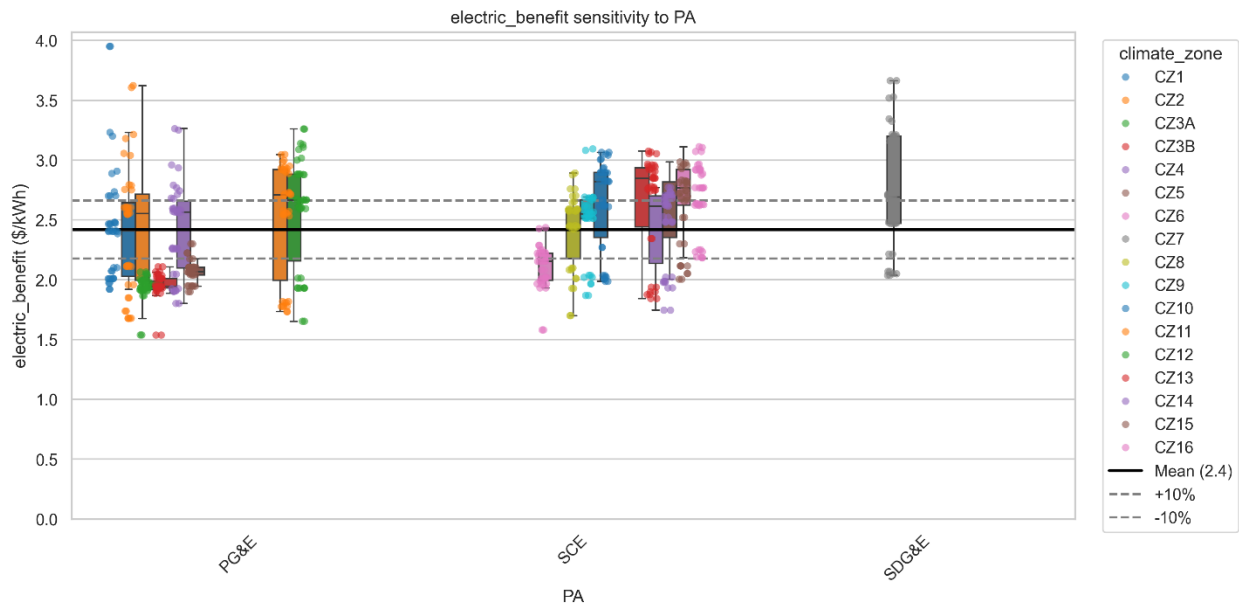


Figure 23: Unit electric benefits vs. building location and IOU.

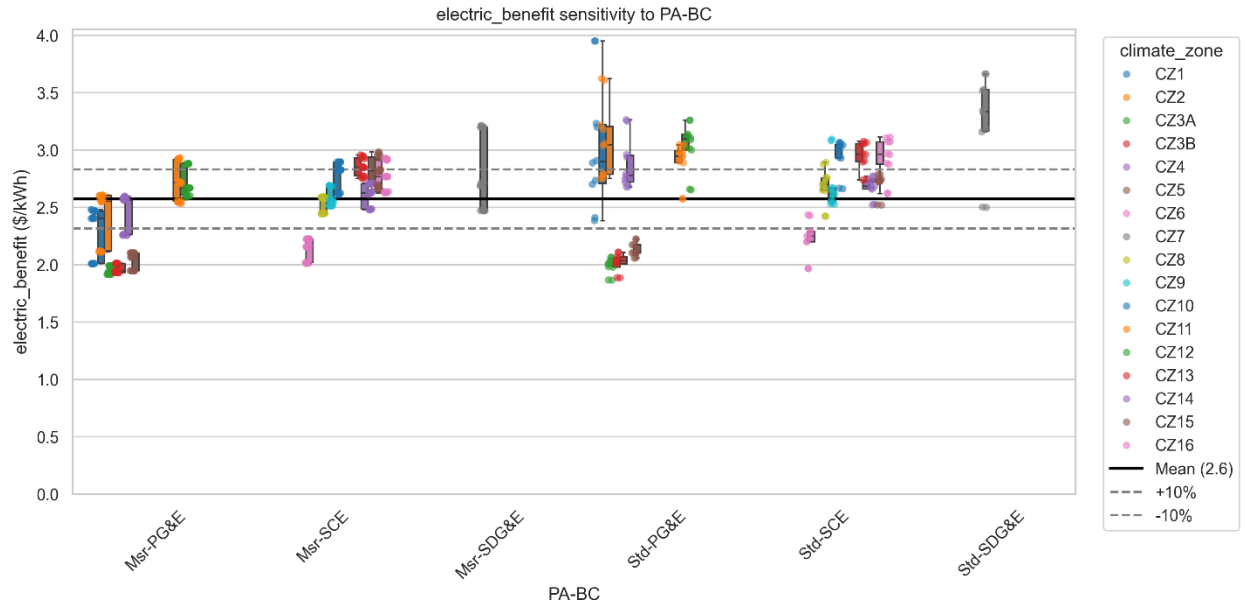


Figure 24: Unit electric benefits vs. building location and IOU with measure/standard cases broken out.

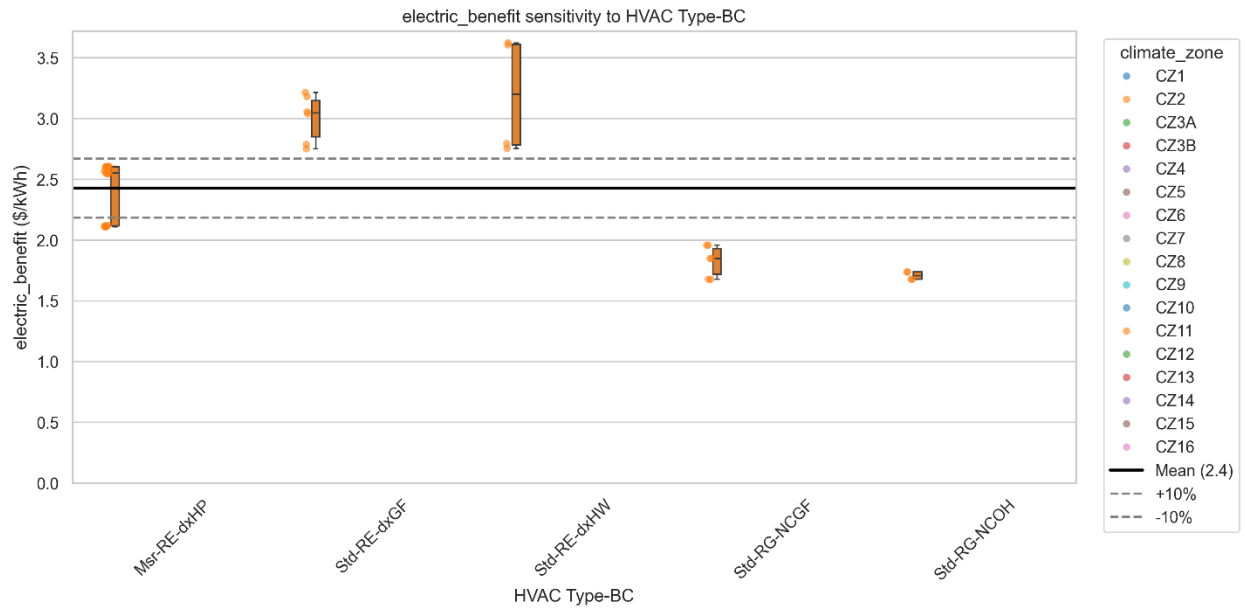


Figure 25: Unit electric benefits vs. building location and HVAC type for building location 2.

SWSV001, DUCT SEAL, RESIDENTIAL

The measure case in this heating-and-cooling MP was defined as duct sealing to reduce total leakage from a “high” or “medium” leakage rate to a “low” leakage rate in a residential building. This MP is still a high savings measure in the portfolio but has produced fewer benefits in recent years. The HVAC, modeled MP serves all residential building types and building locations that have prototypes available in EnergyPlus for existing vintages.

Recommendation: The recommendation for this MP uses a combination of HVAC type and building location, which matches the other residential HVAC load types. In this case, outliers may require more definition to reduce maximum standard deviations.

Table 16: SWSV001 parameter results.

Parameter Name	CLS	Max SD of (\$/kWh)	Avg SD of (\$/kWh)	Parameters
Total Models	612		18%	
Building Type	3	19%	18%	DMo, MFm, SFm
Building Location	16	23%	15%	CZ01, CZ02, CZ03, CZ04, CZ05, CZ06, CZ07, CZ08, CZ09, CZ10, CZ11, CZ12, CZ13, CZ14, CZ15, CZ16
Equipment Type	3	16%	10%	DXGF, DXHP, NCGF
Equipment Efficiency	2	19%	18%	0, 1, 2
Case	3	18%	18%	Pre-HV-DuctSeal-MedToLow, Pre-HV-DuctSeal-HighToLow, Duct_Seal_Measure_Low
BT&CZ	51	28%	14%	DMo&CZ01, DMo&CZ02, ..., SFm&CZ15, SFm&CZ16
HVAC&CZ	52	13%	4.6%	DXGF&CZ01, DXGF&CZ01, ..., NCGF&CZ15, NCGF&CZ16
HVAC&BT	9	16%	10%	DXGF&DMo, DXGF&DMo, ..., NCGF&SFm, NCGF&SFm

The data in [Table 16](#) can be interpreted in the following way:

- This MP included about 600 individual CLS. If all CLS were combined to one representative curve, the result would show a standard deviation of about 18 percent. This spread is visually shown in the [Figure 26](#).
- [Figure 27](#) shows how similar standard and measure cases appear. In this situation, HVAC type did not drive the difference between standard and measure cases, so the graphics appear very similar, but all still include a high deviation.
- The remaining rows show how clusters of different types marginally improved (i.e., lower this standard deviation). Many of the individual parameters remained close to 18 percent average standard deviation.
- When building type and building location were combined as a parameter, the number of combinations (such as DMo&CZ01, DMo&CZ01, or SFm&CZ16) decreased from 612 to

51. This more constrained relationship still shows a high spread of the jitter plot with an average standard deviation of 14 percent and a maximum standard deviation of 28 percent.

- For this residential HVAC measure, the pattern of combining HVAC type and building location improved the variation. The spread of the jitter plot shows an average standard deviation of 4.6 percent and a maximum standard deviation of 13 percent.
- [Figure 28](#) shows the tighter pattern for two HVAC types (i.e., DXHP and NCGF), but one HVAC type still had a few instances of larger higher standard deviation.

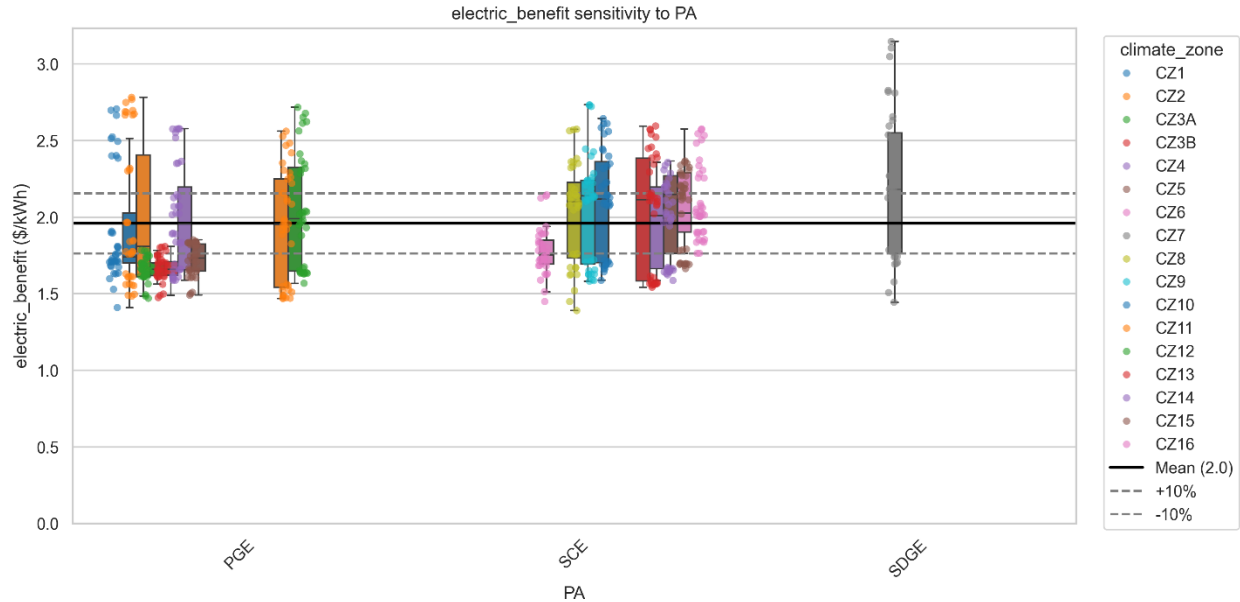


Figure 26: Unit electric benefits versus building location and IOU.

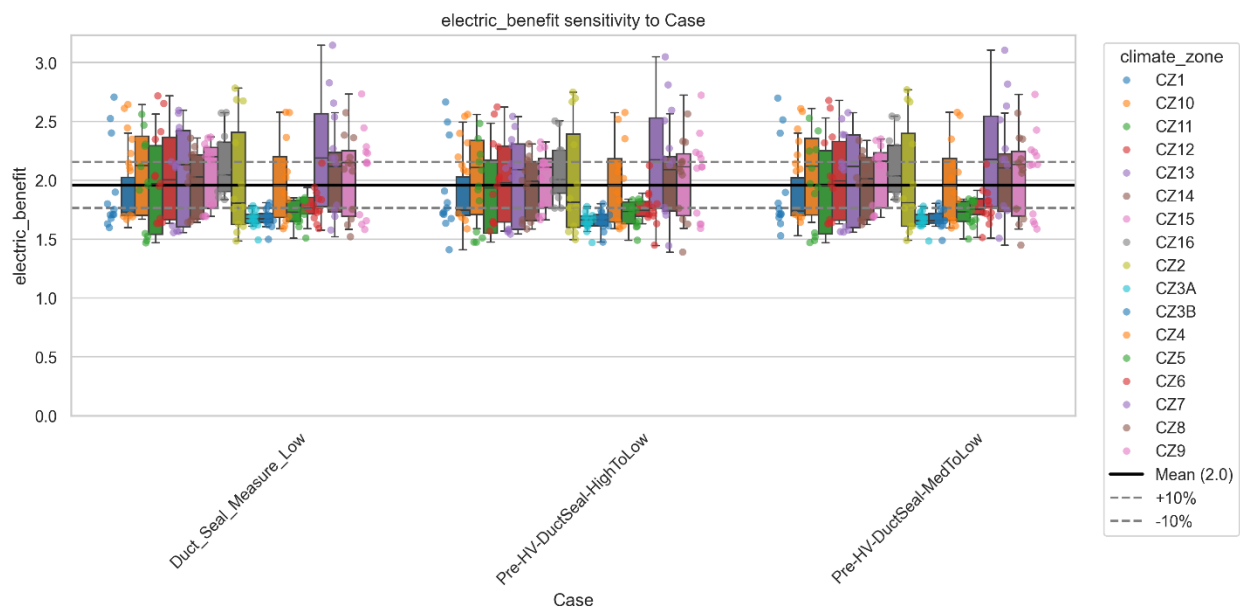


Figure 27: Unit electric benefits versus case type.

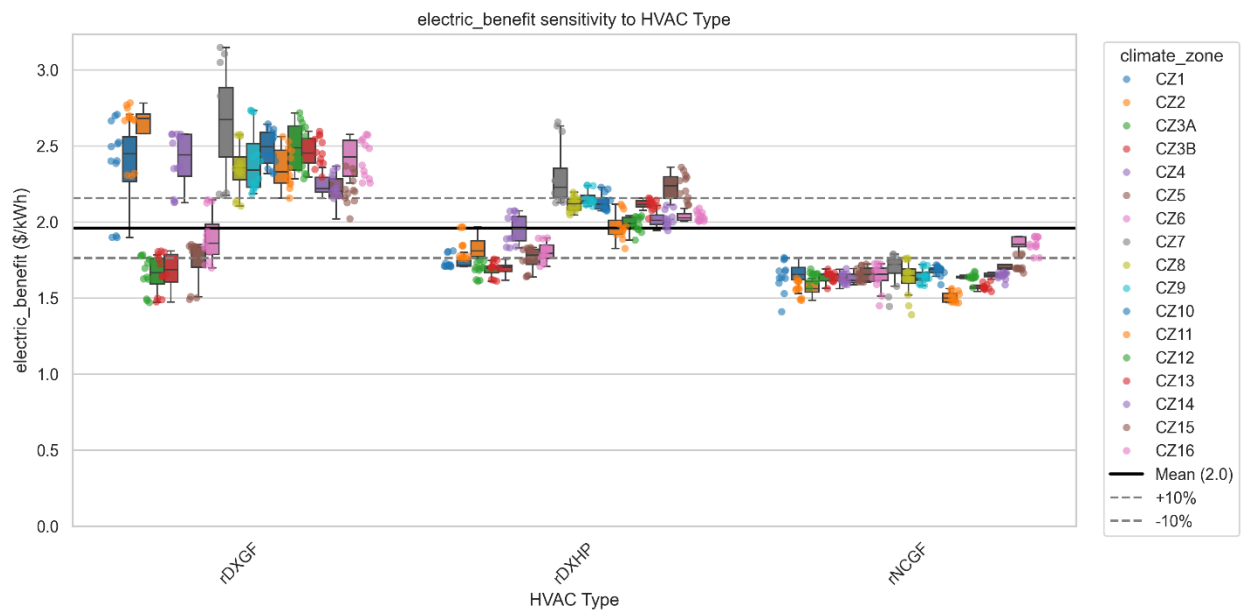


Figure 28: Unit electric benefits versus building location and HVAC type.

SWWH025, HEAT PUMP WATER HEATER, RESIDENTIAL, FUEL SUBSTITUTION

As a fuel substitution measure, the measure case in this water-heating MP was defined as a heat pump water heater that replaced a base case natural gas water heater. In addition to a traditional 240V heat pump water heater, this measure included offerings for a 120V heat pump water heater with or without electric resistance elements. This MP provided TSB to the portfolio, and those benefits continue to expand. The water heating, modeled MP served all residential building types and building locations with prototypes available in EnergyPlus for existing vintages.

Recommendation: The recommendation for this MP suggests that a single CLS could represent the entire MP. It is expected that this similarity follows from the fact that the hot water usage profiles used to model the residential building types are relatively consistent with each other. In addition, the water heaters are assumed to be in an interior unconditioned space without much weather variability. If they are modeled in conditioned space or exterior, the building location may show higher variability. Because equipment types are different between standard and measure cases, it is recommended that separate CLS are developed for each.

Table 17: SWWH025 parameter results.

Parameter Name	CLS	Max SD of (\$/kWh)	Avg SD of (\$/kWh)	Parameters
Total Models	3,000		4.3%	
Building Type	3	4.4%	4.2%	DMo, MFm, SFm
Building Location	17	4.8%	3.1%	CZ01, CZ02, CZ03, CZ04, CZ05, CZ06, CZ07, CZ08, CZ09, CZ10, CZ11, CZ12, CZ13, CZ14, CZ15, CZ16
Equipment Efficiency	8	4.4%	3.9%	2.75, 3.00, 3.30, 3.50, 3.75
Equipment Type	2	4.0%	3.0%	HP_UEF, Instant_UEF ⁷
Capacity Range	6	4.5%	3.7%	30 Gal, 40 Gal, 50 Gal, 60 Gal, 75 Gal, High Draw
Voltage	2	4.3%	4.2%	120V, 240V
ER	2	4.2%	4.2%	With Electric Resistance, Without Electric Resistance
BT&CZ	51	5.1%	2.6%	DMo&CZ01, DMo&CZ02, ..., SFm&CZ15, SFm&CZ16
GW	4	4.7%	3.9%	GW1, GW2, GW3, GW4

The data in [Table 17](#) can be interpreted in the following way:

- This MP included about 3,000 individual CLS. If all CLS were consolidated in one representative curve, the result would show a standard deviation of about 4.3 percent.

⁷ The Instant_UEF equipment type represents the baseline for this fuel substitution MP. While the instantaneous heater utilizes an electric fan during operation, the gas storage baseline does not include any electric consumption.

This spread is visually shown in the [Figure 29](#). This level of variation is reasonable across the full data set.

- [Figure 30](#) shows the relationship between standard and measure cases. Where there is a physical difference in equipment between the standard and measure case, coalescing should be considered separately to improve accuracy. For this measure package where one CLS is recommended, the solution could be one CLS for a heat pump water heater, an instantaneous gas water heater, and a storage gas water heater.
- The remaining rows show how clusters of different types marginally improved (i.e., lowered standard deviation). Many of the individual parameters remained close to the 4 percent average standard deviation.
- When building type and building location were combined as a parameter, the number of combinations in this row (e.g. DMo&CZ01, DMo&CZ01, SFm&CZ16) decreased to 51. This more constrained relationship still shows a tighter cluster of the jitter plot with an average standard deviation of 2.6 percent and a maximum standard deviation of 5 percent, as shown in [Figure 31](#). However, the improvement was not substantially different from combining the entire measure case data set.
- Groundwater temperature groups, where similar groundwater temperatures were gathered, provided little additional benefit. [Figure 32](#) shows the results for groupings of groundwater that were suggested by Cal TF Staff in an October 2024 meeting. These groups are illustrated in Appendix E.

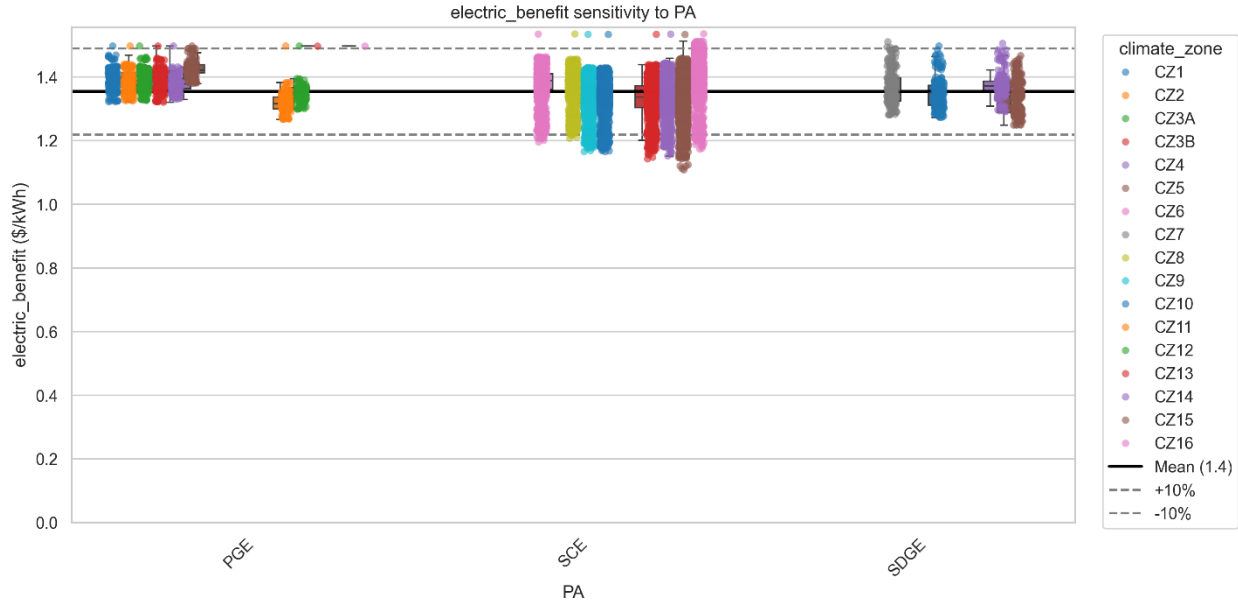


Figure 29: Unit electric benefits versus building location and IOU.

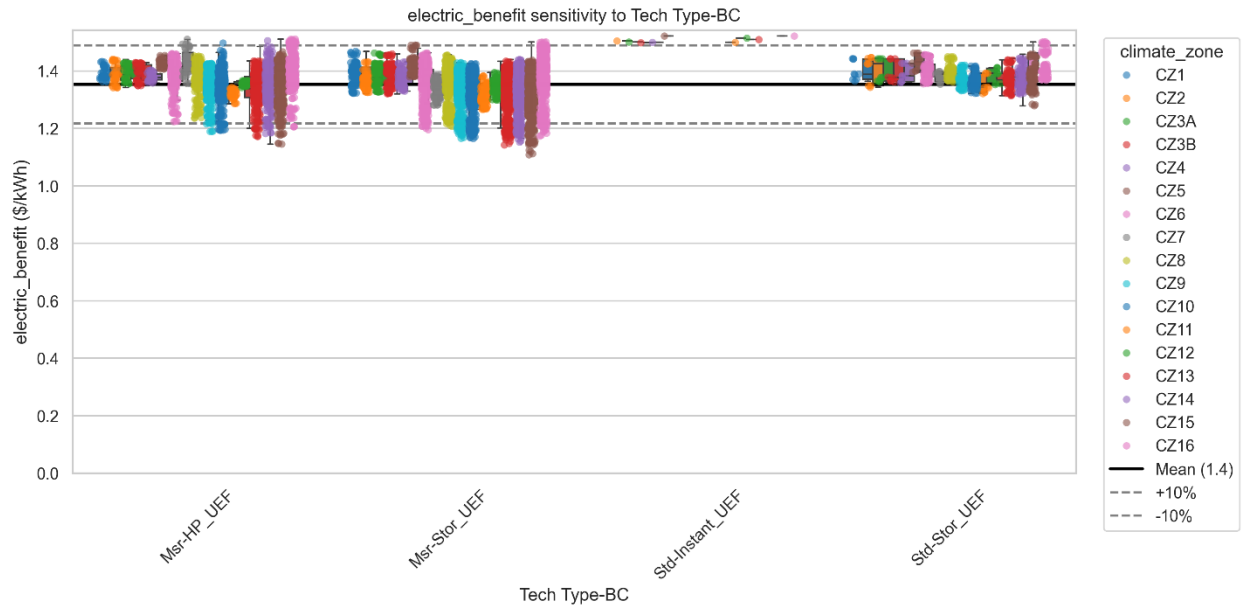


Figure 30: Unit electric benefits versus tech type to show variation between standard and measure cases.

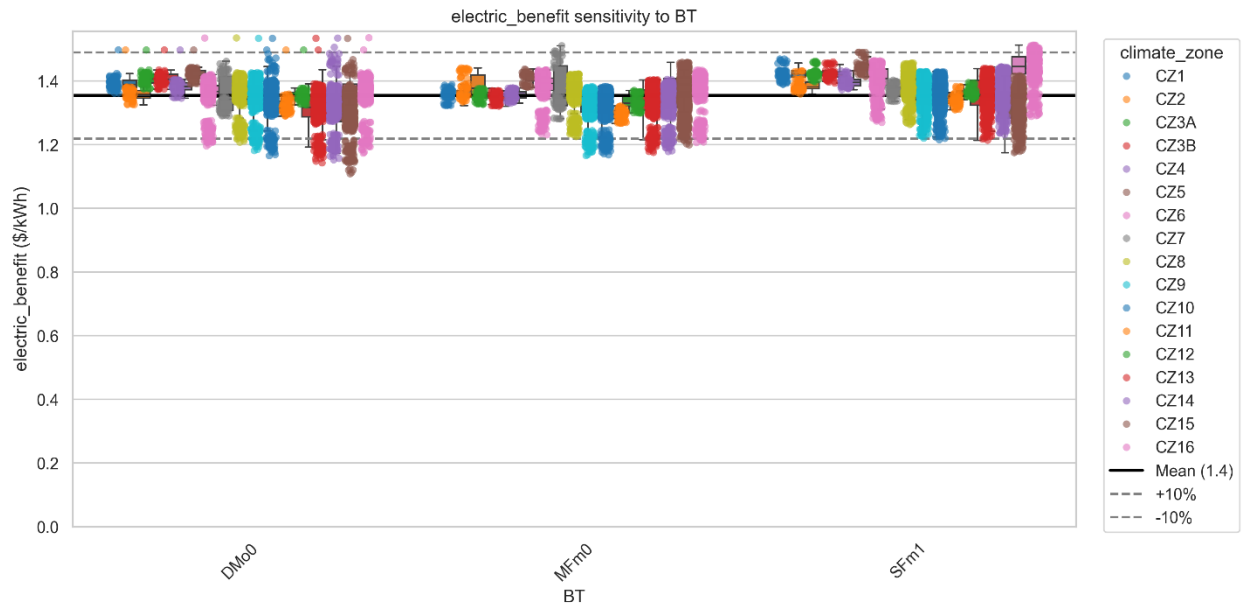


Figure 31: Unit electric benefits versus building location and building type.

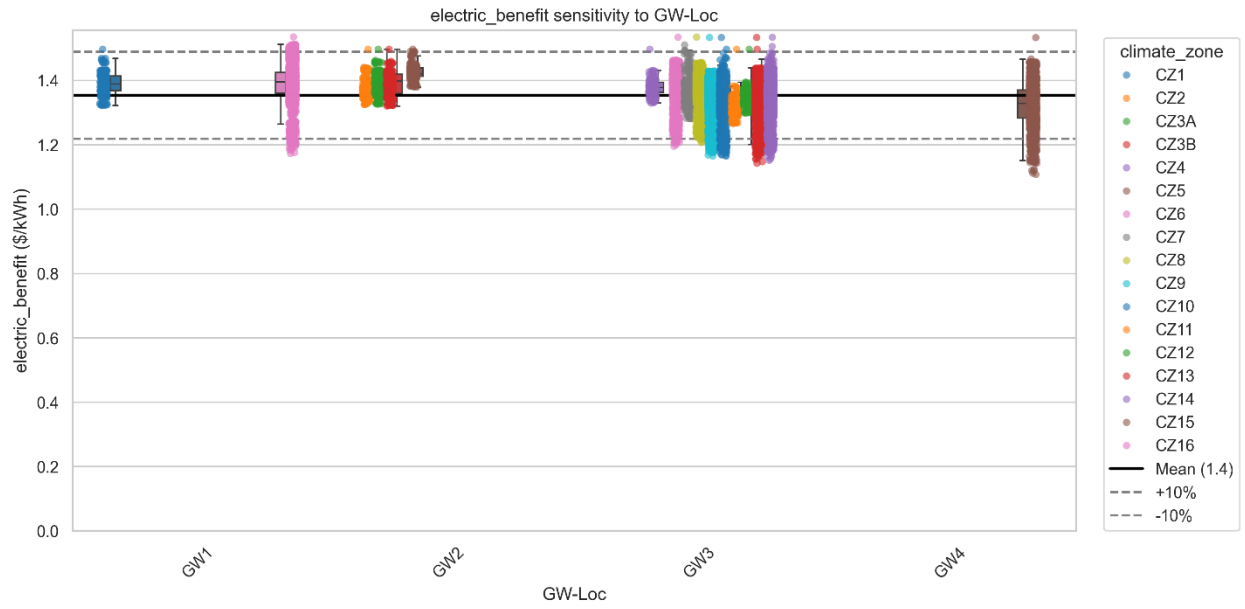


Figure 32: Unit electric benefits versus groundwater groupings.

SWWH014, HEAT PUMP WATER HEATER, RESIDENTIAL

The measure case in this water-heating MP included the traditional 240V heat pump water heater and offerings for 120V heat pump water heaters with or without electric resistance elements. The base case was defined as an electric storage water heater with a storage volume of 30, 40, or 50 gallons. This MP has been moderately valuable to the portfolio but has provided reduced benefits in recent years. The water heating, modeled MP served all residential building types and building locations with prototypes available in EnergyPlus for existing vintages.

Recommendation: The recommendation for this MP suggests that a single CLS could represent the entire MP. Because equipment types are different between standard and measure cases, it is recommended that separate CLS are developed for each.

Table 18: SWWH014 parameter results.

Parameter Name	CLS	Max SD of (\$/kWh)	Avg SD of (\$/kWh)	Parameters
Total Models	3,000		4.3%	
Building Type	3	4.4%	4.2%	DMo, MFm, SFm
Building Location	16	4.8%	3.1%	CZ01, CZ02, CZ03, CZ04, CZ05, CZ06, CZ07, CZ08, CZ09, CZ10, CZ11, CZ12, CZ13, CZ14, CZ15, CZ16
Equipment Efficiency	8	4.4%	3.9%	2.75, 3.00, 3.30, 3.50, 3.75
Equipment Type	2	4.0%	3.0%	HP_UEF, Stor_UEF
Capacity Range	6	4.5%	3.7%	<45, >=45 to <=55, >55 to <=75, >75
Voltage	2	4.3%	4.2%	120V, 240V
ER	2	4.2%	4.2%	With Electric Resistance, Without Electric Resistance
BT&CZ	51	5.1%	2.6%	DMo&CZ01, DMo&CZ02, ..., SFm&CZ15, SFm&CZ16

The data in [Table 18](#) can be interpreted in the following way:

- This MP acted as the energy efficiency counterpart to the fuel substitution measure of SWWH025.
 - Note that this MP matches the model list for the measure case from SWWH025 with the addition of base cases since this MP represents a more complex electric base case than is seen with fuel substitution MPs.
- Model results are frequently shared between MPs, due to the relationship between an energy efficiency and fuel substitution pair, but more cases are likely to exist. The load shapes with their technology ID should be copied directly between MPs.
- Ideally, measures can be linked in the eTRM so that the relationship is more automatic, as there is a risk that updating one measure can cause other measures to get out of sync. As soon as technology IDs with their load shapes are shared between MPs, close versioning procedures are required to avoid causing unintended consequences in the data system.

- This MP also included an analysis of impact load shapes. This additional explanation is included in the next section, "Measure Package Impact Analysis."

SWWH001, FAUCET AERATOR, RESIDENTIAL

The measure case in this water-heating MP was defined as a low-flow faucet aerator or flow control valve installed on a lavatory or kitchen faucet in a residential building. Offerings focused on electric heating were only included in this analysis where energy savings were based upon water savings that would have been heated by the electric equipment. This MP has been moderately valuable to the portfolio but has produced reduced in recent years. Since savings are tied to water heating, the electric water heater measures were identified as an appropriate model for load.

The results from this MP are a good example of two important recommendations:

- How CLS can be leveraged across MPs
- How secondary CLS can be considered

The CLS for this MP follow directly what could be considered a parent measure package of SWWH014 – Residential, Heat Pump Water Heater. Since this measure was not modeled directly in a simulation package, CLS were not directly available. However, a proxy of this usage pattern could be taken from SWWH014, which ensured that usage assumptions for both measures were in alignment. SWWH014 included hot water heating for purposes beyond just faucets, but this data set could be considered the best available data.

In cases like this, the same technology IDs should be used for both measure packages. However, careful thought should be given to the handling of versions. For example, if the load pattern of the residential heat pump water heater is updated, potentially due to code, when should this change impact an existing residential faucet aerator MP? Versioning of CLS can give CPUC control of this transition. Note that without a version that is associated with the technology ID, updating the residential heat pump water heater model would trigger additional steps that may or may not be desired:

- The load shape(s) for the residential heat pump water heater MP that are linked to certain technology IDs would be updated.
- The CEDARS system would update the avoided costs for the combination of technology ID, building location, and IOU.
- Any MP using these combinations of technology ID, building location, and IOU would utilize the new avoided cost data. This data would be available specifically for the new residential heat pump water heater MP, but the same changes may also apply to the previous versions of the residential heat pump water heater MP, the fuel substitution version of this measure package, and possibly water savings measures like aerators and efficient showerheads.

In this MP, the secondary load shape came from energy savings through pumping. These savings were not on-site but instead at a municipal level to maintain pumping pressurization within the water lines. For this reason, water savings should roughly coincide with the portion of pumping savings that is attributed to this project. The impact on the cost-effectiveness of shifting a curve by a proportional amount (e.g., 110 percent of the original amount) did not change the resulting value because unitizing the CLS translated it back to the same curve.

It should be noted that the other common case where a secondary load shape was present in an MP was the case of interactive effects. The shift in this case may not have been proportional and instead

weighted to specific times of the day or year due to the way the HVAC system responded to the saved energy. While the impact was not zero in this case, sample tests show that interactive effects were minor in many cases of HVAC and water heating:

- HVAC MPs showed 0 percent interactive effects (tested on SWHC043⁸).
- Water heating MPs showed 1 percent interactive effects (tested on SWWH014) where water heaters were located in unconditioned spaces.
- Interior lighting MPs showed an average of about 7 percent interactive effects (based upon the commercial interactive effect table in the eTRM).

⁸ Test included a comparison of the savings differences when subtracting building level annual hourly data versus end-use annual hourly data of base and measure case values. The difference should only be due to interactive effects (i.e., additional heating or cooling that may be required when load is added or removed from a conditioned space).

SWCR001, ANTI-SWEAT HEATER CONTROLS

The measure case was defined as anti-sweat heater controls for a reach-in low-temperature display case (freezer, case temperature below 32°F) and medium-temperature display case (cooler, case temperature at or above 32°F). This MP has been highly valuable to the portfolio but has produced reduced benefits in recent years. The commercial refrigeration modeled MP served several building types that typically had display cases. However, only the grocery store prototype was used to simulate energy usage. This one commercial building type was evaluated with all building locations in EnergyPlus for existing vintages.

Recommendation: The recommendation for coalescing this MP includes the building location to keep error low.

Table 19: SWCR001 parameter results.

Parameter Name	CLS	Max SD of (\$/kWh)	Avg SD of (\$/kWh)	Parameters
Total Models	48		2.4%	
Building Type	1	0%	0%	Gro, Htl, RFF, RSD, Rt3, RtL, RtS ⁹
Building Location	16	0.6%	0.3%	CZ01, CZ02, CZ03, CZ04, CZ05, CZ06, CZ07, CZ08, CZ09, CZ10, CZ11, CZ12, CZ13, CZ14, CZ15, CZ16
Equipment Type	3	2.4%	2.4%	No ASH Controls, ASH Controls on LT, ASH Controls on MT

The data in [Table 19](#) can be interpreted in the following way:

- This MP included 52 individual CLS. If all CLS were combined to one representative curve, the result would show a standard deviation of about 2.4 percent. This spread is visually shown in the [Figure 33](#). This level of variation is reasonable across the full data set.
- The remaining rows show how clusters of different types marginally improved (i.e., lower this standard deviation). Note that building type was parameterized, but this measure only applied to grocery stores, so only a single building type was modeled. Also, the impact of equipment type, which represents the base and two measure cases, had virtually no impact, which can be seen in [Figure 34](#).
- The impact of building location was the most significant item for this measure package. By including 16 CLS to reflect the various building locations, the average standard deviation dropped to 0.3 percent, and the maximum standard deviation describing the variation to the final remaining parameter of measure case was 0.6 percent. The consistency of maintaining building location across this and other measure packages could be a good reason to take a consistent approach for commercial refrigeration measure packages as well.

⁹ Only one building type is typically simulated for commercial refrigeration MPs, the grocery store building type. Other parameters are included in this list since they are part of the MP but they adopt the unit savings from the grocery store.

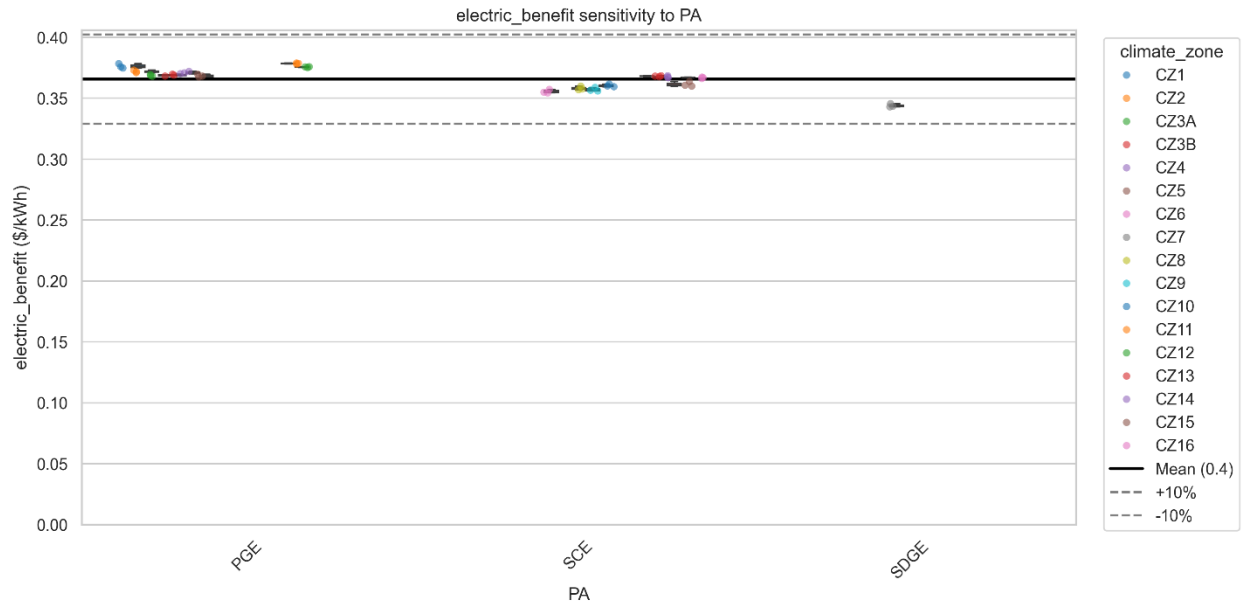


Figure 33: Unit electric benefits vs. building location and IOU.

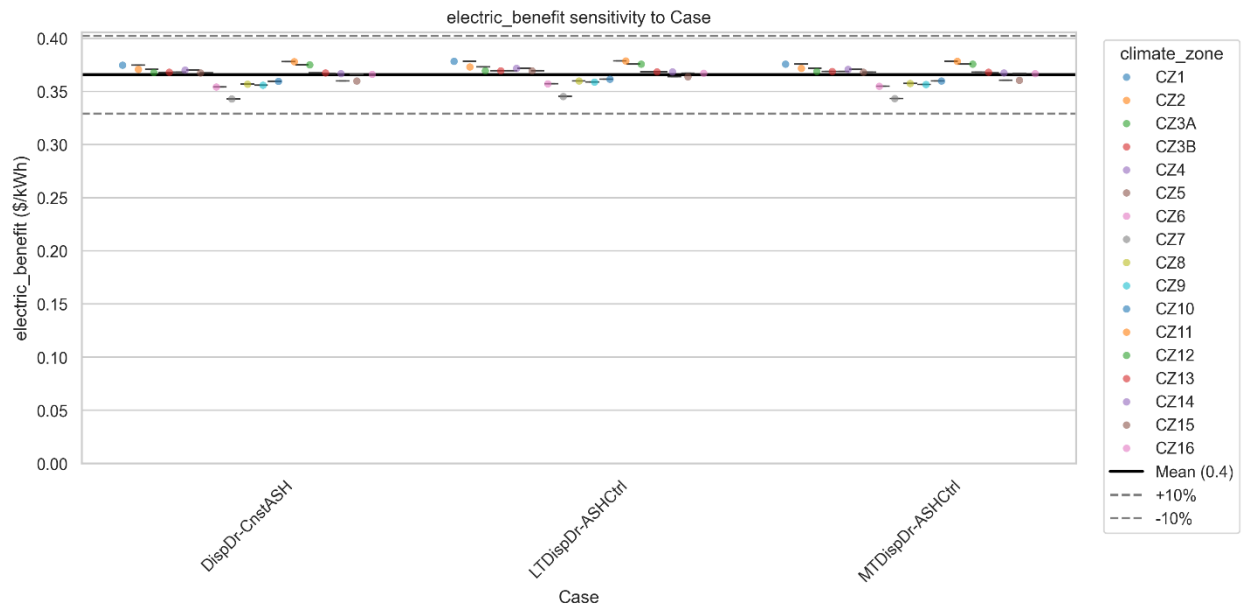


Figure 34: Unit electric benefits vs. building location and display case type.

SWFS021, FRYER, COMMERCIAL, FUEL SUBSTITUTION

The measure case in this MP of the standard and large vat commercial electric fryers accounted for idle energy rate, cooking efficiency rate, and production capacity that met or exceeded the ENERGY STAR® certification requirements. The base case specification represents the performance characteristics of a gas fryer equipment that did not meet ENERGY STAR certification requirements. While this MP did not yet have any savings in the portfolio, the gas fryer MP has produced significant gas savings over the years. Therefore, the potential for this fuel substitution MP remains significant because the existence of new and existing gas fryers in the market is substantial. The non-modeled nature of the measure means that sources other than EnergyPlus must be used. In this case, ComStock data has been used to describe CLS.

Recommendation: The recommendation for this MP includes adding the building type to allow for schedule to be included with both standard and measure cases.

Table 20: SWFS021 parameter results.

Parameter Name	CLS	Max SD of (\$/kWh)	Avg SD of (\$/kWh)	Parameters
Total Models	14		6.6%	
Building Type	7	5.3%	5.3%	EPr, ESe, Hsp, Htl, RFF, RSD, Rtl
Building Location	16	5.6%	5.4%	CZ01, CZ02, CZ03, CZ04, CZ05, CZ06, CZ07, CZ08, CZ09, CZ10, CZ11, CZ12, CZ13, CZ14, CZ15, CZ16

The data in [Table 20](#) can be interpreted in the following way:

- This MP included 14 individual CLS. If all CLS were combined to one representative curve, the result would show a standard deviation of about 6.6 percent. This spread is visually shown in the [Figure 35](#).
- Note that in this case, the spread is tied more to IOU than it is to the building location parameter, which can be seen in [Figure 36](#). These were not weather-dependent load shapes, so the only impact between PAs and not building locations came from the variation of generation avoided costs and discount rate.
- The CLS were obtained from the National Laboratory of the Rockies' ComStock dataset representing commercial electric cooking equipment. Specific fryer shapes were not available, so the general electric food service shapes were selected for available building types for the state of California. This MP included 14 eligible building types, however, ComStock did not provide separate shapes that specifically aligned with the DEER building types. The set of building types analyzed here aligned best with the ComStock data. Similar building types within the MP that do not have direct ComStock analogous data would likely need to adopt the closest available building type data within the dataset.
- The operating schedule throughout the year varied for each building type, which impacted when savings occurred. The closer this operating schedule aligned to peak hours from the generation and TD avoided costs curves, the greater the benefit became.

- Impact curves are also available from the Open Energy Data Initiative¹⁰ (U.S. Department of Energy 2025). Note that the relationship between impact curves and consumption load shape is algebraically tied to unit energy consumption data from the base and measure cases. For reference, DEER impact shapes are shown in comparison to new CLS in [Figure 37](#).

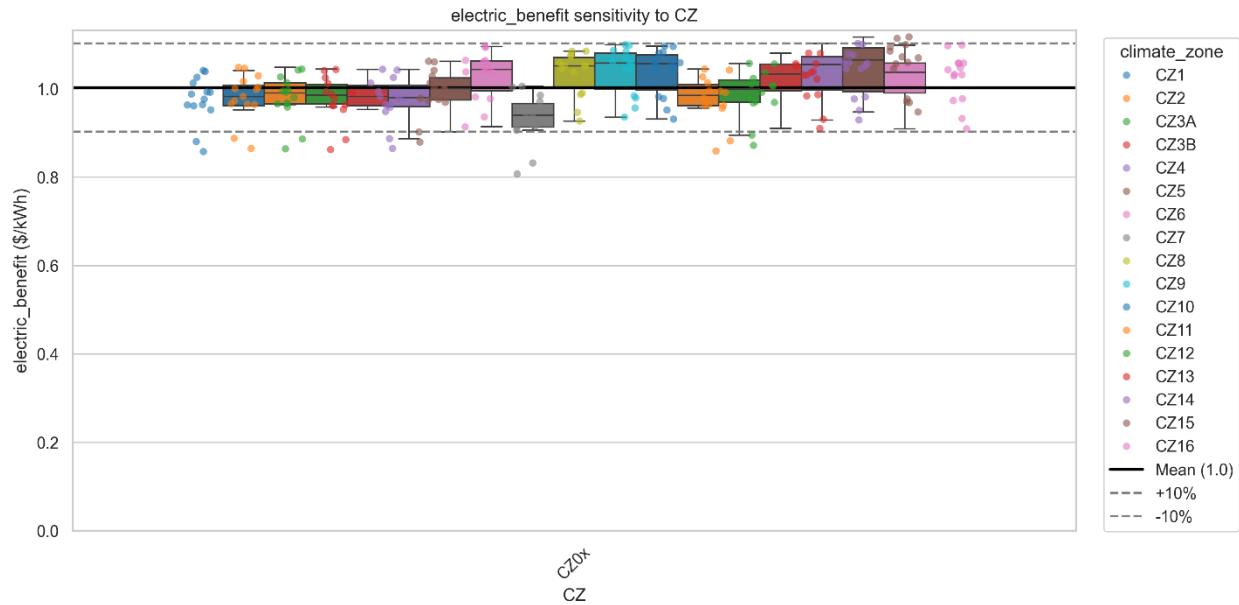


Figure 35: Unit electric benefits vs. building location.

¹⁰ (U.S. Department of Energy 2025)

Extracted end use specific loads: out.electricity.interior_equipment.energy_consumption.kwh and similar for therms

State: CA

Release: 2025 (AMY2018 release 3), most recent

Upgrade: 45

[Upgrade Name](#) Electric Cooking Equipment

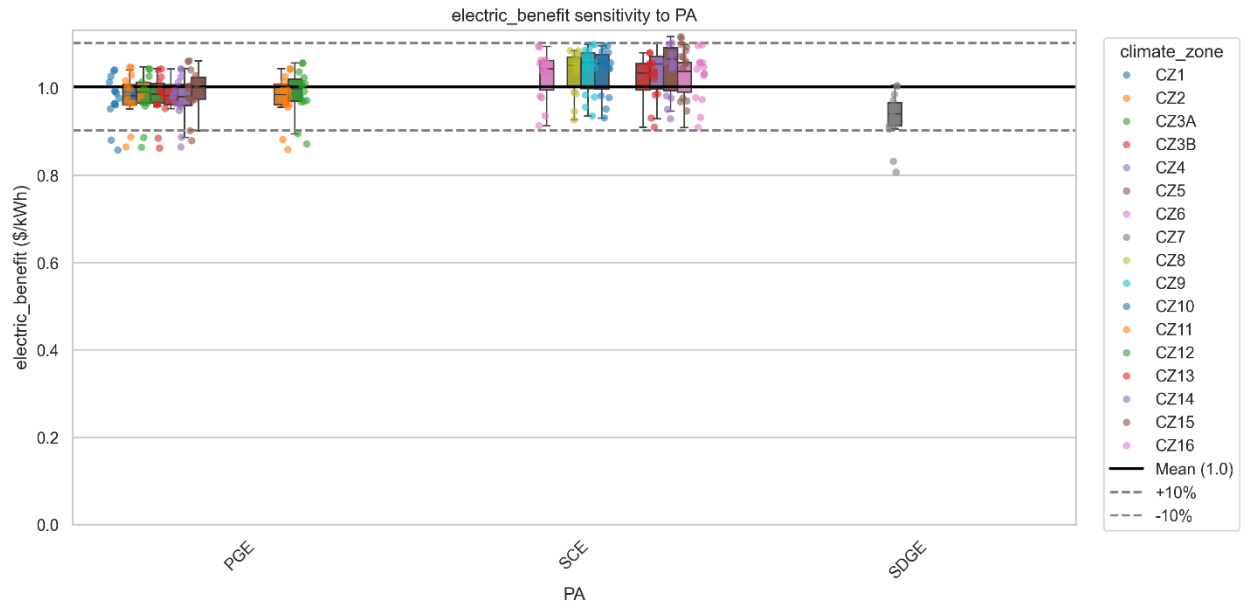


Figure 36: Unit electric benefits vs. building location and IOU.

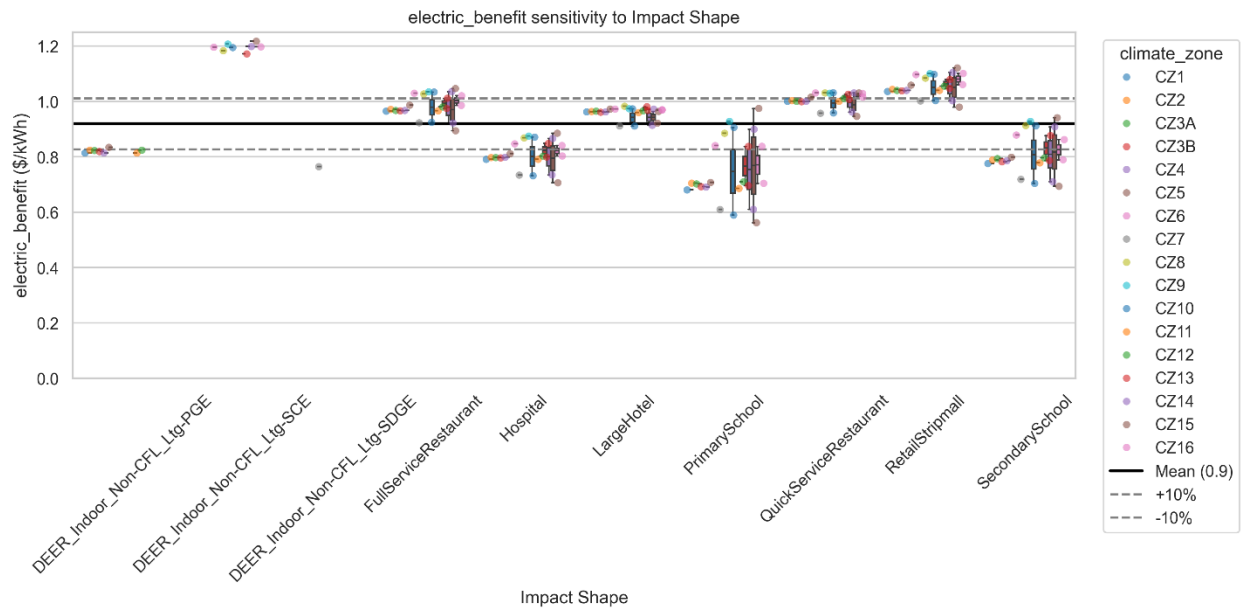


Figure 37: Unit electric benefits vs. impact savings curves.

Quantifying the Error in Dollars of TSB

The tables below provide guidance for when considering whether to consolidate CLS. Some of the reasons collected during this project to support the value of coalescing load shapes fall into categories of cost savings or data quality:

- Deemed values are intended to be market averages.
- Modeled results may provide a false sense of precision and accuracy.
- Too many CLS will make the data inaccessible to a normal person.
- Too many CLS will make quality control not transparent.
- Creating, checking, storing, and maintaining this large data set increases costs.

The primary reasons for not coalescing CLS lies in perceived inaccuracy that the process brings. An estimated monetary value can be quantified by considering the electric benefit value associated with the error that has been quantified in this report. [Table 21](#) shows the average standard deviation associated with the coalescing approach that was recommended. The electric benefit value of this deviation is then provided per kWh in the table below for the 10 MPs that were analyzed.

Table 21: Expected variation per kWh by measure.

Measure Package ID	Measure Name Full	Avg Unit Elec Bens (\$TSB/kWh)	Std Dev (percent)	Unit Elec Benefit (\$TSB/kWh)
SWHC013	Unitary Air-Cooled Air Conditioner, Over 65 kBtu/hr, Commercial	\$1.46	2.8%	\$0.040
SWHC043	Multiple Capacity Unitary Air-Cooled Com AC Between 65 and 240 kBtu/hr	\$1.46	3.0%	\$0.044
SWHC046	Packaged Heat Pump Air Conditioner Commercial, Fuel Substitution	\$1.50	2.7%	\$0.041
SWHC045	Heat Pump HVAC, Residential, Fuel Substitution	\$2.42	5.4%	\$0.131
SWSV001	Duct Seal, Residential	\$1.96	4.6%	\$0.091
SWWH025	Heat Pump Water Heater, Residential, Fuel Substitution	\$1.35	4.3%	\$0.058
SWWH014	Heat Pump Water Heater, Residential	\$1.35	4.3%	\$0.058
SWWH001	Faucet Aerator, Residential	\$1.35	4.3%	\$0.058
SWCR001	Anti-Sweat Heater Controls	\$0.37 ¹¹	0.3%	\$0.001
SWFS021	Fryer, Commercial, Fuel Substitution	\$0.99	6.6%	\$0.065

[Table 22](#) extrapolates this value to benefits realized in 2025. First year net kWh savings values extracted from CEDARS are combined with the unit electric benefit value from the previous table to document a bound for the deviation for 2025 to achieve a reduction of greater than 99% in the

¹¹ Note that Unit Electric Benefits include a component of EUL. It is EUL specifically for this 4-year measure that drives the unit benefits so low.

number of load shapes. The \$796,311 for 2025 represents about 3 percent of the TSB. The overall TSB should not vary by this amount since coalesced values are intended to average roughly to the same amount, as some will be higher OR lower. However, any one TSB value could lie within this 3 percent range.

Table 22: Total expected variation by measure.

Measure Package ID	Measure Name Full	Net Total System Benefit	First Year Net kWh	Variation ¹² \$ TSB @ 1 SD	All CLS	Rec CLS
SWHC013	Unitary Air-Cooled Air Conditioner, Over 65 kBtu/hr, Commercial	\$172,200	142,713	\$5,774	18,000	16
SWHC043	Multiple Capacity Unitary Air-Cooled Com AC - 65 and 240 kBtu/hr	\$75,796	70,588	\$3,082	4,000	16
SWHC046	Packaged Heat Pump Air Conditioner Com, Fuel Substitution	\$34,018	(16,170)	\$659	7,590	16
SWHC045	Heat Pump HVAC, Residential, Fuel Substitution	\$6,763,135	(2,450,233)	\$320,530	640	86
SWSV001	Duct Seal, Residential	\$4,032,247	926,990	\$84,320	612	52
SWWH025	Heat Pump Water Heater, Residential, Fuel Substitution	\$12,483,094	(6,277,505)	\$366,868	3,000	1
SWWH014	Heat Pump Water Heater, Residential	\$82,090	102,570	\$5,994	3,000	1
SWWH001	Faucet Aerator, Residential	\$1,155,546	151,631	\$8,862	3,000	1
SWCR001	Anti-Sweat Heater Controls	\$74,086	207,719	\$221	52	16
SWFS021	Fryer, Commercial, Fuel Substitution	-	-	\$-	14	7
		\$24,872,214		\$796,311	39,908	212

¹² Variation (\$ TSB @ 1 SD) is intended to quantify how the TSB dollar impact of what variation may become. This amount represents the full TSB impact associated with one standard deviation of error across the entire savings for 2025. It should be noted that the coalesced CLS are intended to make some value higher and some values lower, so the average should be similar (and not off by one standard deviation).

Recommendations

The results of this report provide guidance for two important areas when creating load shapes for the PY28 cycle: consistent creation and coalescing frameworks.

The creation of CLS across a number of measure packages led to some valuable guidelines for a consistent creation framework:

1. EnergyPlus prototypes should be created to start on the same day of the week. For EnergyPlus simulations in PY2026 and before, the day differs between residential (start day = Thursday) and commercial (start day = Sunday) prototypes, but this start day should be aligned with the Ex Ante review team. Coordination with the CPUC and their consults shows that there is support for making this change for PY28 MPs. As of the creation of this report, this recommendation has been adopted and enacted.
2. Weather data between EnergyPlus simulations and avoided cost data should match. This alignment typically occurs between the Ex Ante and ACC consultants, who match the weather impacts of each tool. For PY28, CZ2025 weather data will be used for both.
3. The choice of the calendar year is also critical to avoid a leap year and set the holiday schedule.
4. The start day of the week for avoided cost data should match the start day used in the EnergyPlus simulations. This stays aligned by choosing a consistent calendar. The choice of a 2009 calendar designates Thursday as the start day. Note that without alignment between the prototypes and the avoided cost data, the day of the week is the most sensitive variable that must be aligned. Whenever realignment is needed for the day of the week, weather data and holidays both fall out of alignment.
5. Defining the DS-Type of the CLS changes the calculation considerably. A DS-Type of “kW” is expected to be roughly 15 percent smaller because of the orders of magnitude difference between kW and kWh values. With Cal TF support, tests have been run to demonstrate this difference. The DS-Type for past DEER impact load shapes has been exclusively “kWh,” and this choice is expected to remain. This analysis has been done with a DS-Type of “kWh.”
6. Technology IDs are named to link the ID to a CLS. Consistency in both parameterizing and separating parameters will significantly simplify future use of the data. Ideally, something more unique than a “-” or a “_” should be used to separate parameters since these are also regularly used within parameters. The order of parameters should also be consistent to support the use of CLS between MPs.
7. Linking technology IDs with CLS 8760 data should be standardized and documented in a manner that can be reproduced.
8. Every effort to avoid uploading duplicative data should be made. Keeping load shapes identical (e.g., the measure case of an energy efficiency and fuel sub-MP) will be extremely difficult without rigorous control of technology IDs and versions. Note that without this control, updating one measure package could unintentionally change the cost-effectiveness of related measures if the technology ID and version are not closely maintained.

The analysis of CLS across a variety of end uses and types of MPs has shown several general results for the coalescing framework:

- Commercial HVAC MPs are most highly correlated when considering two parameters of building type and building location that have shown a variation of less than 1 percent standard deviation. Significant reductions of load shapes follow from 4,000 to 18,000 CLS per MP to 357 CLS per MP.
- **Recommendation:** For commercial HVAC MPs that include both cooling-only and cooling-and-heating types, the standard recommendation of selecting the median CLS for each building type/building location combination¹³ can provide a substantial reduction in CLS and maintain low standard deviation.
- Groupings of building types and building locations can further reduce the number of CLS from 357 to 16 per MP with an increase to about 3 percent standard deviation.
- Residential HVAC MPs are most highly correlated when considering two parameters of building location and HVAC type that show a variation of less than 6 percent standard deviation. It should be noted that maximum standard deviations can still be high for these residential MPs. In the case of SWHC045, either HVAC type could be more specifically defined for hydronic systems or modeled with less definition to avoid higher variation within a group.
- **Recommendation:** For residential HVAC MPs, the standard recommendation of selecting the median CLS for each building location/HVAC type can provide a substantial reduction in CLS and maintain low average standard deviation. Note that outliers have been seen in this area.
- Water heating MPs have significant correlation across the entire MP. A 4 percent average standard deviation can be seen across all the parameters in the residential heat pump measure package.
- **Recommendation:** For residential water heating MPs, the standard recommendation of averaging over the entire MP maintains low average standard deviation. To further reduce variation, selecting the median value by building location improves accuracy. The same result has not yet been tested for commercial water heating MPs, but similar results are expected.
- Commercial refrigeration MPs are very highly correlated when considering building location only.
- **Recommendation:** For grocery-focused commercial refrigeration measures, only a single building type is typically modeled, and thus building location is the best opportunity for consolidation. However, coalescing based upon building location is recommended for consistency with other MPs.
- Food service MPs are responsive to schedule changes. These weather-independent CLS can be fully grouped with an average standard deviation of less than 7 percent. Including

¹³ When choosing a median CLS, this median refers to a curve that produces median unit electric benefits. Note that median CLS should be identified for both the base and the measure case.

the seven building types could remove this difference. Building location differences are only due to PA differences in TD and discount rate.

- When establishing an average CLS, these rules should be considered:
 - Choosing a typical case could tie results to an actual model to be checked, rather than creating a more complex average or weighted average CLS.
 - Separate coalescing should be considered for standard and measure cases, especially when the HVAC type or equipment type is different.
 - When median models are chosen separately for the standard and measure cases, maintaining similar parameters will help keep a positive correlation between the error of the base and measure cases.
- For non-modeled measures, there are a handful of resources that can be used for CLS, including:
 - End use load shapes from modeled measures of the same system type or end use
 - The National Laboratory of the Rockies' ComStock (National Laboratory of the Rockies 2025) and ResStock (National Laboratory of the Rockies 2025) energy interval datasets; these datasets can be filtered for state, building type, and measure type, and provide end use level 15-minute interval data
 - Hourly calculator outputs, such as the DEER Water Heater Calculator
 - Emerging technology, EM&V, or metering studies that provide energy modeling data; even datasets that do not provide full annual data can be extrapolated in some cases

Future Areas of Research

Future areas of research include:

- For commercial HVAC MPs that include a parameter of HVAC type, this additional parameter should be investigated to understand if it fully describes the HVAC system that is being modeled or if there are additional parameters included separately in defining new permutations. A potential example of this is seen in the hot water HVAC systems of multifamily prototypes.
- Understanding the relationship between the error in a CLS versus the error in impact load shapes is beyond the scope of this project. Only limited results have been investigated, as described in the section title “Measure Package Impact Shape Analysis” below, but results look promising so far.
- The CPUC is expected to require facility level data for CLS. The difference between facility and end-use data after solving for an impact curve will be the interactive effects. It should be determined if those interactive effects are impactful with respect to benefits. If this value is small, end-use data should be strongly considered because relevant end uses can easily be clouded by other unrelated loads, which makes it harder to perform quality control for this data.
- Additional work can be done to quantify the impact of schedule changes on load shapes. Understanding this impact along with the food service measure package can lend support when considering how and when a new load shape is required but also how load shifting measures should be considered.
- A direct comparison of unit electric benefits between new CLS (\$/kWh) and existing DEER impact profiles could be calculated to understand differences that will occur. CLS will need to be converted to impact profiles for each MP where the calculation will be carried out.
- The development of groups that could be used for building location or building type should be linked to physical characteristics. New tools like prototype scorecards should be leveraged to support this grouping effort if stakeholders feel like this path could be valuable.
- Establishing and finding consensus on a variation threshold that is acceptable is important to allow consistent coalescing.
- Input from this report could be used to support the CPUC in creating a tool that measure developers can use to coalesce CLS.

Measure Package Impact Shape Analysis

The scope of analysis in the project targets CLS analysis. This section, which extends the discussion to include impact shape analysis, is important, but it goes beyond the scope of this project. The above analysis was able to document findings that suggest coalescing of CLS such as:

- Water heating MPs only show an average standard deviation of ~4 percent across all consumption load shapes.
- Commercial HVAC MPs only show an average standard deviation of ~1 percent across all consumption load shapes when analyzed by building type and building location.

The amount of coalescing will ultimately be related to the amount of variation that is deemed reasonable within a CLS. It is important to consider how this CLS data will be utilized within the CPUC's cost-effectiveness calculator. The equations below show the relevant relationship (ignoring other miscellaneous or refrigeration cost/benefit):

$$TSB_{Fuel\ Sub}(\$) = Benefits_{Gas} - Supply\ Cost_{Electric}$$

$$TSB_{EE}(\$) = Benefits_{Gas} + Benefits_{Electric}$$

Generally, the electric supply cost and electric benefit are the opposite in sign, but calculated similarly as:

$$Benefit_{Electric}(\$) = Unit\ Energy\ Savings\ (kWh) \times Impact\ Profile\ Avoided\ Cost\ \left(\frac{\$}{kWh} \right)$$

When considering using CLS, the same electric benefits can be calculated as:

$$Benefit_{Electric}(\$) = UEC_{Base} \times CLS\ Electric\ Benefit_{Base} - UEC_{Meas} \times CLS\ Electric\ Benefit_{Meas}$$

The standard deviation values from the previous section are specifically associated with the CLS electric benefit values that have been included in all the previous jitter plots.

When considering the error associated with the electric benefit for fuel substitution, the standard deviation documented previously translates directly to the full electric benefit.¹⁴ This occurs because the baseline gas benefit does not change. In other words, there is no additional error associated with the base case. Since gas benefits are typically larger than electric costs, the error from the measure case also becomes smaller with respect to the full TSB.

However, when considering the error associated with the electric benefit for energy efficiency, the standard deviation exists in both the base and measure cases. Understanding the nature of these errors is important to understanding the full impact on electric benefits for energy efficiency MPs. Additional work should be done to explore the nature of errors between the base and measure case. The important implications that remain include:

- Error for both terms should be considered.
- The choice of how to coalesce will impact this error.

From the small sample of test runs, it is recommended that:

- Coalescing the base and measure case separately is important to ensure that errors do not become additive (i.e., typically considered to be the sum of squares). In some cases when standard and measure cases are similar in nature, separate CLS are not needed.
- Coalescing should strive to have a median value of unit electric benefits to ensure that errors balance more equally across a full permutation set. This can be done by selecting the CLS that represents the median value.

¹⁴ Note that when the baseline includes mixed fuels, such as furnaces or tankless water heaters, the benefits can include positive electric benefits in addition to the negative electric supply cost.

- Coalescing could avoid complicated analytics and improve transparency by utilizing a median case rather than using complex weighting or averaging calculations to develop a representative load shape.

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Appendix A: Stakeholder Training

Project Plan Overview Highest Level

Impact “Savings” Load Shapes → Usage Load Shapes

Due to the most recent guidance from the CPUC, please replace GLSPs with Consumption Load Shapes

Project Plan Overview

Current Scenario

Impact “Savings” Load Shapes → Usage Load Shapes

2011 DEER Elec. Load Shapes

14 Residential
7 Non-Residential

2022 Electric CLS (in eTRM) – *almost 6,000 CLSs*

453 Residential CLSs
5,314 Non-Residential CLSs

CLS = Consumption Load Shape
(previously) GLSP = Generalized Load Shape Parameters

Due to the most recent guidance from the CPUC, please replace GLSPs with Consumption Load Shapes

Project Plan Overview

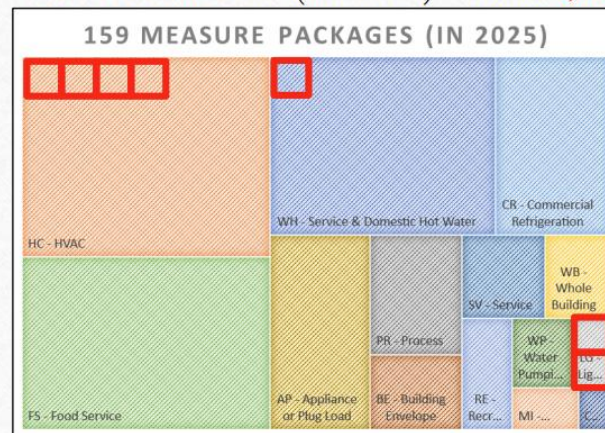
Understanding Current Scenario

Impact “Savings” Load Shapes → Usage Load Shapes

2011 DEER Elec. Load Shapes

14 Residential
7 Non-Residential

2022 Electric CLSs (in eTRM) – *almost 6,000 CLSs*



2 Lighting
4 HVAC
1 Water Heating

CLS = Consumption Load Shape
GLSP = Generalized Load Shape Parameters

Due to the most recent guidance from the CPUC, please replace GLSPs with Consumption Load Shapes

Project Plan Overview

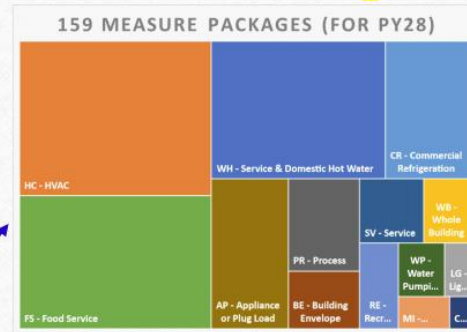
Research Question: To what level of detail should new usage load shapes be created?

Impact “Savings” Load Shapes → Usage Load Shapes

2011 DEER Elec. Load Shapes

14 Residential
7 Non-Residential

2026 Raw Electric CLSs*



PAs / Measure Developers
(9/2025 – 6/2026)

CLS = Consumption Load Shape

GLSP = Generalized Load Shape Parameters

→ Consolidated Usage Load Shapes

2026 Electric CLSs (in eTRM)



CalNEXT
(~9 – 12 / 2025)



CALIFORNIA
Public Utilities Commission
(TBD - 5 – 12 / 2025)

* CLSs derived at the permutation level from Energy Plus or Measure Package assumptions/best practices

Project Plan Overview

Tasks:

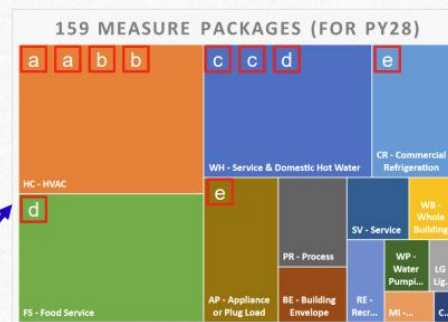
1. Create usage load shapes
2. Analytically compare to coalesce (add cost-avoidance data)
3. Determine the “Rules” (general guidance)

Impact “Savings” Load Shapes → Usage Load Shapes

2011 DEER Elec. Load Shapes

14 Residential
7 Non-Residential

2026 Raw Electric CLSs



Based upon
Rules

→ Consolidated Usage Load Shapes

2026 Electric CLSs (in eTRM)



CLS = Consumption Load Shape
GLSP = Generalized Load Shape Parameters

*Mapping to Use Category is illustrative and may differ based upon Project Plan

Project Plan Overview

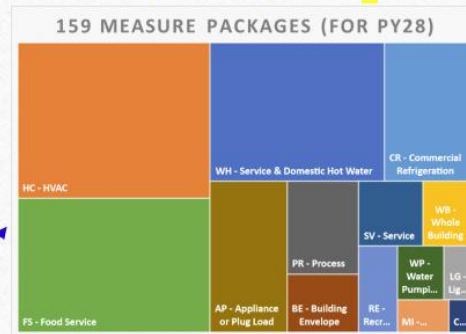
Research Question: To what level of detail should new usage load shapes be created?

Impact “Savings” Load Shapes → Usage Load Shapes

2011 DEER Elec. Load Shapes

14 Residential
7 Non-Residential

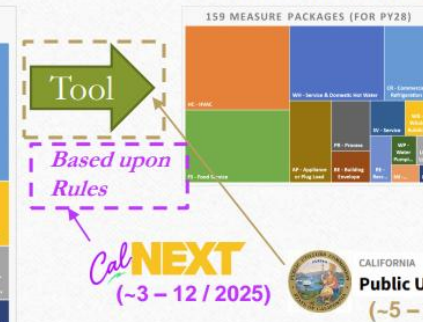
2026 Raw Electric CLSs*



PAs / Measure Developers
(9/2025 – 6/2026)

→ Consolidated Usage Load Shapes

2026 Electric CLSs (in eTRM)



* CLSs derived at the permutation level from Energy Plus or Measure Package assumptions/best practices

CLS = Consumption Load Shape
GLSP = Generalized Load Shape Parameters

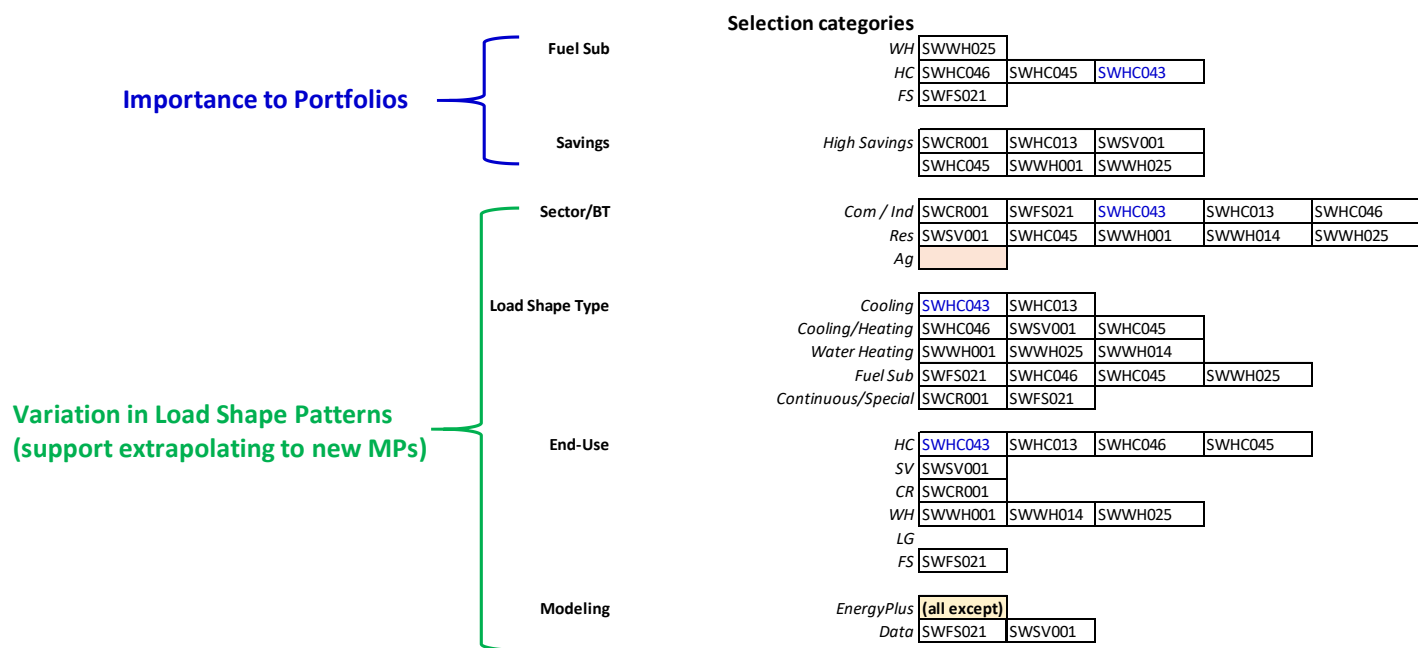
Appendix B-1: Initial, Full Measure List for Consideration

App B-1: Full Measure List

Load Group	Load Shape Type	MeasureID	Measure Name	Simulate	Sector	Sum of TSB (2022)	Sum of TSB (2023)	Sum of TSB (2024)
Continuous	Continuous	SWCR001	Anti-Sweat Heater Controls	E+	Com	5,741,067	3,151,586	1,875,568
		SWFS021	Fryer, Commercial, Fuel Substitution	Data	Com			
		SWAP001	Refrigerator or Freezer, Residential	Data	Res	243	9,563	3,444
	Food Service	SWCR015	Medium-Temperature Case Doors	E+	Com	6,978,232	5,750,740	1,674,373
		SWFS003	Combination Oven, Commercial	Data	Com	5,545,647	4,773,643	1,322,928
		SWFS005	Steamer, Commercial	Data	Com	734,709	556,022	374,865
Cooling	Cooling only	SWHC005	Water-Cooled Chiller	E+	Com	22,706		
		SWHC013	Unitary Air-Cooled AC, Over 65 kBtu/hr, Commercial	E+	Com	567,990	775,221	282,160
Heating/Cooling	Heating/Cooling	SWHC046	Packaged Heat Pump AC, Commercial, Fuel Substitution	E+	Com	29,463	183,259	81,071
		SWHC044	Ductless HVAC, Residential, Fuel Substitution	E+	Res	201,648	445,970	370,448
	Heating/Cooling-eff	SWSV001	Duct Seal, Residential	E+	Res	13,239,020	8,587,887	8,369,716
		SWHC014	Unitary Air-Cooled AC or HP, Under 65 kBtu/hr, Commercial	E+	Com	1,866,698	4,060,571	2,199,154
	Heating/Cooling-eff/control	SWHC045	Heat Pump HVAC, Residential, Fuel Substitution	E+	Res	1,930,002	5,064,122	6,709,190
	HVAC Controls	SWHC018	VSD for HVAC Fan Controls, Commercial	E+	Com	138,104	496,352	469,471
Water Heating	Water Heating	SWWH001	Faucet Aerator, Residential	Data	Res	4,218,272	11,113,184	5,164,479
		SWWH014	Heat Pump Water Heater, Residential	E+	Res	355,299	461,453	145,117
		SWWH025	Heat Pump Water Heater, Residential, Fuel Substitution	E+	Res	(289,325)	88,862	6,898,829
	Water Heating-eff/control	SWWH027	Heat Pump Water Heater, Commercial, Fuel Substitution	WHC	Com	278,173	507,747	4,242,405
			Large Heat Pump Water Heater, Commercial and Multifamily,					
		SWWH028	Fuel Substitution	E+	Com	619,516	5,514,724	79,083,633
		SWWH031	Heat Pump Water Heater, Commercial	WHC	Com	101,916	38,628	122,962

Appendix B-2: Measure List for Project

Load Group	Load Shape Type	MeasureID	Measure Name	E3MeaElecEndUseShape	Simulate	Sector	Sum of TSB (20	Sum of TSB (20	Sum of TSB (20
Continuous	Continuous	SWCR001	Anti-Sweat Heater Controls	DEER:HVAC_Chillers	E+	Com	5,741,067	3,151,586	1,875,568
		SWFS021	Fryer, Commercial, Fuel Substitution	DEER:Indoor_Non-CFL_Ltg	Data	Com			
		SWHC043	Multiple Capacity Unitary Air-Cooled Commercial AC (65–240	DEER:HVAC_Split-Package_AC	E+	Com			
Heating/Cooling	Heating/Cooling	SWHC013	Unitary Air-Cooled AC, Over 65 kBtu/hr, Commercial	DEER:HVAC_Split-Package_AC/HP	E+	Com	567,990	775,221	282,160
		SWHC046	Packaged Heat Pump AC, Commercial, Fuel Substitution	DEER:HVAC_Split-Package_HP	E+	Com	29,463	183,259	81,071
		SWSV001	Duct Seal, Residential	DEER:HVAC_Eff_AC	E+	Res	13,239,020	8,587,887	8,369,716
		SWHC045	Heat Pump HVAC, Residential, Fuel Substitution	DEER:HVAC_Eff_HP	E+	Res	1,930,002	5,064,122	6,709,190
Water Heating	Water Heating	SWWH001	Faucet Aerator, Residential	DEER:Res_ClothesDishWasher	Data	Res	4,218,272	11,113,184	5,164,479
		SWWH014	Heat Pump Water Heater, Residential	DEER:Res_ClothesDishWasher	E+	Res	355,299	461,453	145,117
		SWWH025	Heat Pump Water Heater, Residential, Fuel Substitution	DEER:Res_ClothesDishWasher	E+	Res	(289,325)	88,862	6,898,829



Appendix B-2: Measure List for Project (cont.)

Measure Developer	Measure ID	Measure Description	Hourly Data	Norm Unit	Weather Data	Version	Description of Pull Requests
TRC	SWWH025	Heat Pump Water Heater, Residential, Fuel Substitution	Whole Bldg & Water Heating	Each	CZ2022	10	https://github.com/sound-data/DEER-Prototypes-EnergyPlus/pull/144
TRC	SWWH014	Heat Pump Water Heater, Residential	Whole Bldg & Water Heating	Each	CZ2022	08	https://github.com/sound-data/DEER-Prototypes-EnergyPlus/pull/149
TRC	SWWH001	Faucet Aerator, Residential	Whole Bldg & Water Heating	Each	CZ2022		
TRC	SWCR001	Anti-Sweat Heater Controls	Whole Bldg & Elec Heat, Cooling, Fan, MT/LT Compressor, MT/LT Evap Fan, MT/LT Anti-Sweat	Len-ft	CZ2022	05	https://github.com/sound-data/DEER-Prototypes-EnergyPlus/pull/63
Solaris	SWHC046	Packaged Heat Pump AC, Commercial, Fuel Substitution	Whole Bldg & Elec Heat, Cooling, Fan	Cap-Tons	CZ2022	04	SWHC046 official pull request https://github.com/sound-data/DEER-Prototypes-EnergyPlus/pull/83 SWHC046 development pull request https://github.com/similaris/DEER-Prototypes-EnergyPlus/pull/42
Solaris	SWHC045	Heat Pump HVAC, Residential, Fuel Substitution	Whole Bldg & Elec Heat, Cooling, Fan	Cap-Tons	CZ2022	06	SWHC045 measure case was originally modeled by DNV (without a pull request). The approved version did not include definitions for baselines in the repository. We documented the baseline definitions here: https://github.com/sound-data/DEER-Prototypes-EnergyPlus/pull/118 . SWHC045 proposed update official pull request: https://github.com/sound-data/DEER-Prototypes-EnergyPlus/pull/130 . This version uses TRC templated prototypes.
Energy Solutions	SWHC013	Unitary Air-Cooled AC, Over 65 kBtu/hr, Commercial	Whole Bldg & Elec Heat, Cooling, Fan	Cap-Tons	CZ2022	08	https://github.com/sound-data/DEER-Prototypes-EnergyPlus/pull/113
CPUC	SWSV001	Duct Seal, Residential	Whole Bldg & Elec Heat, Cooling, Fan	Area-ft ²	CZ2022	05	This measure was originally created by the CPUC as a DEER measure.
Energy Solutions	SWHC043	Multiple Capacity Unitary Air-Cooled Commercial AC (65–240 kBtu/hr)	Whole Bldg & Elec Heat, Cooling, Fan	Cap-Tons	CZ2022	08	This measure is defined as a unitary air-cooled AC unit with a multi-speed indoor fan and a compressor with either 1) variable speed compressor(s), 2) multiple-step compressor(s), or 3) multiple compressors operating on a single refrigeration circuit (tandem compressors). https://github.com/sound-data/DEER-Prototypes-EnergyPlus/pull/115
TRC	SWFS021	Fryer, Commercial, Fuel Substitution	n/a	Each	n/a		

Appendix B-2: Measure List for Project (cont.)

Measure Developer	Measure ID	Measure Description	EUL	Sector	Start Day	Number of Models	Parameters	Hourly Data
TRC	SWWH025	Heat Pump Water Heater, Residential, Fuel Substitution	20	Res	Thursday	3163	Building Location Equipment Type Equipment Efficiency Capacity Range Voltage ER	Whole Bldg & Water Heating
TRC	SWWH014	Heat Pump Water Heater, Residential	20	Res	Thursday			
TRC	SWWH001	Faucet Aerator, Residential	10	Res	Thursday			
TRC	SWCR001	Anti-Sweat Heater Controls	4	Non-Res	Sunday	48	Building Location Case Temperature	Whole Bldg & Elec Heat, Cooling, Fan, MT/LT Compressor, MT/LT Evap Fan, MT/LT Anti-Sweat
Solaris	SWHC046	Packaged Heat Pump AC, Commercial, Fuel Substitution	20	Non-Res	Sunday	7590	Building Type Building Location Equipment Type Equipment Efficiency	Whole Bldg & Elec Heat, Cooling, Fan
Solaris	SWHC045	Heat Pump HVAC, Residential, Fuel Substitution	23	Res	Thursday	640	Building Type Building Location Equipment Type Equipment Efficiency	Whole Bldg & Elec Heat, Cooling, Fan
Energy Solutions	SWHC013	Unitary Air-Cooled AC, Over 65 kBtu/hr, Commercial	20	Non-Res	Sunday	17894	Building Type Building Location Equipment Type Equipment Efficiency Capacity Range Vintage	Whole Bldg & Elec Heat, Cooling, Fan
CPUC	SWSV001	Duct Seal, Residential	18	Res	Thursday	612	Building Type Building Location Equipment Type Equipment Efficiency Measure Case	Whole Bldg & Elec Heat, Cooling, Fan
Energy Solutions	SWHC043	Multiple Capacity Unitary Air-Cooled Commercial AC (65–240 kBtu/hr)	20	Non-Res	Sunday	4068	Building Type Building Location Equipment Efficiency Capacity Range Vintage	Whole Bldg & Elec Heat, Cooling, Fan
TRC	SWFS021	Fryer, Commercial, Fuel Substitution	12	Non-Res	Monday	14	Building Type	n/a

Appendix C: Graphics Explanation

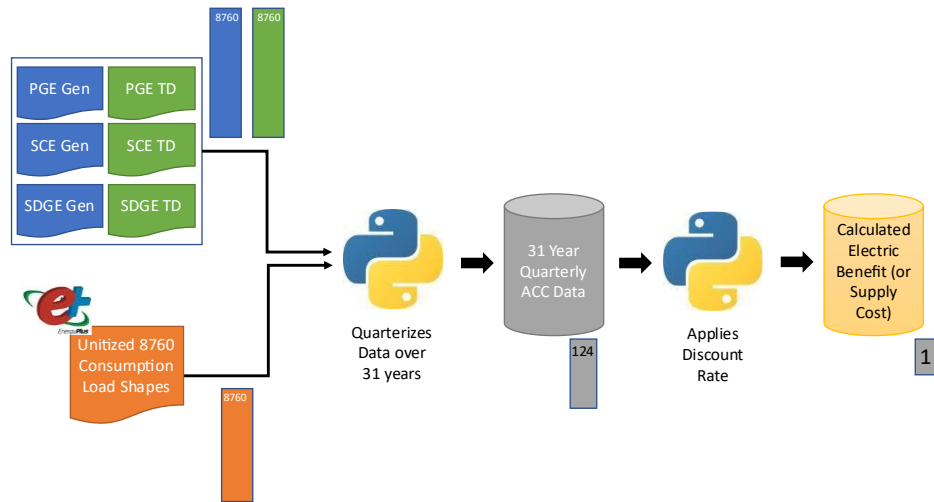


Figure 38: Data flow for unitized electric benefits.

Data flow from Consumption Load Shape (8760 data set) to single value of Unitized Electric Benefits (\$/kWh)

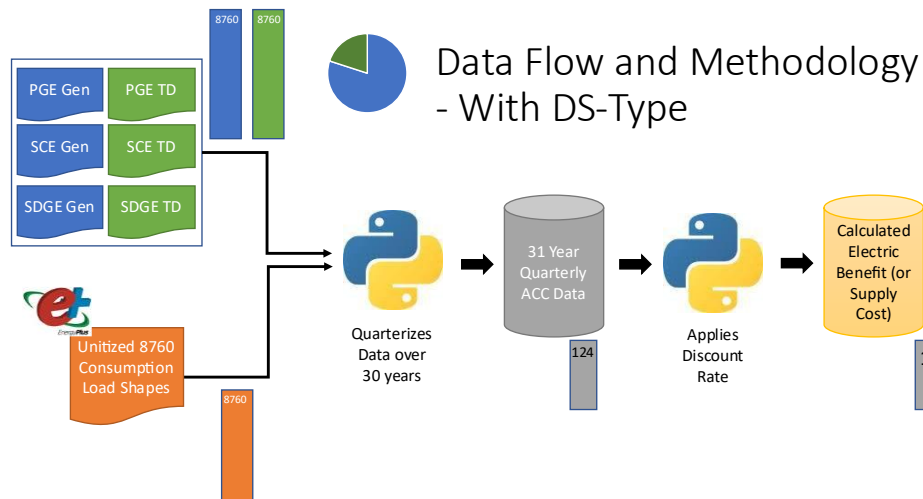


Figure 39: Demand savings type graphical impact.

Graphical impact of DS-Type decision;

- DS-Type of “kWh” uses kWh value with TD avoided cost
- DS-Type of “kW” uses kW value with TD avoided cost

Note that kWh is typically 3 orders of magnitude larger

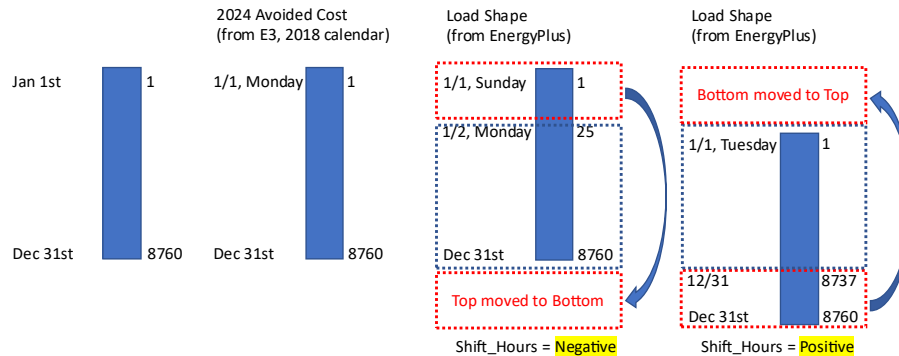


Figure 40: Visualization of how data shifting is accomplished.

Visual of how data shift is required when “Start Day of the Week” does not match between CLS and Avoided Cost data. Most critical to align day of the week, but mis-aligns weather data and holidays.

Methodology overview in words

Methodology

- Create Consumption Load Shapes (CLS) from existing models
- Calculate Unit Electric Benefits (or Electric Supply Costs) from CLS
 - Meaning of Unit Electric Benefit (\$/1 kWh)
 - For a Fuel Sub Measure:
 - Therm Savings 225 therms (from MP permutation)
 - Unit Therm Benefits \$28.98 / therm (not changing, dependent IOU and measure/CETRun parameters)
 - kWh Savings (negative) -1,650 kWh (from MP permutations)
 - Unit Electric Supply Cost (changing) (new from CLS * ACC)
 - Refrigerant Cost \$245.02 (from RACC-FSC tool)
 - TSB (\$) = Gas Benefits – Electric Supply Cost – Refrigerant Cost
 - Note Dampening Impact
 - Larger “Electric Supply Cost” means smaller TSB
 - Gas Benefits are ~3x Electric Supply Cost
 - 10% difference in Unit Electric Supply Cost translates to about 5% difference TSB
 - Note relationship changes with a nonfuel sub measure
 - Larger “Electric Benefits” means larger TSB

Calculated by CET

Figure 41: Methodology overview to calculate total system benefit.

Anatomy of Graphics

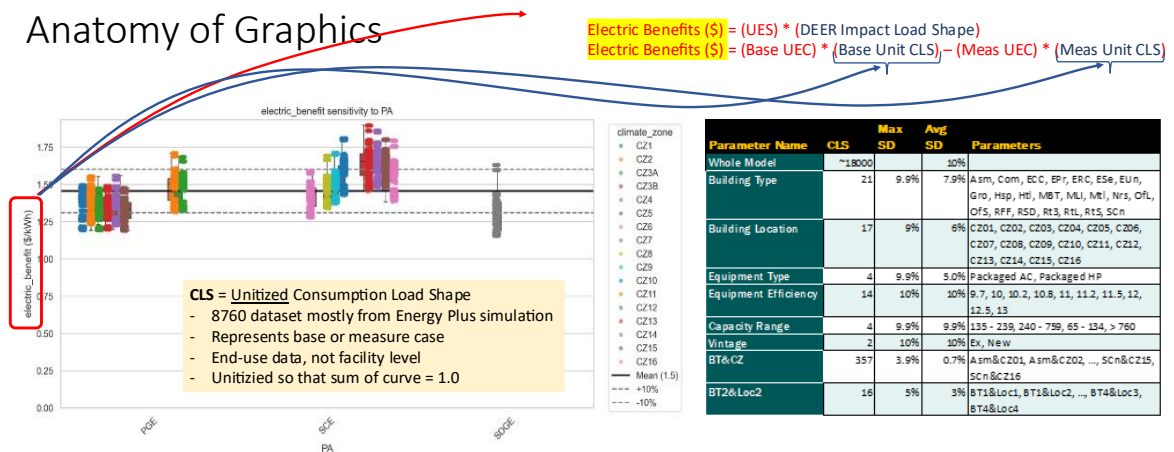


Figure 42: Graphical depiction of the connection between jitter plots, CLS and summary tables.

Graphic description:

- “electric_benefit (\$/kWh)” is plotted vertically on all jitter plots

Electric Benefit calculation is showed using savings or UEC (Unit Energy Consumption)

Anatomy of Graphics

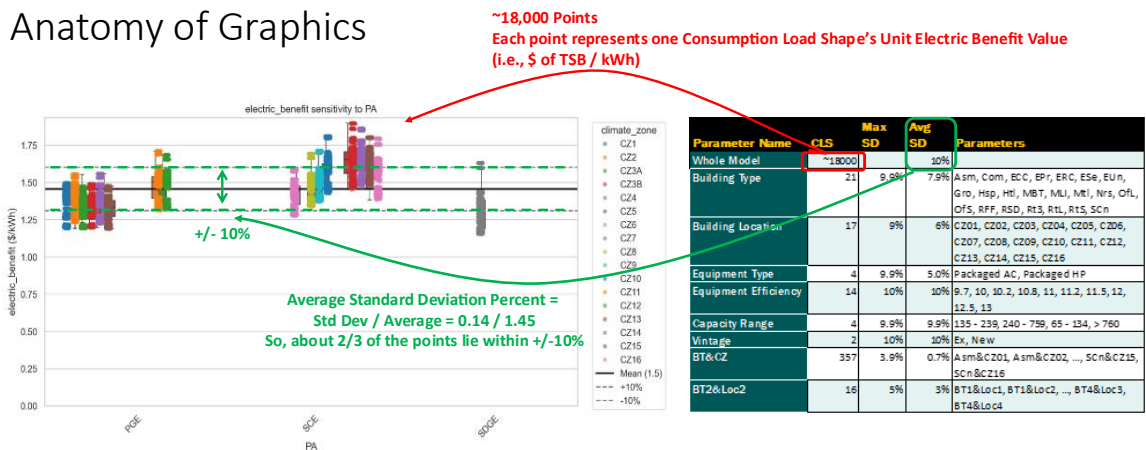


Figure 43: Graphical depiction of the connection between jitter plots, CLS and summary tables.

Graphic description:

- Represent the unitized \$TSB per kWh value for a consumption load shape; each CLS is described and compared with this value by one point on this jitter plot.
- Average Standard Deviation (Avg SD) is shown as the average value across all points in that group of the unitized electric benefit

Anatomy of Graphics

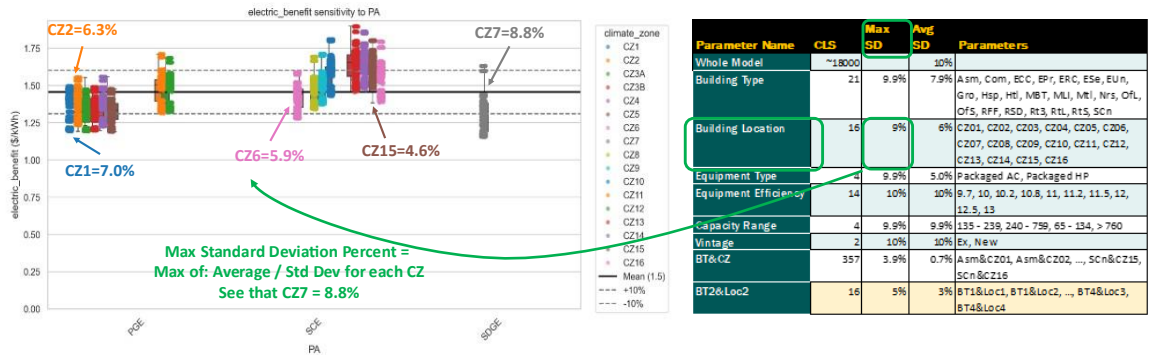


Figure 44: Graphical depiction of the connection between jitter plots, CLS and summary tables.

Graphic description:

- Maximum Standard Deviation (Max SD) is shown to describe an outlier of the data that might exist.
- Valuable to look for a low Avg SD, but also be able to explain why the Max SD might be higher.
- **Yellow Highlighted** rows are the ones that are recommended, but this ultimate decision is dependent upon the trade-off between risk and simplicity and the ability to implement advanced strategies.

Appendix D: Graphics Library

The following graphics library is intended to provide a full set of jitter plots that were developed for this analysis. In all cases, the analysis covered all parameters that influence measure package permutations. In many cases, similar results are seen across several of the parameters. To illustrate a point, examples are shown in the report, but not all are included in the body of the report to limit confusion when results are very similar. This library includes several types of plots:

- Summary table that shows each parameter or combination of parameters with its corresponding analysis
- Single parameter jitter plots show the relationship of the single parameter named and always separates building location through color coding
- Focused jitter plots show all of the data from a specific type of single parameter (e.g., only building location 2 or only building type small office)
- Grouped parameter jitter plots show the relationship of more than one parameter
- Standard versus measure case jitter plots show the difference or similarity between the base and measure cases of a single measure package

Table 23: Measure package list.

Load Group	Fuel Sub	Measure ID	Measure Description
Heating and Cooling	No	SWHC013	Unitary Air-Cooled AC, Over 65 kBtu/hr, Commercial
	No	SWHC043	Multiple Capacity Unitary Air-Cooled Com AC (65–240 kBtu/hr)
	Yes	SWHC046	Packaged Heat Pump AC, Commercial, Fuel Substitution
	Yes	SWHC045	Heat Pump HVAC, Residential, Fuel Substitution
	No	SWSV001	Duct Seal, Residential
Water Heating	Yes	SWWH025	Heat Pump Water Heater, Residential, Fuel Substitution
	No	SWWH014	Heat Pump Water Heater, Residential
	No	SWWH001	Faucet Aerator, Residential (<i>electric offerings</i>)
Continuous	No	SWCR001	Anti-Sweat Heater Controls
	Yes	SWFS021	Fryer, Commercial, Fuel Substitution

SWHC013, Unitary Air-Cooled AC, Over 65 kBtu/hr, Commercial

Parameter Name	CLS	Max SD	Avg SD	Parameters
Whole Model	~18000		10%	
Building Type	21	9.9%	7.9%	Asm, Com, ECC, EPr, ERC, ESe, EUn, Gro, Hsp, Htl, MBT, MLI, Mtl, Nrs, OfL, OfS, RFF, RSD, Rt3, RtL, RtS, SCn
Building Location	16	9%	6%	CZ01, CZ02, CZ03, CZ04, CZ05, CZ06, CZ07, CZ08, CZ09, CZ10, CZ11, CZ12, CZ13, CZ14, CZ15, CZ16
Equipment Type	2	9.9%	5.0%	Packaged AC, Packaged HP
Equipment Efficiency	14	10%	10%	9.7, 10, 10.2, 10.8, 11, 11.2, 11.5, 12, 12.5, 13
Capacity Range	4	9.9%	9.9%	135 - 239, 240 - 759, 65 - 134, > 760
Vintage	2	10%	10%	Ex, New
BT&CZ	336	3.9%	0.7%	Asm&CZ01, Asm&CZ02, ..., SCn&CZ15, SCn&CZ16
BT2&Loc2	16	5%	3%	BT1&Loc1, BT1&Loc2, ..., BT4&Loc3, BT4&Loc4

Table 24: SWHC013 parameter results

SWHC013 – Parameter specific jitter plots

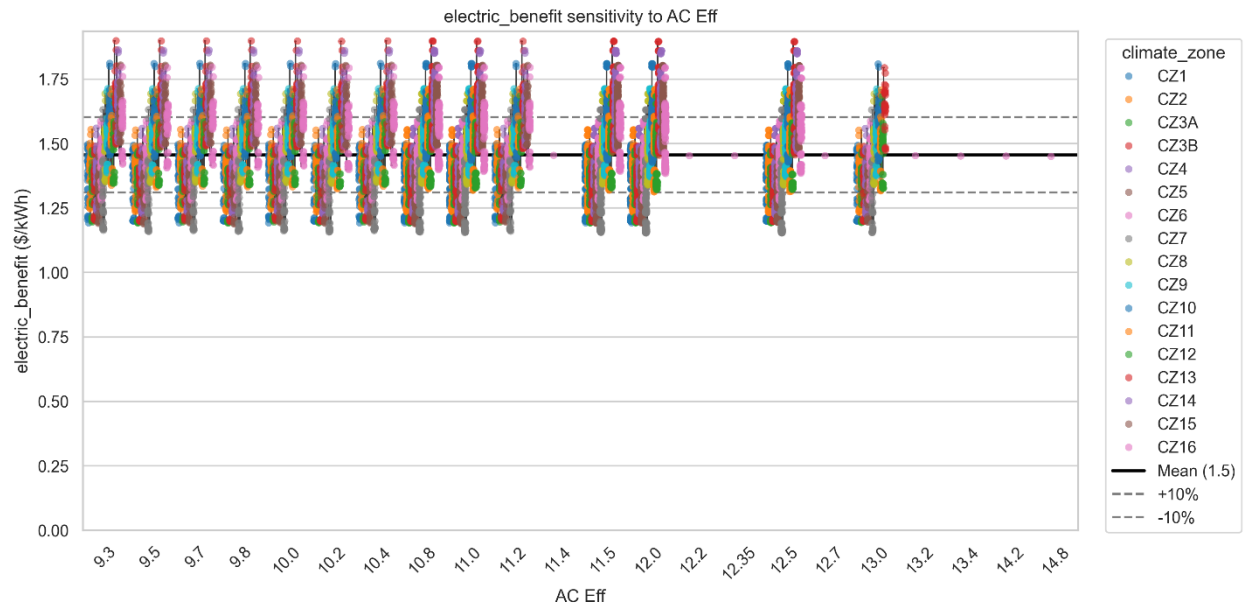


Figure 45: Unit electric benefits vs. building location and AC efficiency

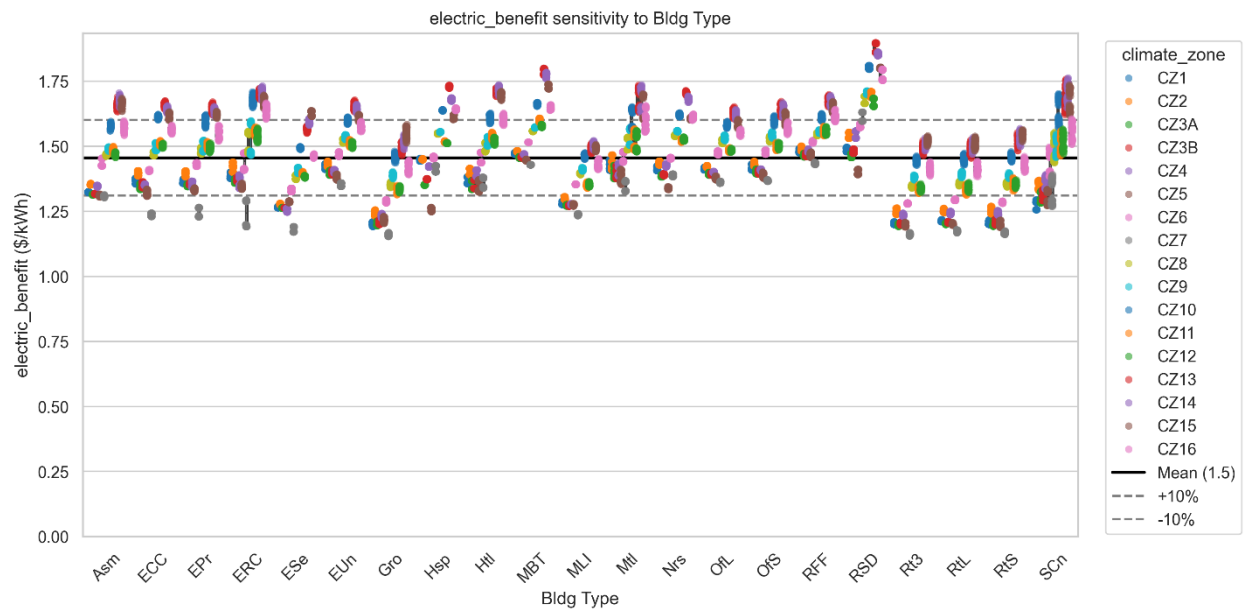


Figure 46: Unit electric benefits vs. building location and building type.

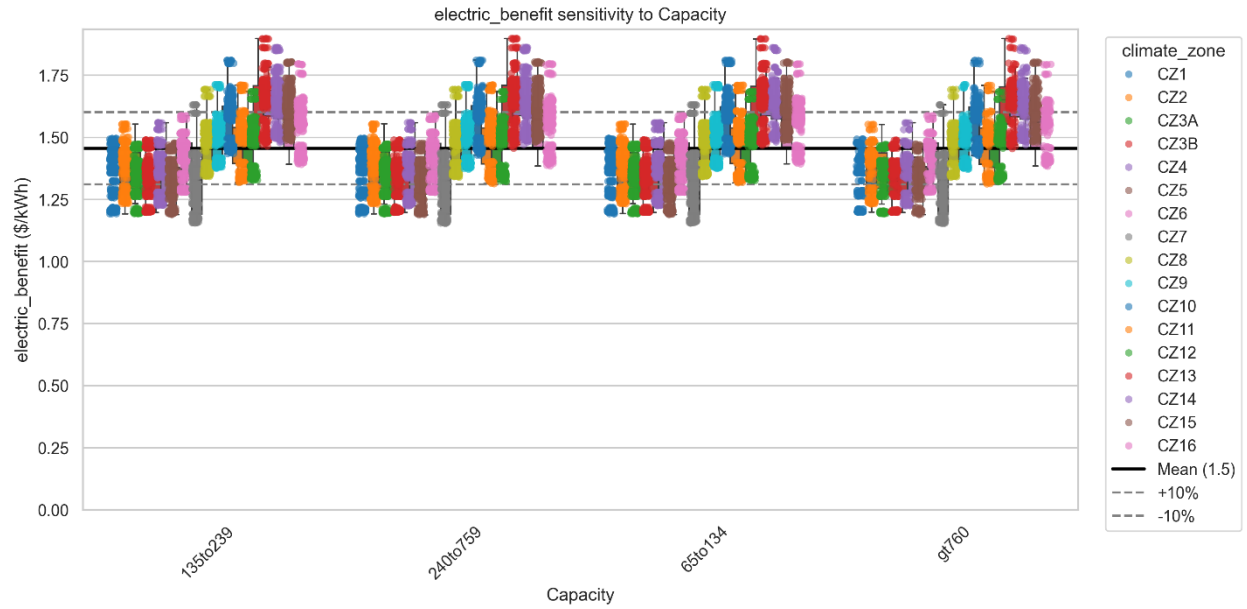


Figure 47: : Unit electric benefits vs. building location and capacity

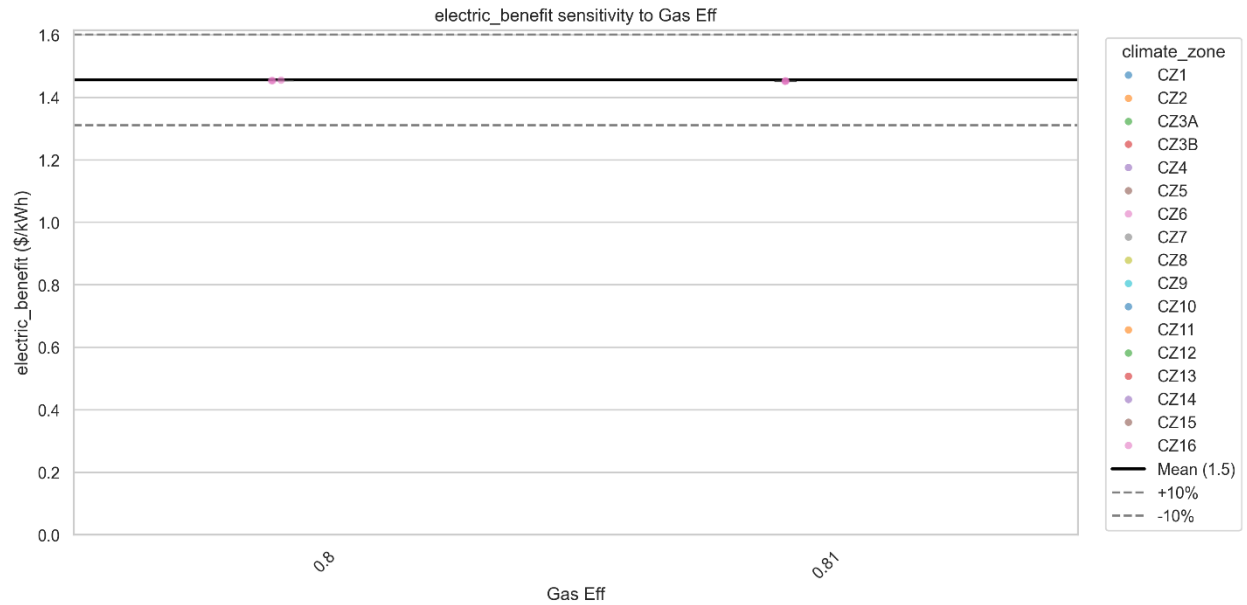


Figure 48: Unit electric benefits vs. building location and gas efficiency.

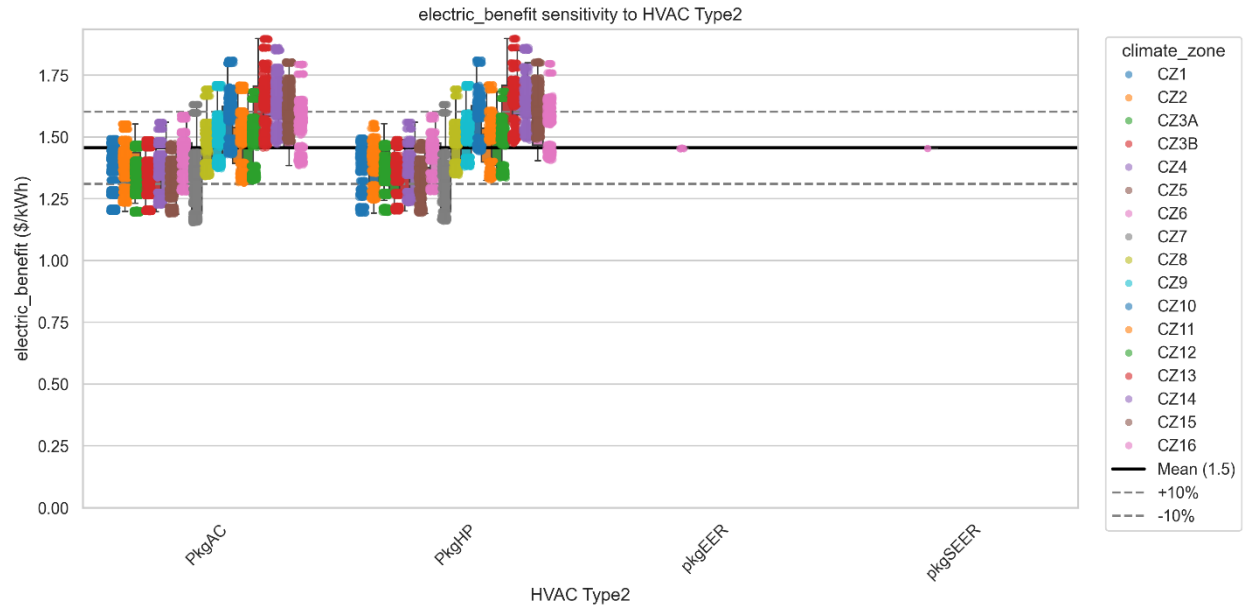


Figure 49: Unit electric benefits vs. building location and HVAC type.

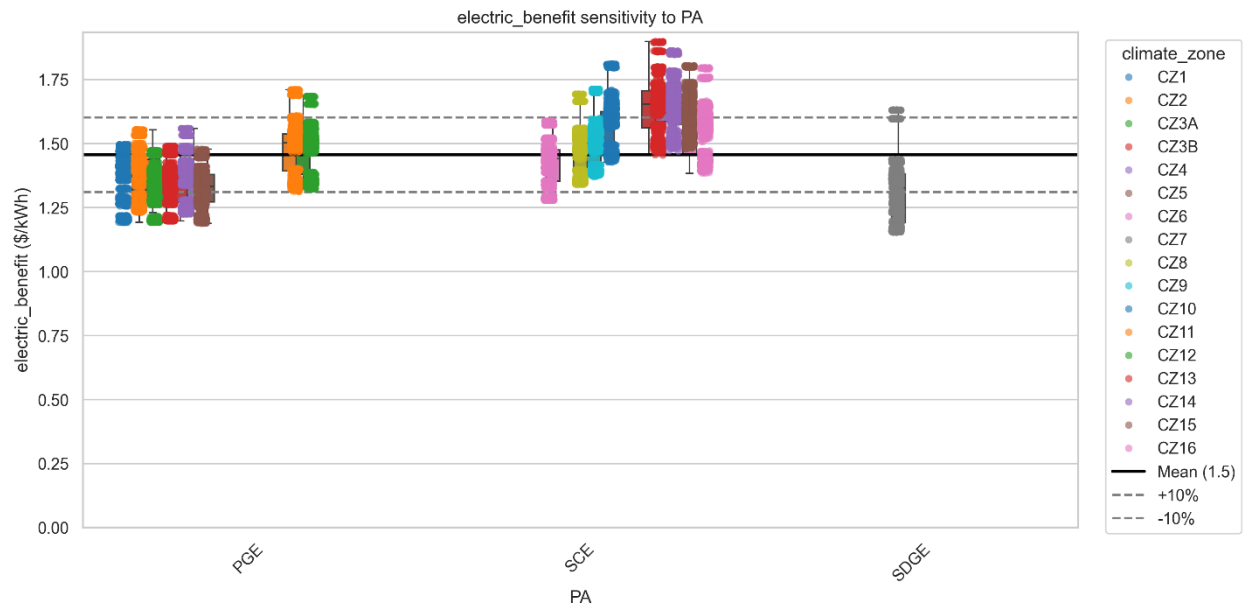


Figure 50: Unit electric benefits vs. building location and PA.

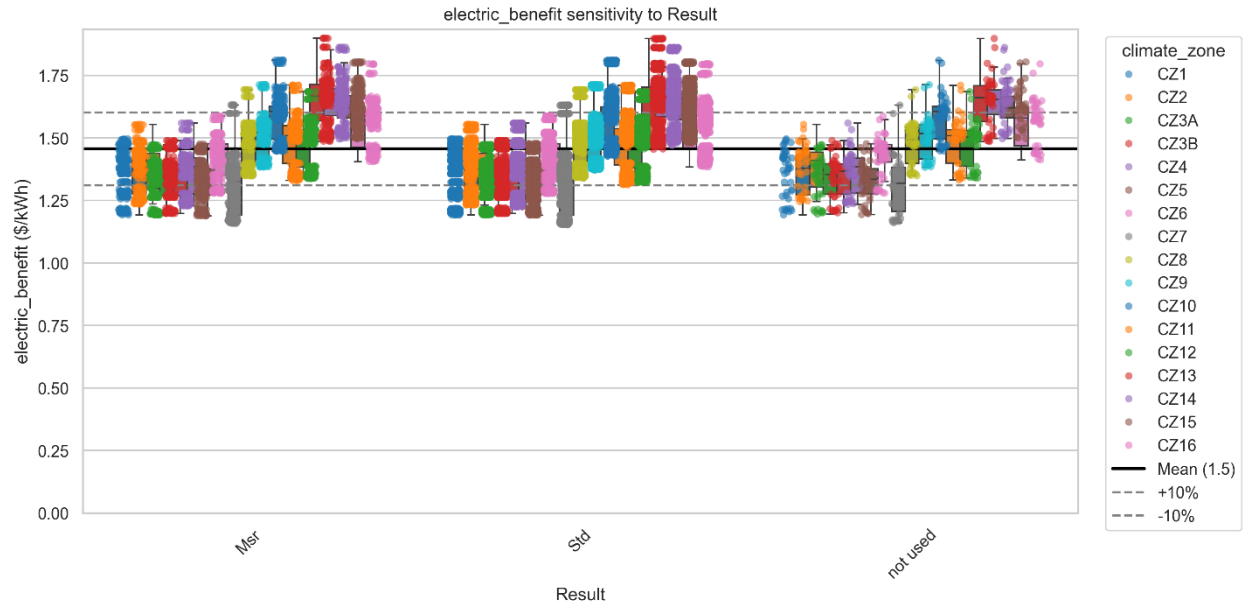


Figure 51: Unit electric benefits vs. building location and base case.

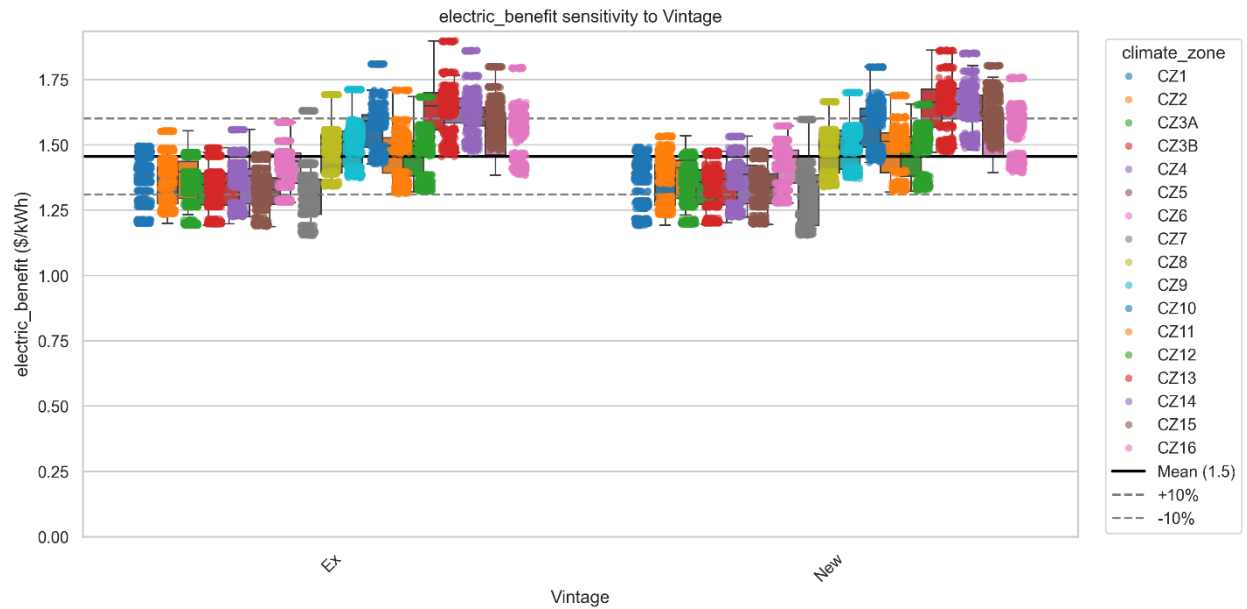


Figure 52: Unit electric benefits vs. building location and vintage.

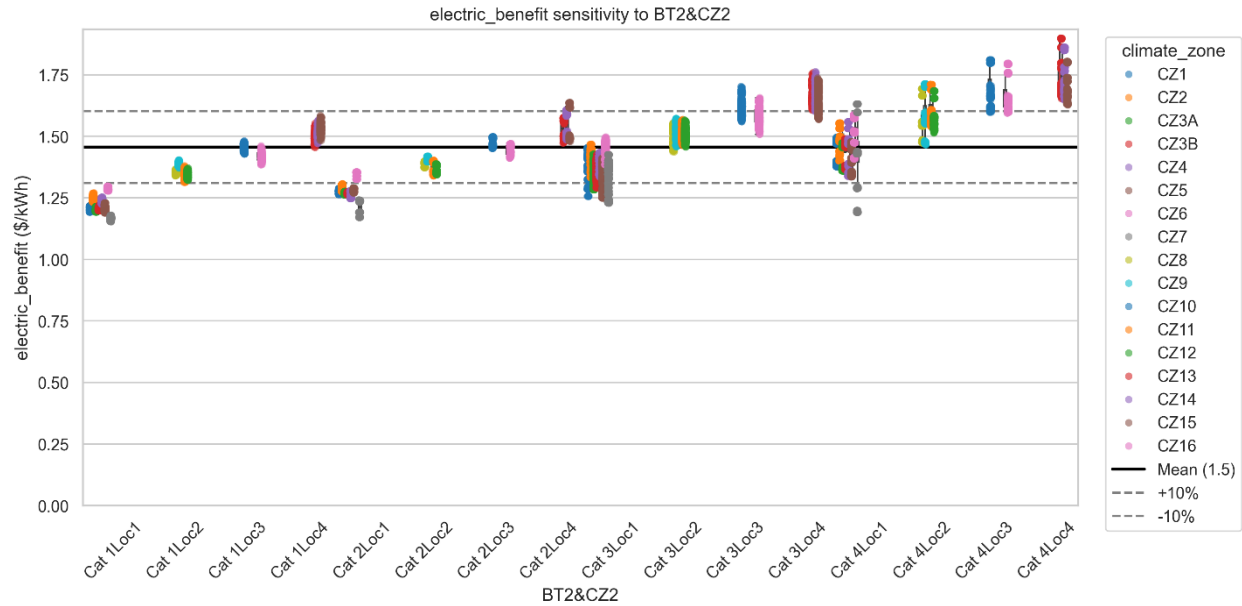


Figure 53: Unit electric benefits vs. building location and groups of building type & building location.

SWHC013 – Building Type specific

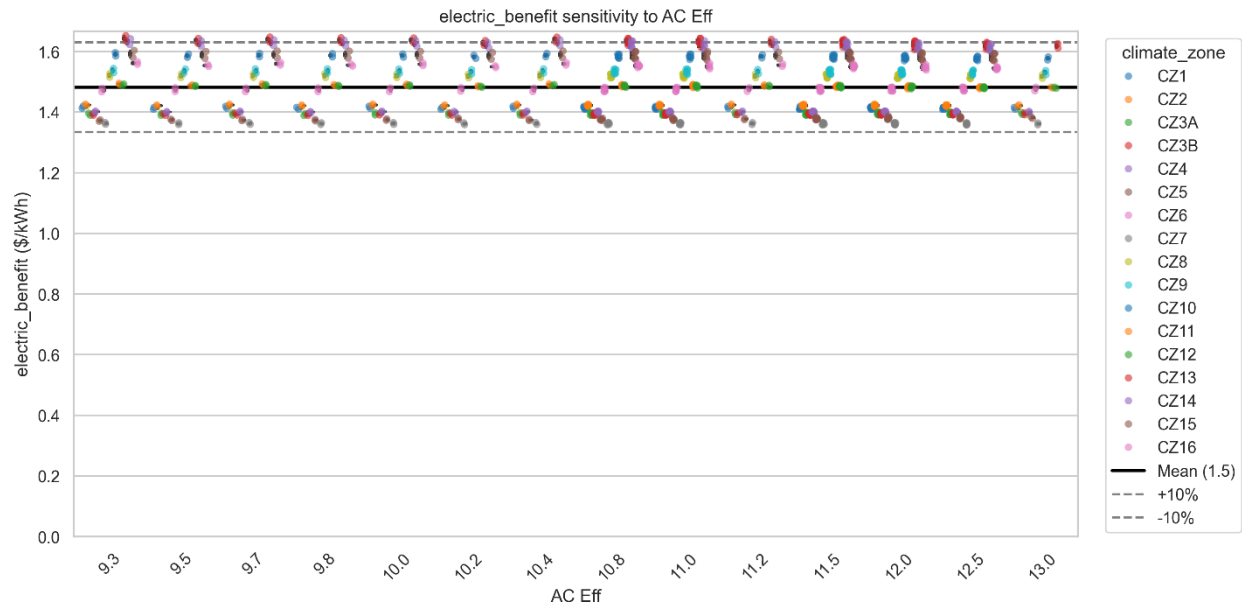


Figure 54: Unit electric benefits vs. building location and AC efficiency for large offices.

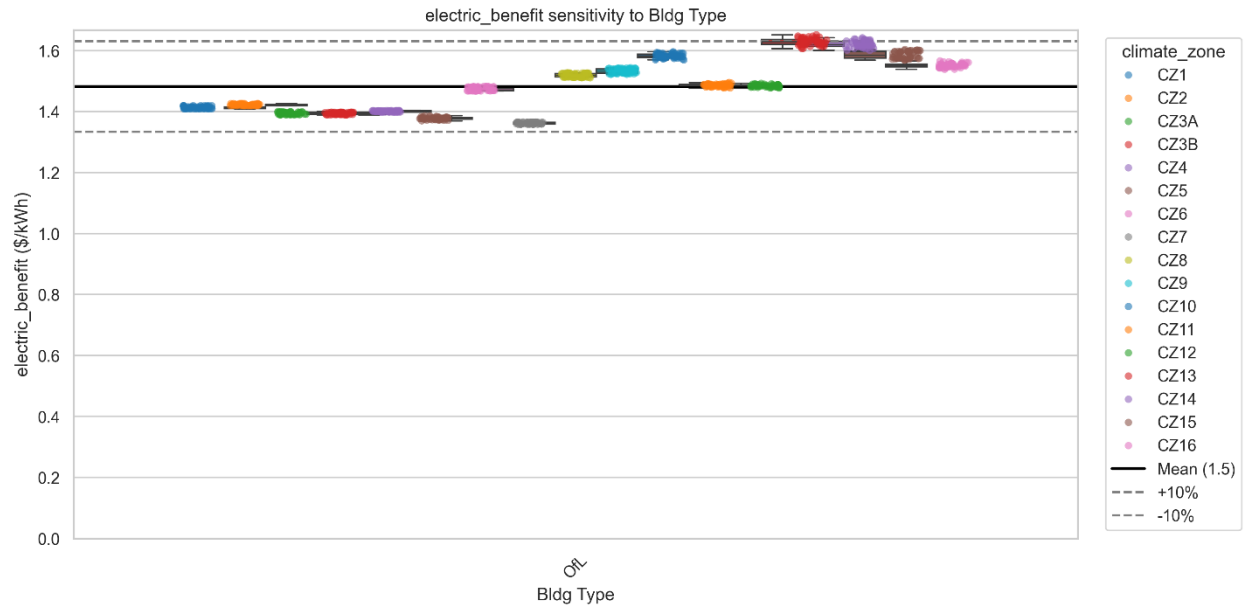


Figure 55: Unit electric benefits vs. building location for large offices.

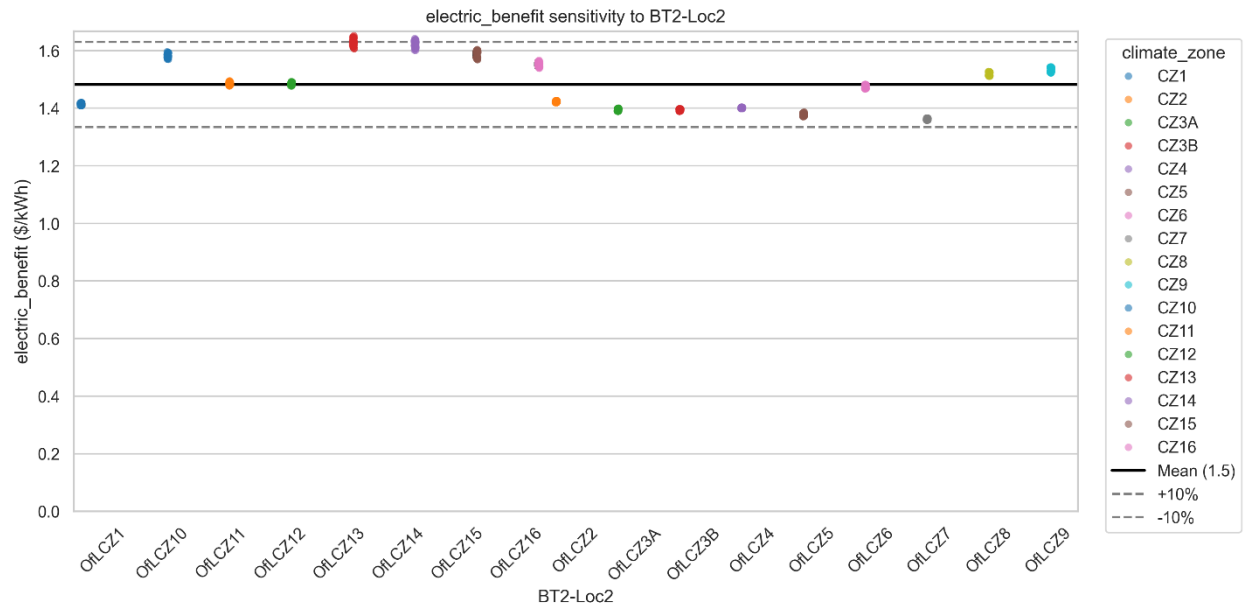


Figure 56: Unit electric benefits vs. building location and groups of building type & building location for large offices.

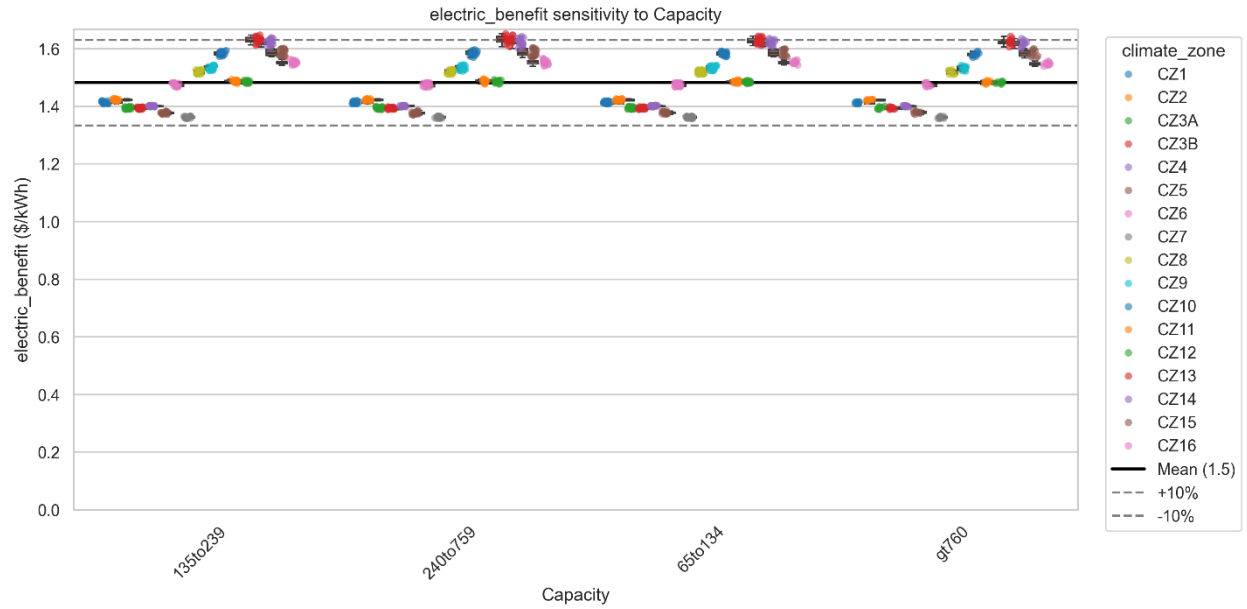


Figure 57: Unit electric benefits vs. building location and capacity for large offices.

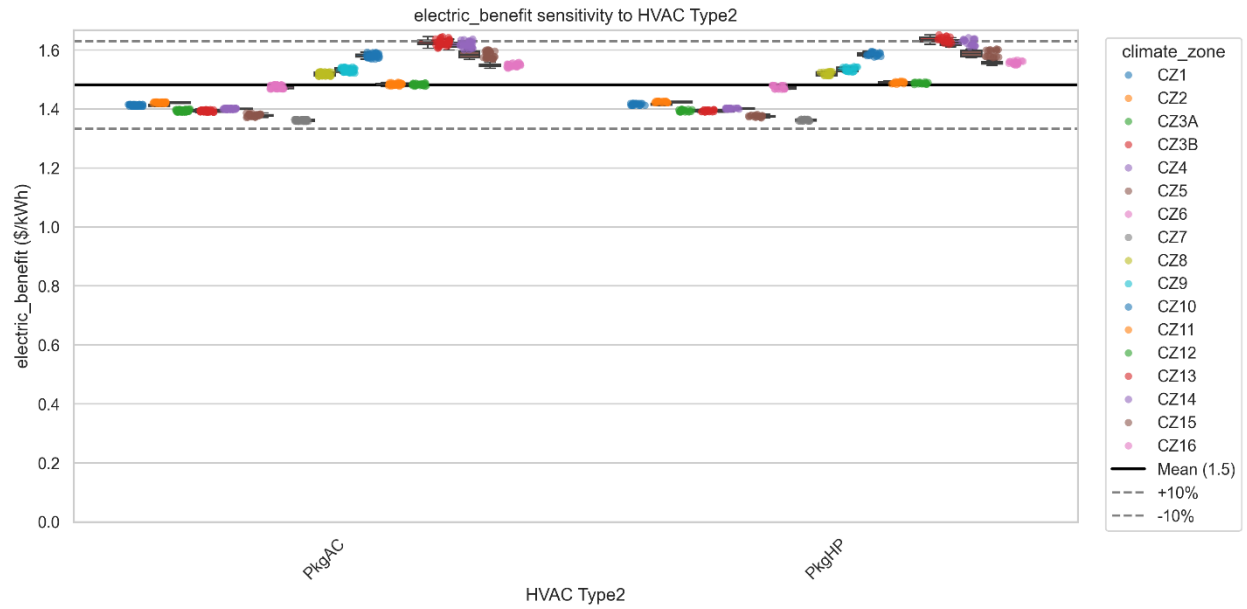


Figure 58: Unit electric benefits vs. building location and HVAC type for large offices.

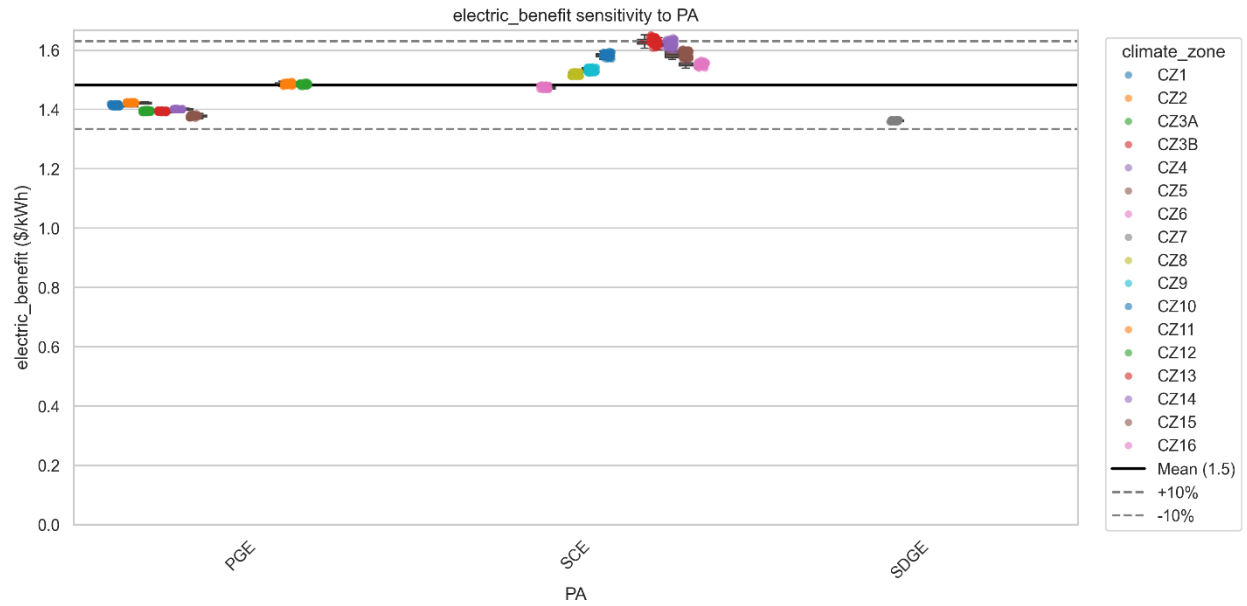


Figure 59: Unit electric benefits vs. building location and PA for large offices.

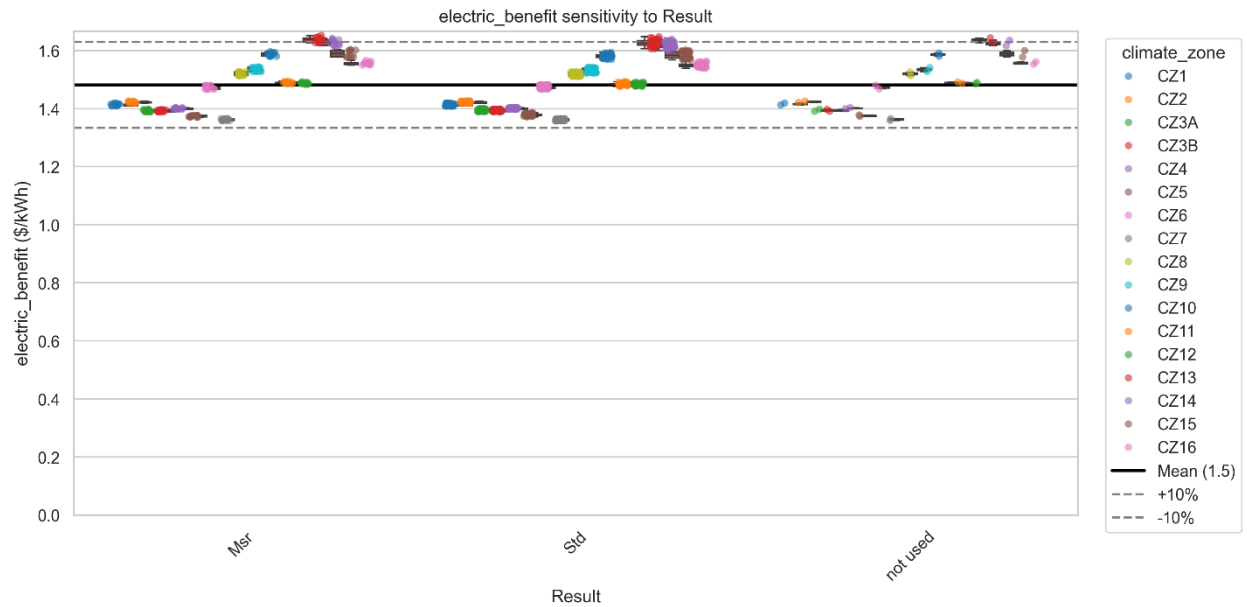


Figure 60: Unit electric benefits vs. building location and base case for large offices.

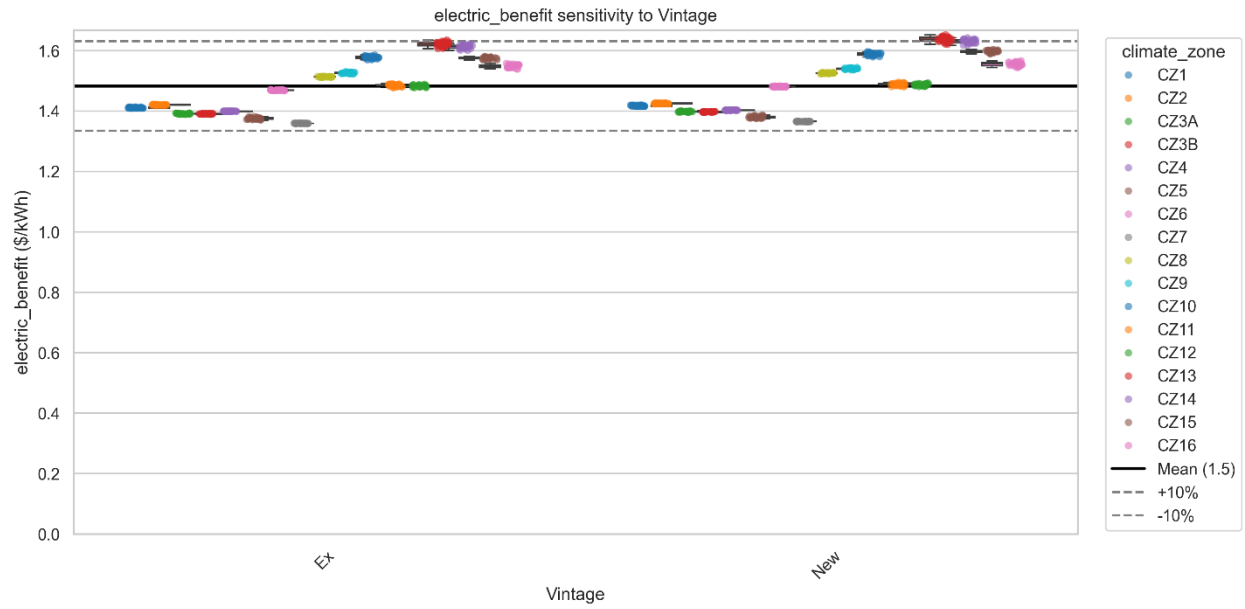


Figure 61: Unit electric benefits vs. building location and vintage for large offices.

SWHC013 – Base and Measure Case jitter plots

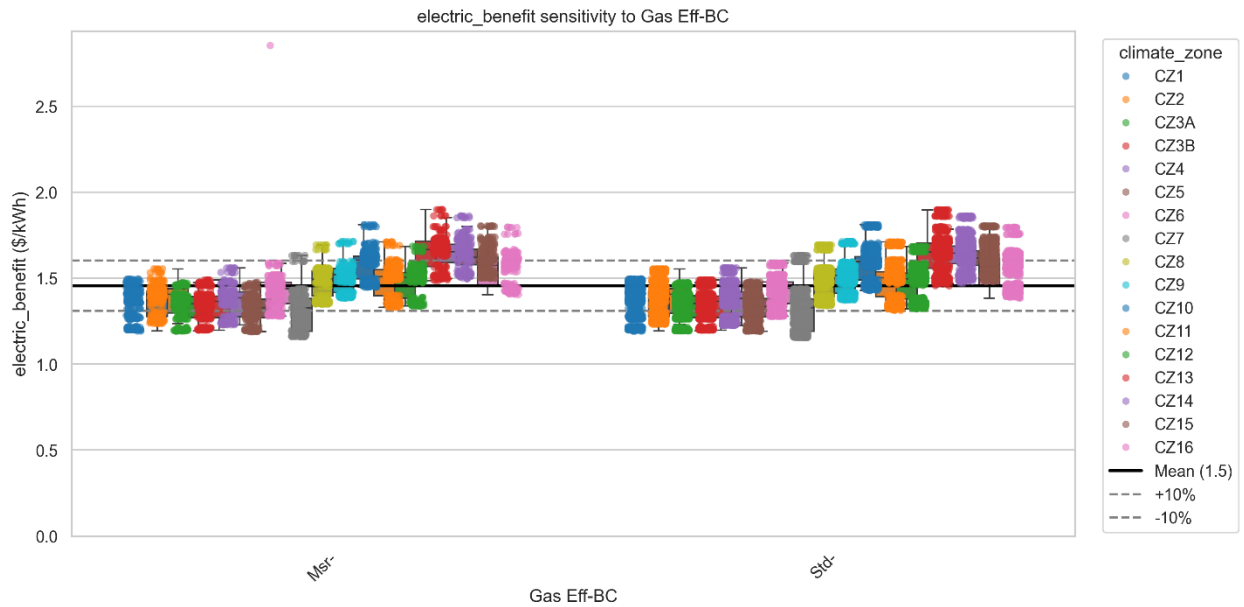


Figure 62: Unit electric benefits vs. building location and base case.

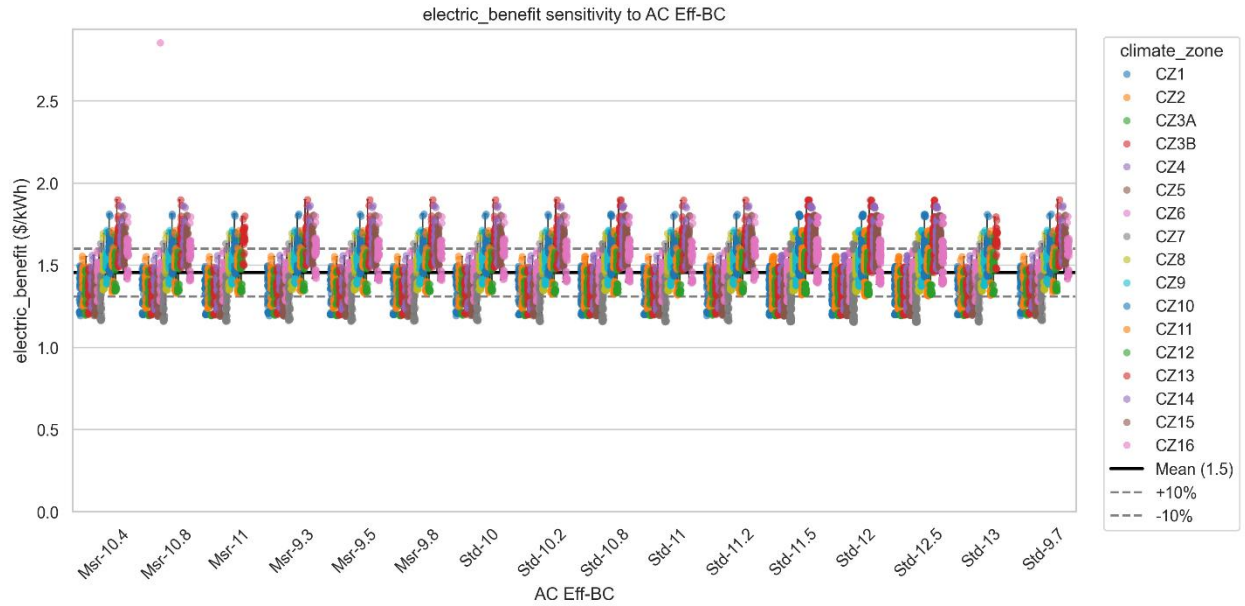


Figure 63: Unit electric benefits vs. building location and base case and equipment efficiency.

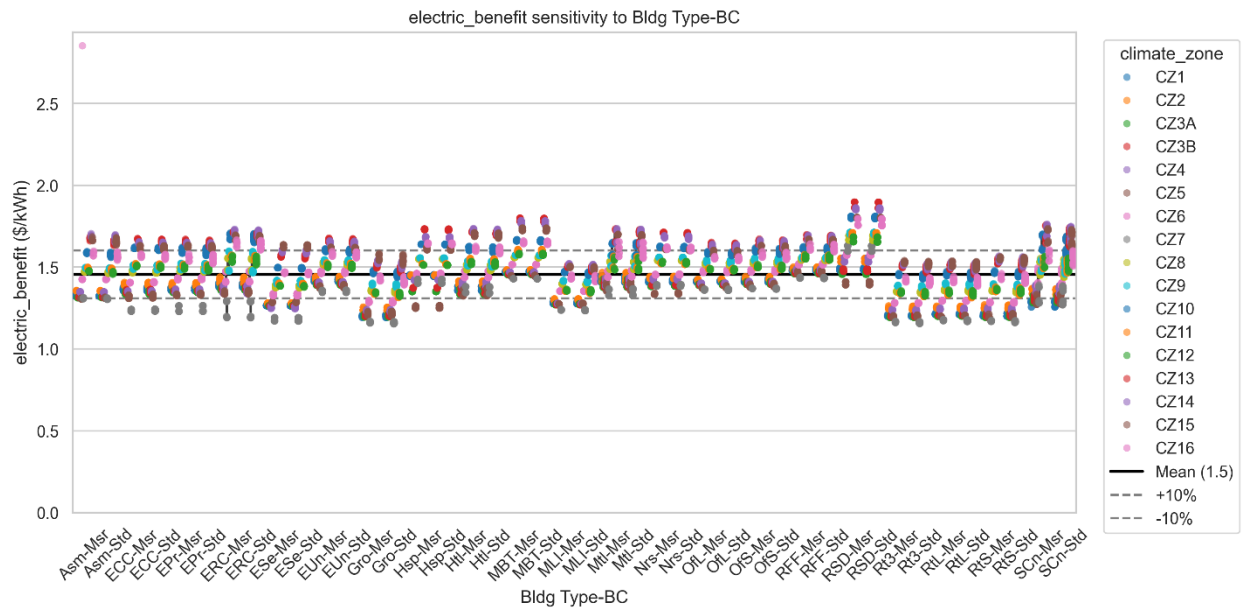


Figure 64: Unit electric benefits vs. building location and base case and building type.

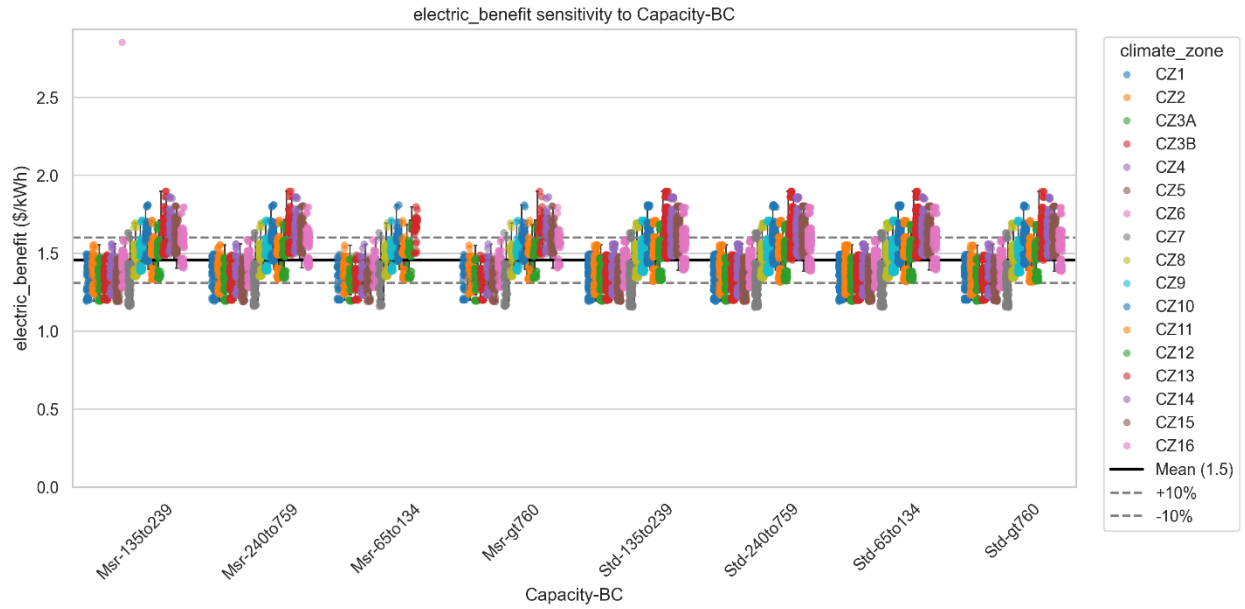


Figure 65: Unit electric benefits vs. building location and base case and capacity.

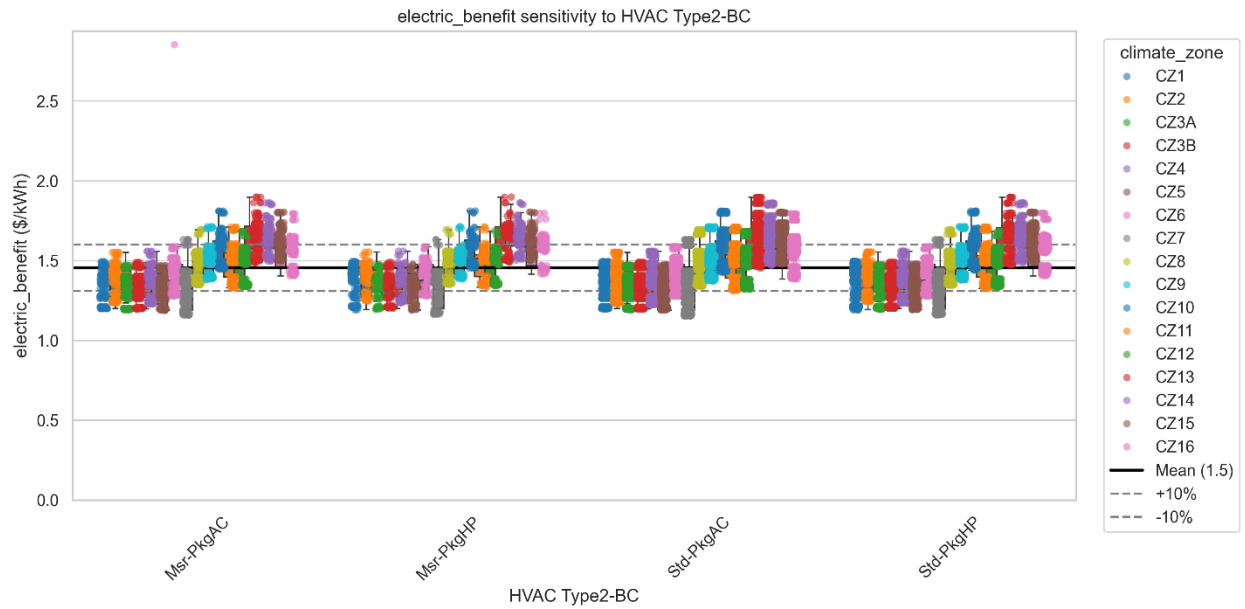


Figure 66: Unit electric benefits vs. building location and base case and HVAC type.

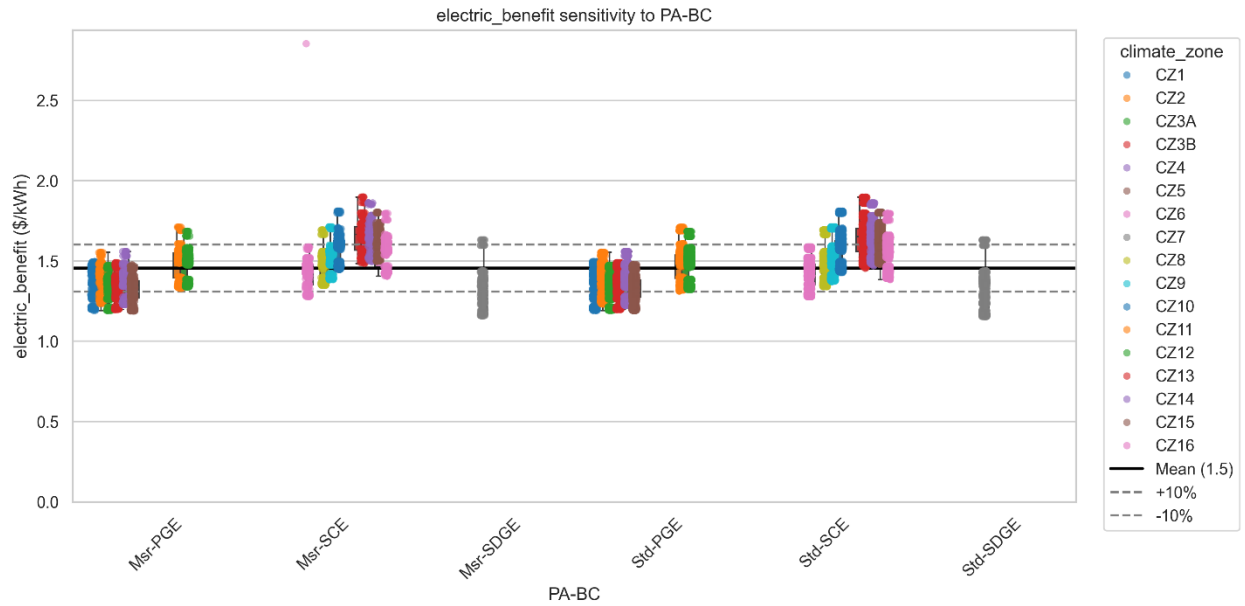


Figure 67: Unit electric benefits vs. building location and base case and IOU.

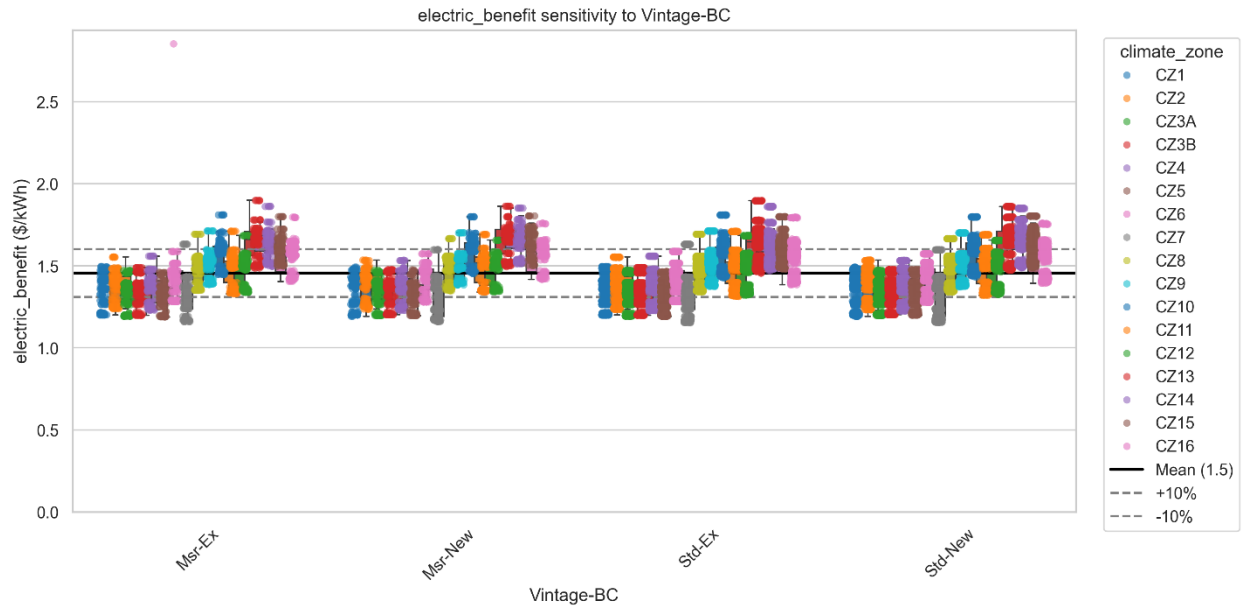


Figure 68: Unit electric benefits vs. building location and base case and vintage.

SWHC043, Multiple Capacity Unitary Air-Cooled Commercial AC (65–240 kBtu/hr)

Parameter Name	CLS	Max SD	Avg SD	Parameters
Whole Model	~4,000		10%	
Building Type	21	9.8%	7.5%	Asm, Com, ECC, EPr, ERC, ESe, EUn, Gro, Hsp, Htl, MBT, MLI, Mtl, Nrs, OfL, OfS, RFF, RSD, Rt3, RtL, RtS, SCn
Building Location	16	8%	6%	CZ01, CZ02, CZ03, CZ04, CZ05, CZ06, CZ07, CZ08, CZ09, CZ10, CZ11, CZ12, CZ13, CZ14, CZ15, CZ16
Equipment Efficiency	5	10%	9.9%	10.8, 11, 12, 12.5, 13
Capacity Range	2	10%	10%	135 - 239, 65 - 134
Vintage	2	10%	9.9%	Ex, New
BT&CZ	336	4.1%	0.8%	Asm&CZ01, Asm&CZ02, ..., SCn&CZ15, SCn&CZ16
BT2&CZ2	16	4.7%	3.0%	BT1&Loc1, BT1&Loc2, ..., BT4&Loc3, BT4&Loc4

Table 25: SWHC043 parameter results

SWHC043 – Parameter specific jitter plots

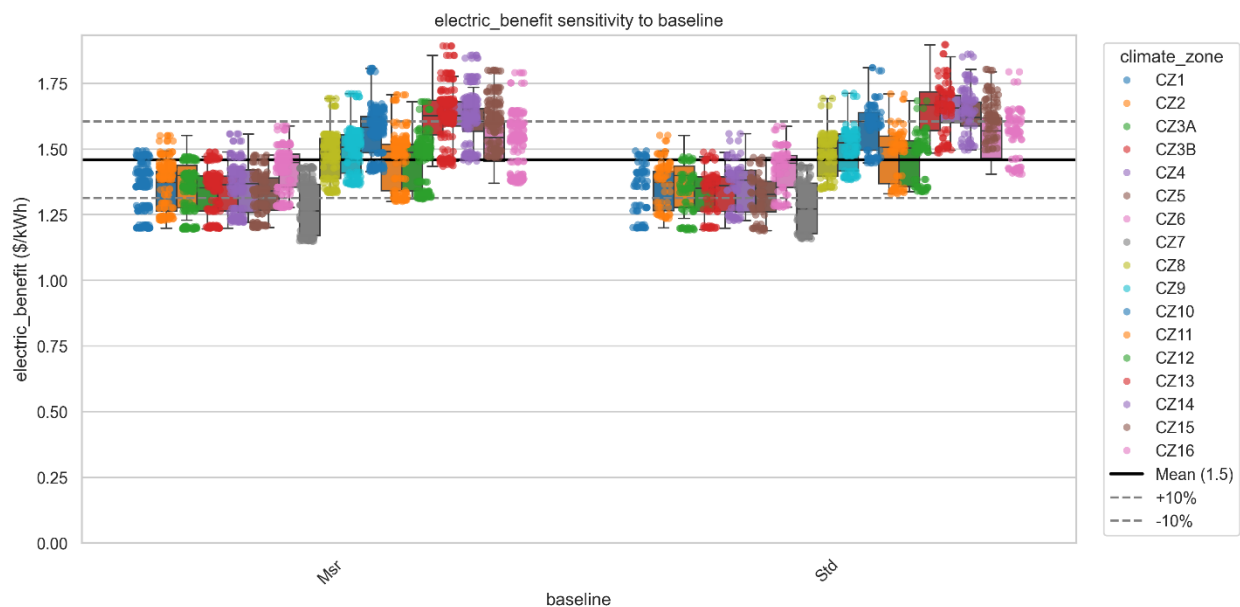


Figure 69: Unit electric benefits vs. building location and base case.

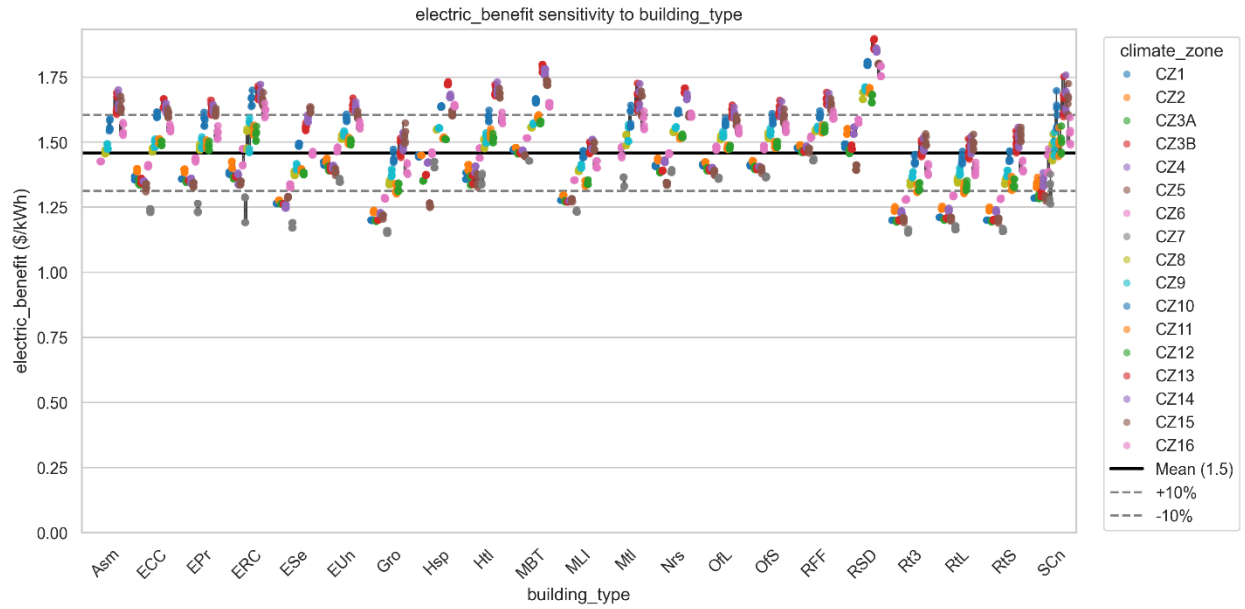


Figure 70: Unit electric benefits vs. building location and building type.

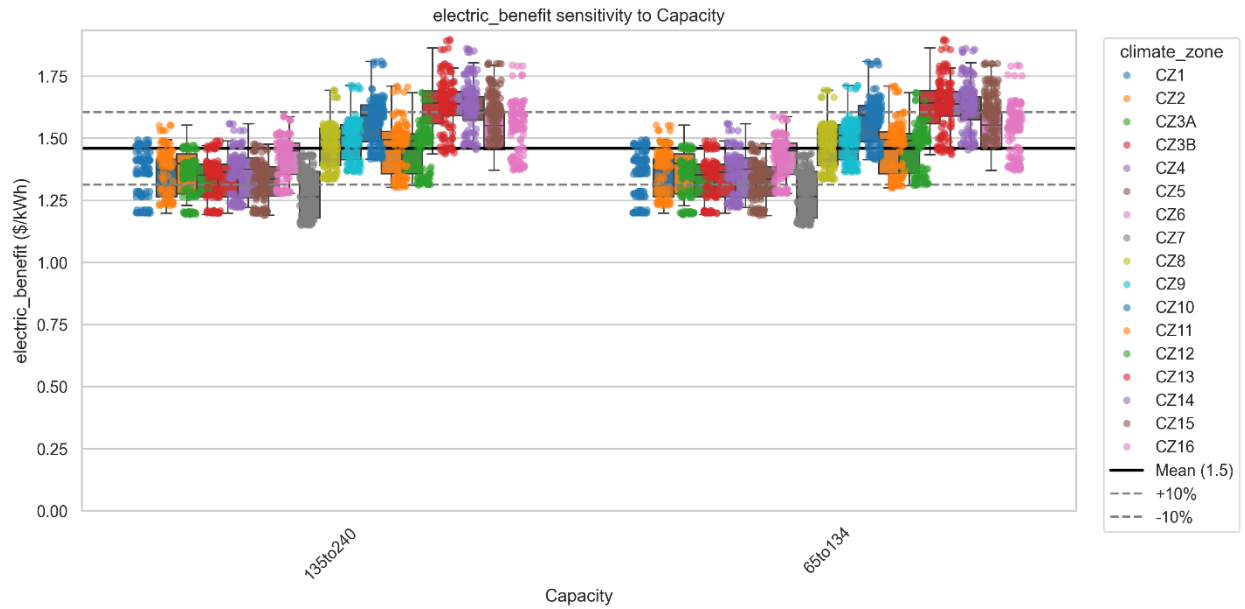


Figure 71: Unit electric benefits vs. building location and capacity.

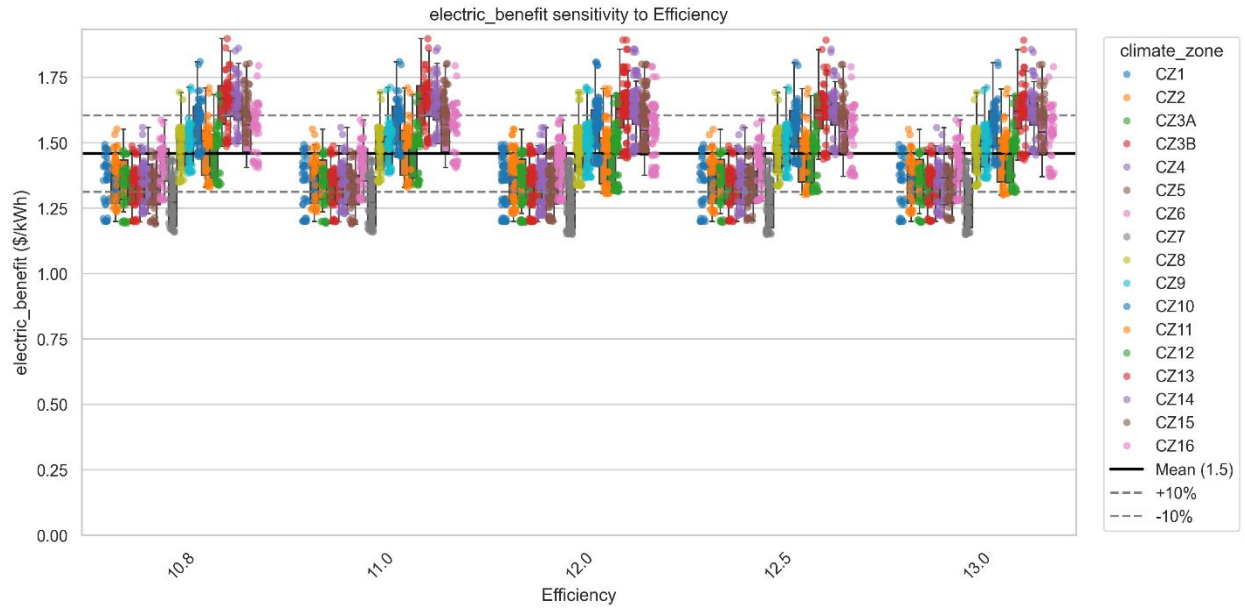


Figure 72: Unit electric benefits vs. building location and efficiency.

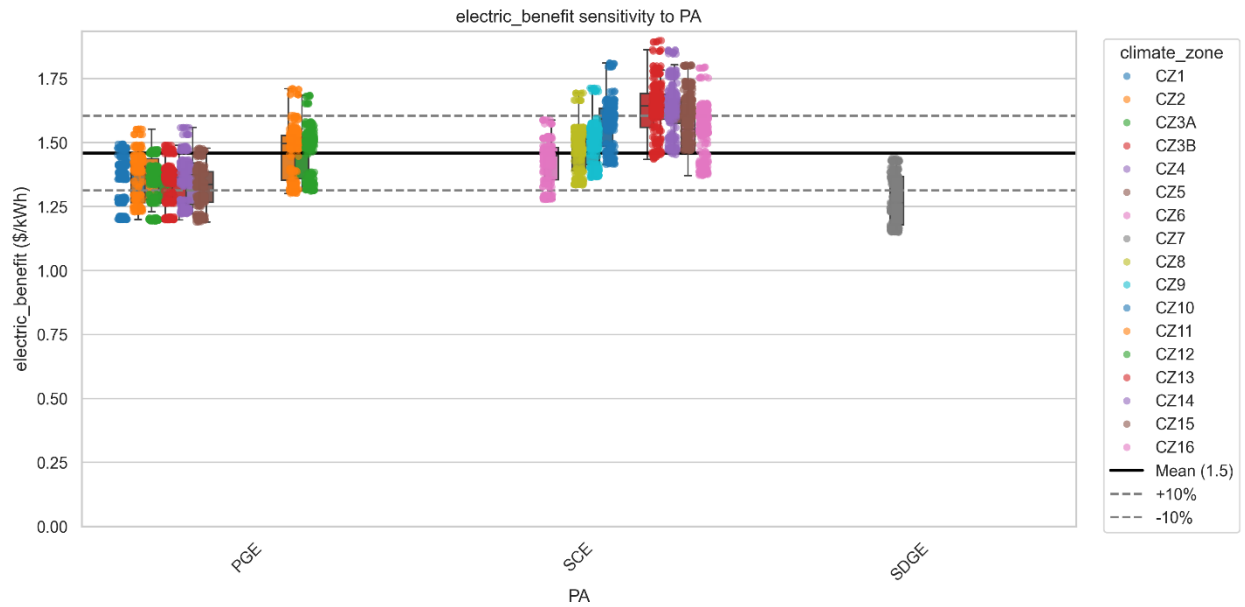


Figure 73: Unit electric benefits vs. building location and IOU.

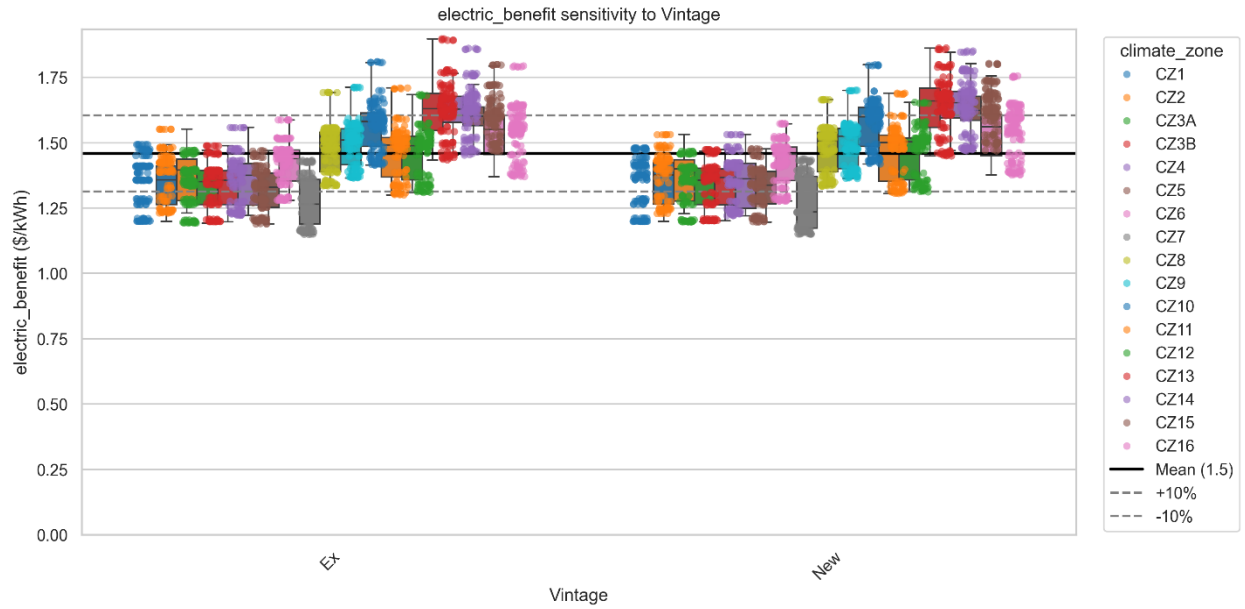


Figure 74: Unit electric benefits vs. building location and vintage.

SWHC043 – Building Type specific

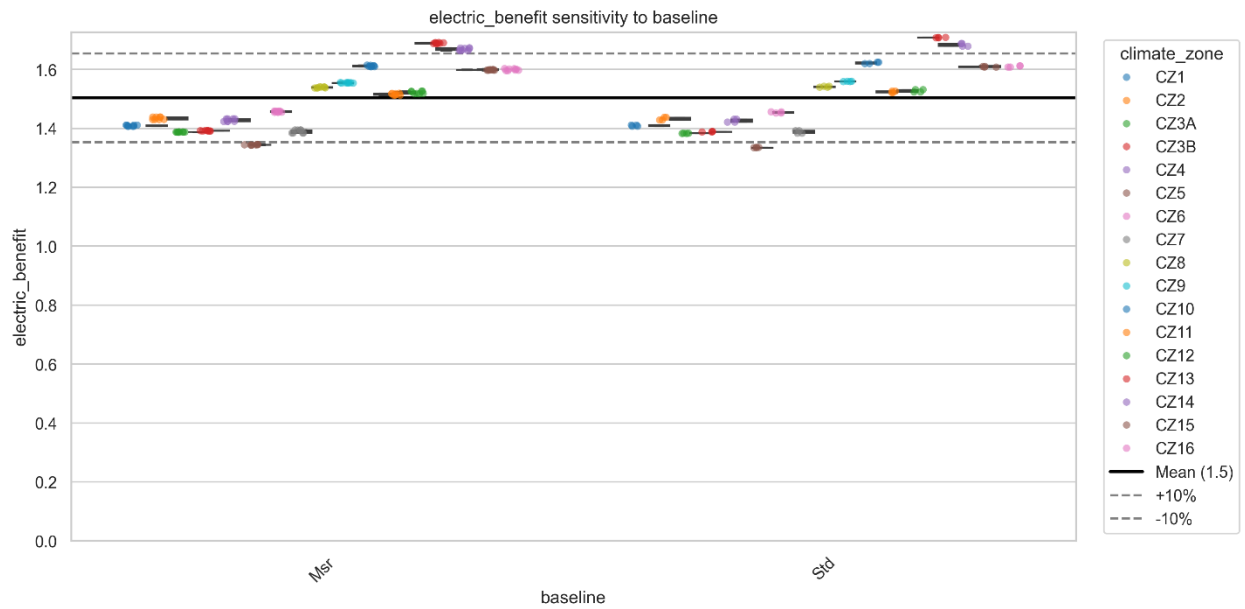


Figure 75: Unit electric benefits vs. building location and base case for nursing homes.

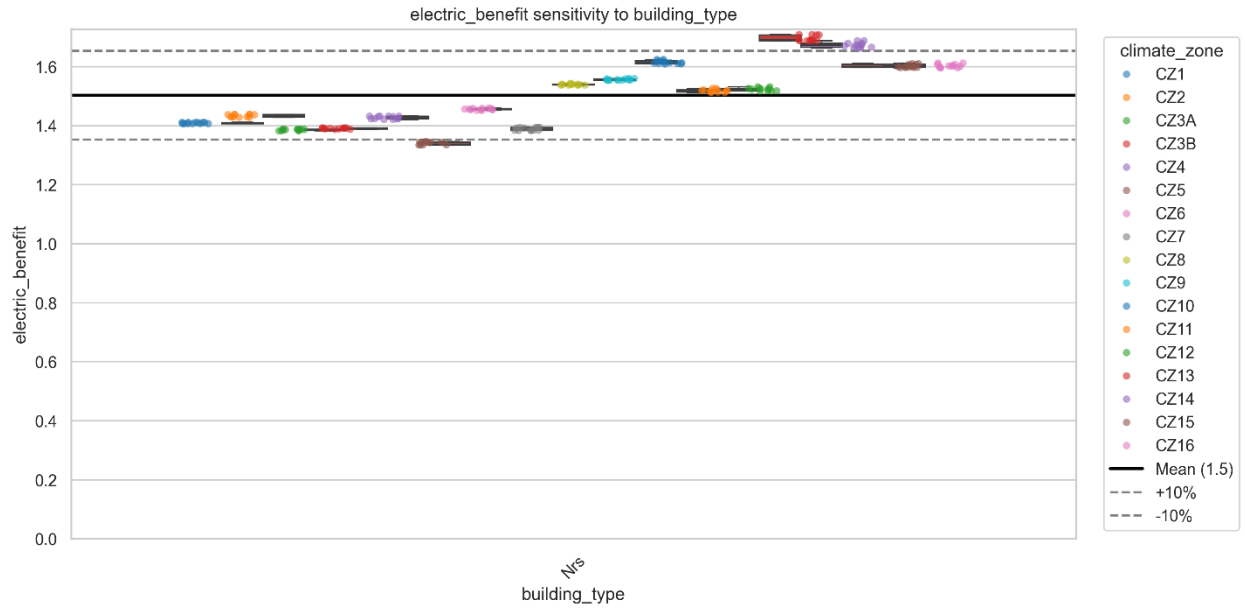


Figure 76: Unit electric benefits vs. building location and for nursing homes.

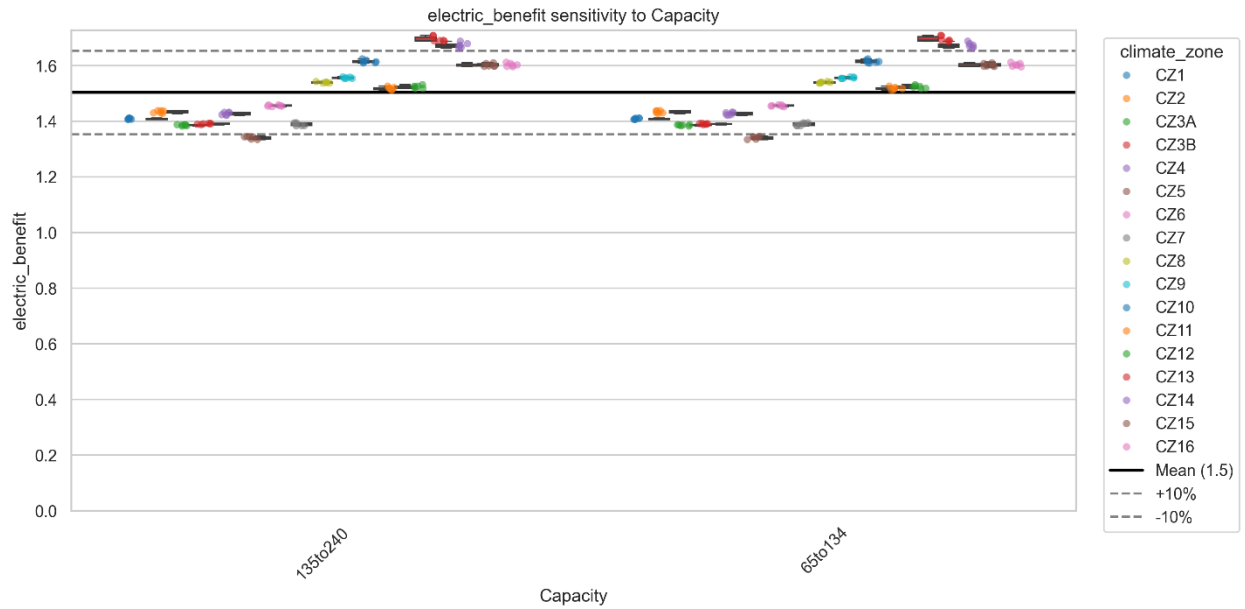


Figure 77: Unit electric benefits vs. building location and capacity for nursing homes.

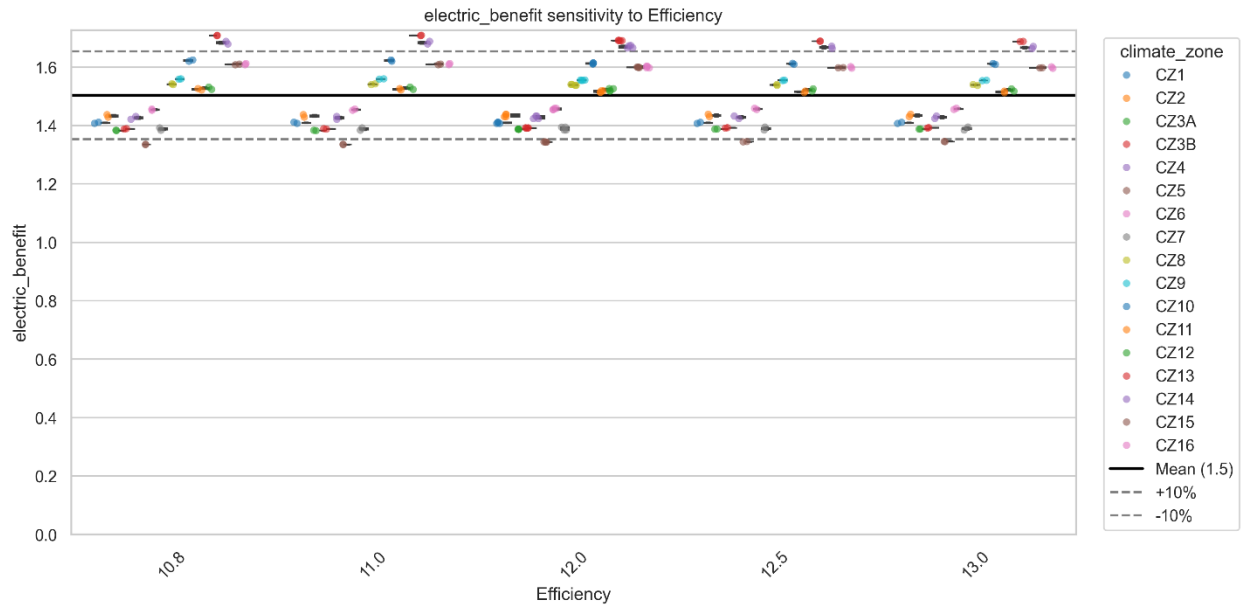


Figure 78: Unit electric benefits vs. building location and efficiency for nursing homes.

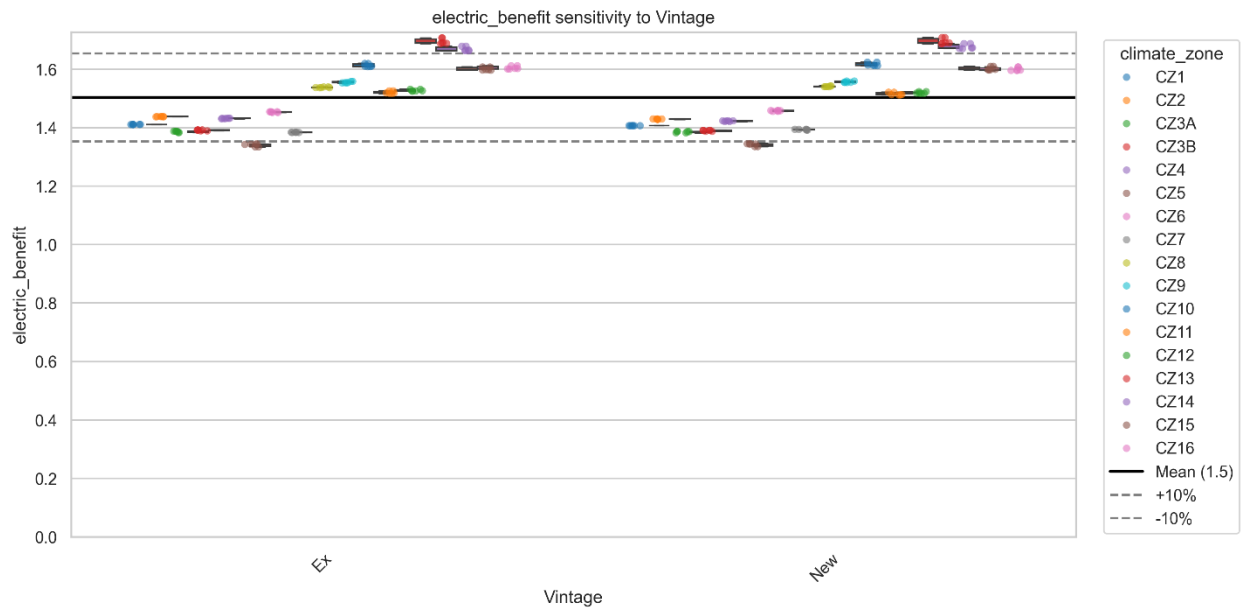


Figure 79: Unit electric benefits vs. building location and vintage for nursing homes.

SWHC043 – Base and Measure Case jitter plots

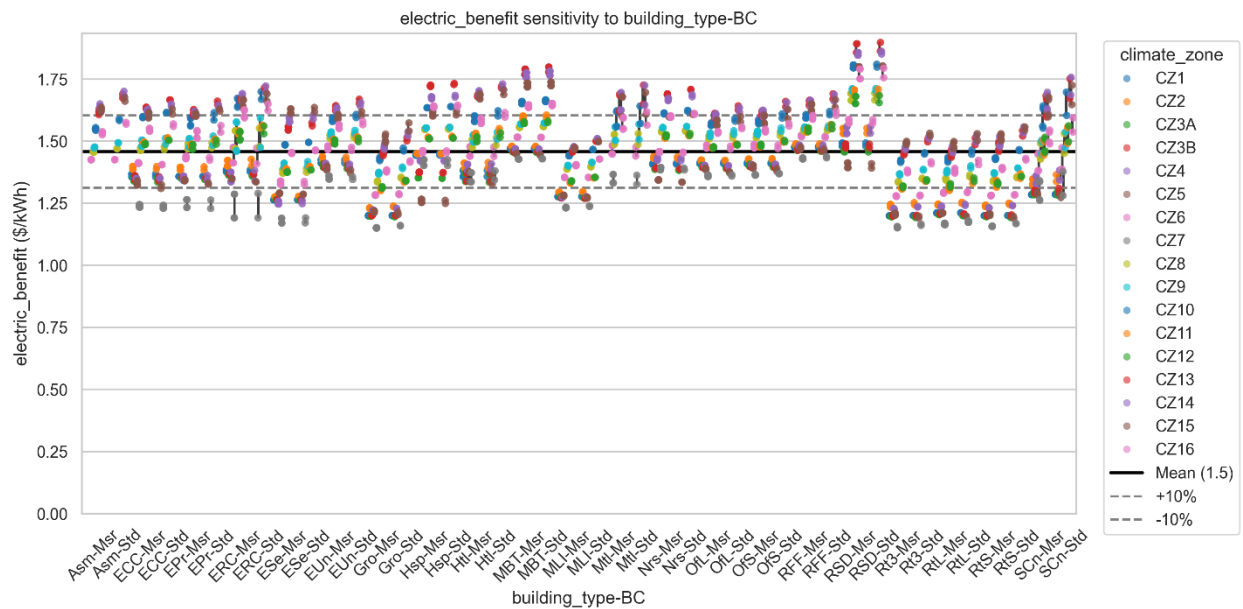


Figure 80: Unit electric benefits vs. building location and base case and building type.

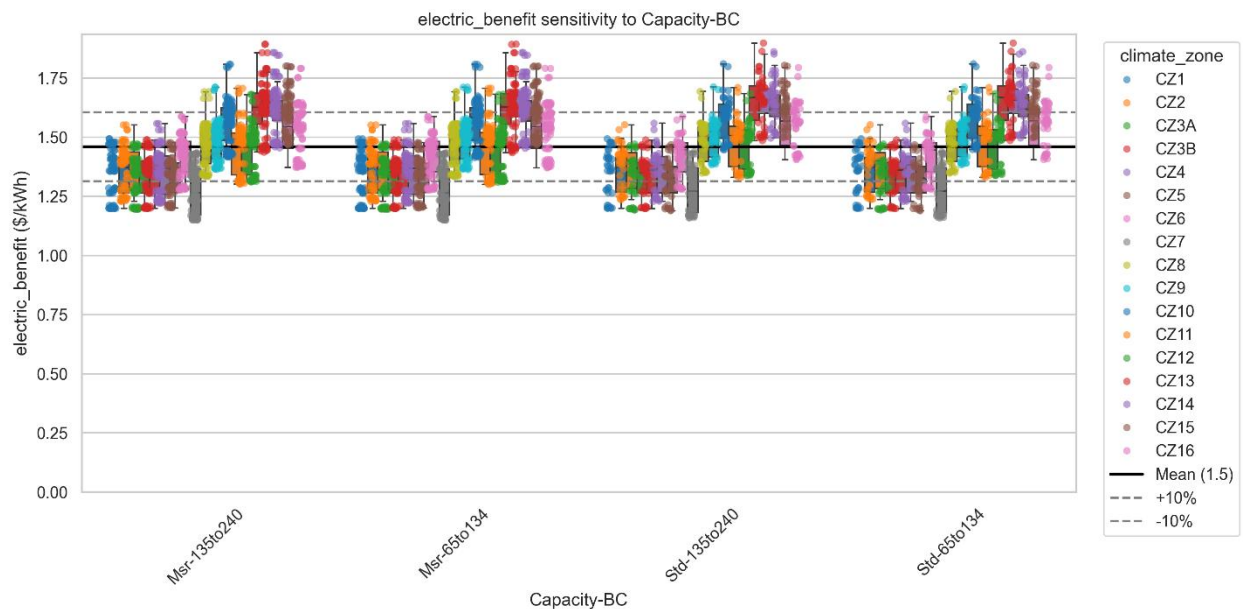


Figure 81: Unit electric benefits vs. building location and base case and capacity.

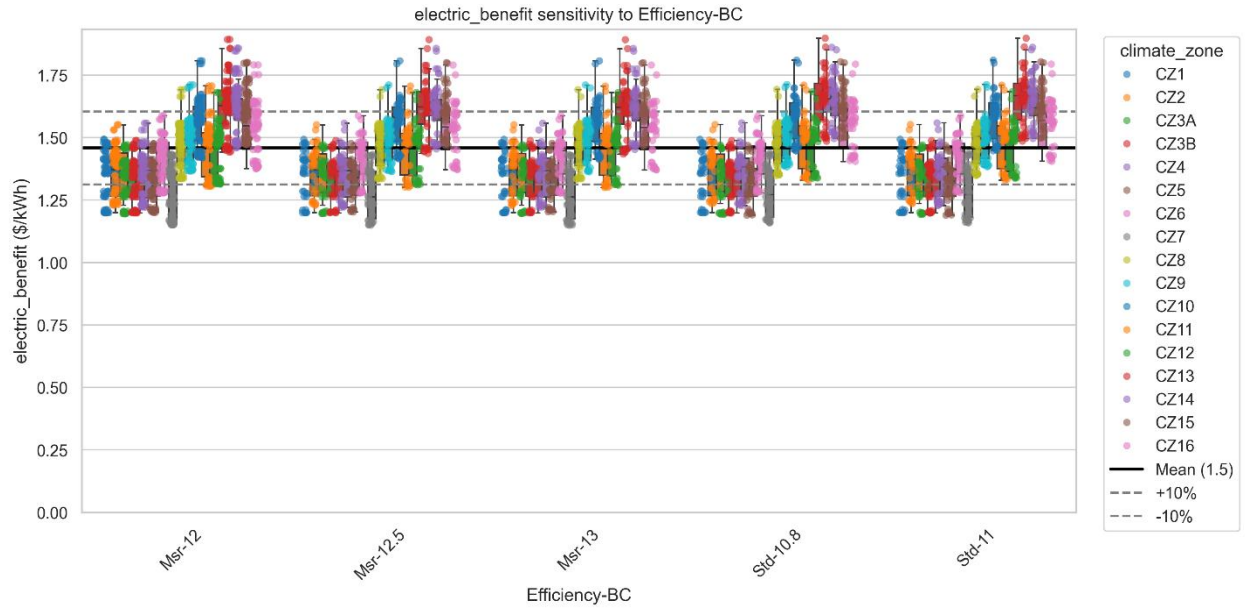


Figure 82: Unit electric benefits vs. building location and base case and equipment efficiency.

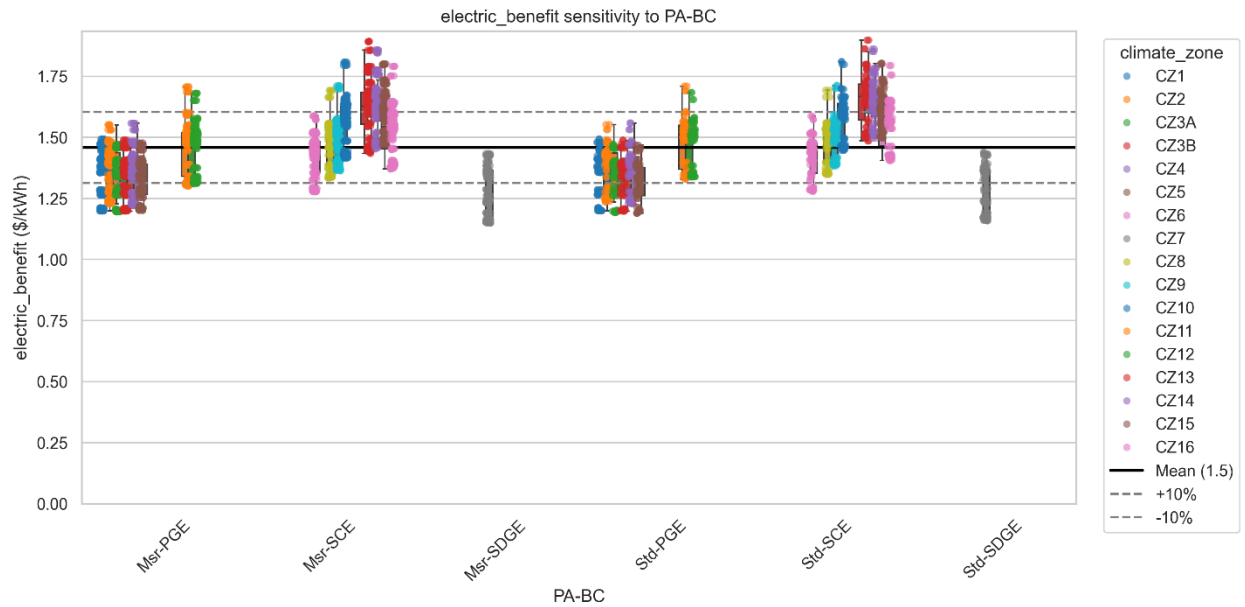


Figure 83: Unit electric benefits vs. building location and base case and IOU.

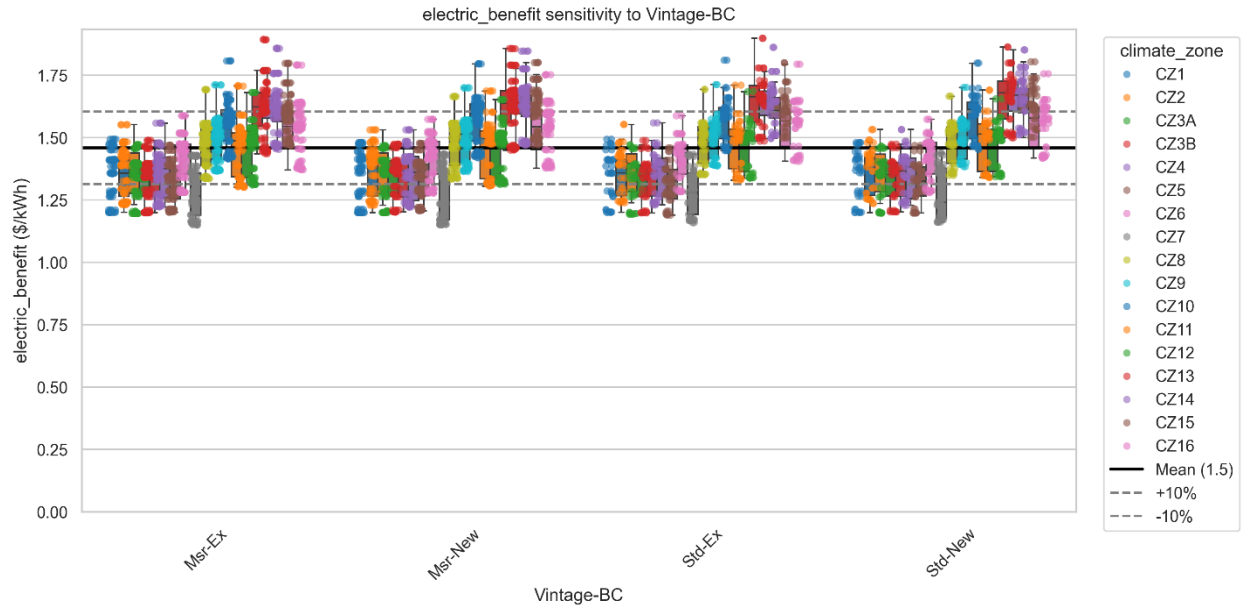


Figure 84: Unit electric benefits vs. building location and base case and vintage.

SWHC045 Heat Pump HVAC, Residential, Fuel Substitution

Parameter Name	CLS	Max SD	Avg SD	Parameters
Total Models	640		18%	
Building Type	3	20%	17%	DMo, MFm, SFm
Building Location	16	22%	14%	CZ01, CZ02, CZ03, CZ04, CZ05, CZ06, CZ07, CZ08, CZ09, CZ10, CZ11, CZ12, CZ13, CZ14, CZ15, CZ16
Equipment Type	5	17%	13%	DXGF, DXHP, DXHW, NCGF, NCOH
Equipment Efficiency	9	16%	14%	12.4, 14.3, 15.2, 16, 16.9, 17.8 18.7, 19.6, No Cooling
HVAC&CZ	86	21%	5.4%	DXGF&CZ01, DXGF&CZ01, ..., NCOH&CZ15, NCOH&CZ16
HVAC&CZ2	20	25%	18%	DXGF&Loc1, DXGF&Loc2, ..., NCOH&Loc3, NCOH&Loc4

Table 26: SWHC045 parameter results

SWHC045 – Parameter specific jitter plots

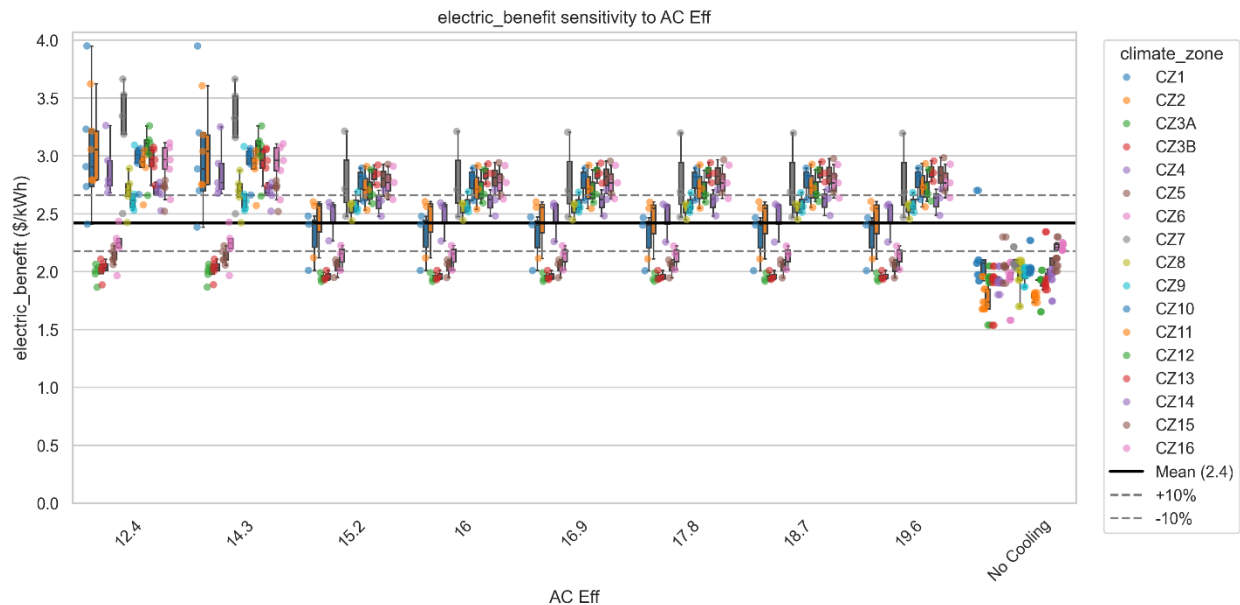


Figure 85: Unit electric benefits vs. building location and equipment efficiency.

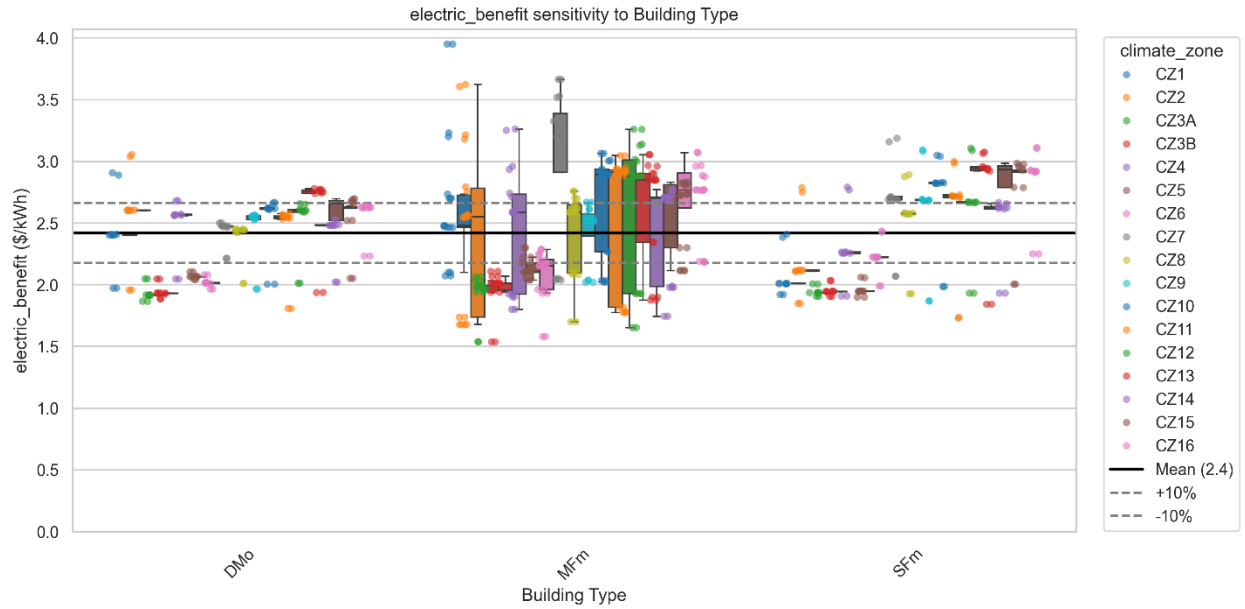


Figure 86: Unit electric benefits vs. building location and building type.

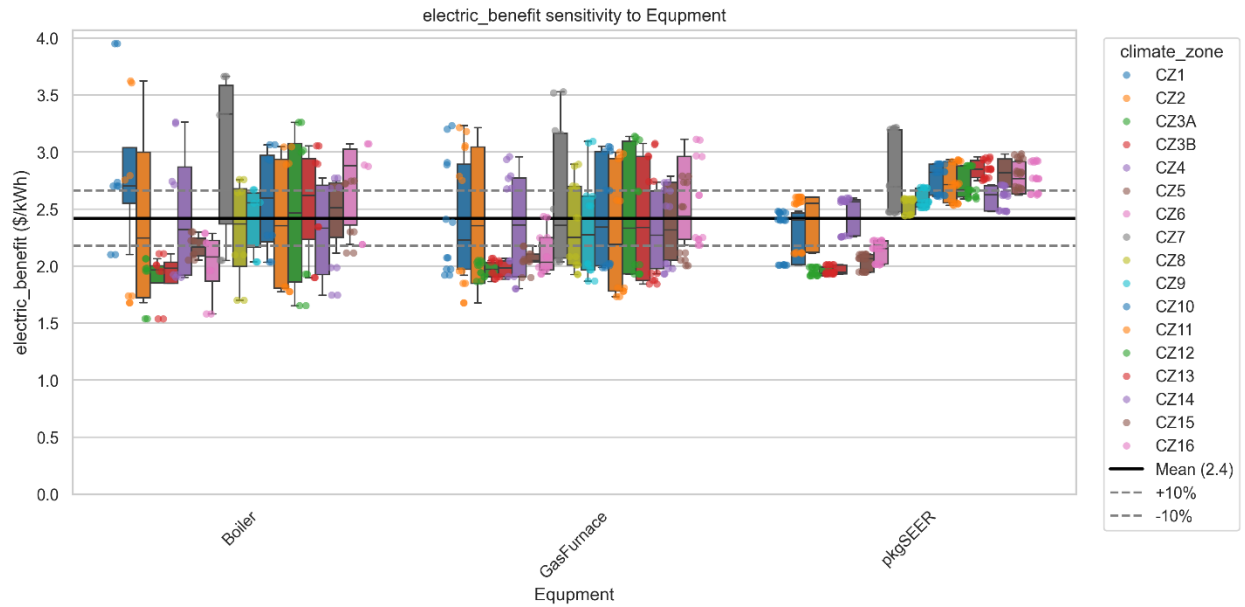


Figure 87: Unit electric benefits vs. building location and equipment type.

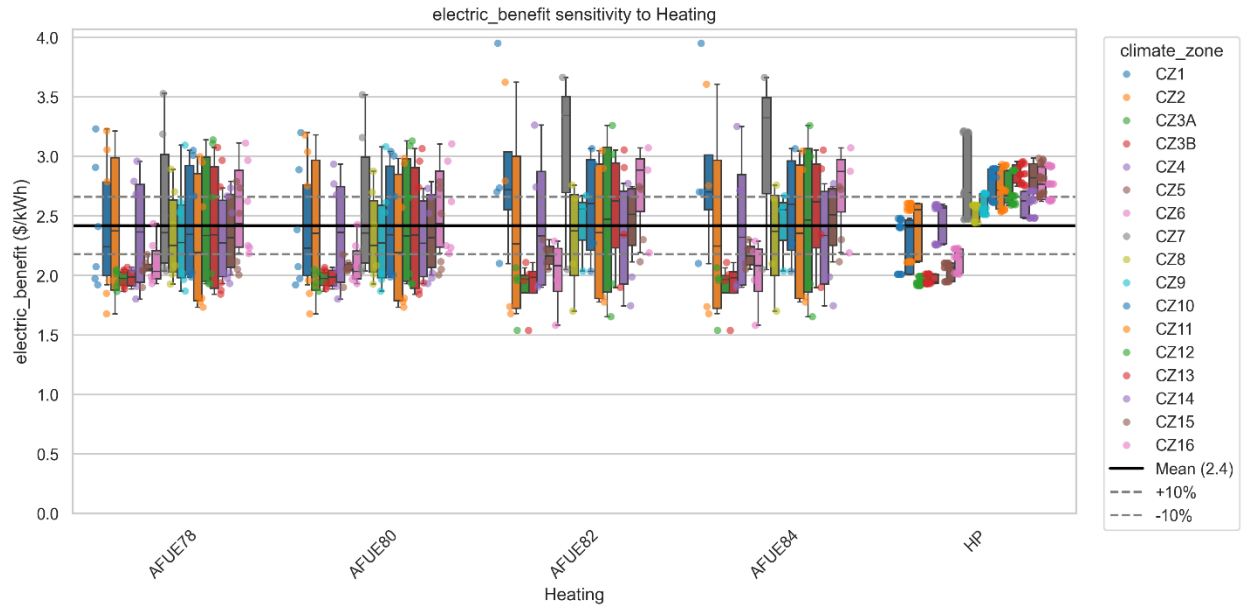


Figure 88: Unit electric benefits vs. building location and heating efficiency.

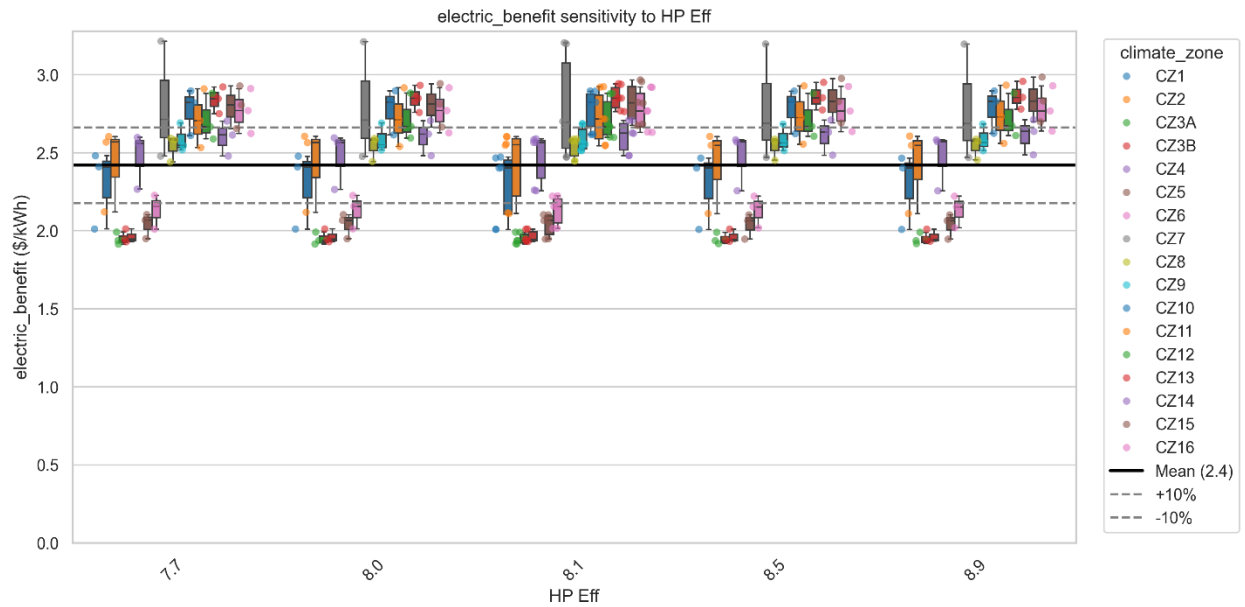


Figure 89: Unit electric benefits vs. building location and heat pump efficiency.

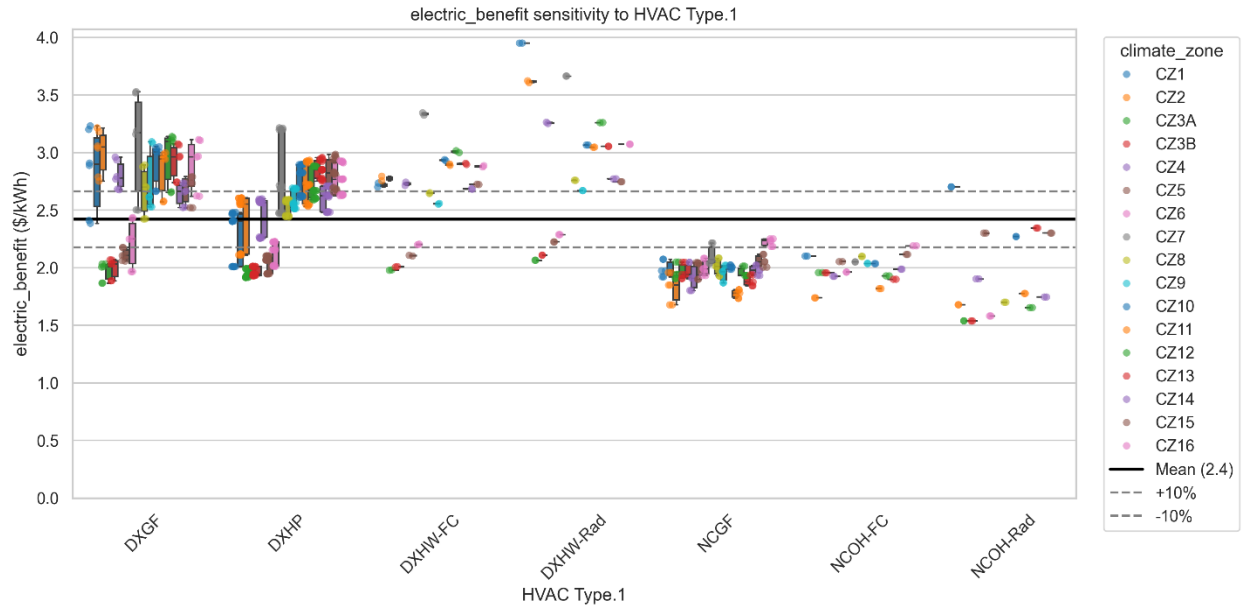


Figure 90: Unit electric benefits vs. building location and HVAC type.

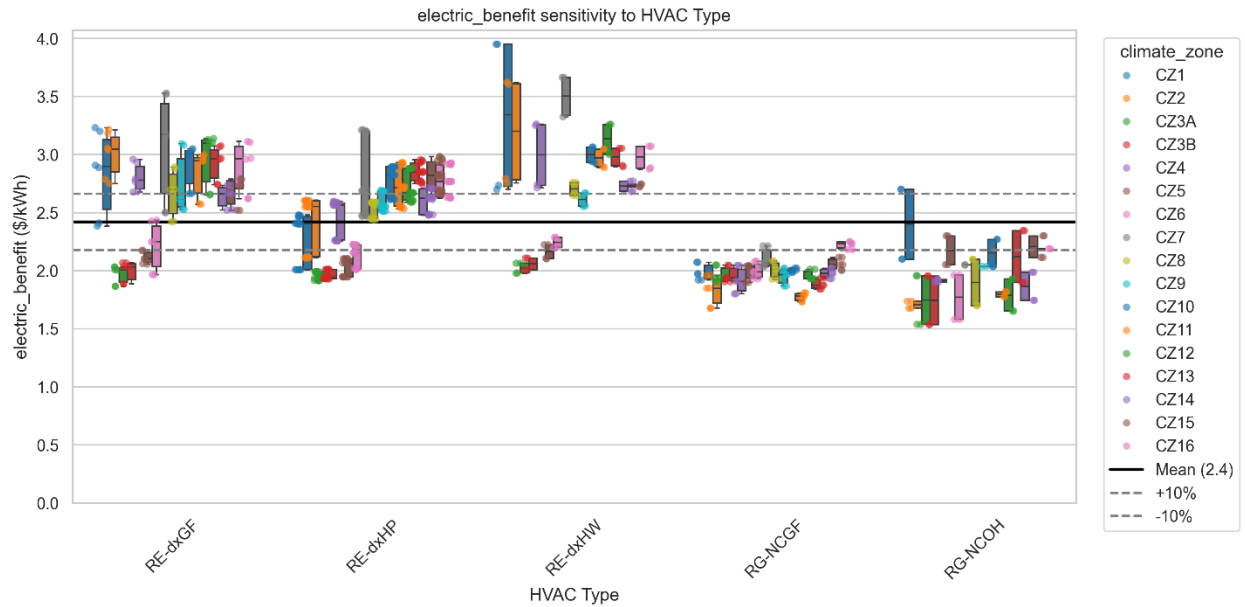


Figure 91: Unit electric benefits vs. building location and HVAC type.

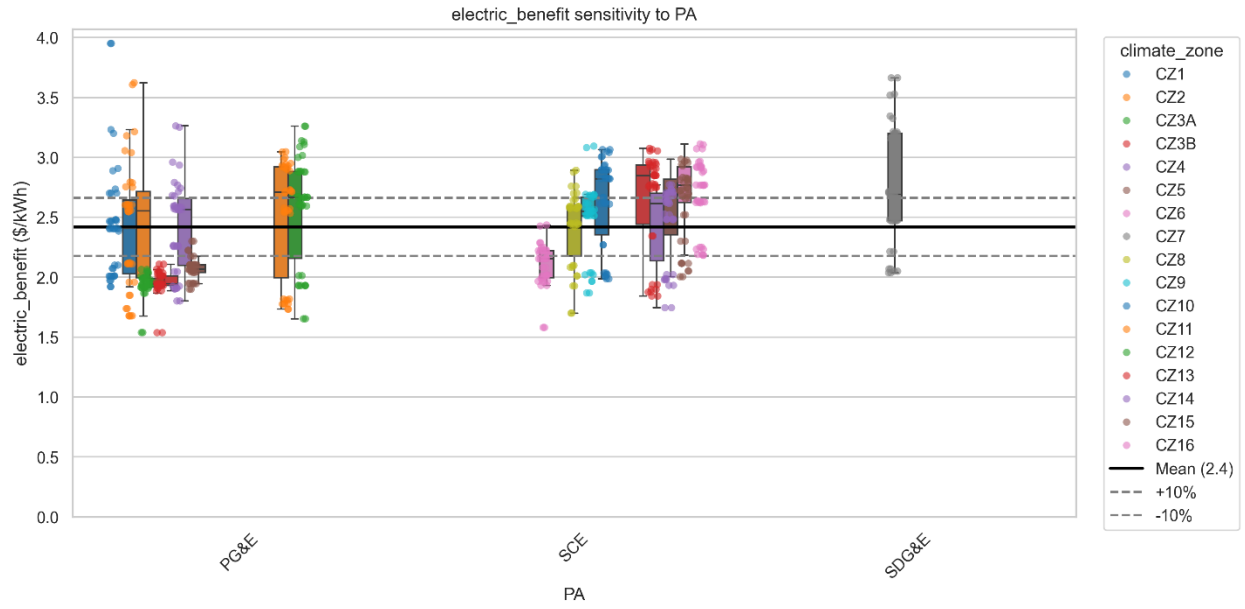


Figure 92: Unit electric benefits vs. building location and IOU.

SWHC045 – Group Plots

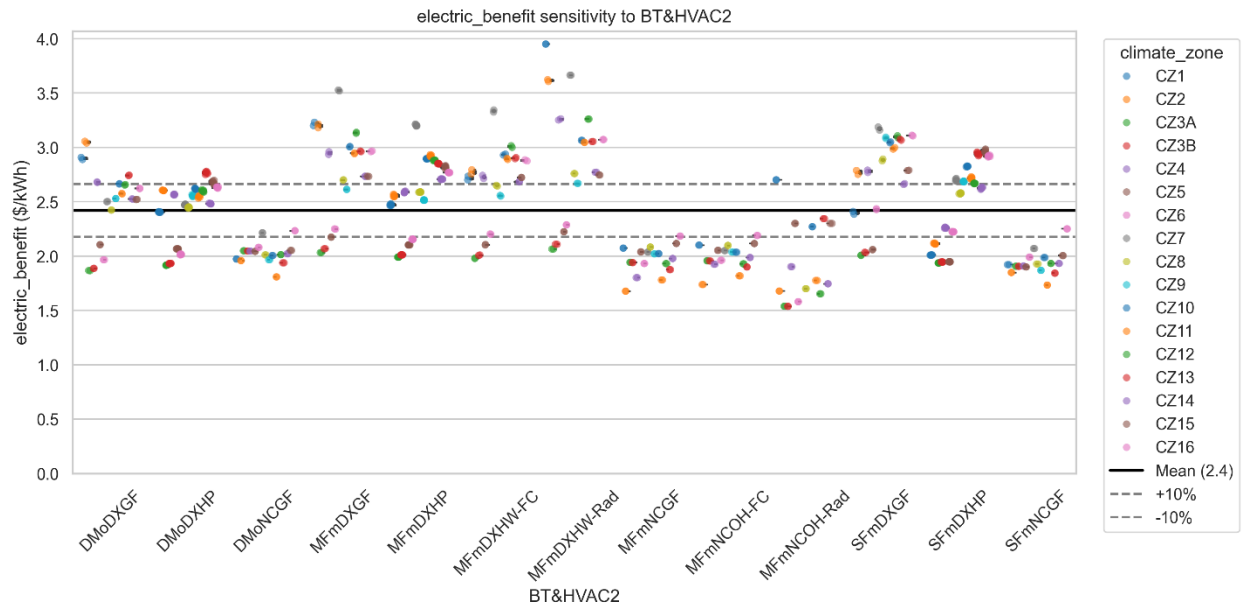


Figure 93: Unit electric benefits with two parameters of building type and HVAC type.

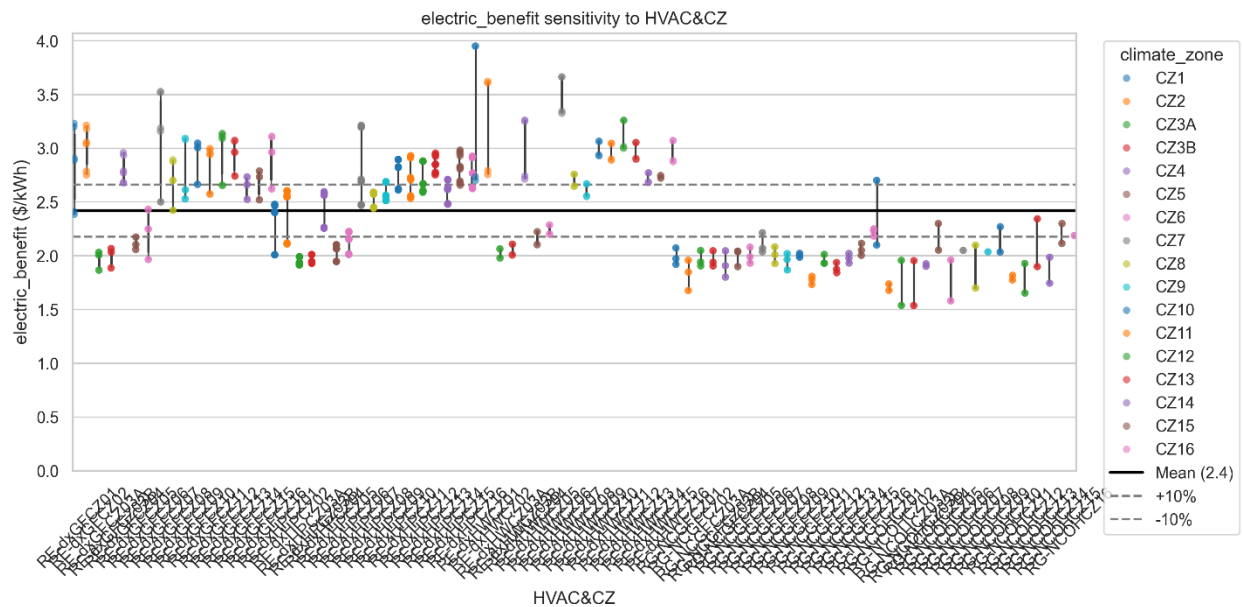


Figure 94: Unit electric benefits with two parameters of HVAC type and building location.

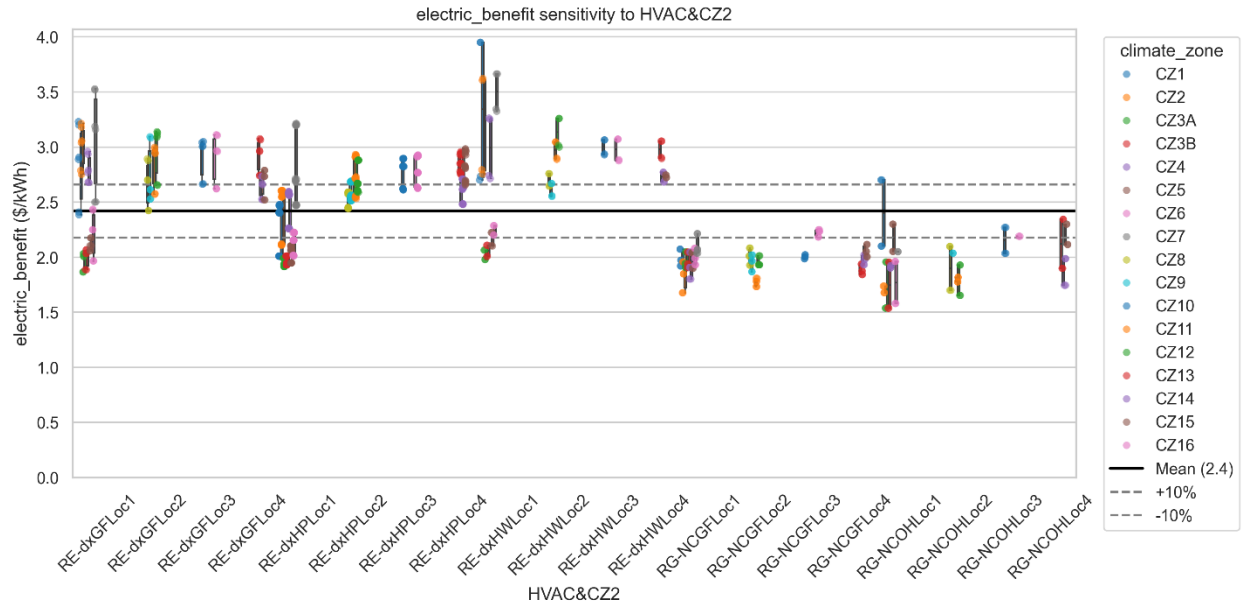


Figure 95: Unit electric benefits with groupings for HVAC type and building location groups.

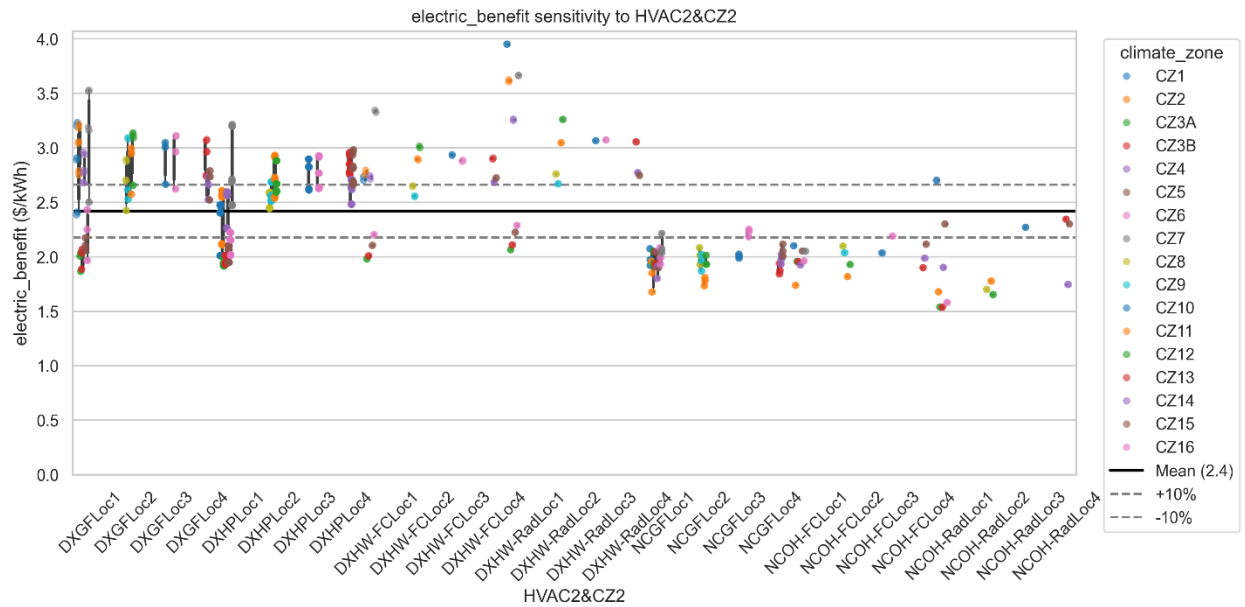


Figure 96: Unit electric benefits with groupings for HVAC type and building location groups.

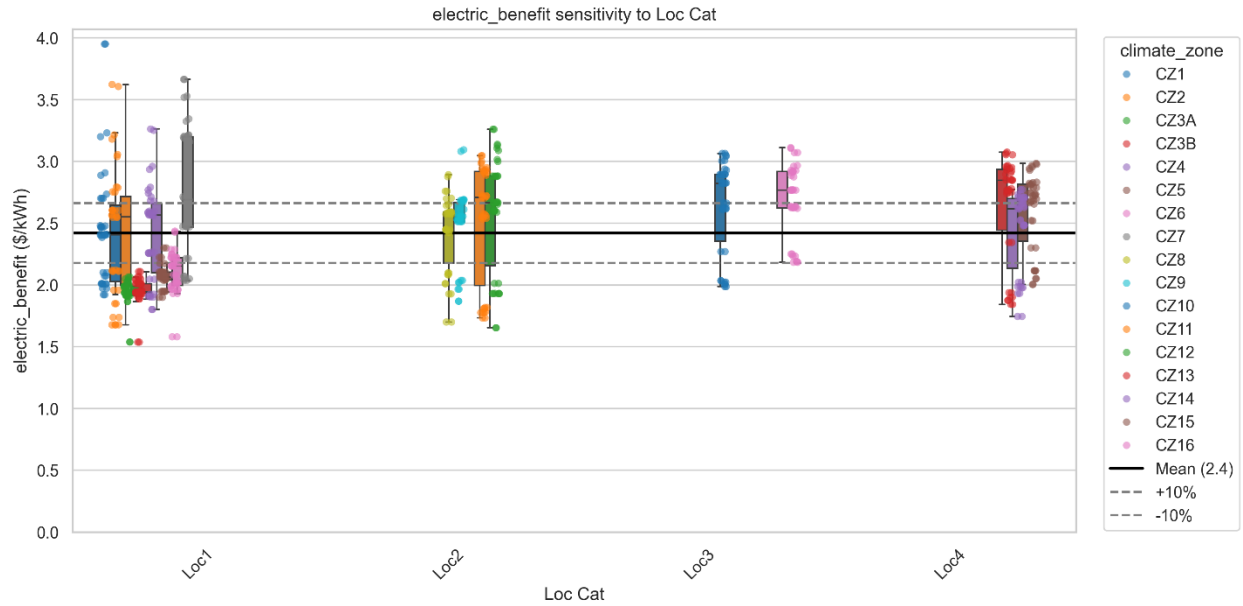


Figure 97: Unit electric benefits with groupings for building location.

SWHC045 – Base and Measure Case jitter plots

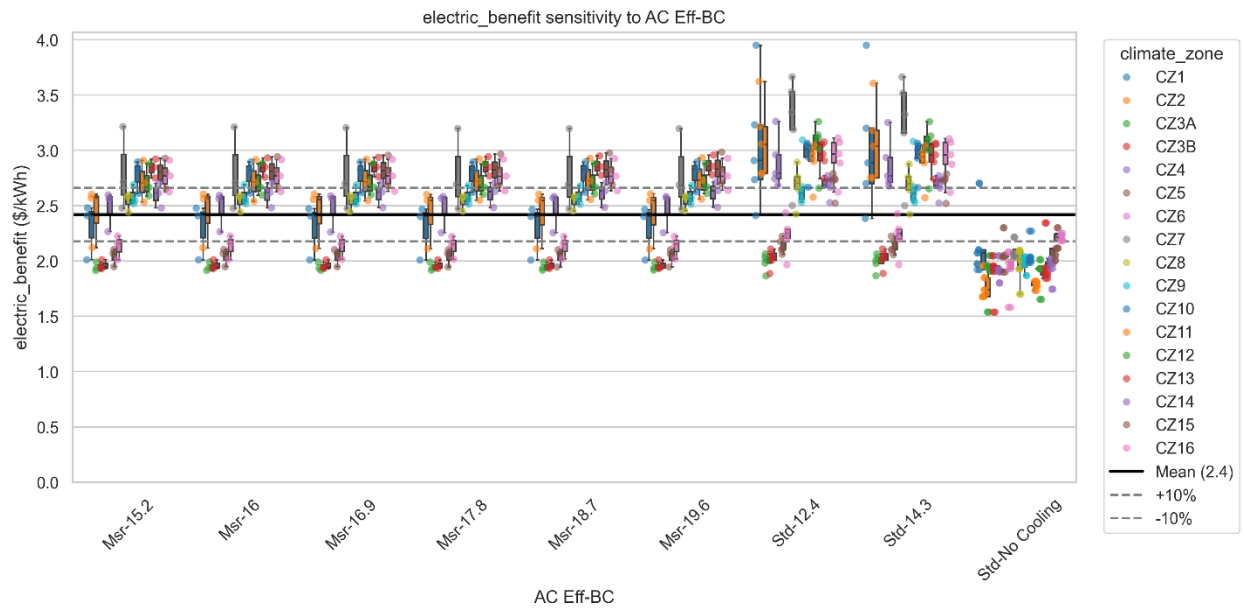


Figure 98: Unit electric benefits vs. building location and base case and equipment efficiency.

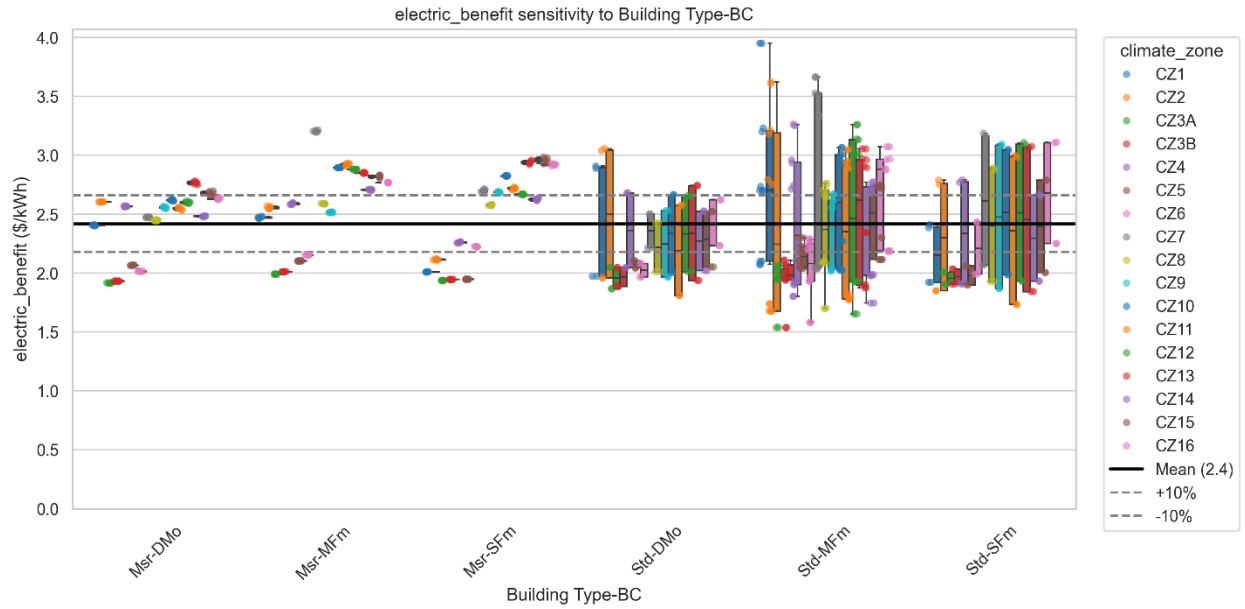


Figure 99: Unit electric benefits vs. building location and base case and building type.

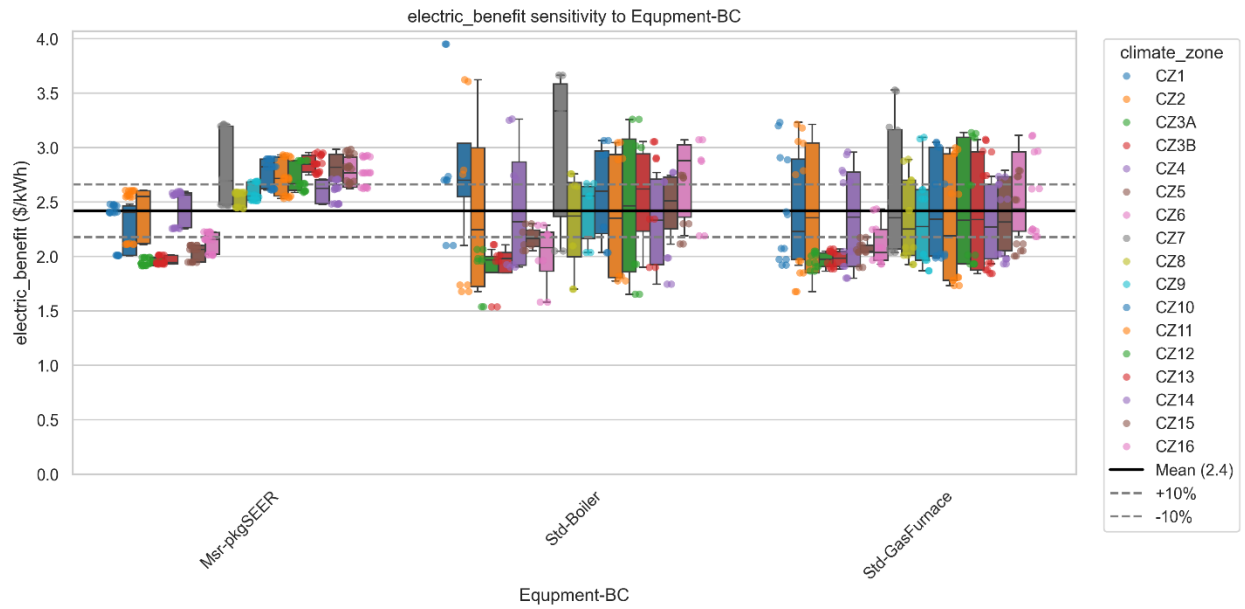


Figure 100: Unit electric benefits vs. building location and base case and equipment type.

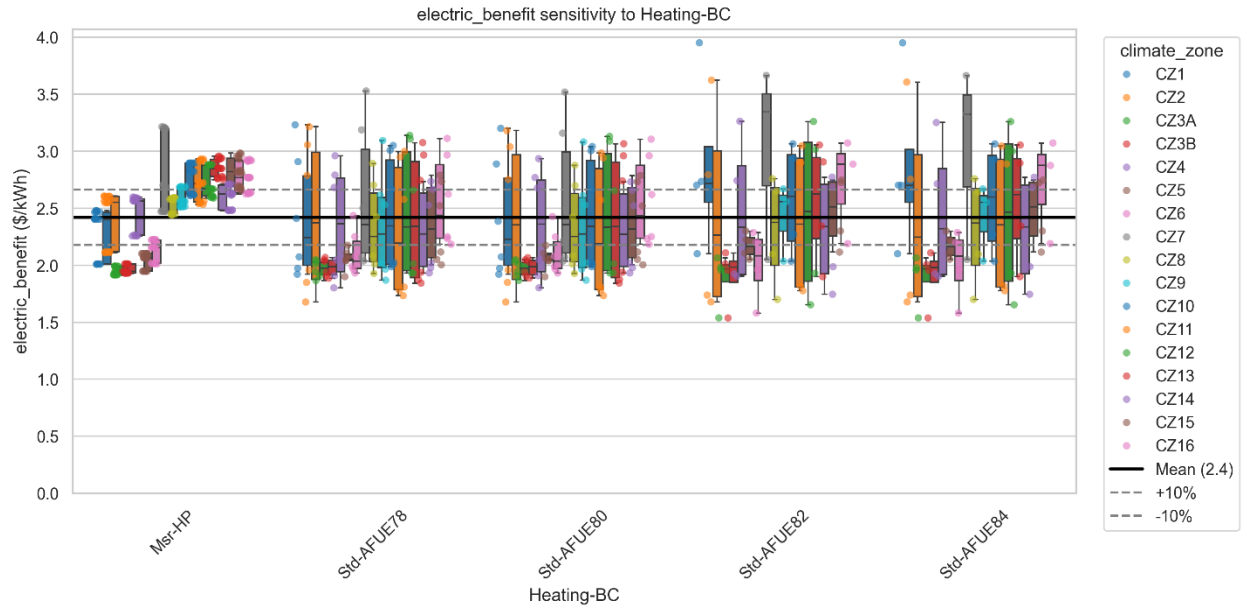


Figure 101: Unit electric benefits vs. building location and base case and heating efficiency.

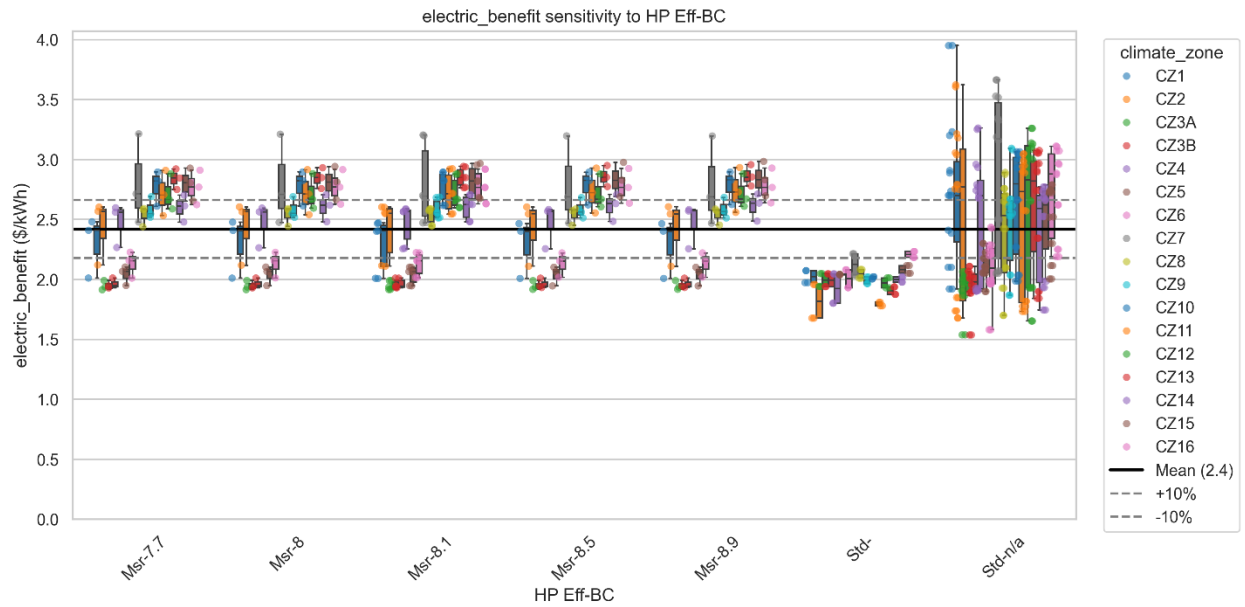


Figure 102: Unit electric benefits vs. building location and base case and HP efficiency.

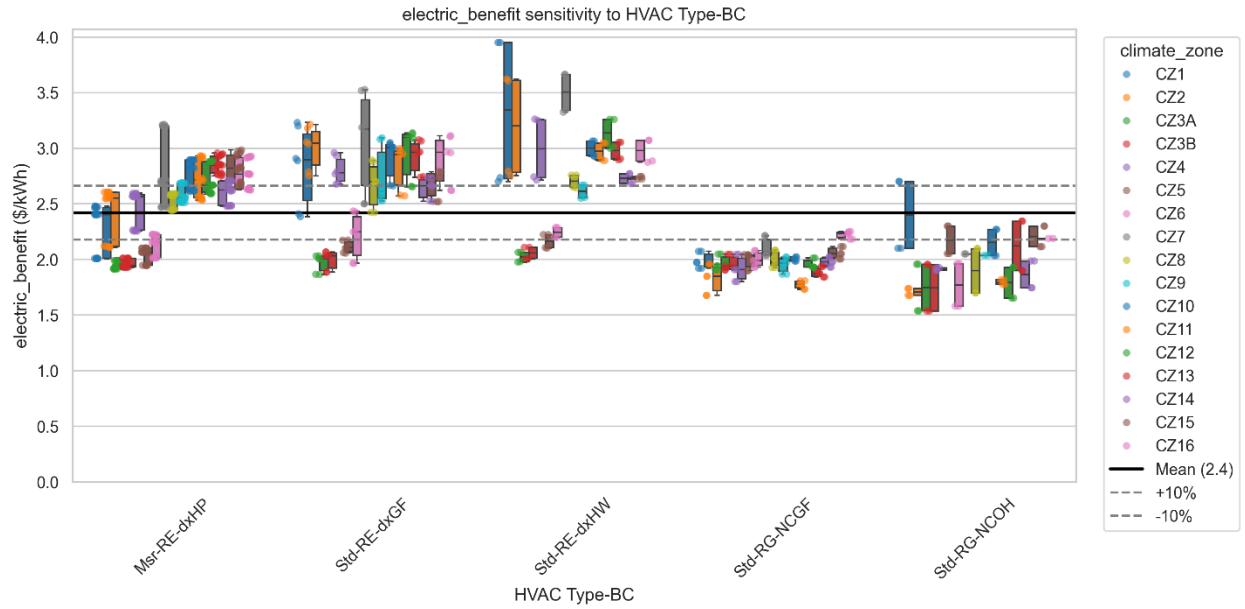


Figure 103: Unit electric benefits vs. building location and base case and HVAC type.

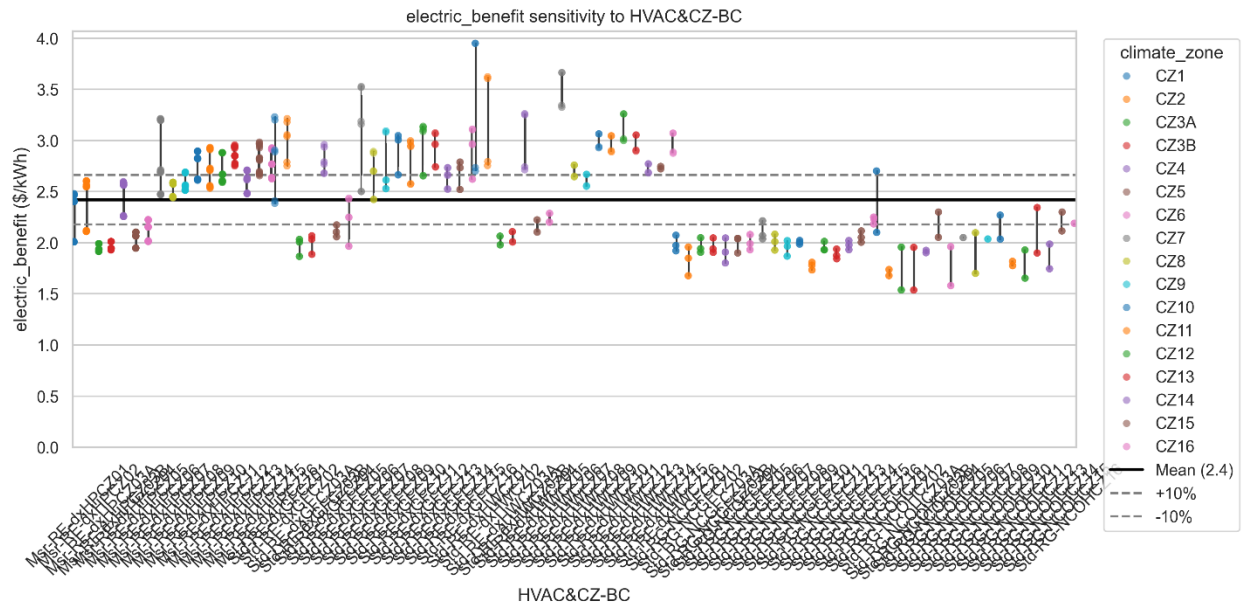


Figure 104: Unit electric benefits vs. building location and base case and two parameters of HVAC type and building location.

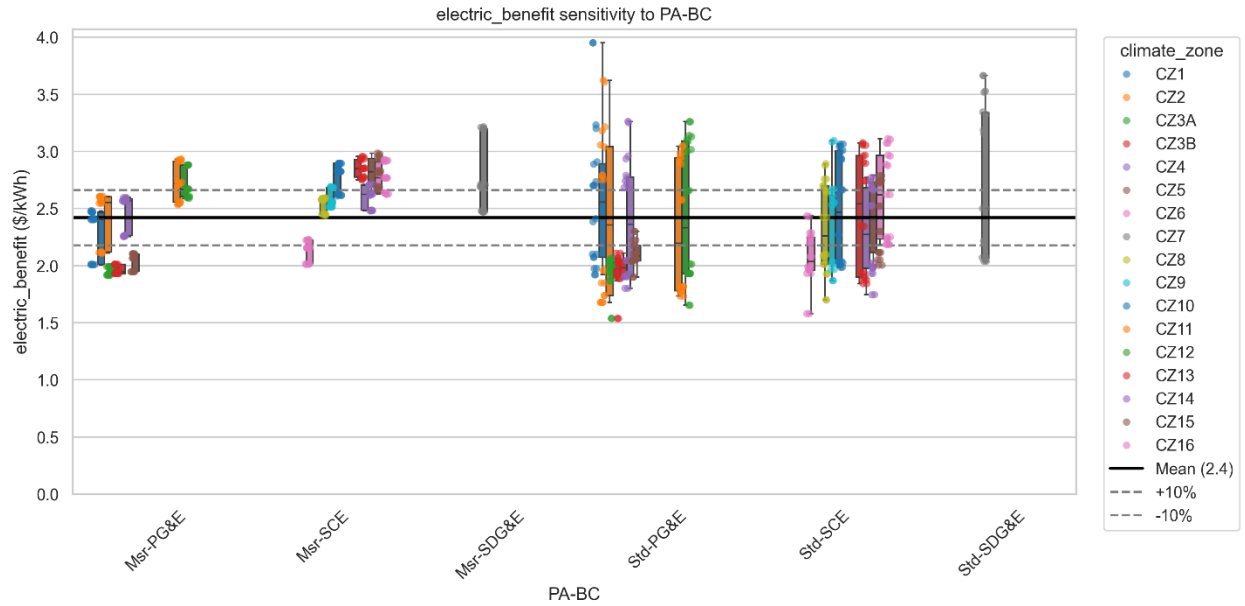


Figure 105: Unit electric benefits vs. building location and base case and IOU.

Note that additional graphics for separated standard and measure cases for a specific climate zone (i.e., CZ02) and graphics for no cooling cases removed are also available.

SWHC046 Packaged Heat Pump AC, Commercial, Fuel Substitution

Parameter Name	CLS	Max SD	Avg SD	Parameters
Whole Model	~7,500		12%	
Building Type	21	13%	11%	Asm, Com, ECC, EPr, ERC, ESe, EUn, Gro, Hsp, Htl, MBT, MLI, Mtl, Nrs, OfL, OfS, RFF, RSD, Rt3, RtL, RtS, SCn
Building Location	16	8%	5%	CZ01, CZ02, CZ03, CZ04, CZ05, CZ06, CZ07, CZ08, CZ09, CZ10, CZ11, CZ12, CZ13, CZ14, CZ15, CZ16
Equipment Type	5	12%	12%	IEER-rated Package Heat Pump, SEER2-rated Package Heat Pump, SEER2-rated Package Heat Pump 1 Stage, SEER2-rated Package Heat Pump 2 Stage, SEER2-rated Split Heat Pump
Equipment Efficiency	18	13%	12%	11.4, 12.2, 12.35, 12.7, 13.2, 13.4, 13.5, 14, 14.2, 14.4, 14.5, 14.8, 15, 15.4, 15.5, 16, 16.3, 17.3
BT&CZ	336	2.7%	0.7%	Asm&CZ01, Asm&CZ02, ..., SCn&CZ15, SCn&CZ16
BT2&CZ2	16	5.3%	2.7%	BT1&Loc1, BT1&Loc2, ..., BT4&Loc3, BT4&Loc4

Table 27: SWHC046 parameter results

SWHC046 – Parameter specific jitter plots

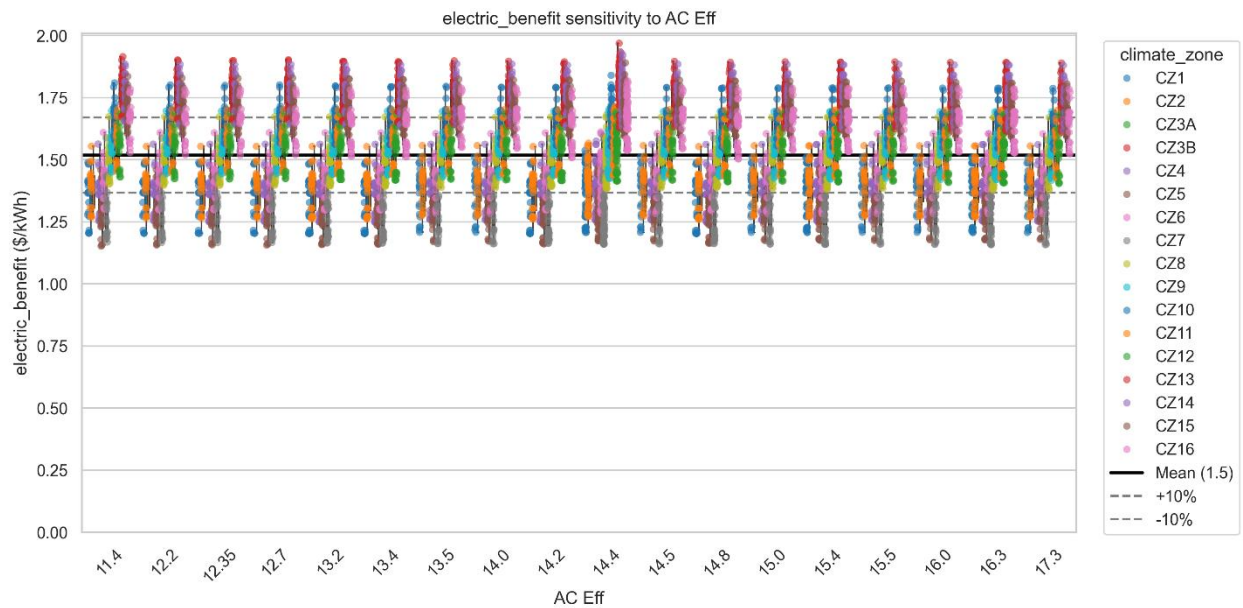


Figure 106: Unit electric benefits vs. building location and equipment efficiency.

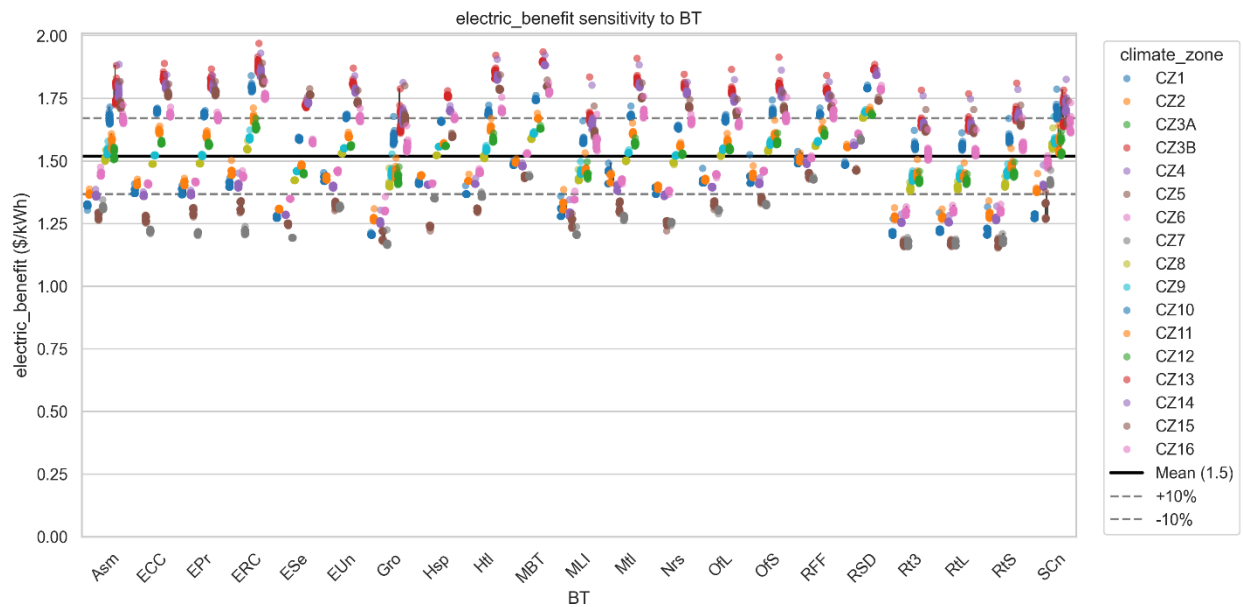


Figure 107: Unit electric benefits vs. building location and building type.

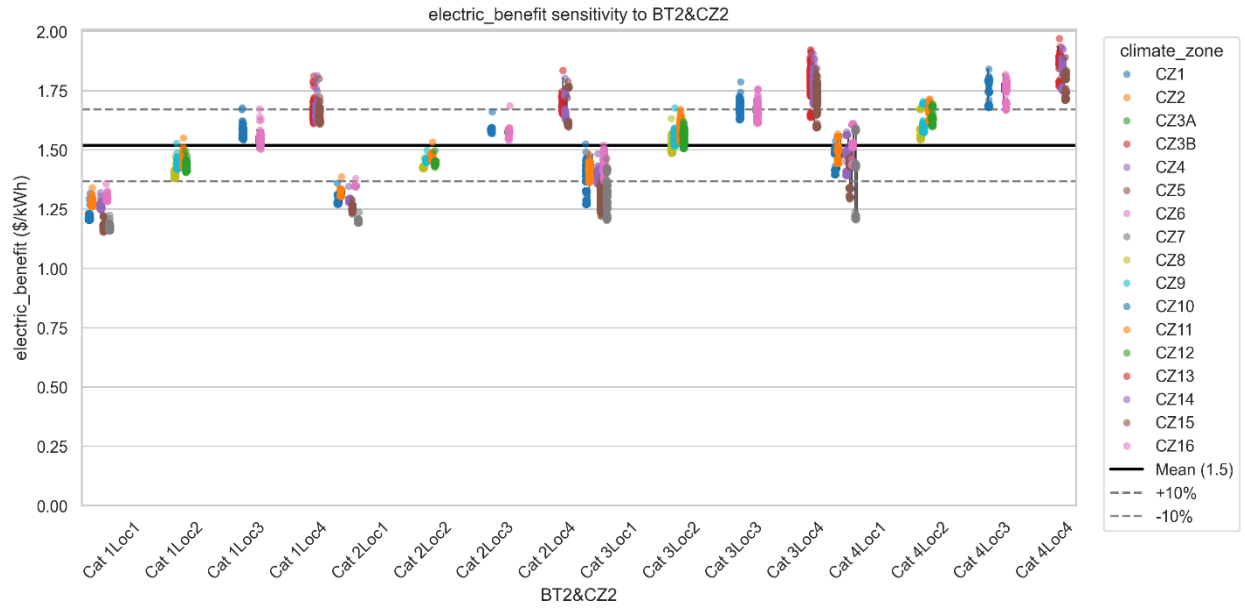


Figure 108: Unit electric benefits with groupings for building type and building location.

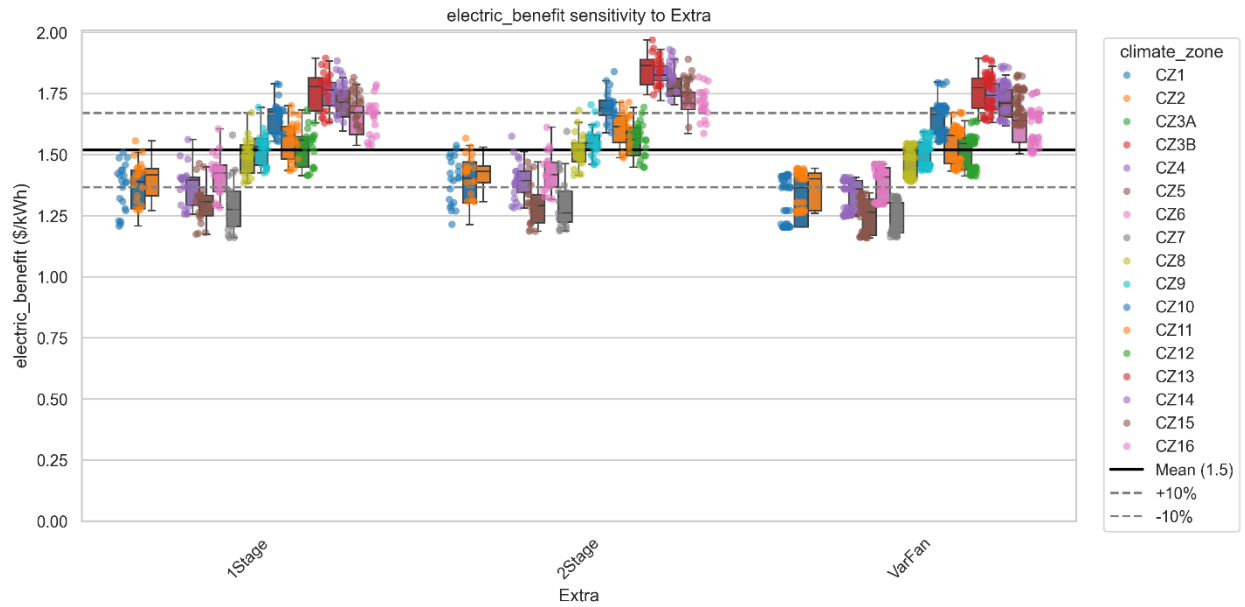


Figure 109: Unit electric benefits vs. building location and cooling type.

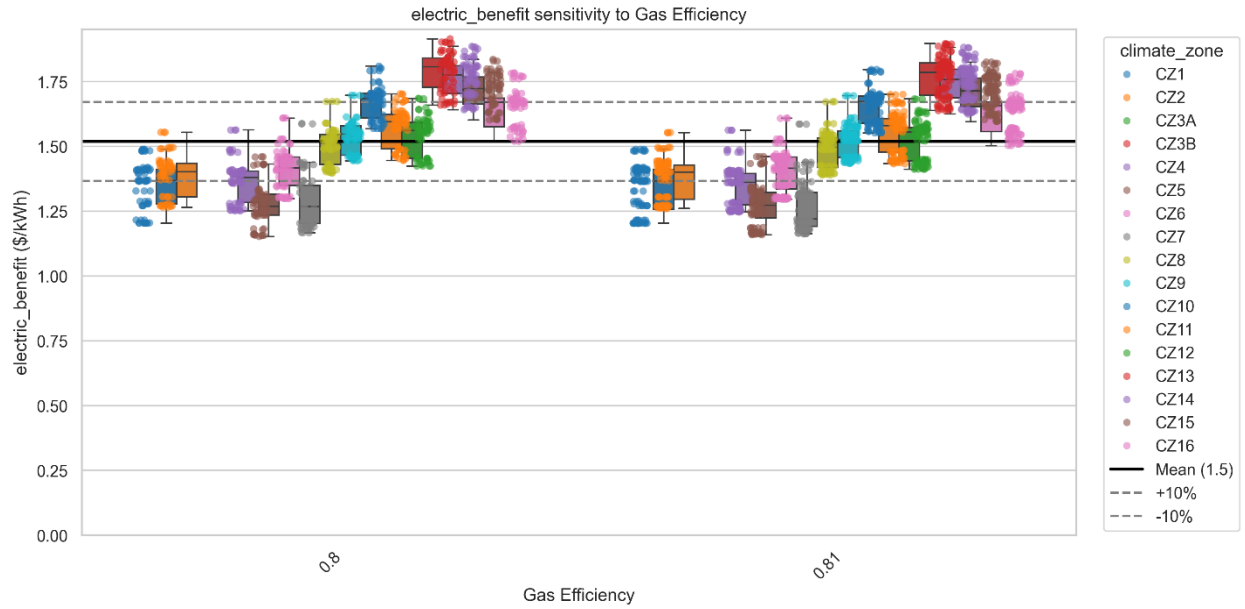


Figure 110: Unit electric benefits vs. building location and furnace efficiency.

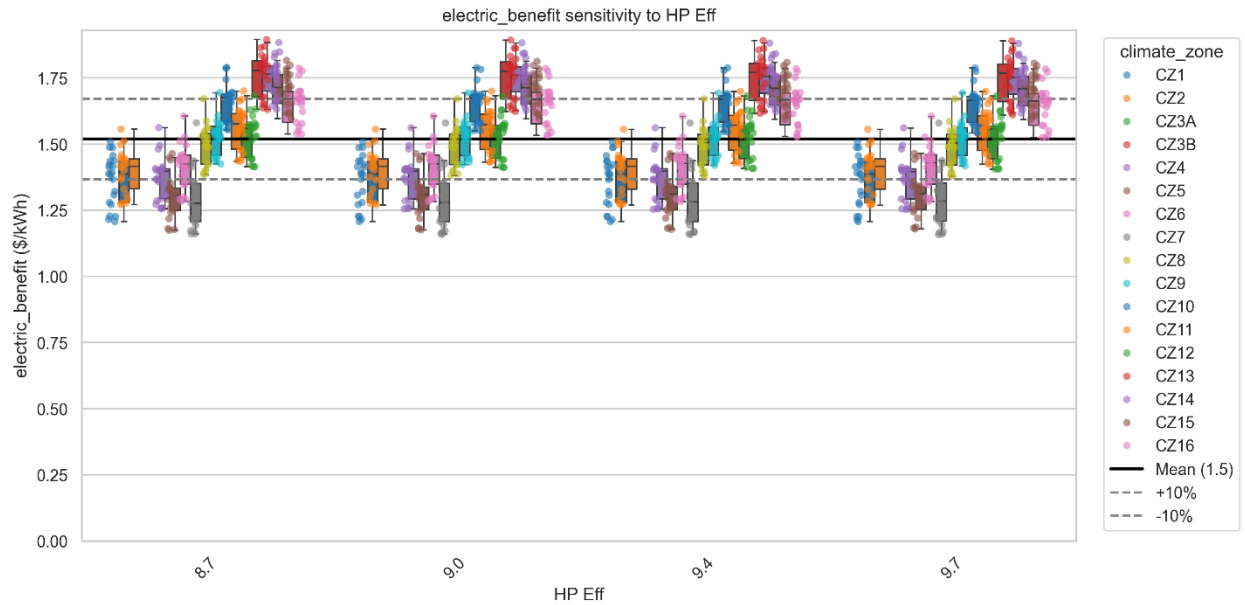


Figure 111: Unit electric benefits vs. building location and heat pump efficiency.

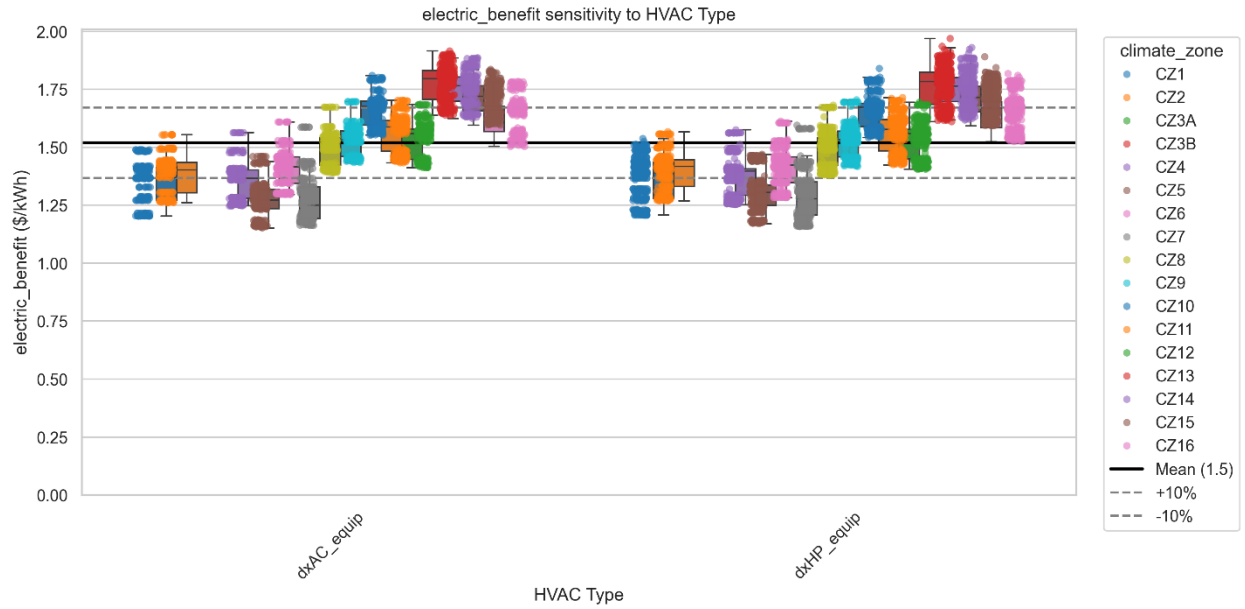


Figure 112: Unit electric benefits vs. building location and HVAC type.

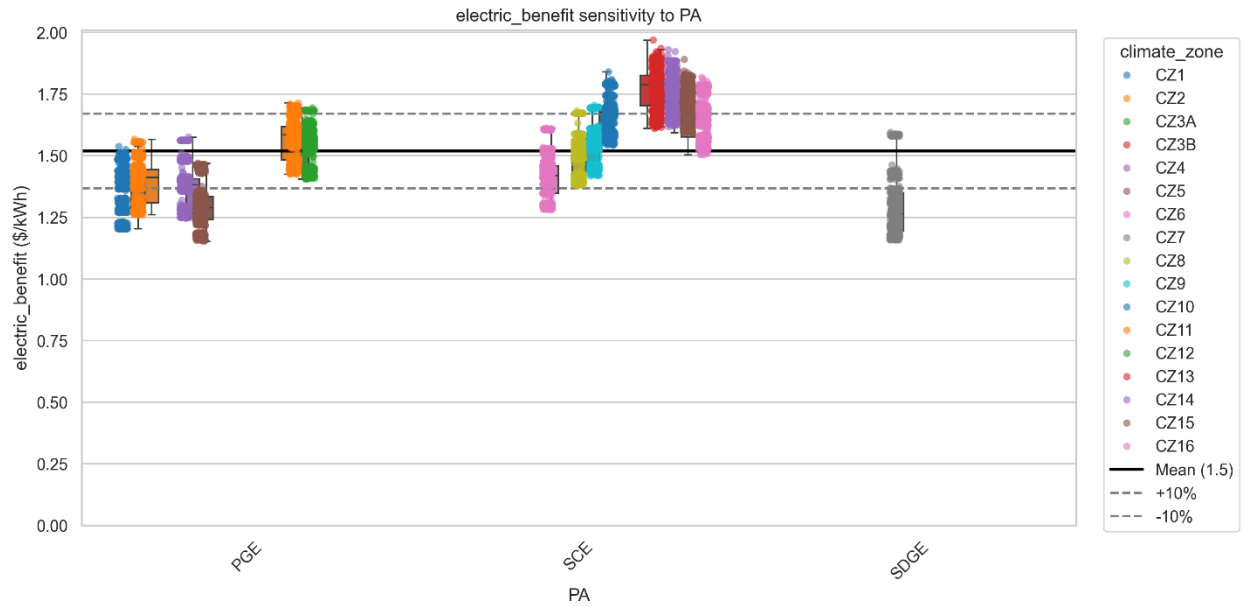


Figure 113: Unit electric benefits vs. building location and IOU.

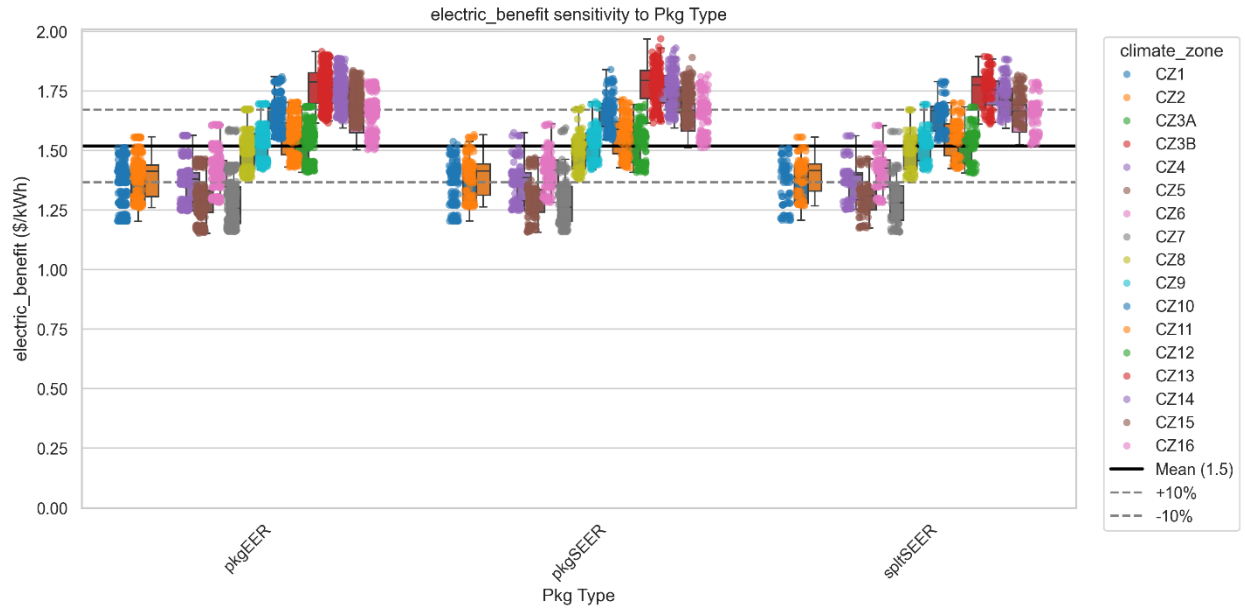


Figure 114: Unit electric benefits vs. building location and HVAC type.

SWHC046 - Climate Zone specific (CZ08)

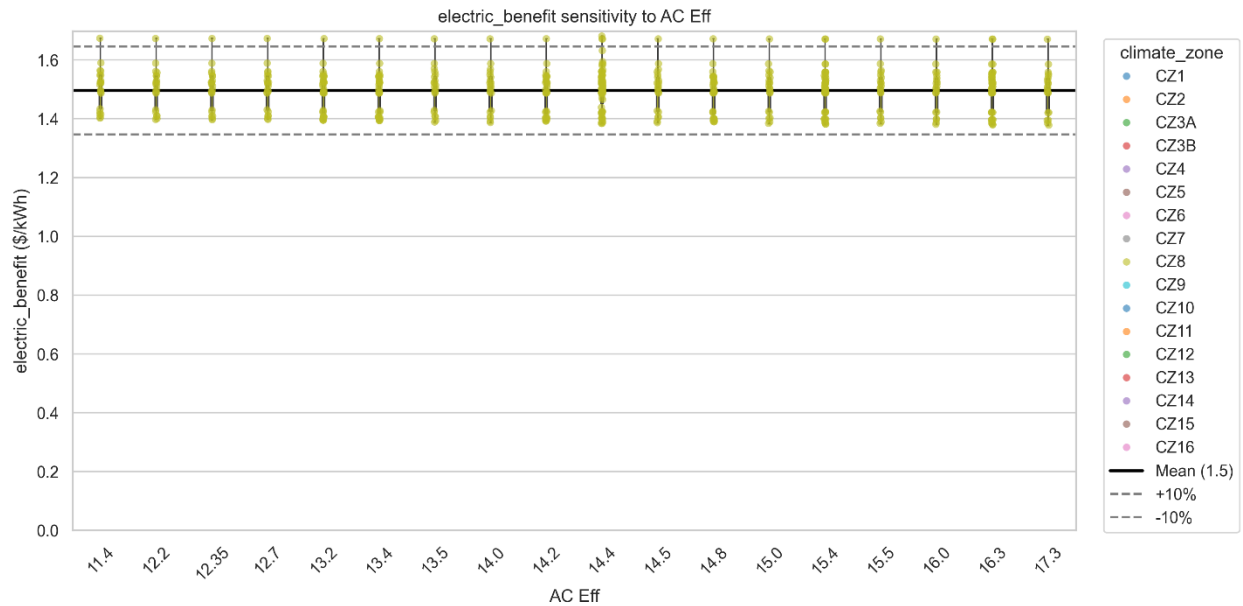


Figure 115: Unit electric benefits vs. equipment efficiency for building location 2.

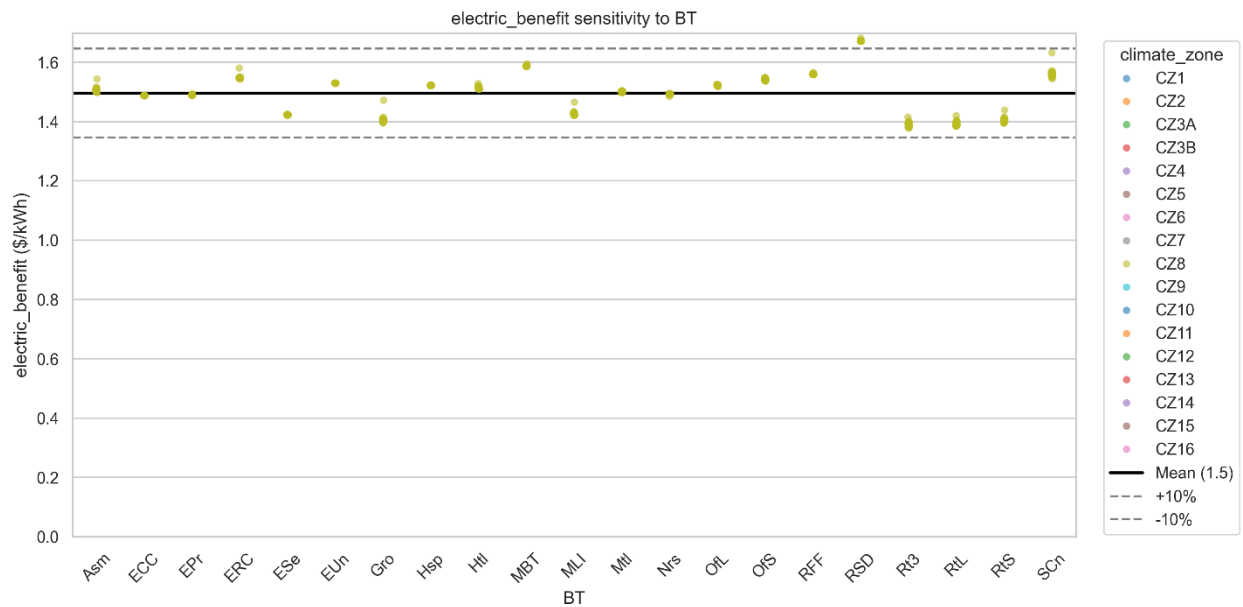


Figure 116: Unit electric benefits vs. building type for building location 2.

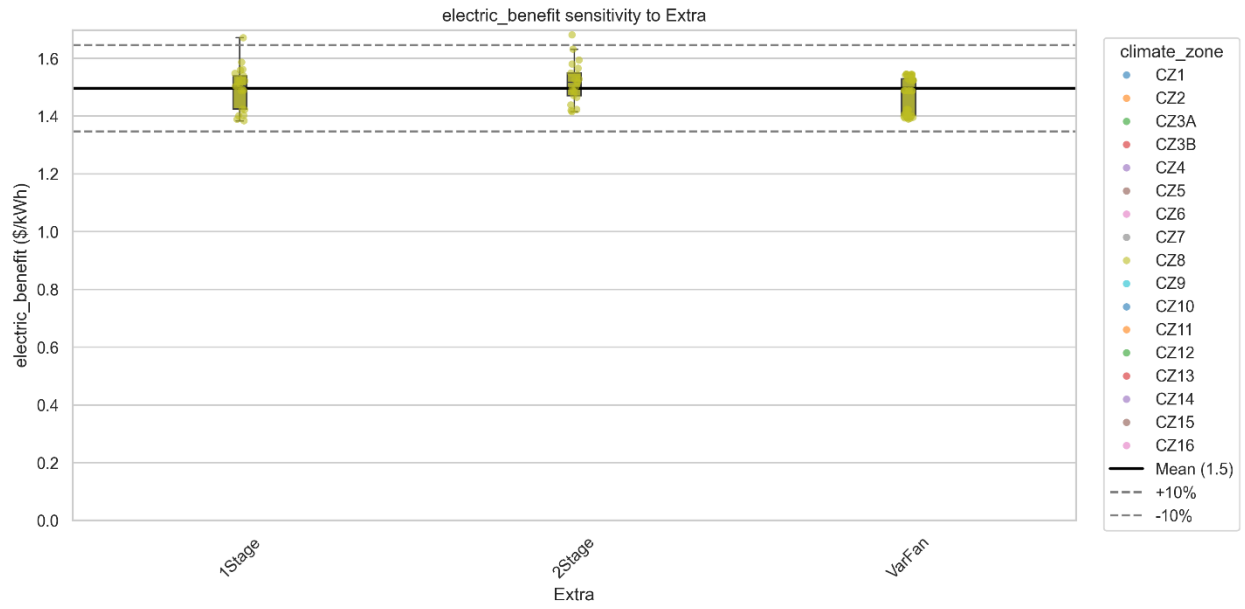


Figure 117: Unit electric benefits vs. cooling type for building location 2.

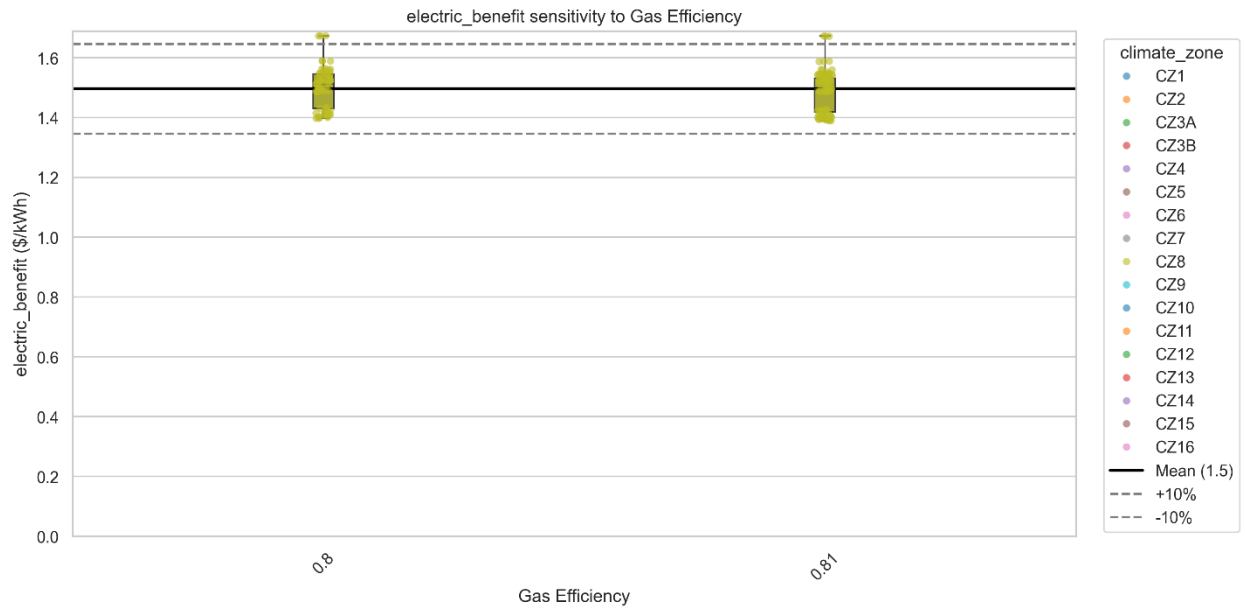


Figure 118: Unit electric benefits vs. gas efficiency for building location 2.

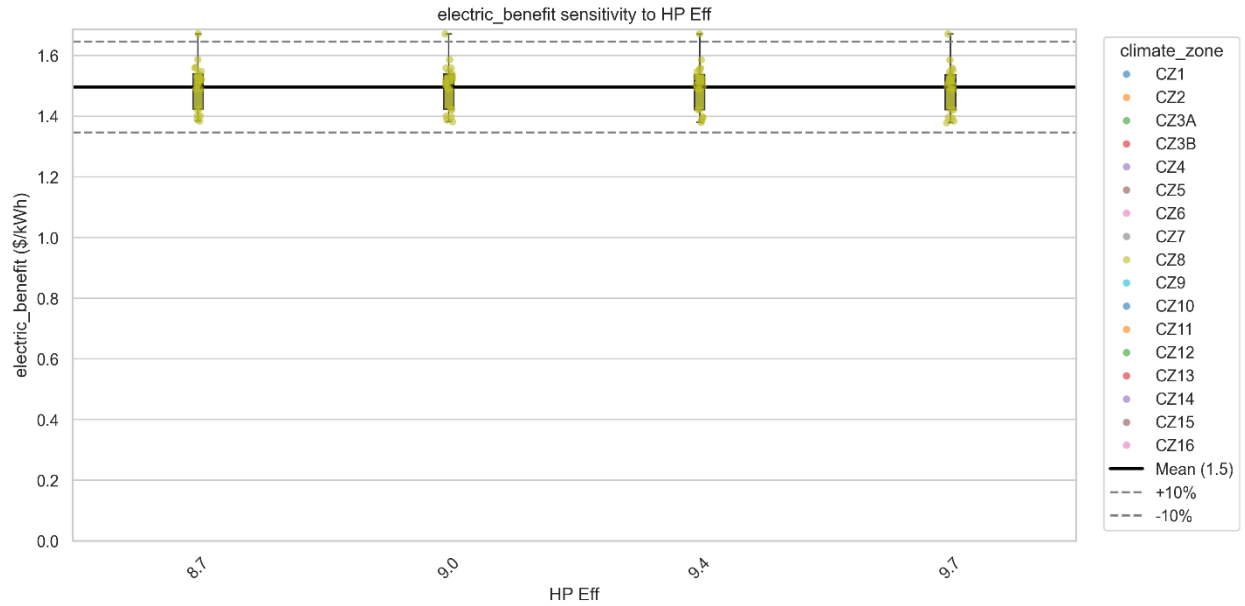


Figure 119: Unit electric benefits vs. heat pump efficiency for building location 2.

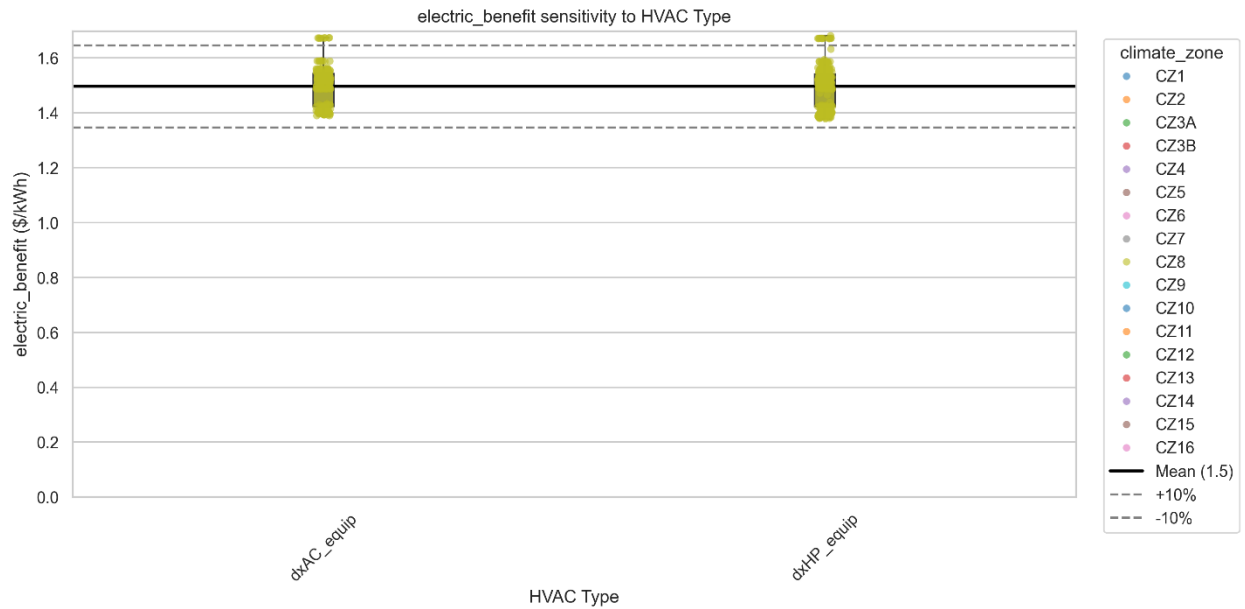


Figure 120: Unit electric benefits vs. HVAC type for building location 2.

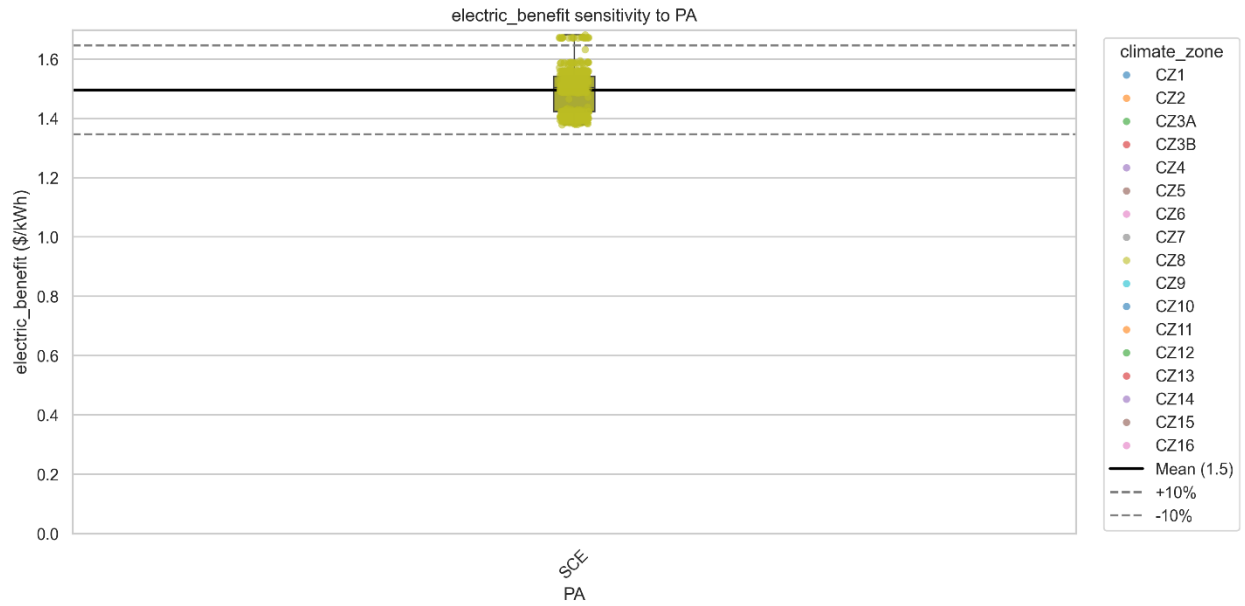


Figure 121: Unit electric benefits vs. IOU for building location 2.

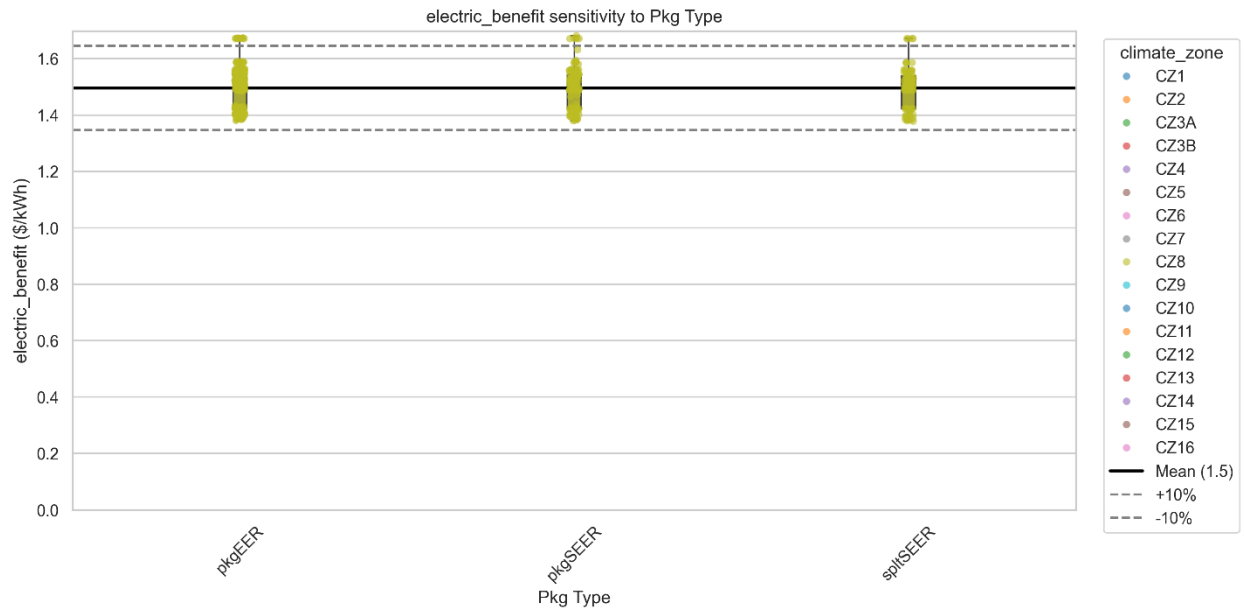


Figure 122: Unit electric benefits vs. HVAC type for building location 2.

SWHC046 – Base and Measure Case jitter plots

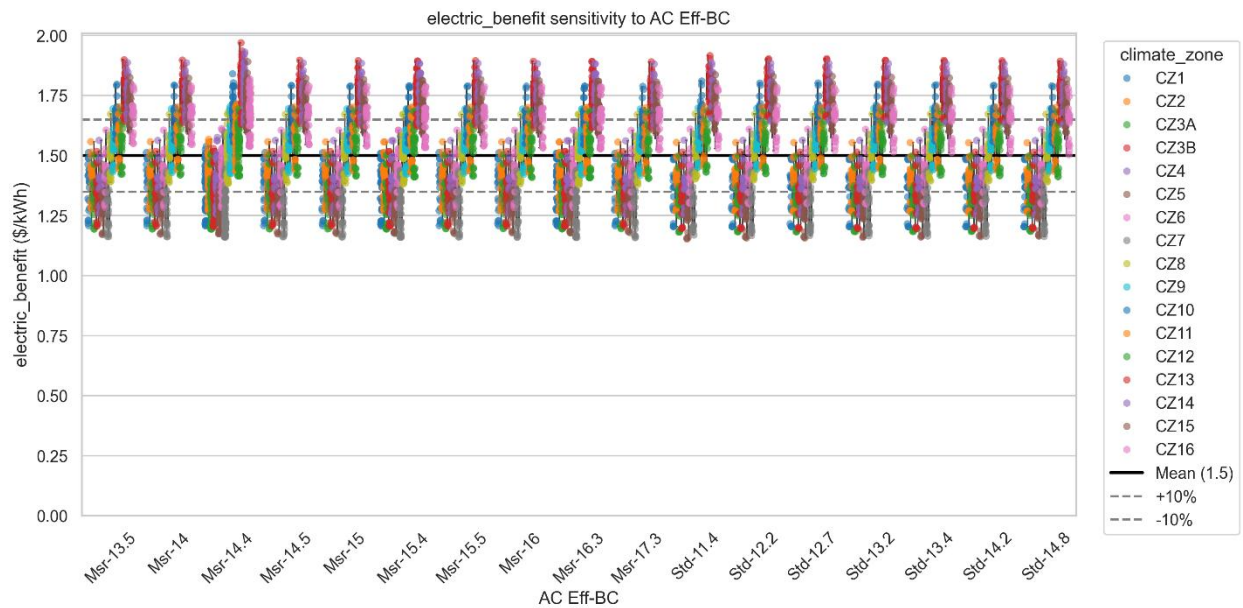


Figure 123: Unit electric benefits vs. building location and base case and AC efficiency.

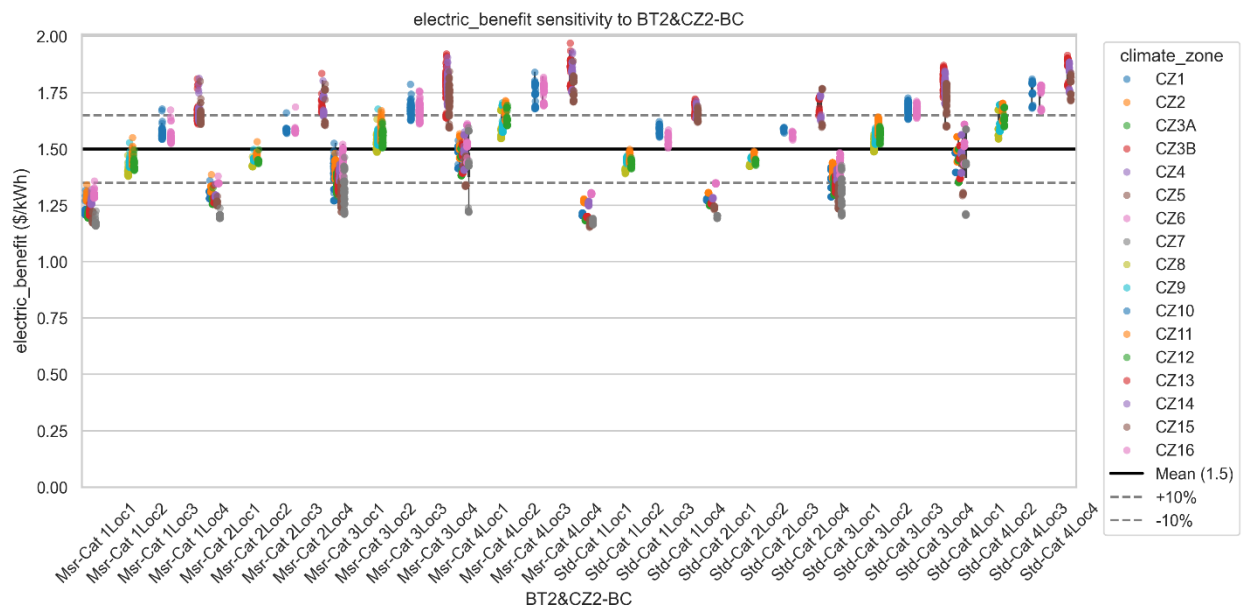


Figure 124: Unit electric benefits vs. building location and base case and groupings for building type and building location.

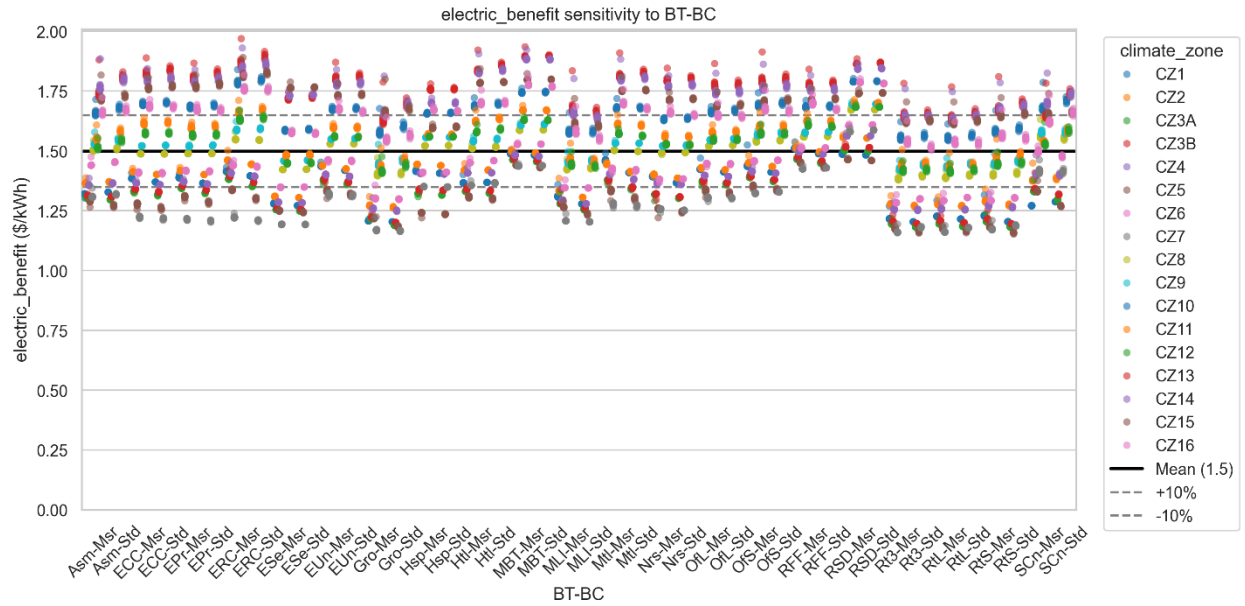


Figure 125: Unit electric benefits vs. building location and base case and building type.

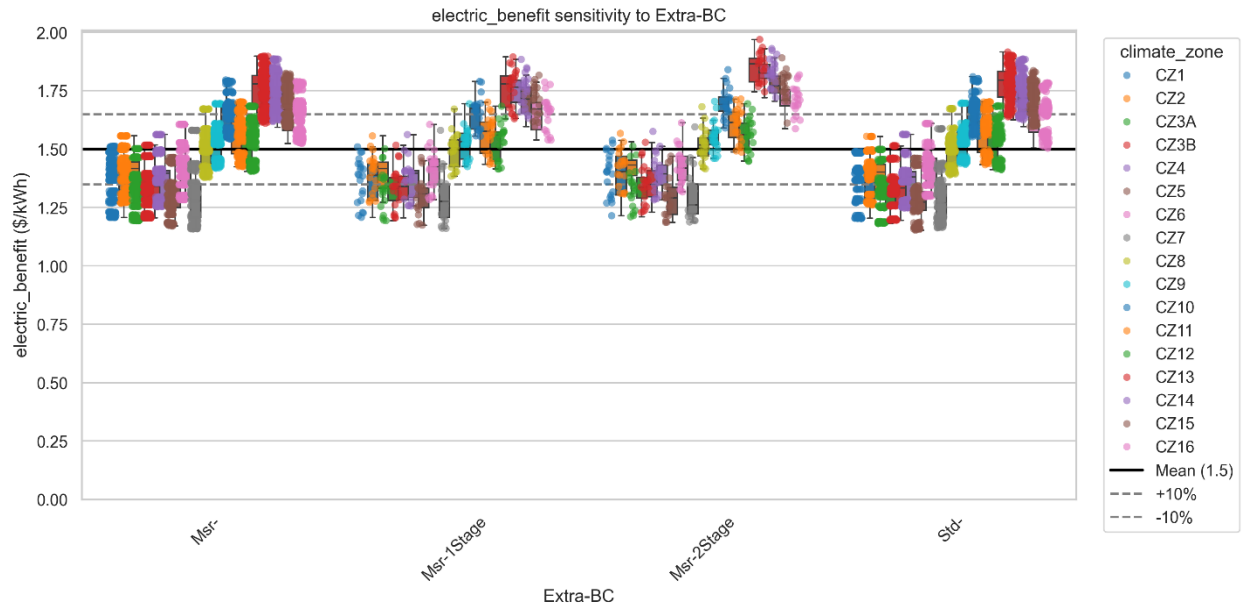


Figure 126: Unit electric benefits vs. building location and base case and cooling stage.

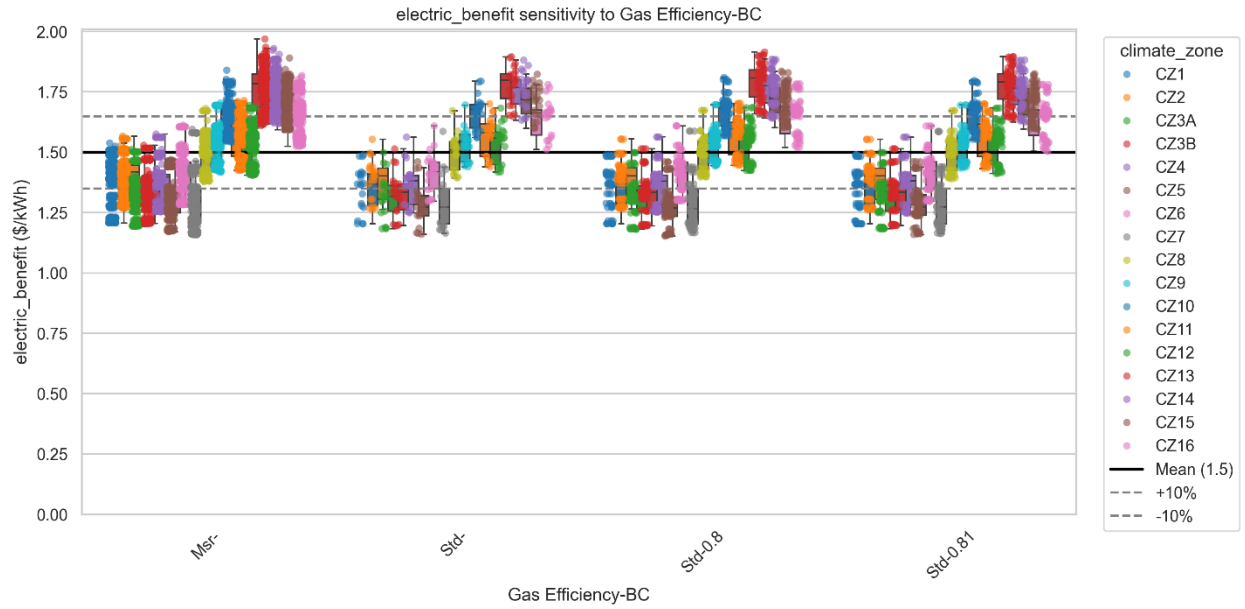


Figure 127: Unit electric benefits vs. building location and base case and furnace efficiency.

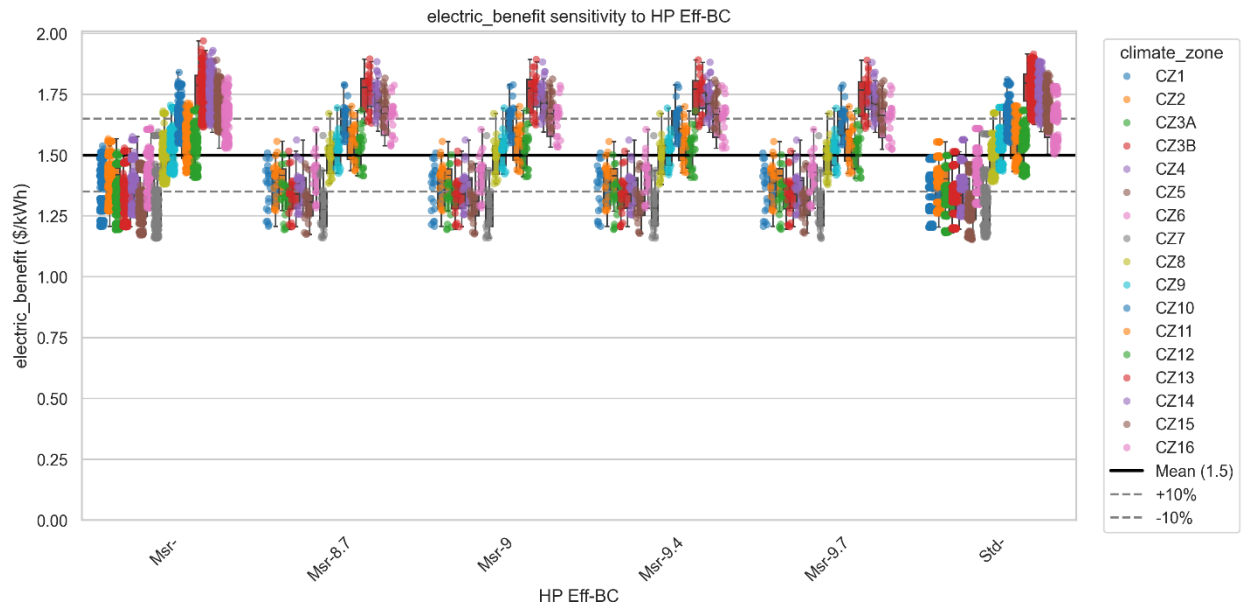


Figure 128: Unit electric benefits vs. building location and base case and HP efficiency.

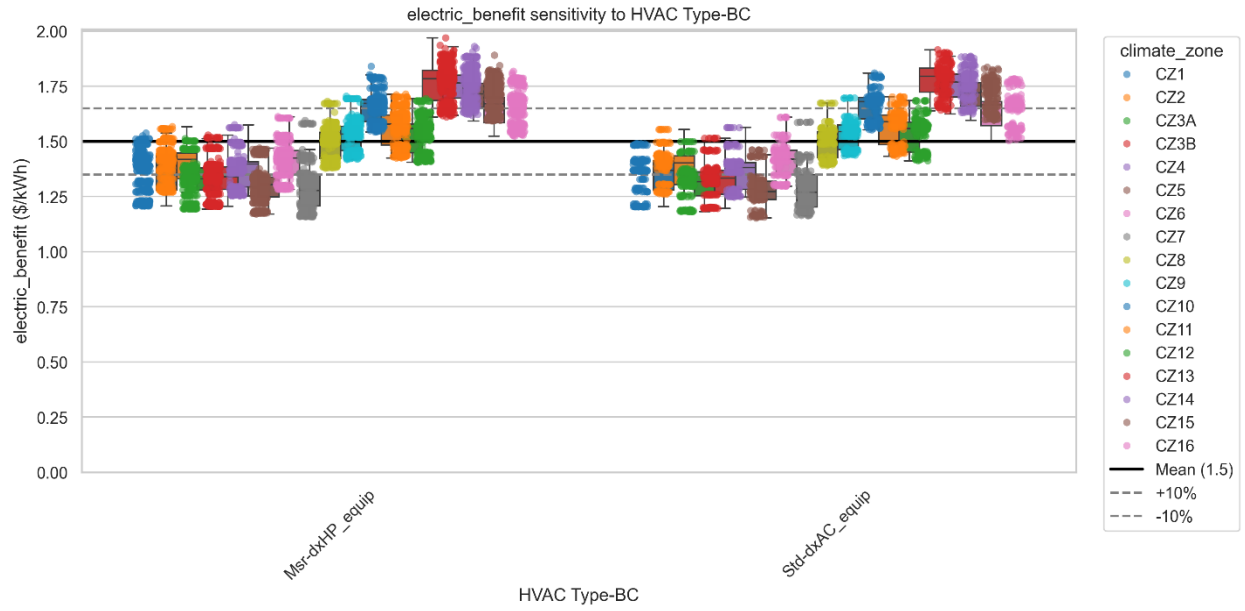


Figure 129: Unit electric benefits vs. building location and base case and equipment type.

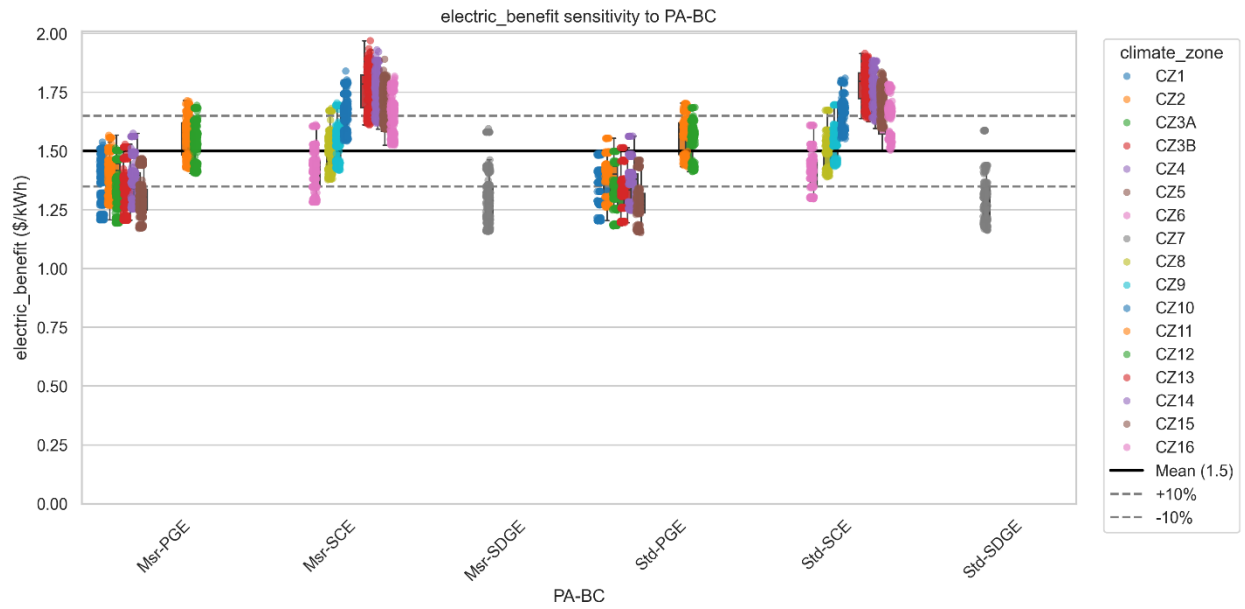


Figure 130: Unit electric benefits vs. building location and base case and IOU.

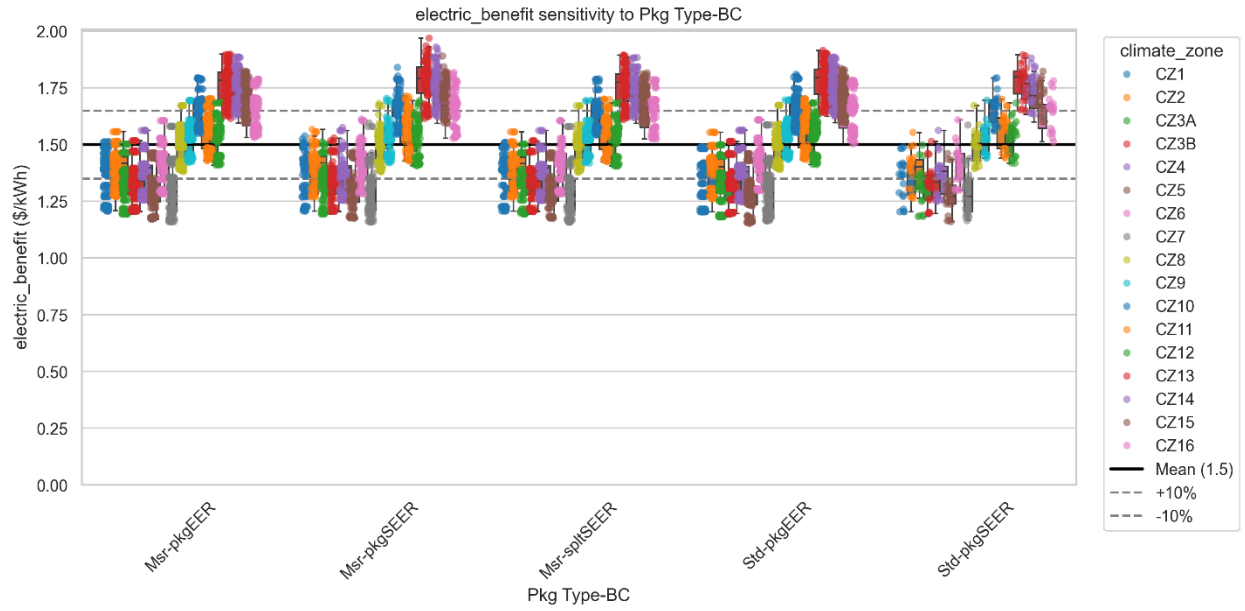


Figure 131: Unit electric benefits vs. building location and base case and package unit type.

SWSV001 Duct Seal, Residential

Parameter Name	CLS	Max SD	Avg SD	Parameters
Total Models	612		18%	
Building Type	3	19%	18%	DMo, MFm, SFm
Building Location	16	23%	15%	CZ01, CZ02, CZ03, CZ04, CZ05, CZ06, CZ07, CZ08, CZ09, CZ10, CZ11, CZ12, CZ13, CZ14, CZ15, CZ16
Equipment Type	3	16%	10%	DXGF, DXHP, NCGF
Equipment Efficiency	2	19%	18%	
Case	3	18%	18%	Pre-HV-DuctSeal-MedToLow, Pre-HV-DuctSeal-HighToLow, Duct_Seal_Measure_Low
BT&CZ	51	28%	14%	DMo&CZ01, DMo&CZ02, ..., SFm&CZ15, SFm&CZ16
HVAC&CZ	52	13%	4.6%	DXGF&CZ01, DXGF&CZ01, ..., NCGF&CZ15, NCGF&CZ16
HVAC&BT	9	16%	10%	DXGF&DMo, DXGF&DMo, ..., NCGF&SFm, NCGF&SFm

Table 28: SWSV001 parameter results

SWSV001 – 1 or 2 Parameter specific jitter plots

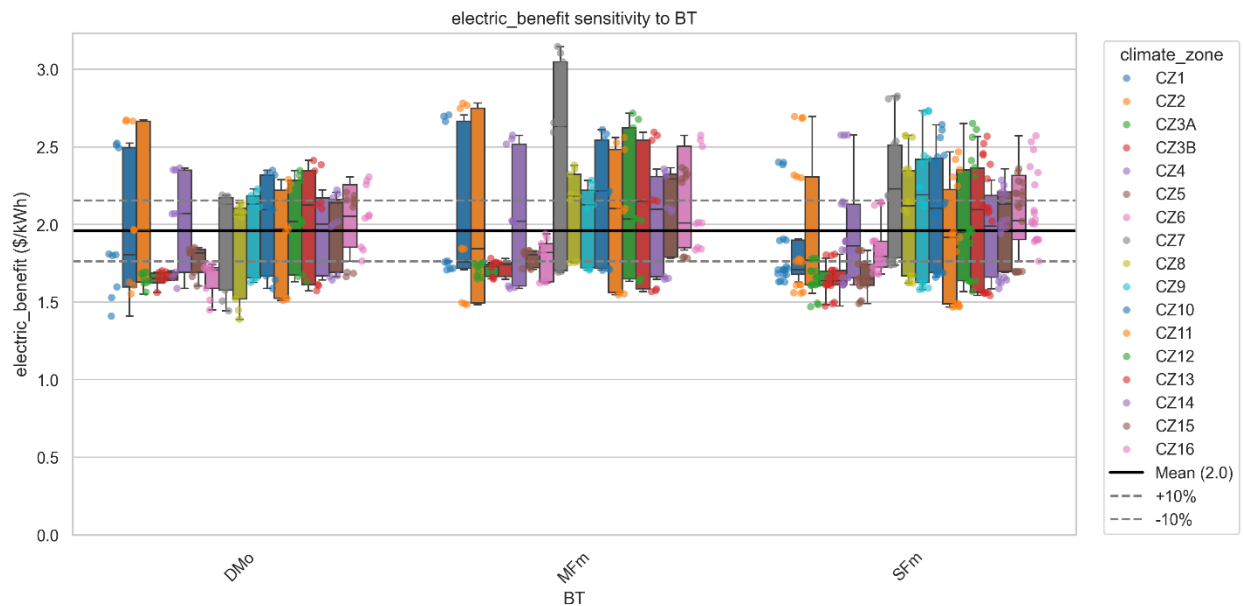


Figure 132: Unit electric benefits vs. building location and building type.

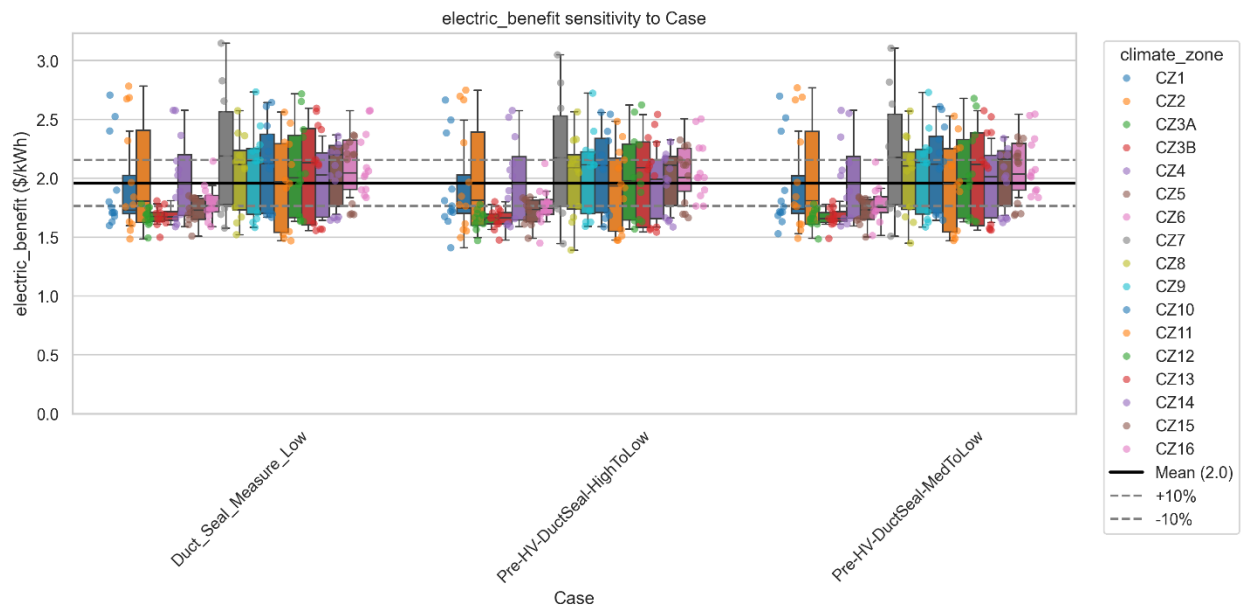


Figure 133: Unit electric benefits vs. building location and base case.

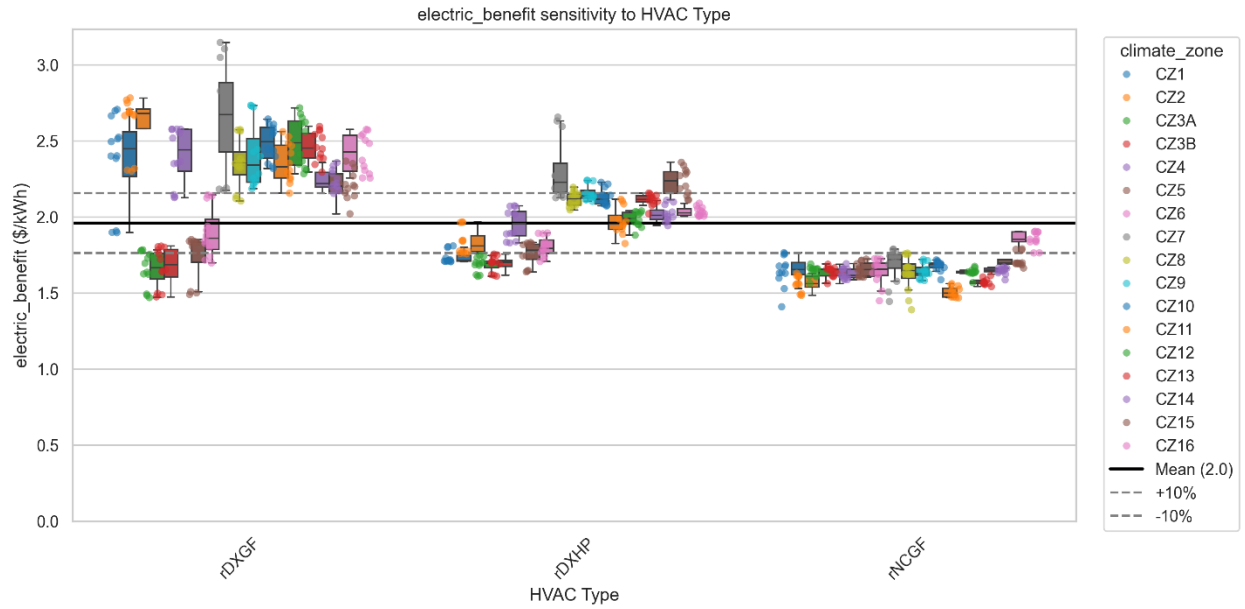


Figure 134: Unit electric benefits vs. building location and HVAC type.

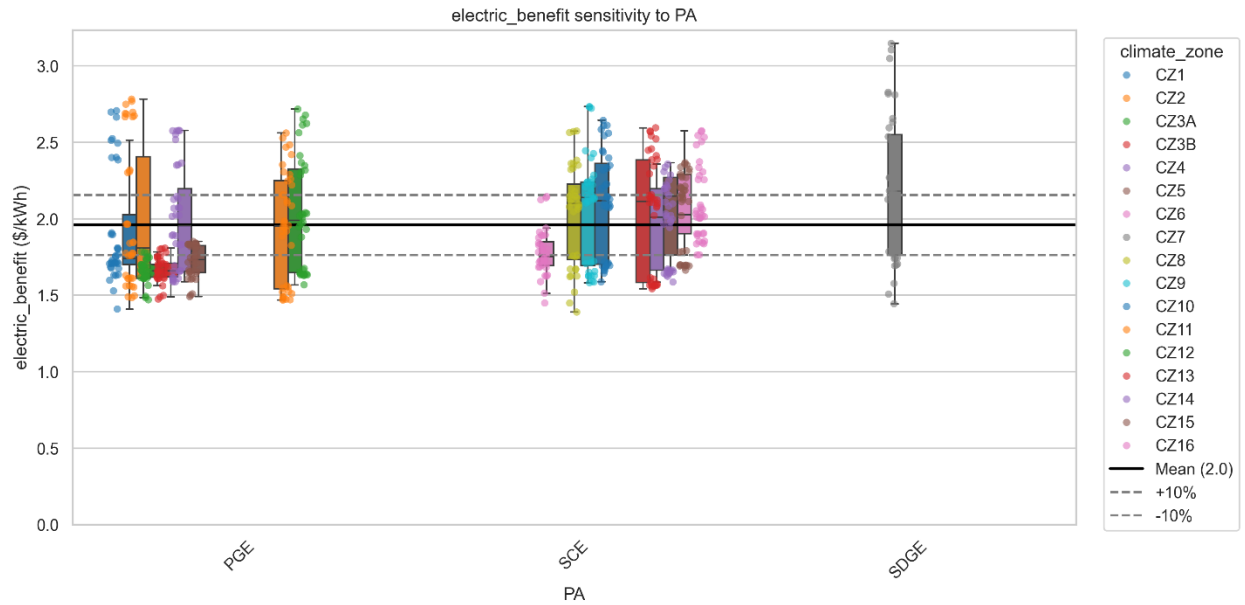


Figure 135: Unit electric benefits vs. building location and IOU.

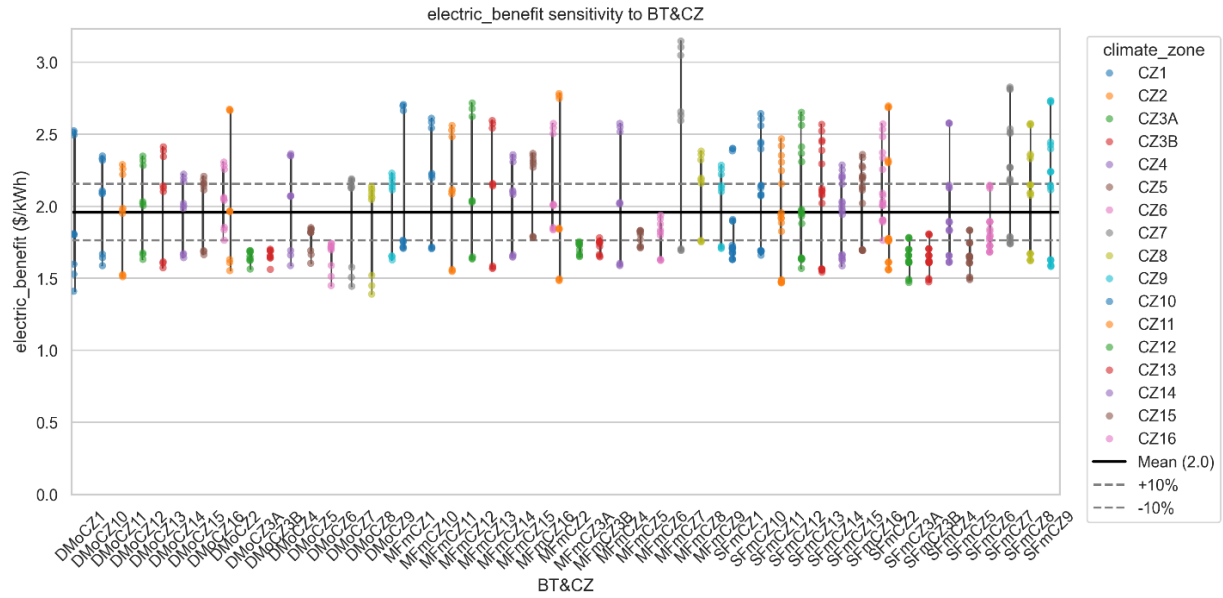


Figure 136: Unit electric benefits vs. building location and two parameters of building type and building location.

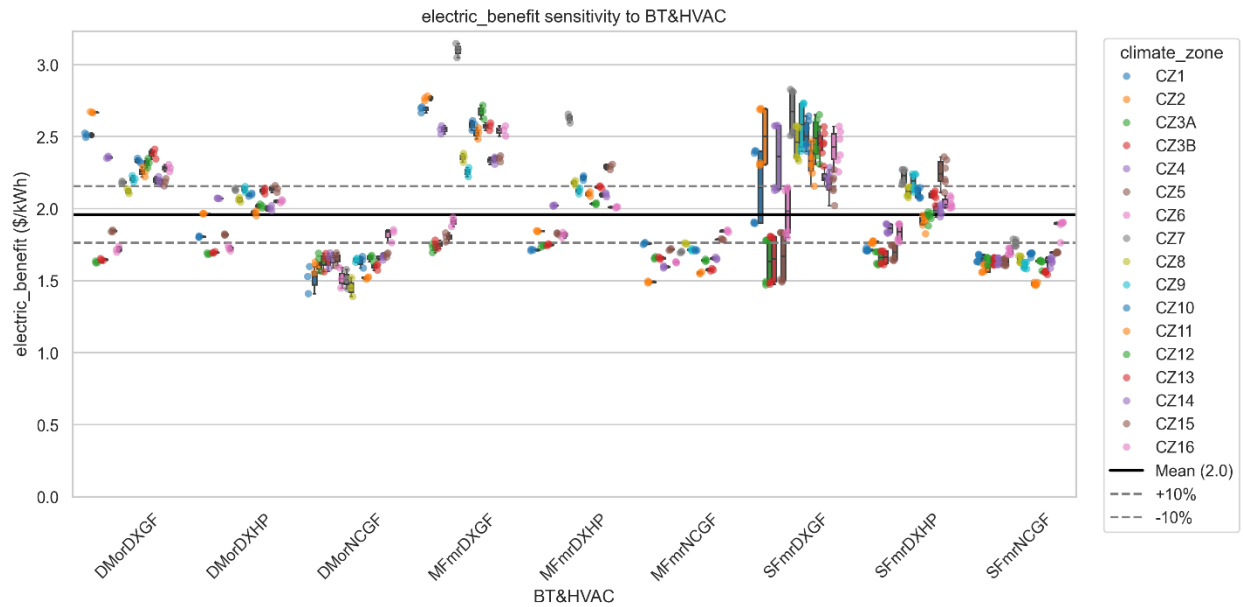


Figure 137: Unit electric benefits vs. building location and two parameters of building type and HVAC type.

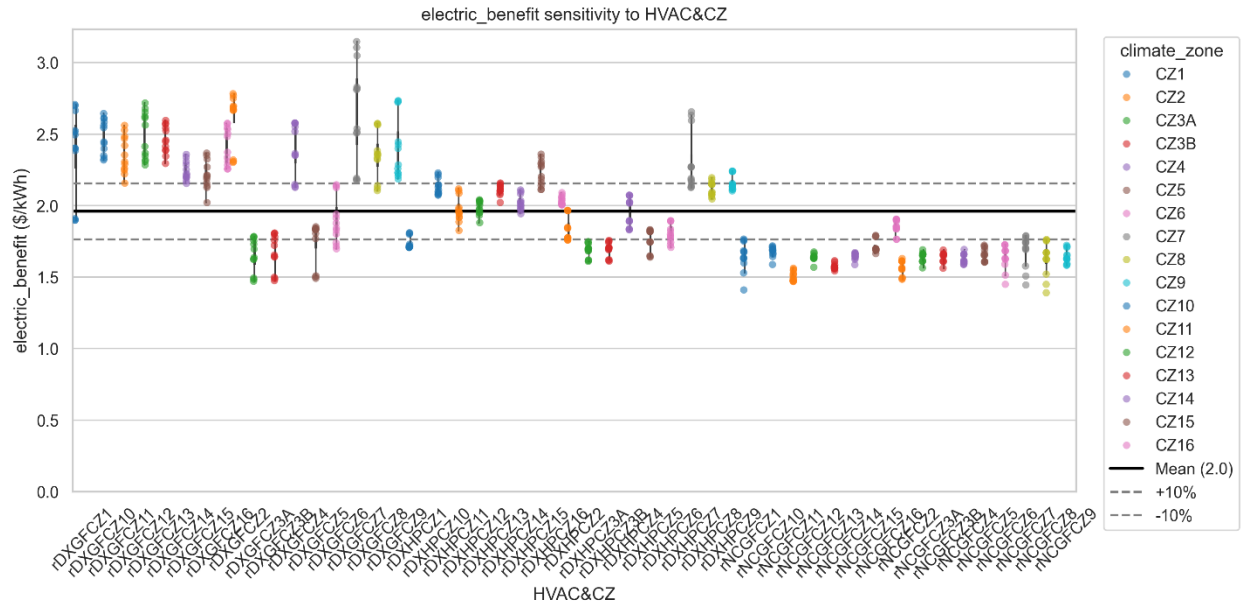


Figure 138: Unit electric benefits vs. building location and two parameters of building location and HVAC type.

SWSV001 – Climate zone specific (CZ10)

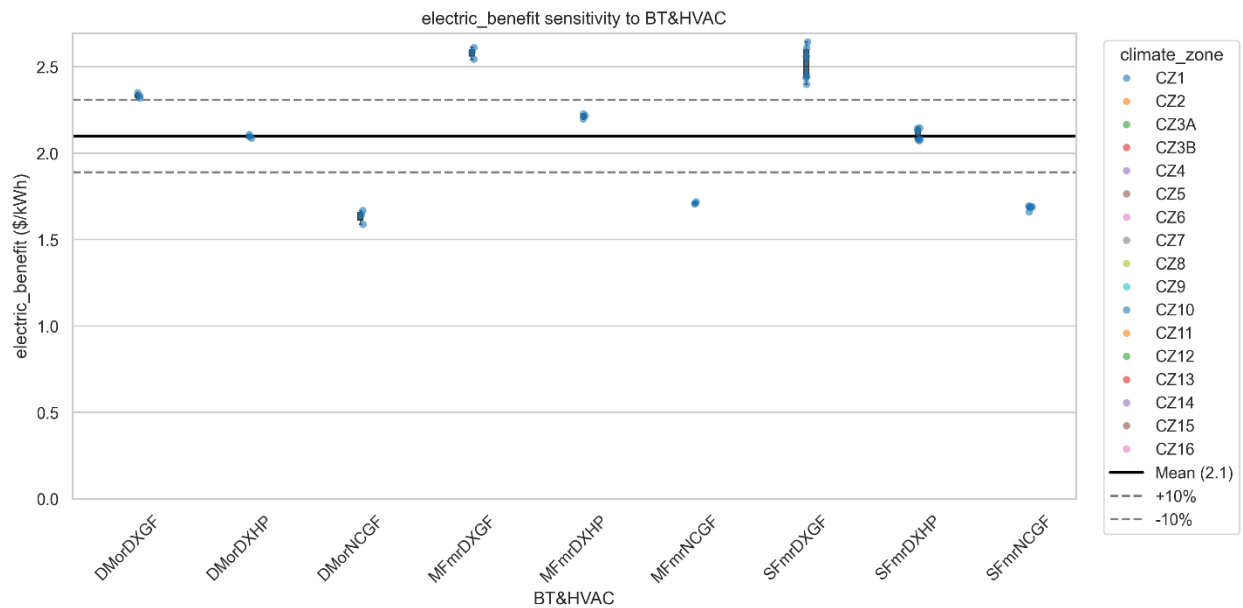


Figure 139: Unit electric benefits vs. building type and HVAC type for building location 10.

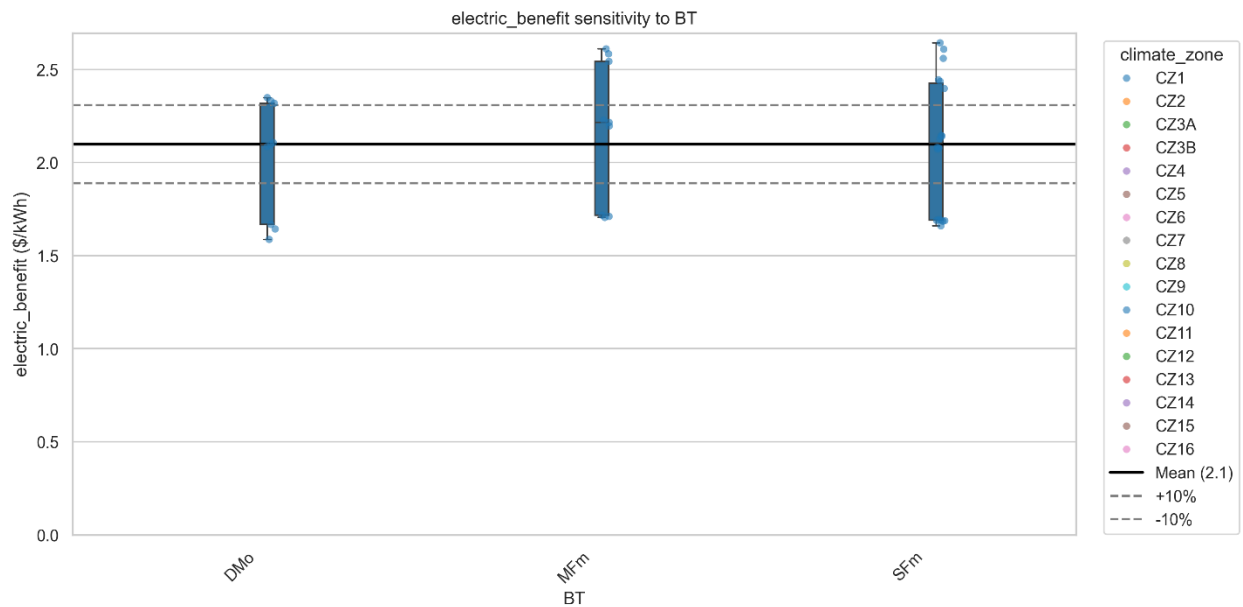


Figure 140: Unit electric benefits vs. building type for building location 10.

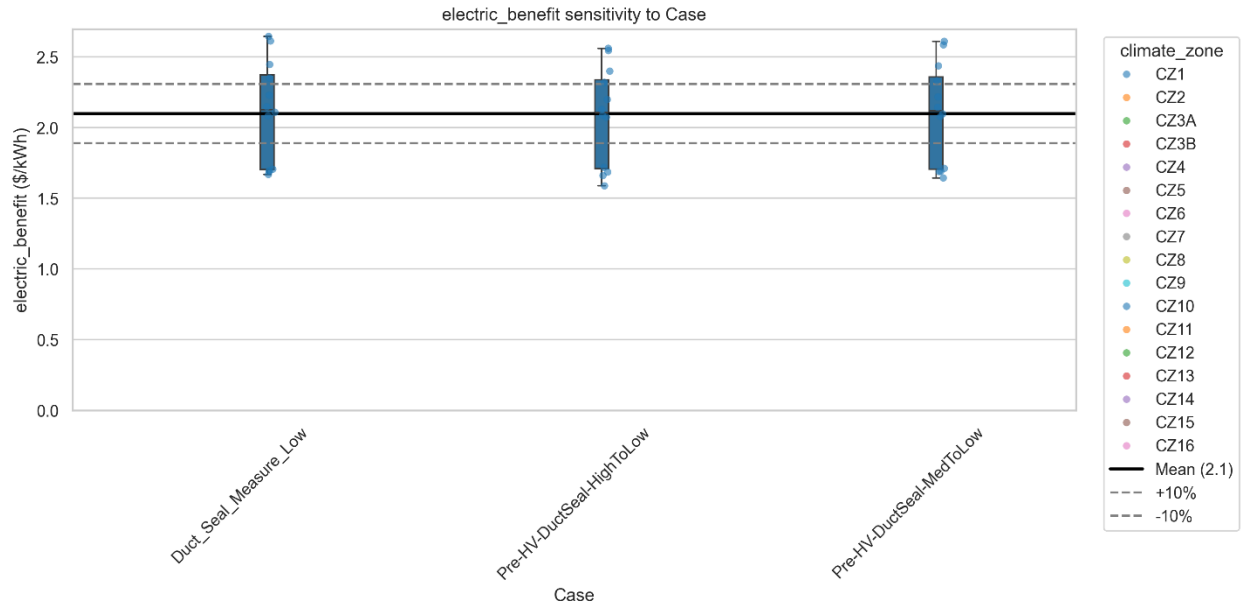


Figure 141: Unit electric benefits vs. base case for building location 10.

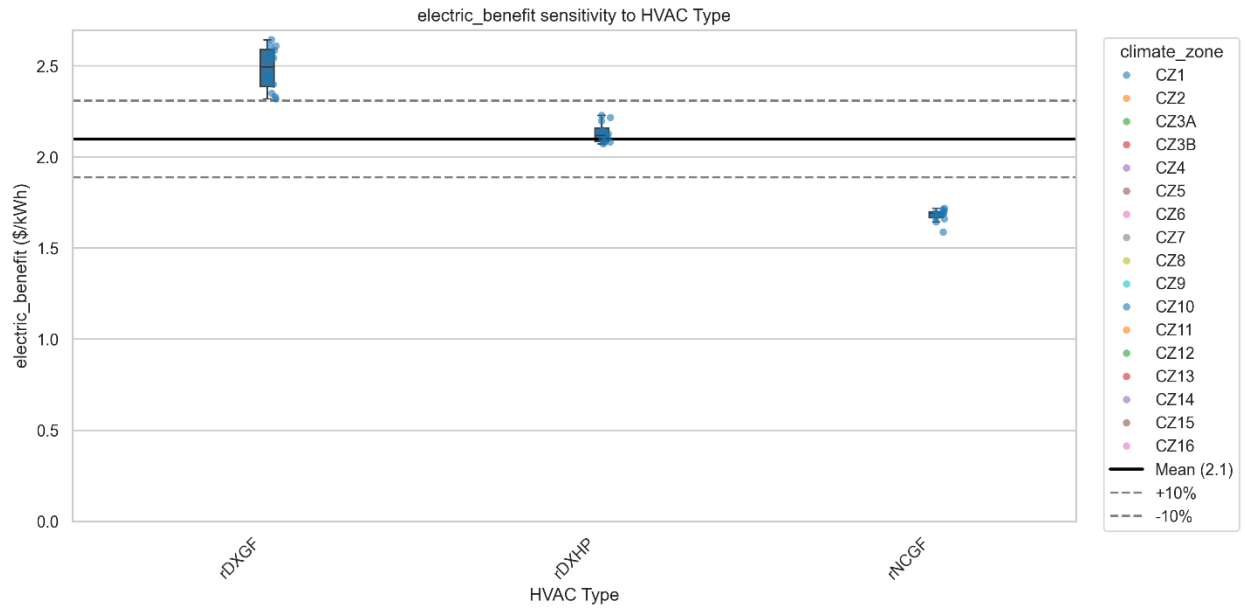


Figure 142: Unit electric benefits vs. HVAC type for building location 10.

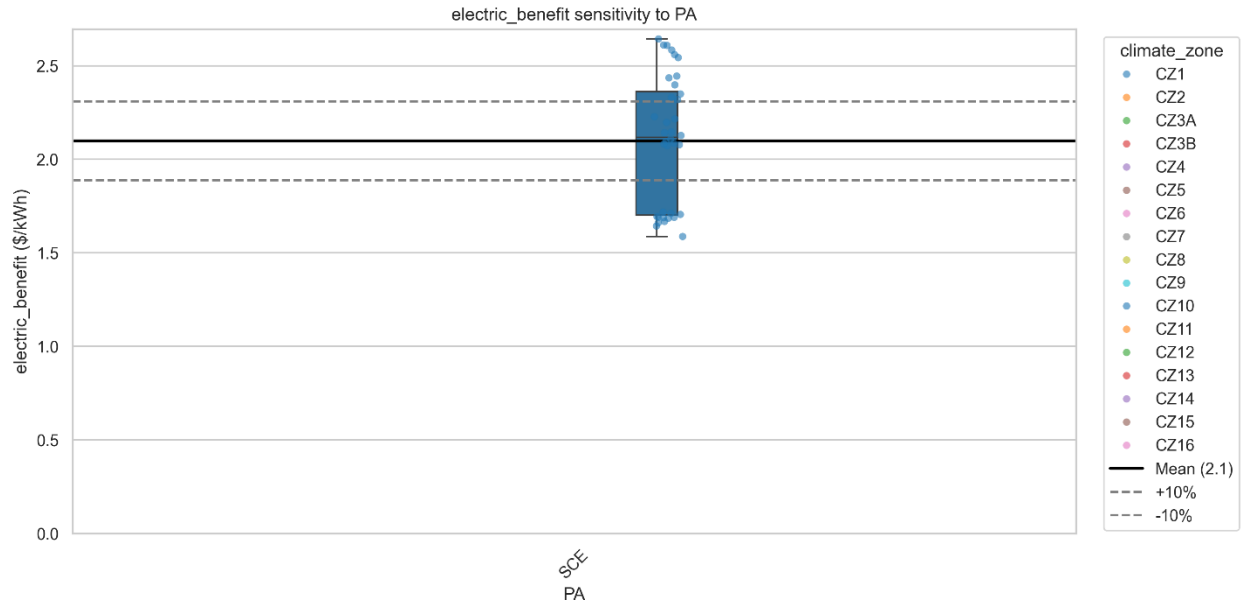


Figure 143: Unit electric benefits vs. PA for building location 10.

SWWH025 Heat Pump Water Heater, Residential, Fuel Substitution

Parameter Name	CLS	Max SD	Avg SD	Parameters
Total Models	3,000		4%	
Building Type	3	4%	4%	DMo, MFm, SFm
Building Location	17	5%	3%	CZ01, CZ02, CZ03, CZ04, CZ05, CZ06, CZ07, CZ08, CZ09, CZ10, CZ11, CZ12, CZ13, CZ14, CZ15, CZ16
Equipment Efficiency	8	4%	4%	2.75, 3.00, 3.30, 3.50, 3.75
Equipment Type	2	4%	3%	HP_UEF, Instant_UEF
Capacity Range	6	4%	4%	30 Gal, 40 Gal, 50 Gal, 60 Gal, 75 Gal, High Draw
Voltage	2	4%	4%	120V, 240V
ER	2	4%	4%	With Electric Resistance, Without Electric Resistance
BT&CZ	51	5%	3%	DMo&CZ01, DMo&CZ02, ..., SFm&CZ15, SFm&CZ16

Table 29: SWWH025 parameter results

Representative of SWHC014 and SWWH001 also

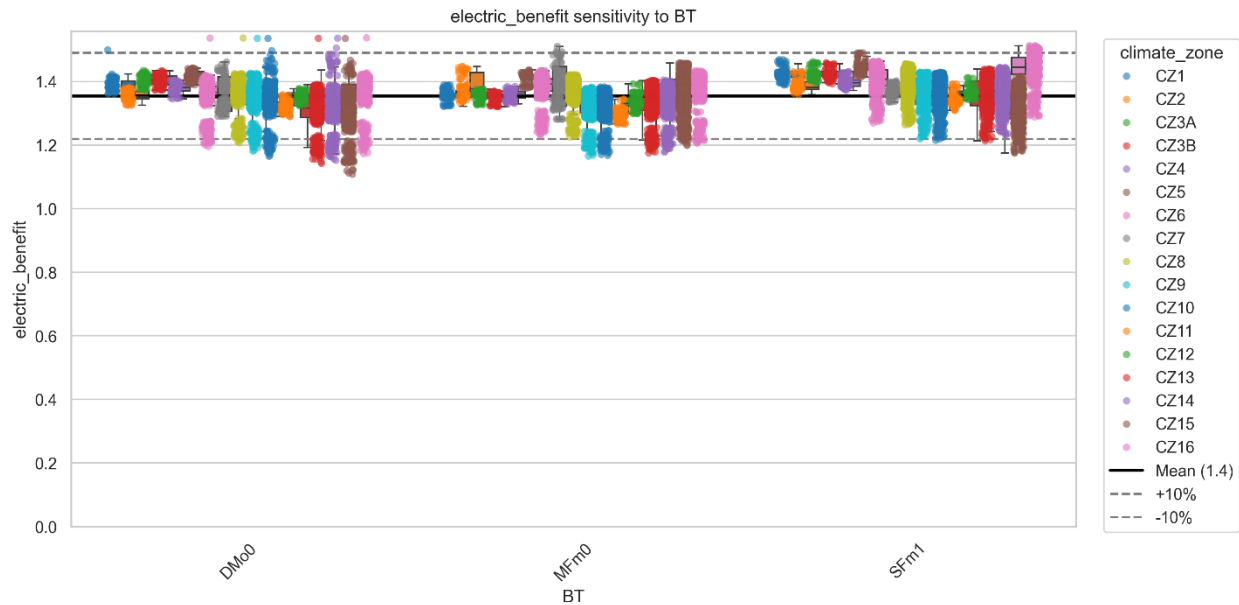


Figure 144: Unit electric benefits vs. building location and building type.

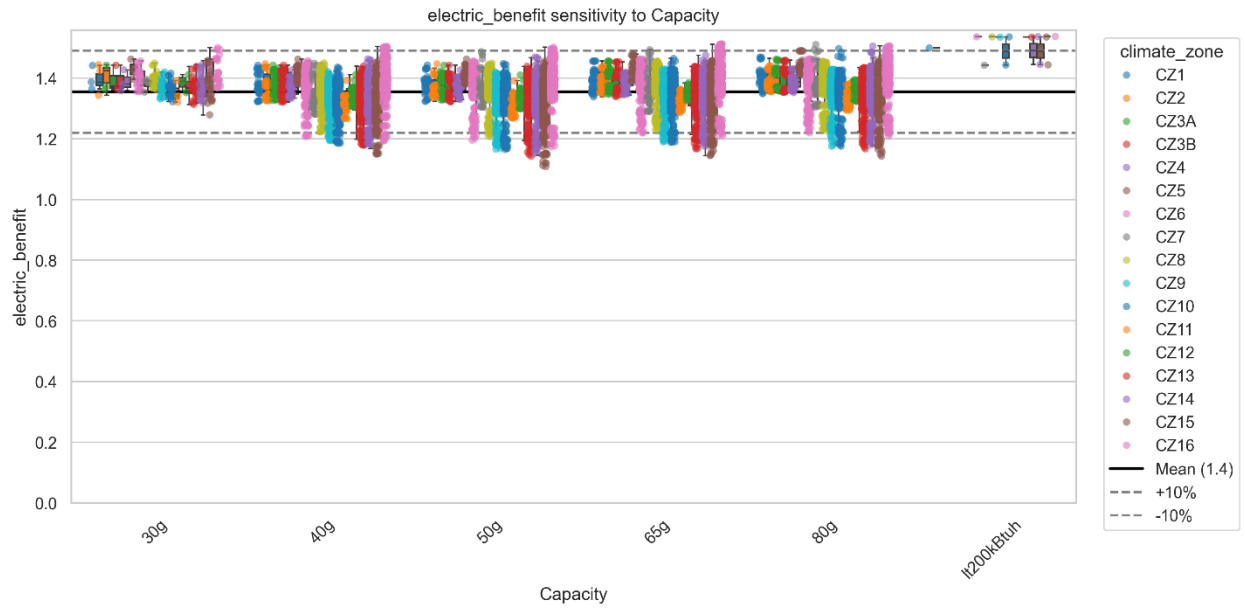


Figure 145: Unit electric benefits vs. building location and capacity.

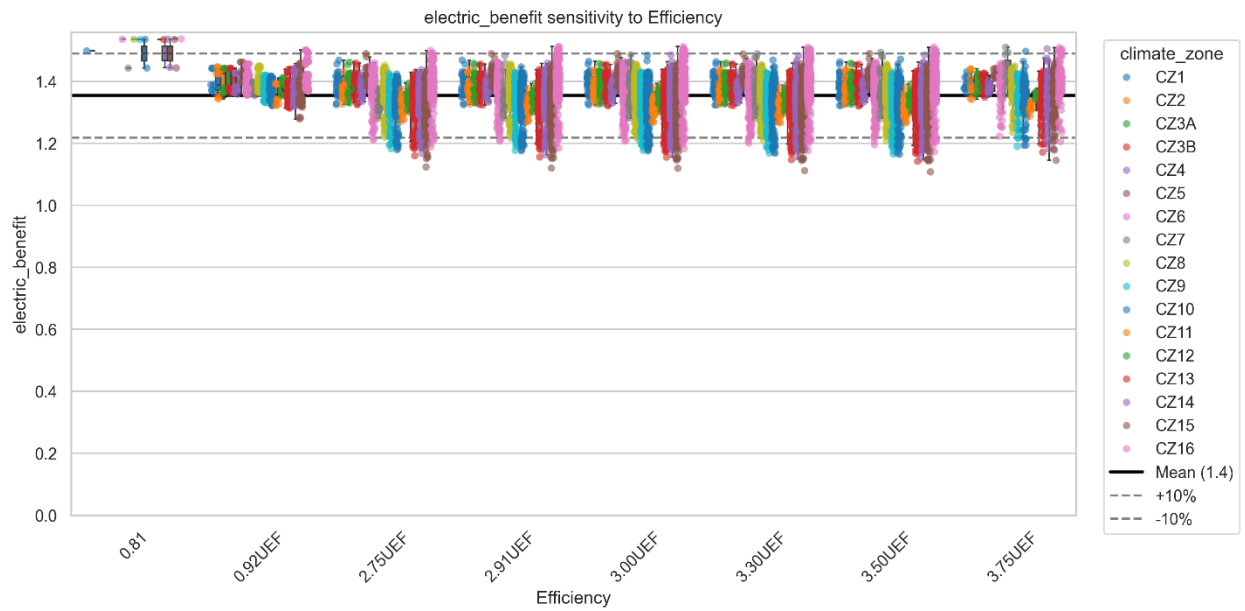


Figure 146: Unit electric benefits vs. building location and equipment efficiency.

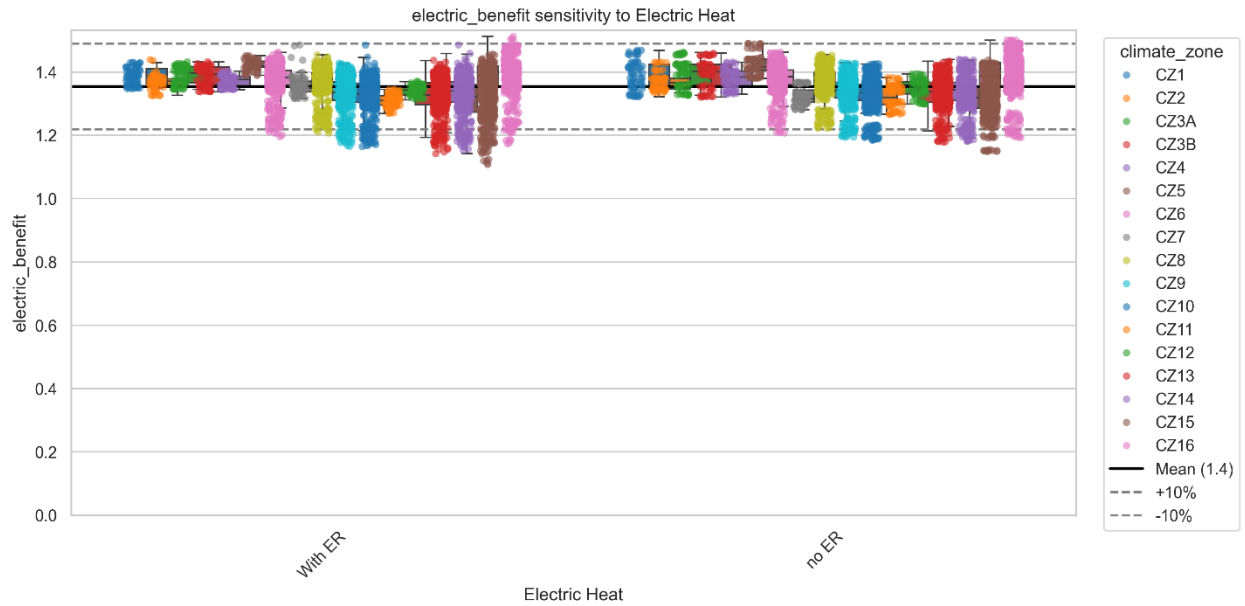


Figure 147: Unit electric benefits vs. building location and electric resistance.

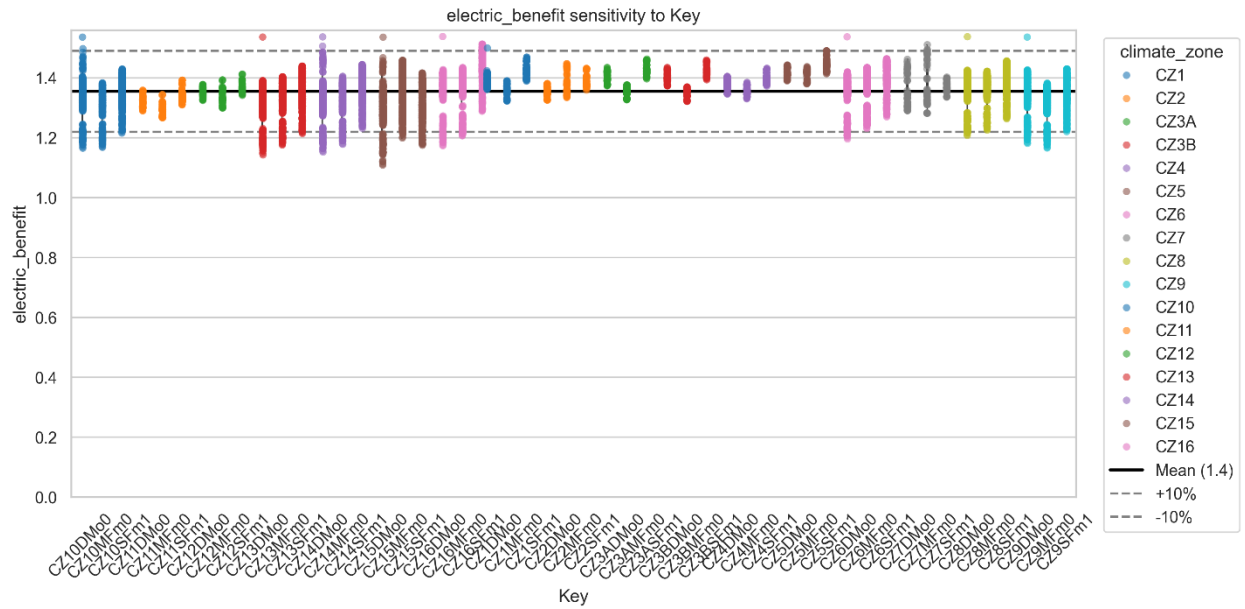


Figure 148: Unit electric benefits vs. building location and two parameters of building type with building location.

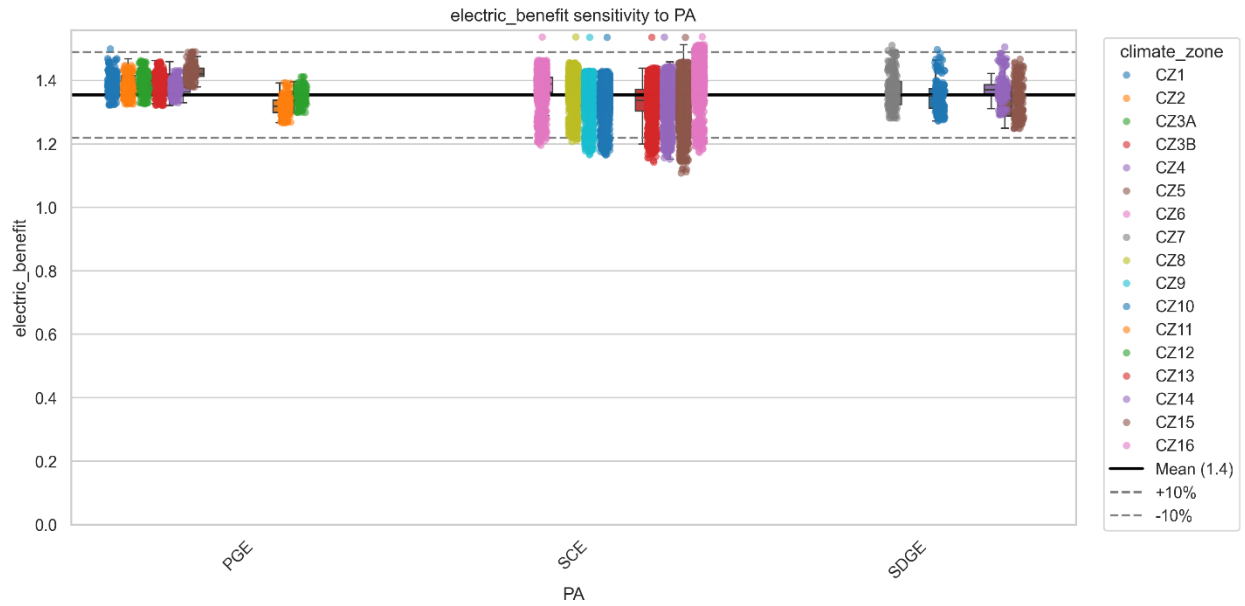


Figure 149: Unit electric benefits vs. building location and IOU.

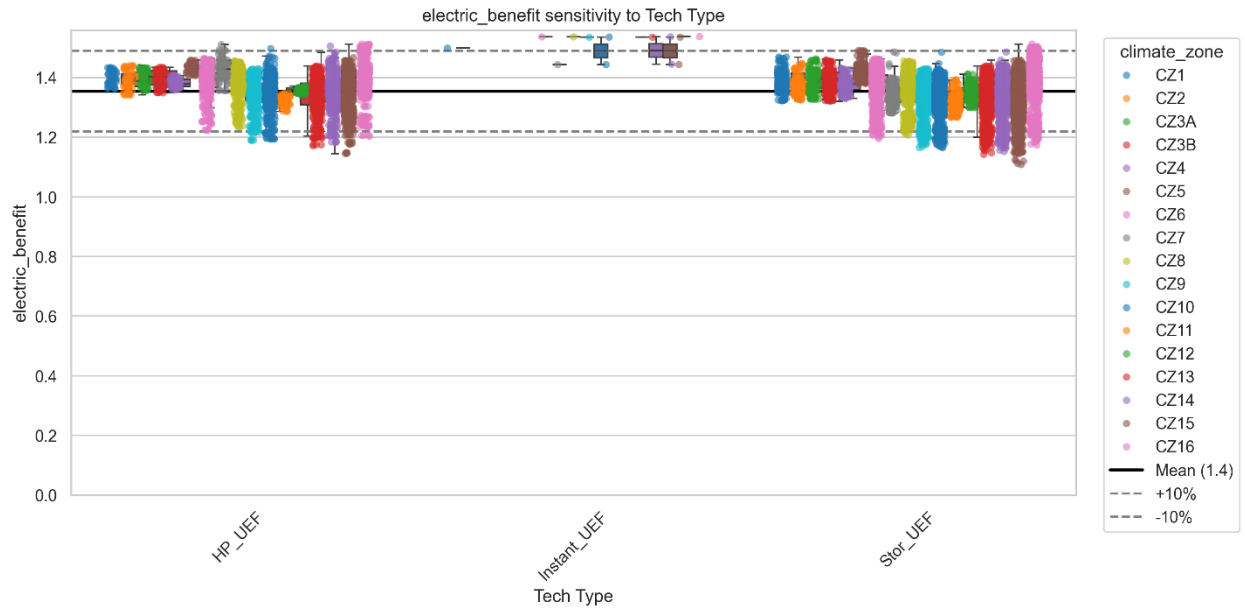


Figure 150: Unit electric benefits vs. building location and technology type.

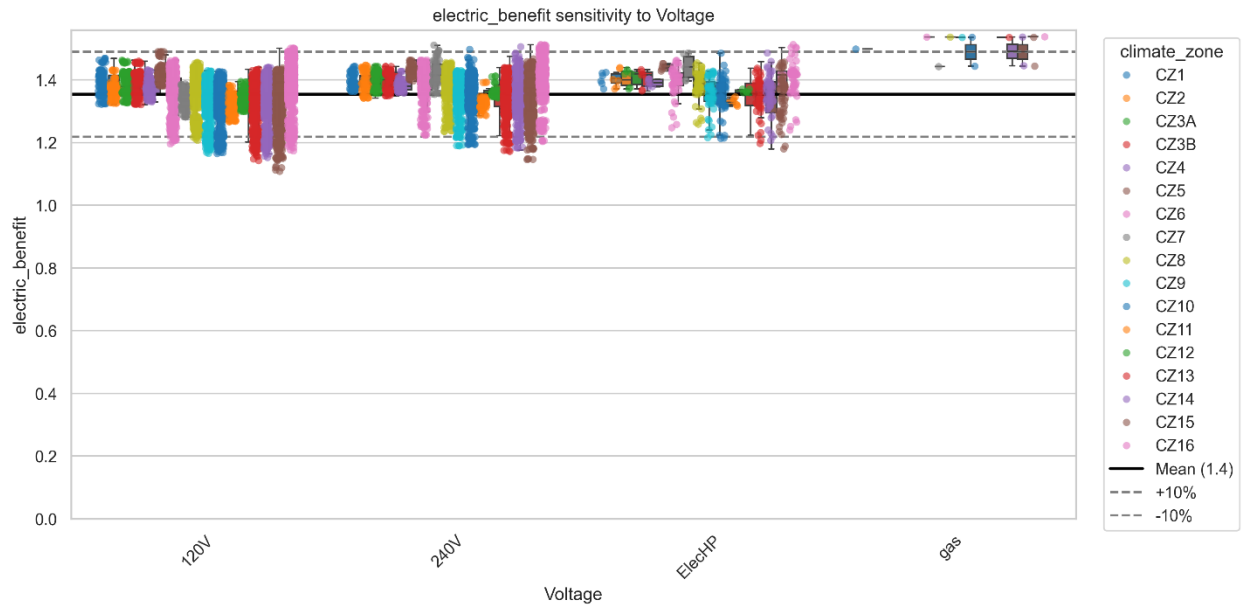


Figure 151: Unit electric benefits vs. building location and HP voltage.

SWWH025 – Groups

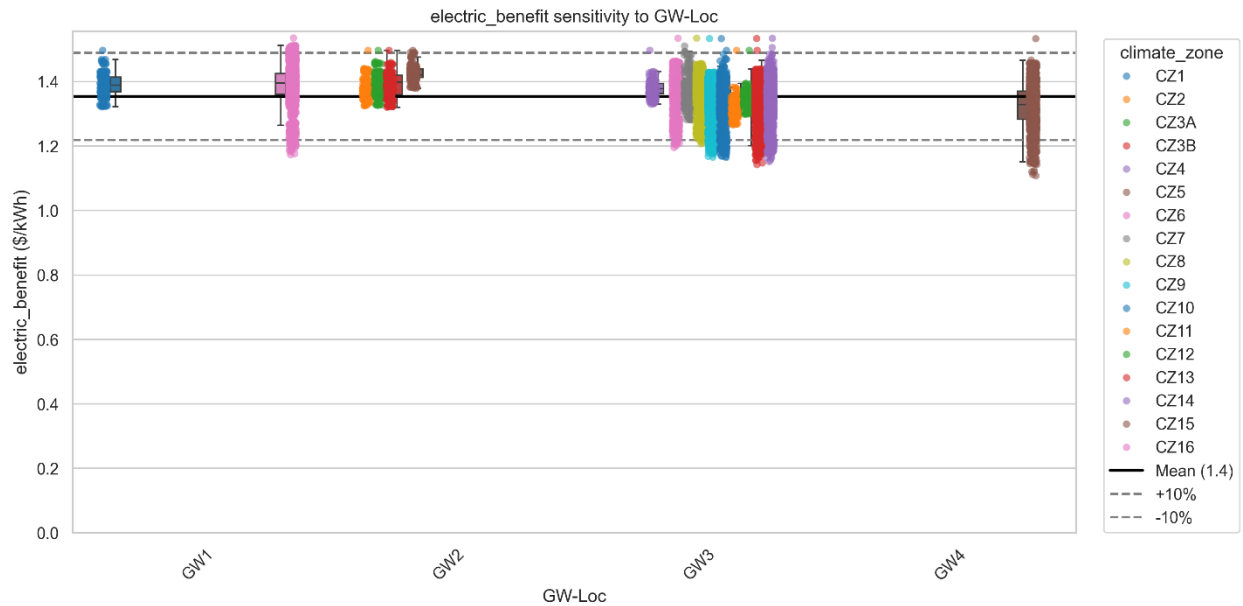


Figure 152: Unit electric benefits with groupings for ground water temperature.

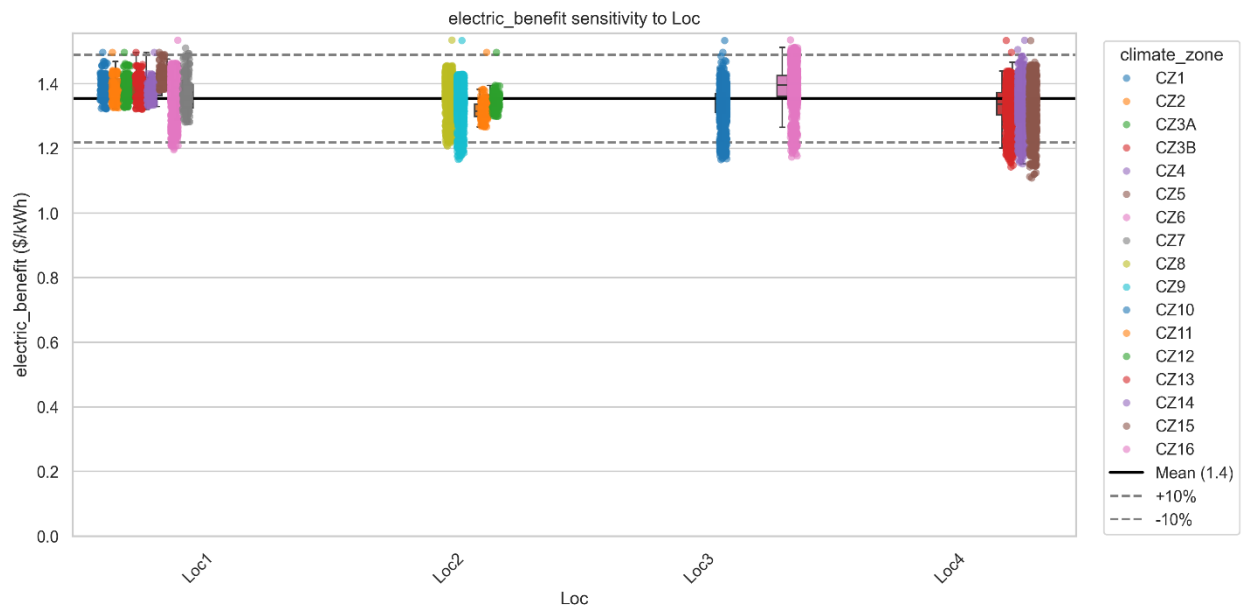


Figure 153: Unit electric benefits with groupings for building location.

SWWH025 – Climate zone specific (CZ6)

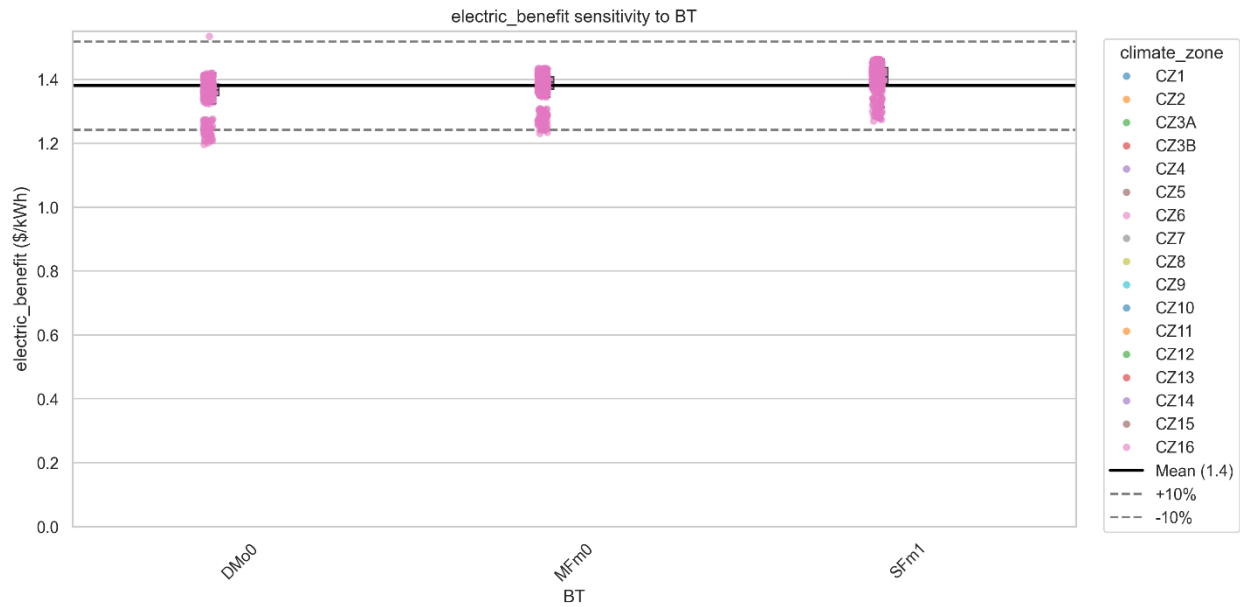


Figure 154: Unit electric benefits vs. IOU for building location 6.

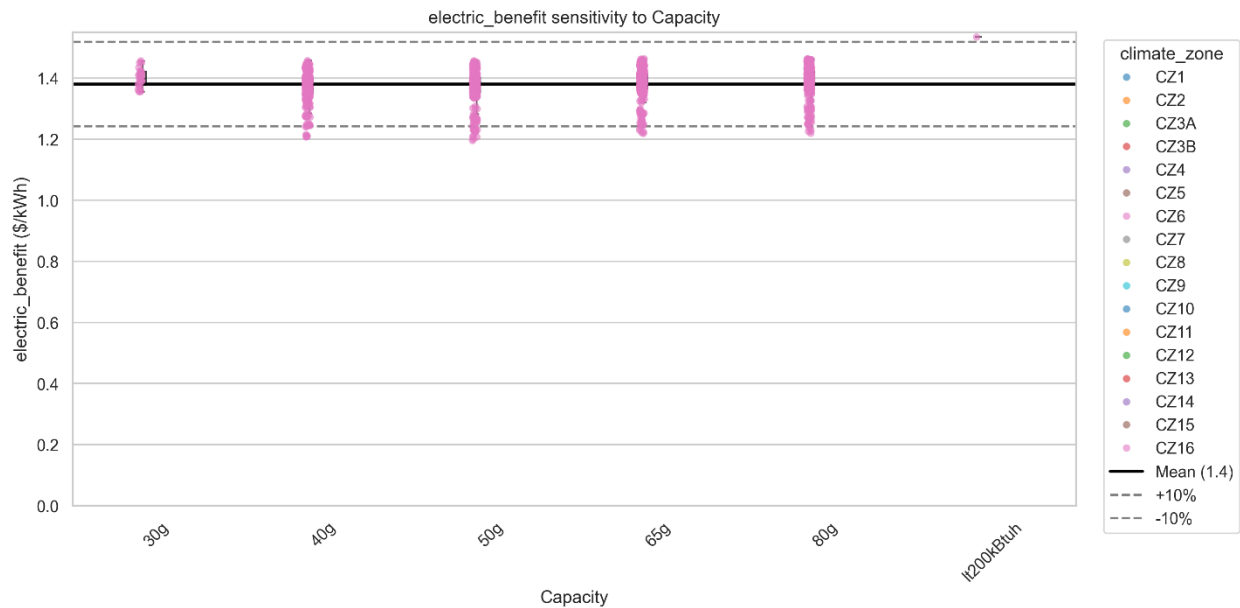


Figure 155: Unit electric benefits vs. capacity for building location 6.

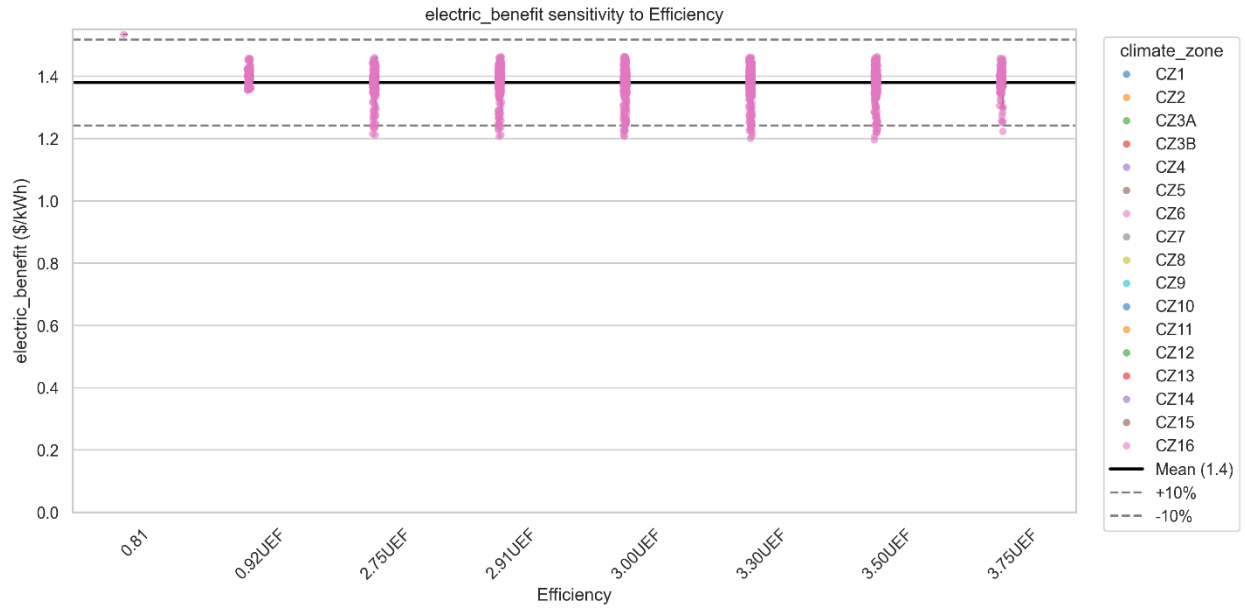


Figure 156: Unit electric benefits vs. efficiency for building location 6.

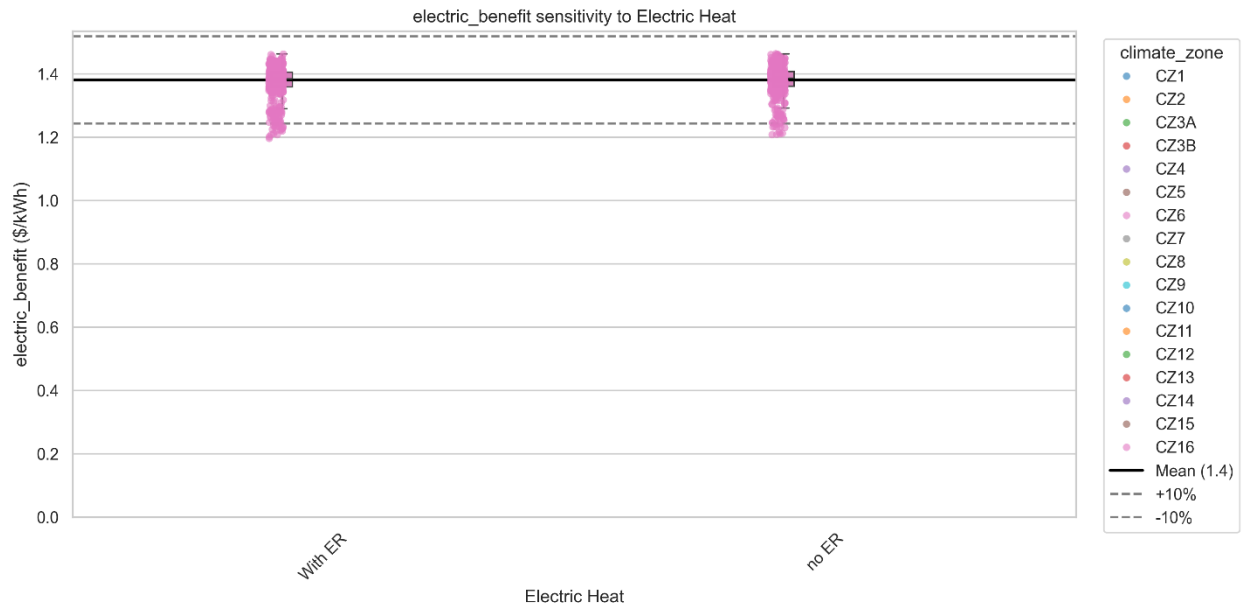


Figure 157: Unit electric benefits vs. electric resistance for building location 6.

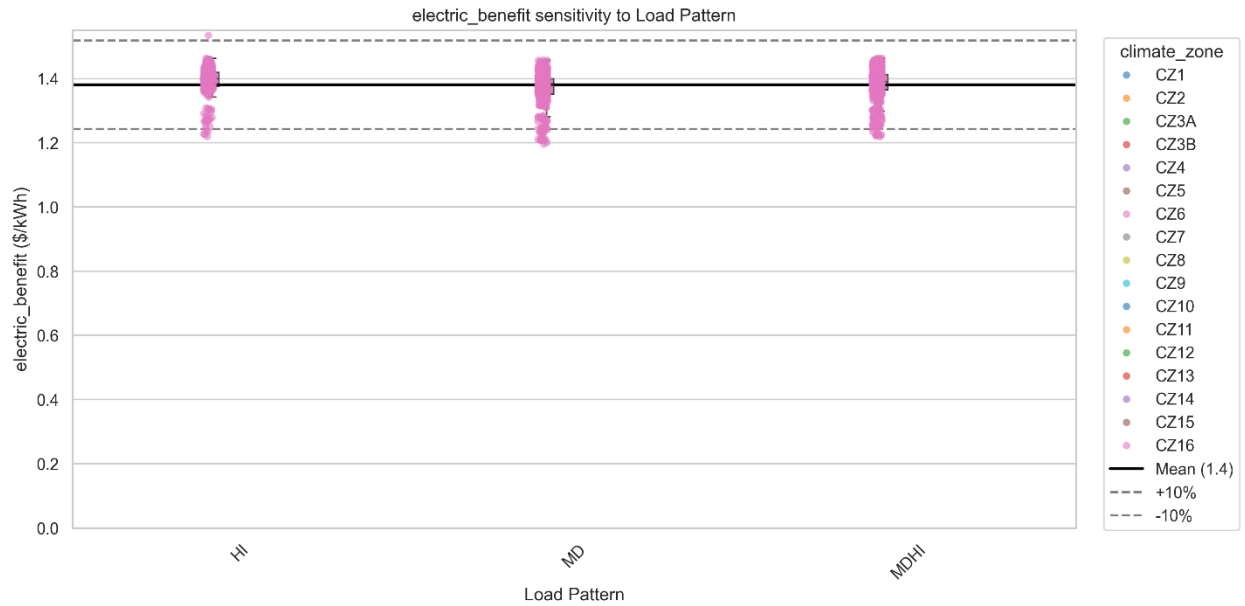


Figure 158: Unit electric benefits vs. load pattern for building location 6.

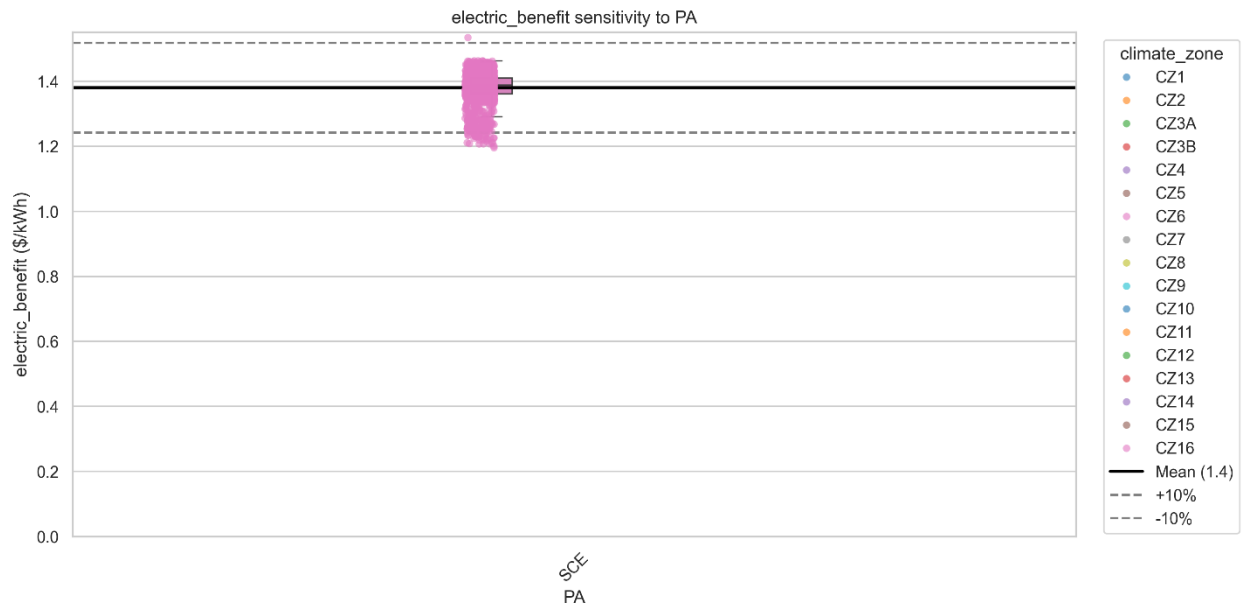


Figure 159: Unit electric benefits vs. IOU for building location 6.

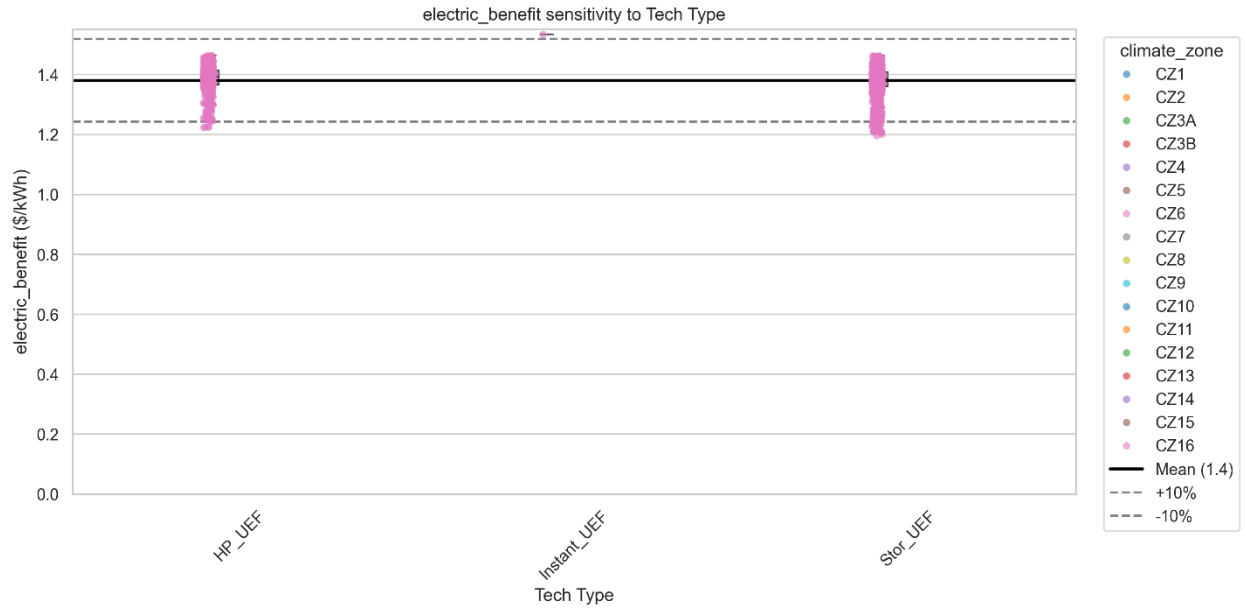


Figure 160: Unit electric benefits vs. technology type for building location 6.

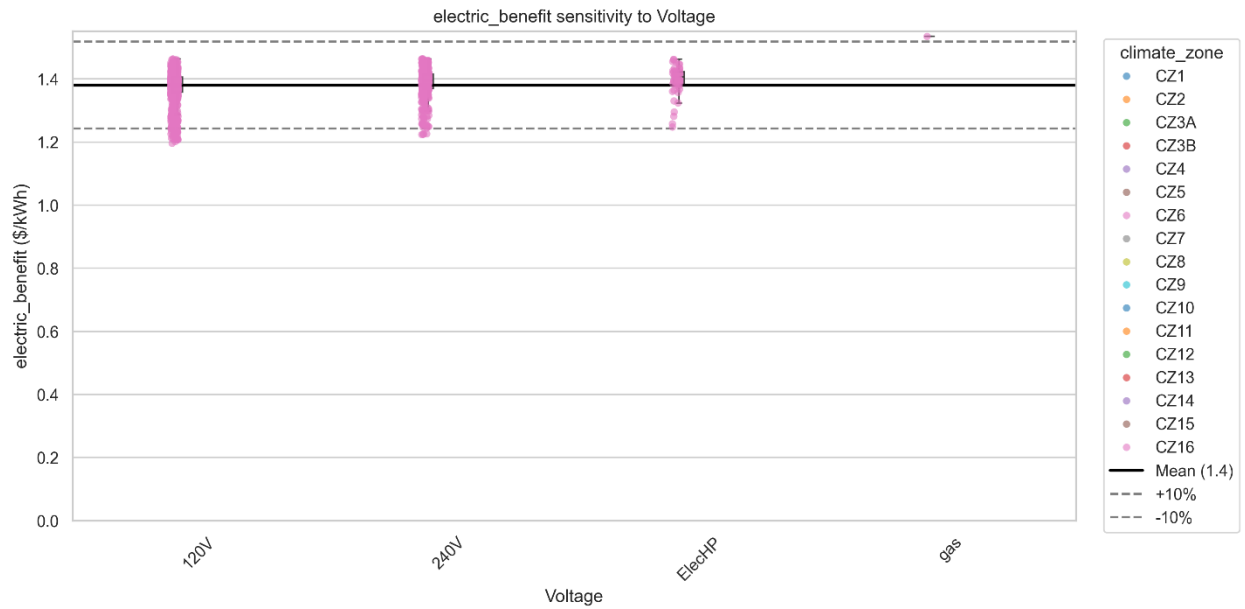


Figure 161: Unit electric benefits vs. HP voltage for building location 6.

SWWH025 – Base and Measure Case jitter plots

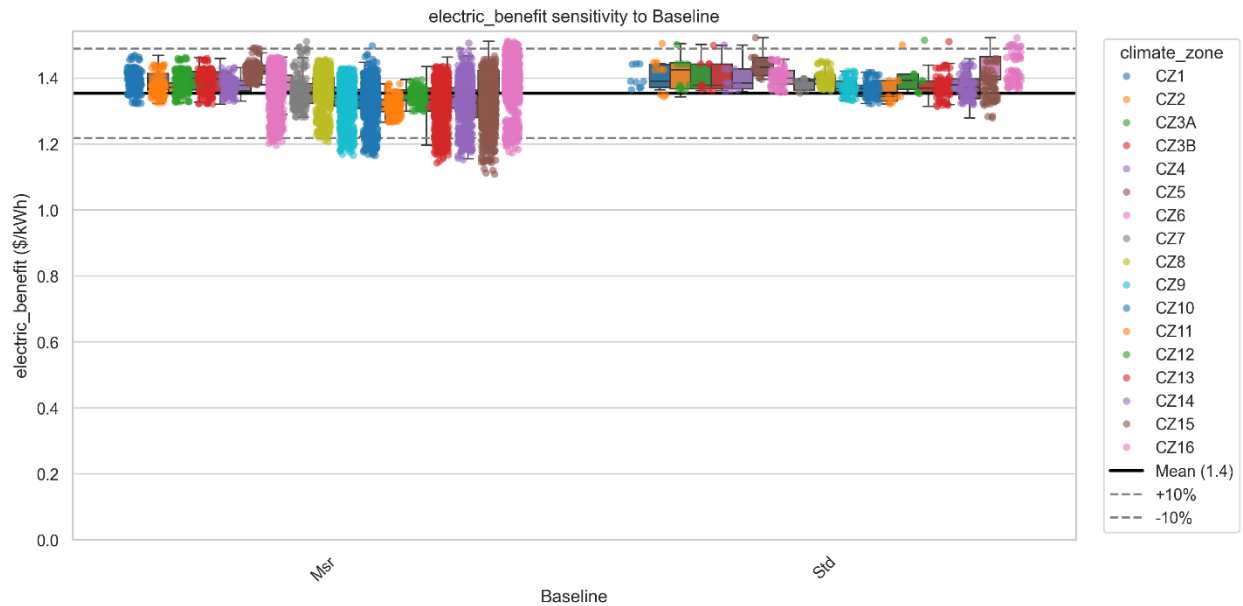


Figure 162: Unit electric benefits vs. building location and base case.

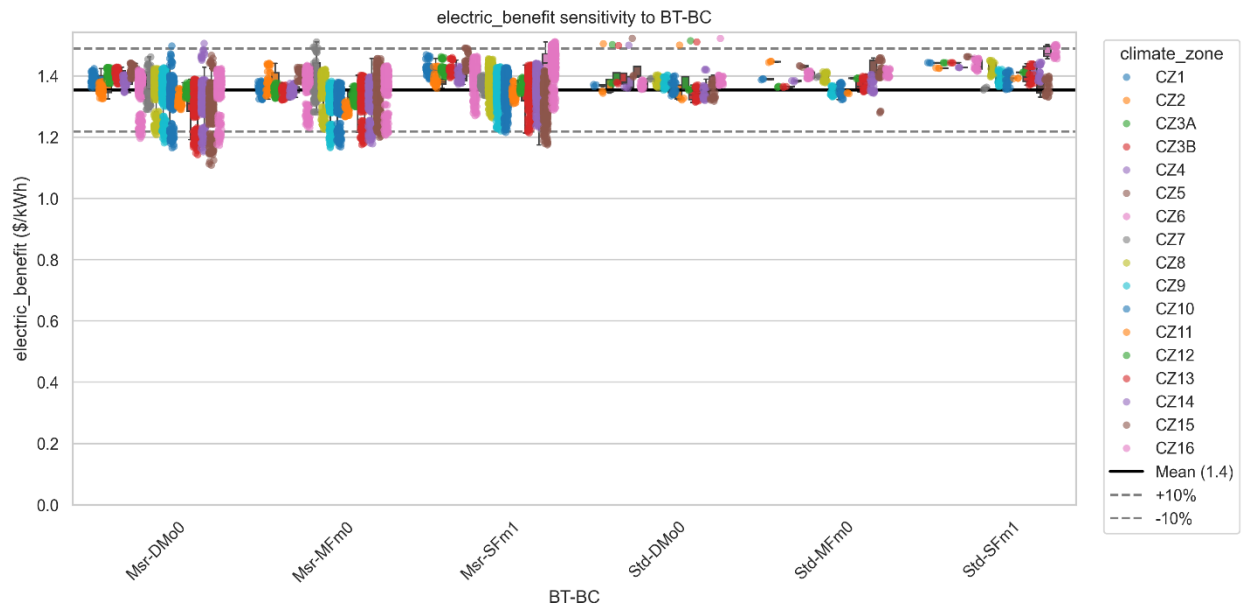


Figure 163: Unit electric benefits vs. building location and base case and building type.

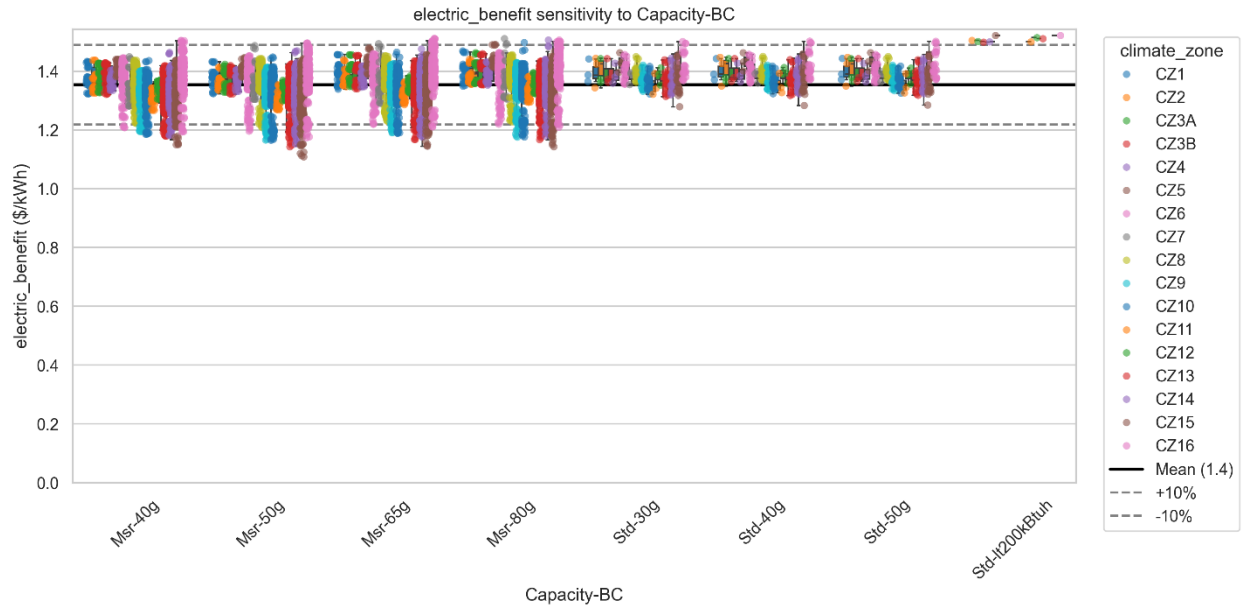


Figure 164: Unit electric benefits vs. building location and base case and capacity.

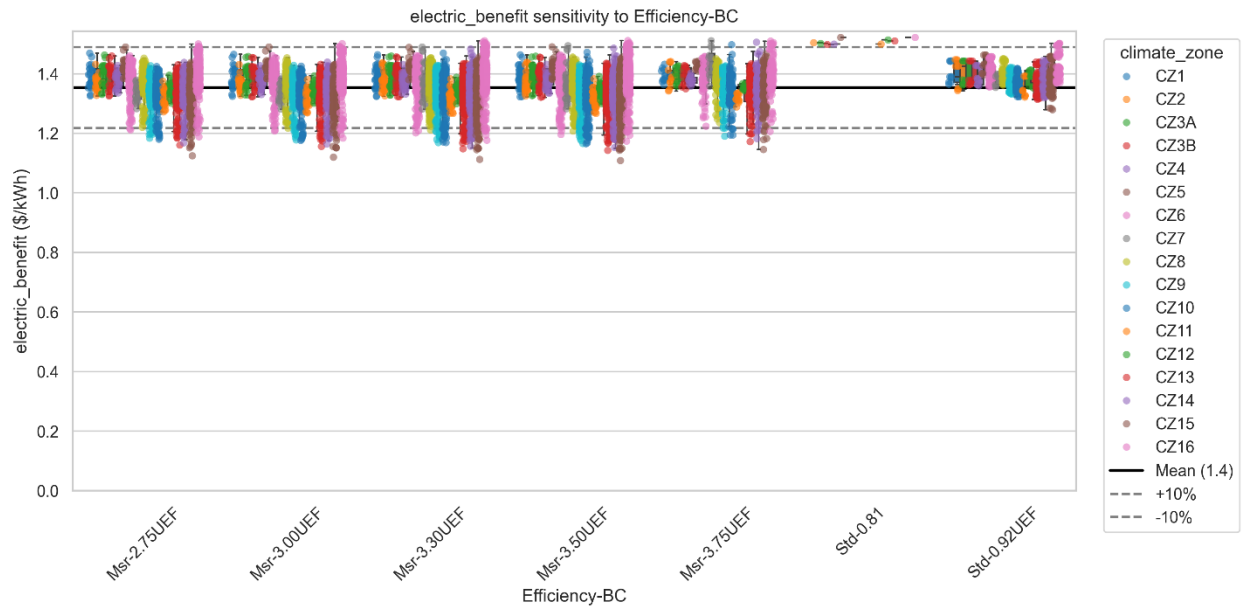


Figure 165: Unit electric benefits vs. building location and base case and equipment efficiency.

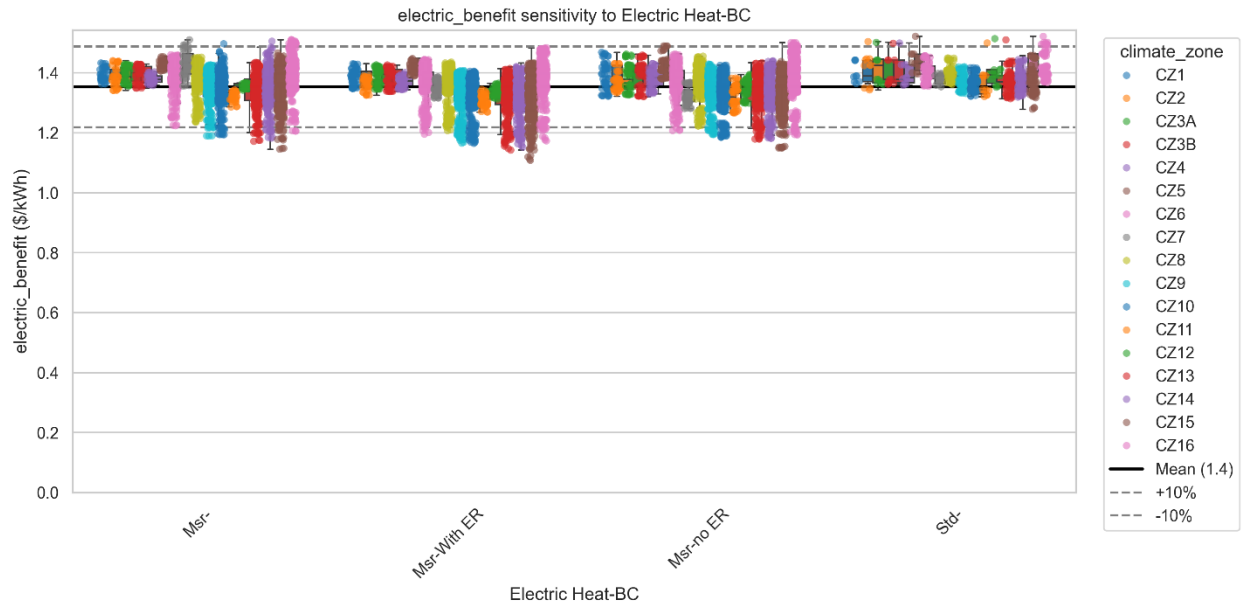


Figure 166: Unit electric benefits vs. building location and base case and electric resistance.

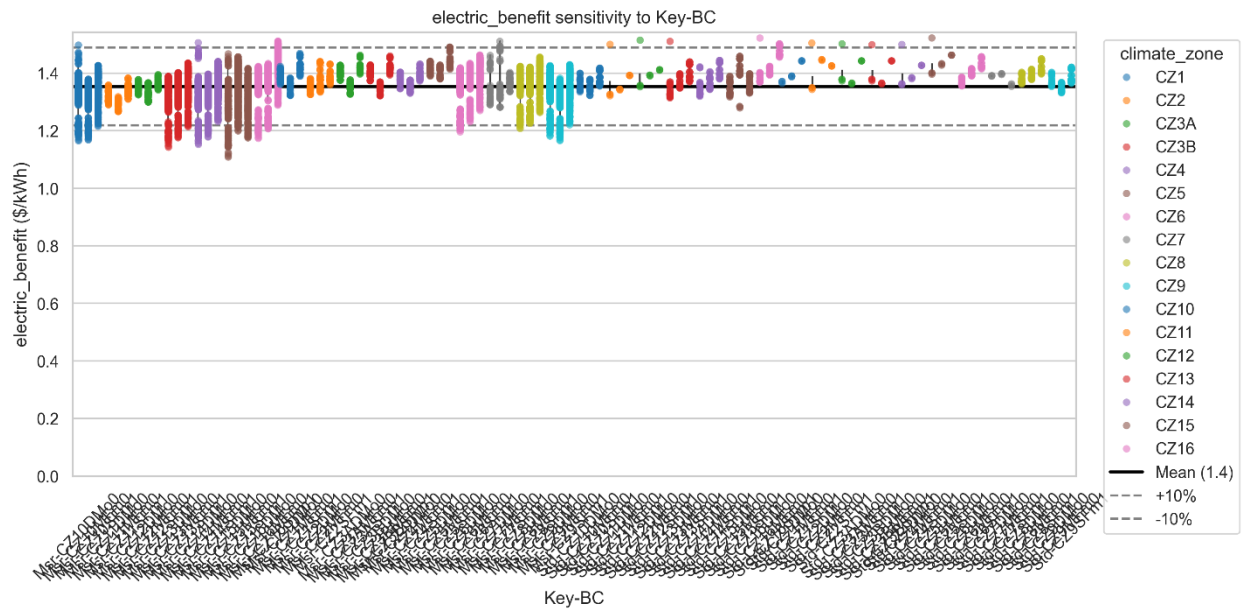


Figure 167: Unit electric benefits vs. building location and base case and two parameters of building type and building location.

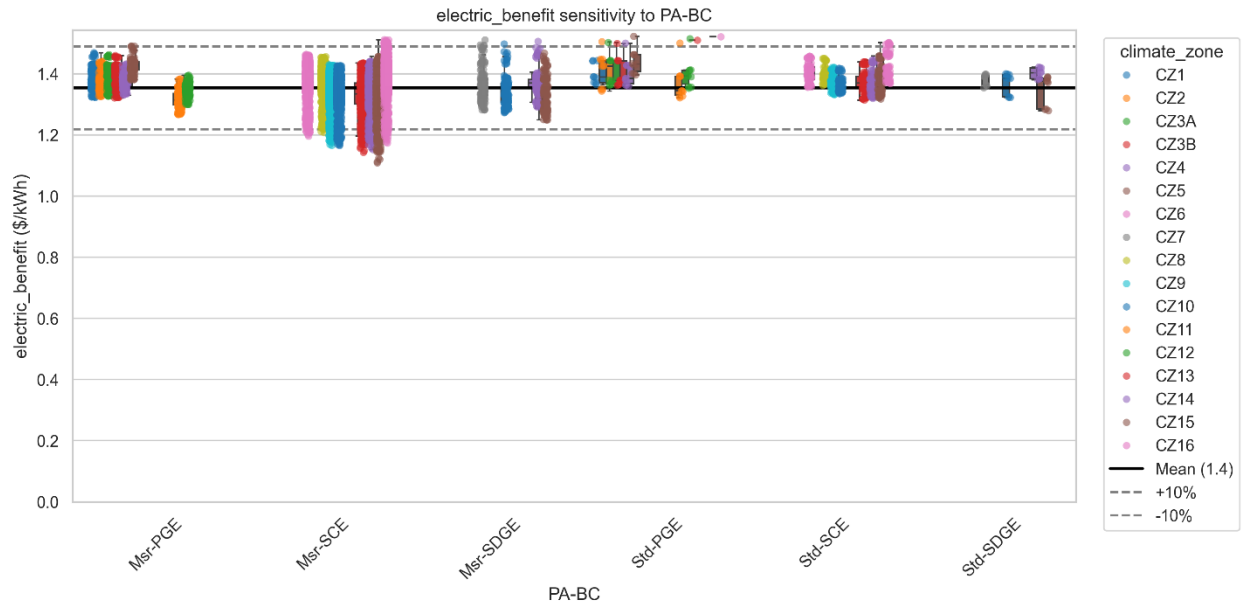


Figure 168: Unit electric benefits vs. building location and base case and IOU.

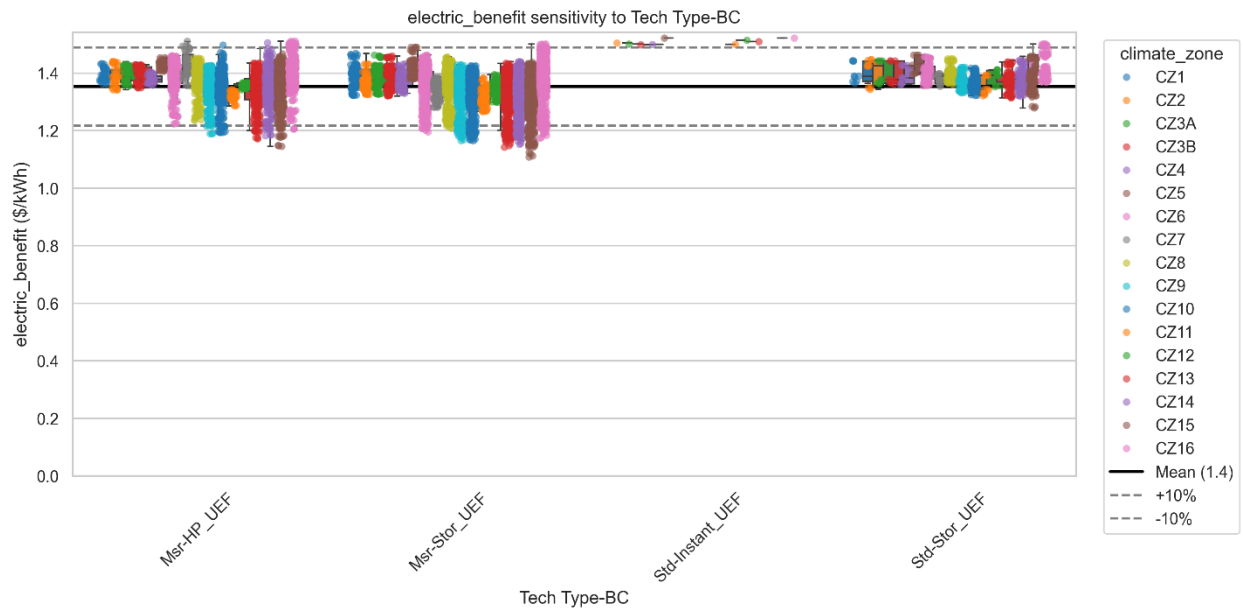


Figure 169: Unit electric benefits vs. building location and base case and technology type.

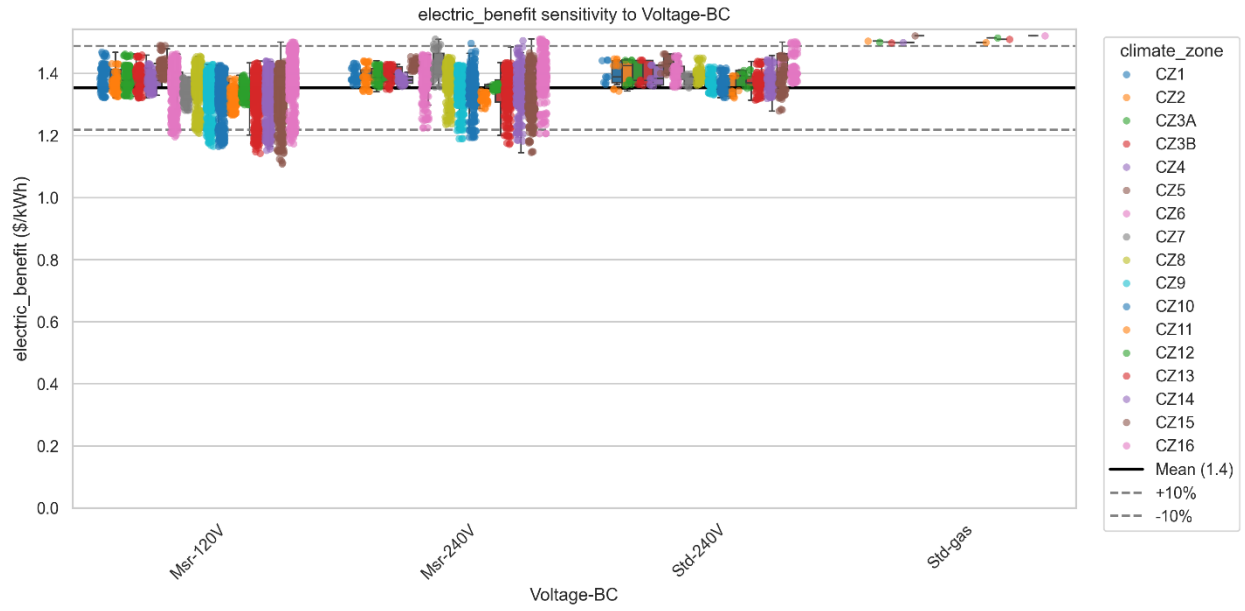


Figure 170: Unit electric benefits vs. building location and base case and HP voltage.

SWCR001 Anti-Sweat Heater Controls

Parameter Name	CLS	Max SD	Avg SD	Parameters
Total Models	48		2.4%	
Building Type	1	0%	0%	Gro, Htl, RFF, RSD, Rt3, RtL, RtS
Building Location	16	0.6%	0.3%	CZ01, CZ02, CZ03, CZ04, CZ05, CZ06, CZ07, CZ08, CZ09, CZ10, CZ11, CZ12, CZ13, CZ14, CZ15, CZ16
Equipment Type	3	2.4%	2.4%	No Controls, LT, MT

Table 30: SWCR001 parameter results

SWCR001 – Parameter specific jitter plots

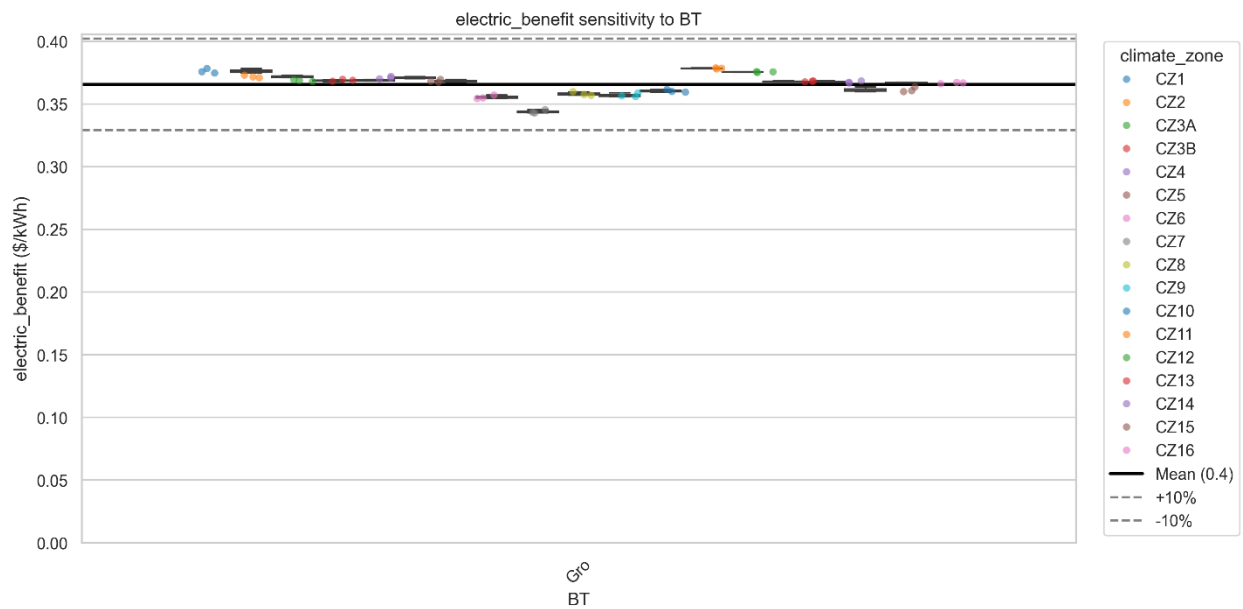


Figure 171: Unit electric benefits vs. building location.

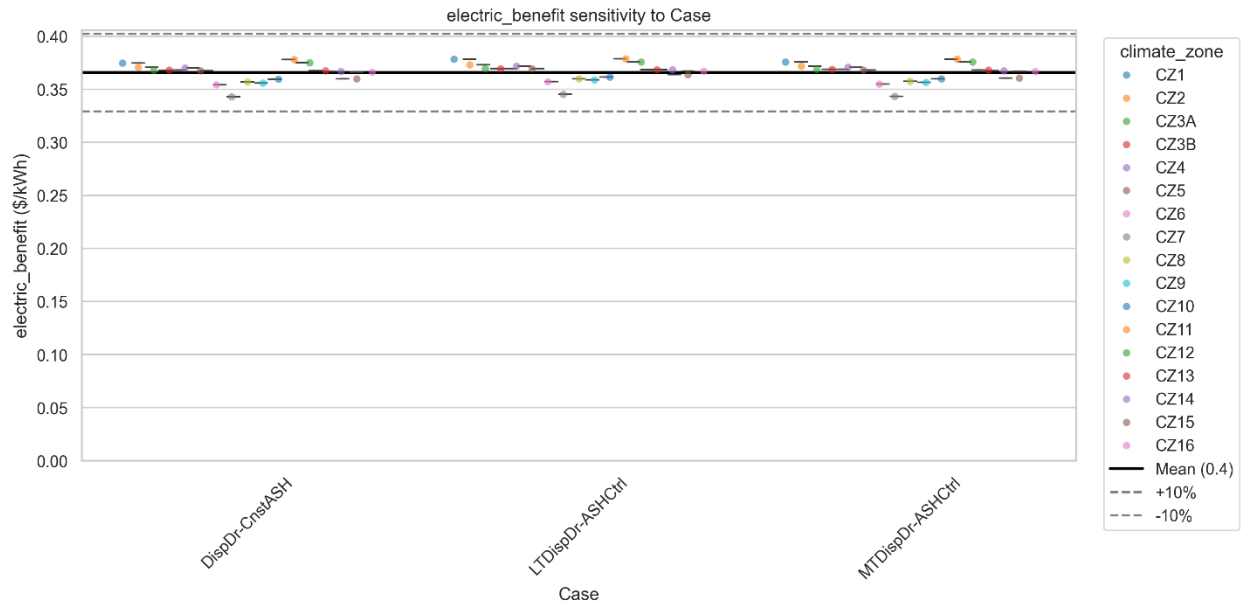


Figure 172: Unit electric benefits vs. building location and base case.

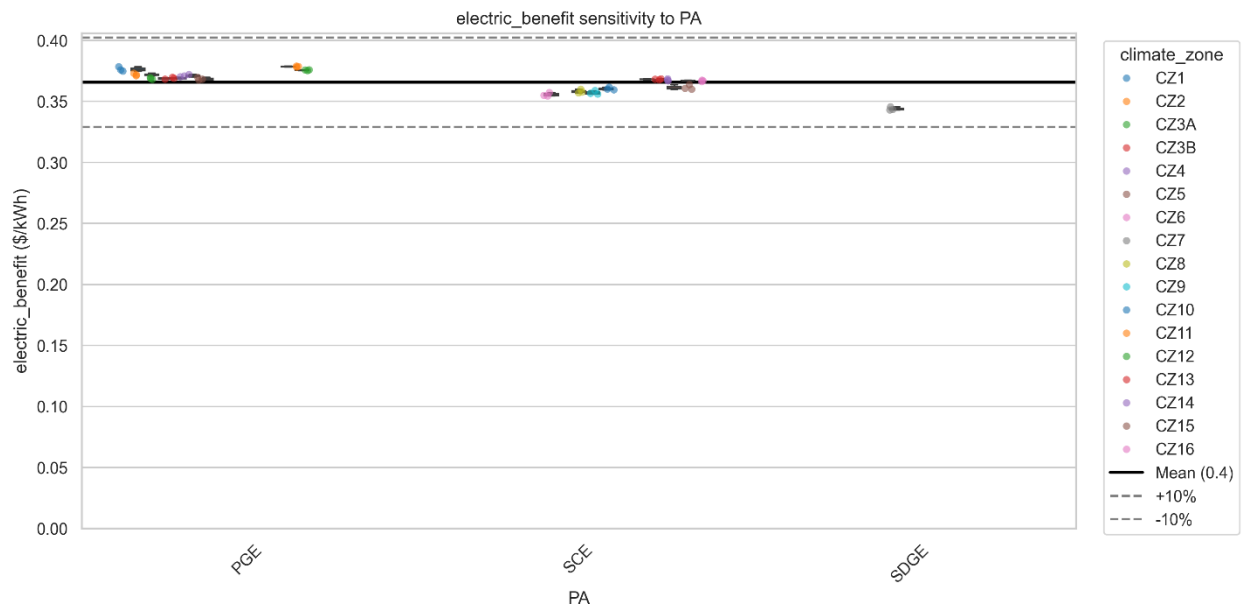


Figure 173: Unit electric benefits vs. building location and IOU.

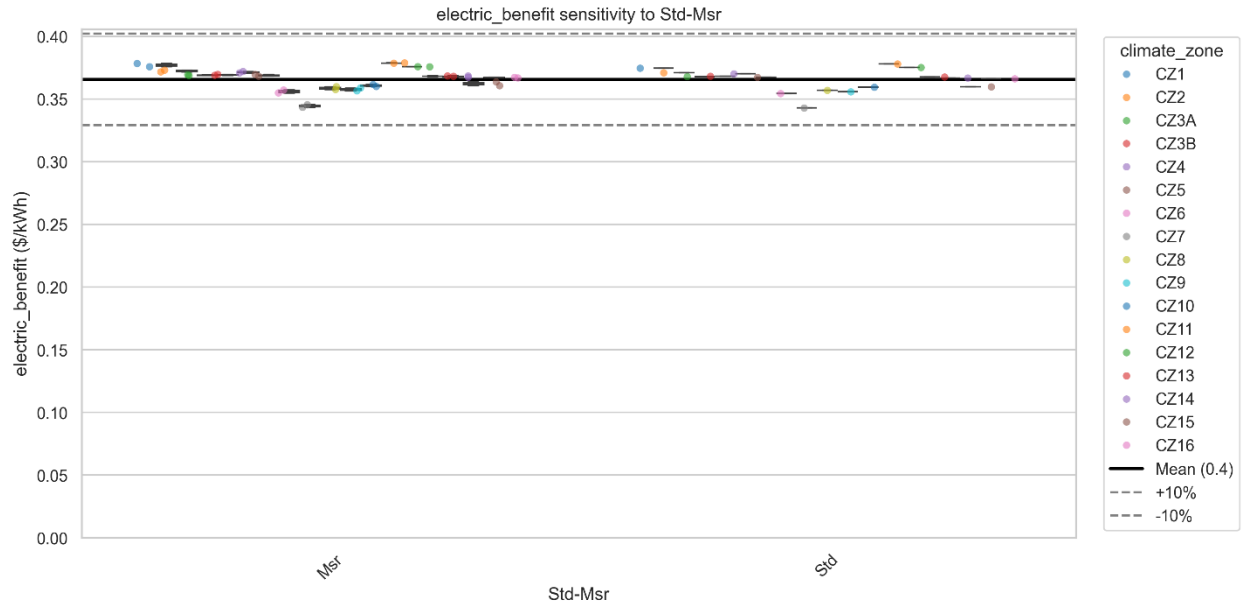


Figure 174: Unit electric benefits vs. building location and base case.

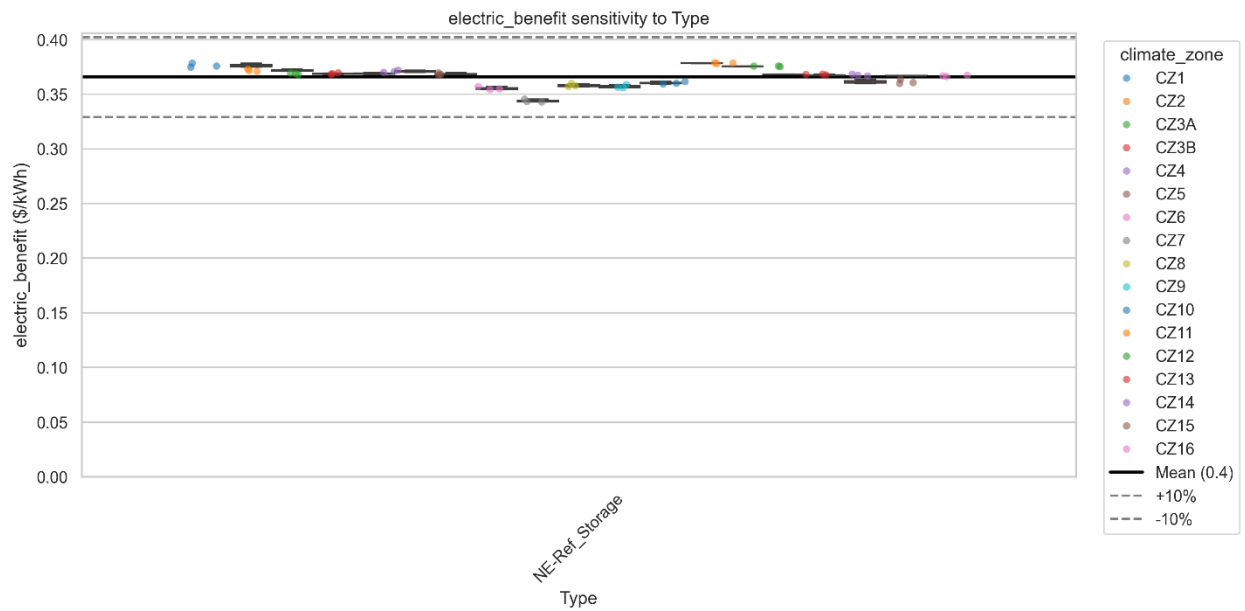


Figure 175: Unit electric benefits vs. building location and IOU and equipment type.

SWFS021 Fryer, Commercial, Fuel Substitution

Parameter Name	CLS	Max SD	Avg SD	Parameters
Total Models	14		6.6%	
Building Type	7			EPr, ESe, Hsp, Htl, RFF, RSD, RtL
Building Location	16	6.2%	4.1%	CZ01, CZ02, CZ03, CZ04, CZ05, CZ06, CZ07, CZ08, CZ09, CZ10, CZ11, CZ12, CZ13, CZ14, CZ15, CZ16

Table 31: SWFS021 parameter results

SWFS021 – Parameter specific jitter plots

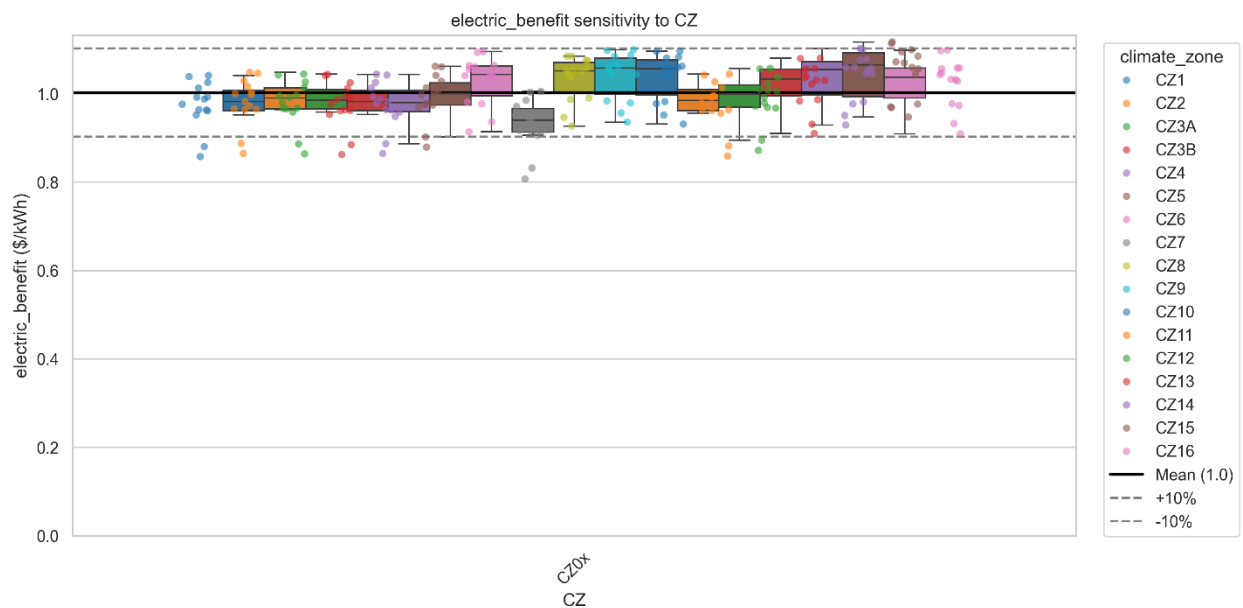


Figure 176: Unit electric benefits vs. building location.

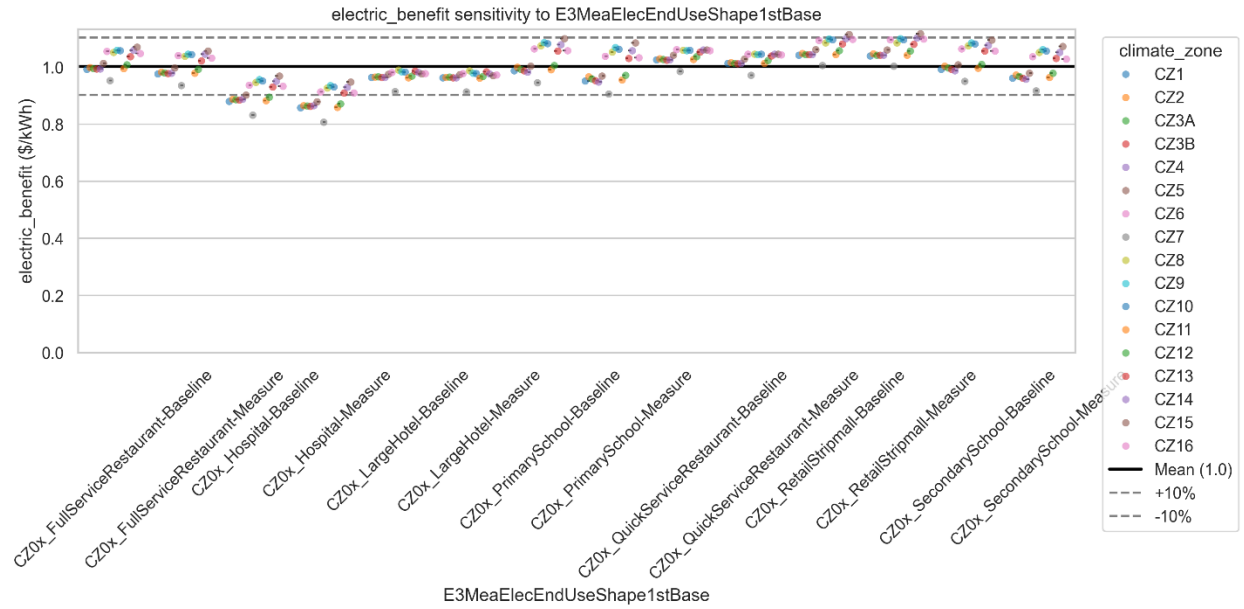


Figure 177: Unit electric benefits vs. building location and IOU and two parameters of building type and base case.

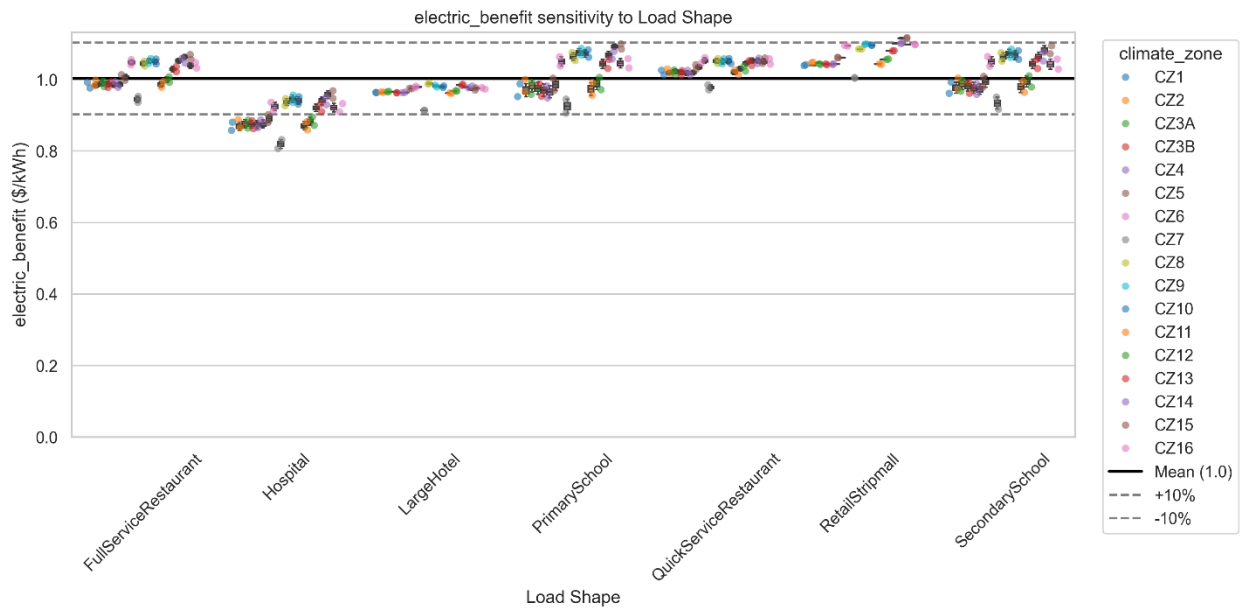


Figure 178: Unit electric benefits vs. building location and building type.

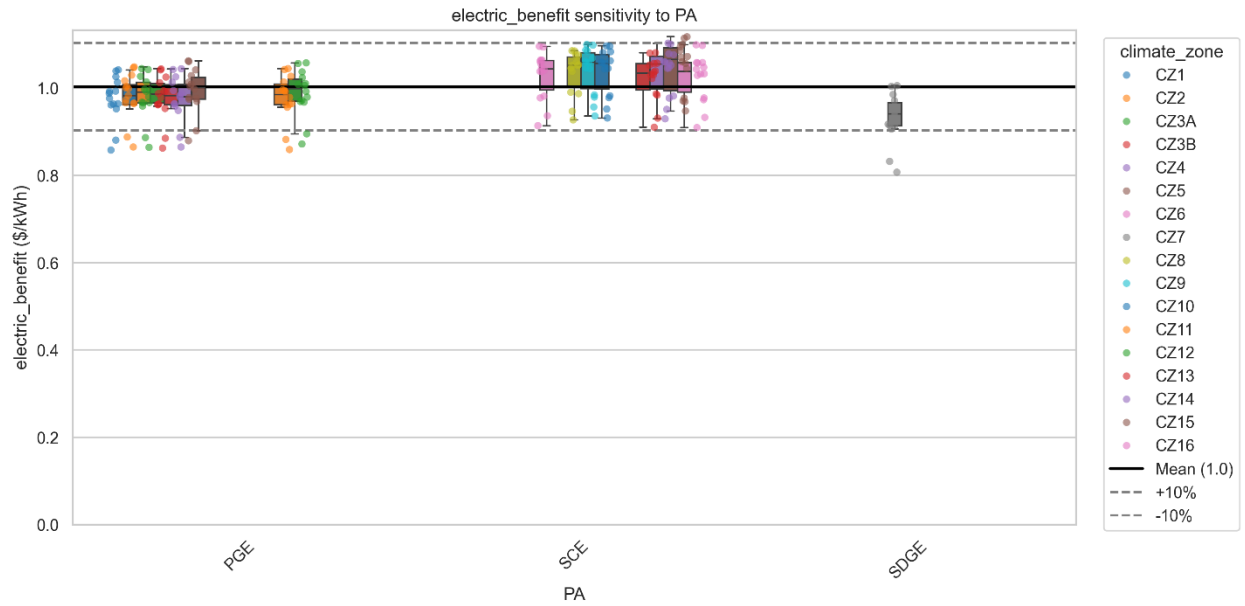


Figure 179: Unit electric benefits vs. building location and IOU.

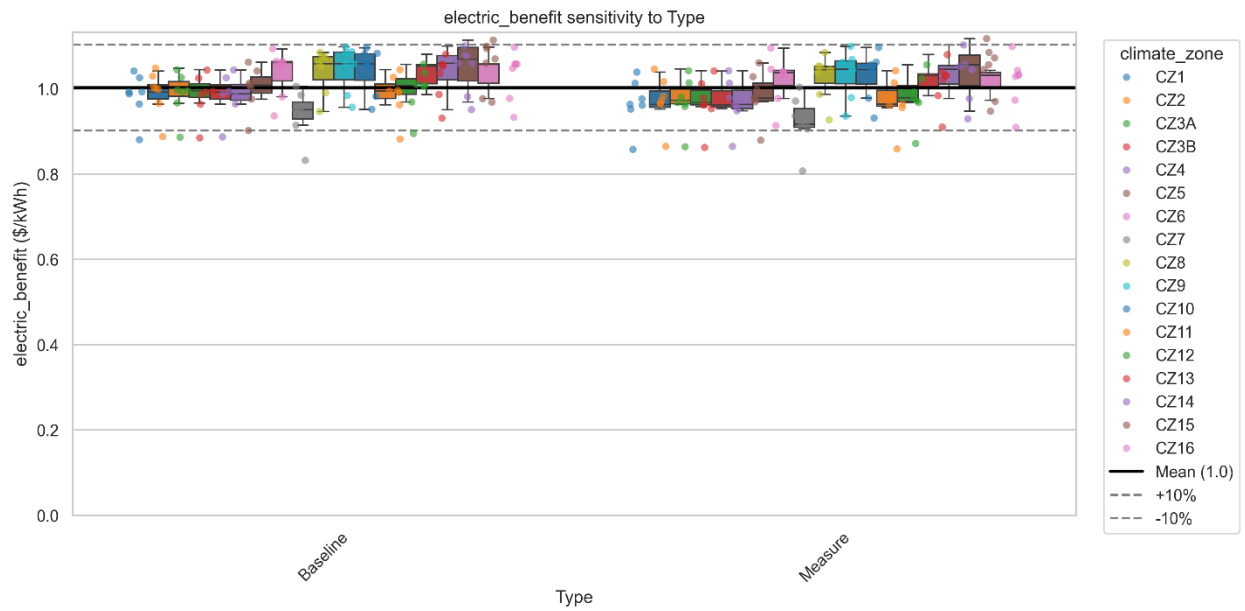


Figure 180: Unit electric benefits vs. building location and base case.

SWFS021 – Impact Load Shape

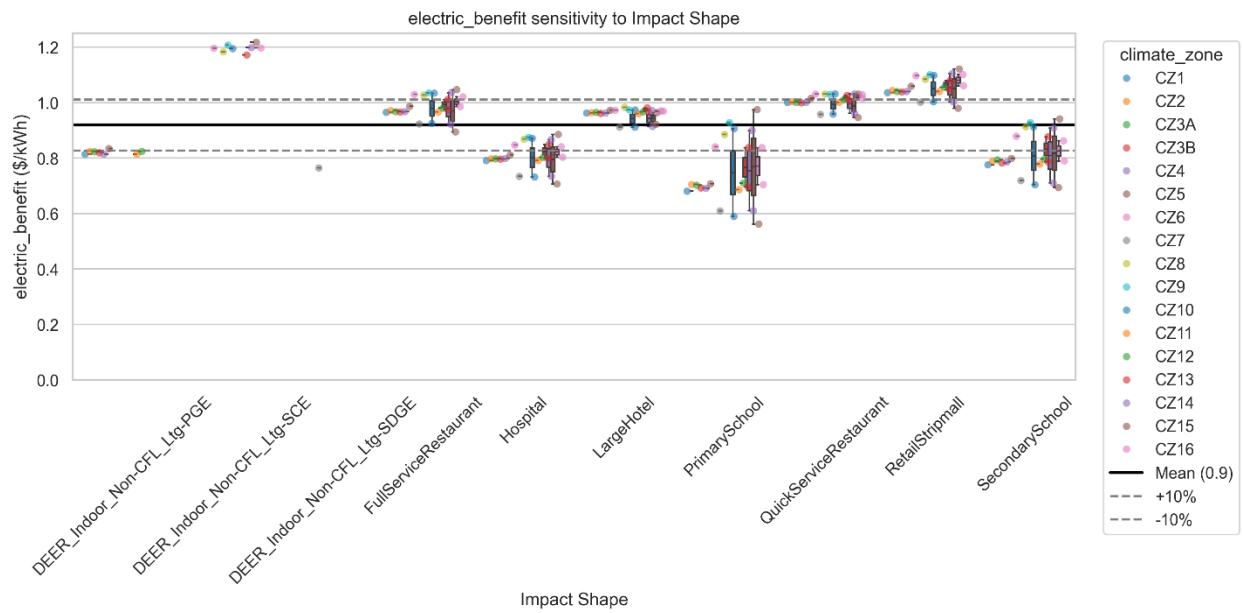


Figure 181: Unit electric benefits of impact profile vs. building location and building type.

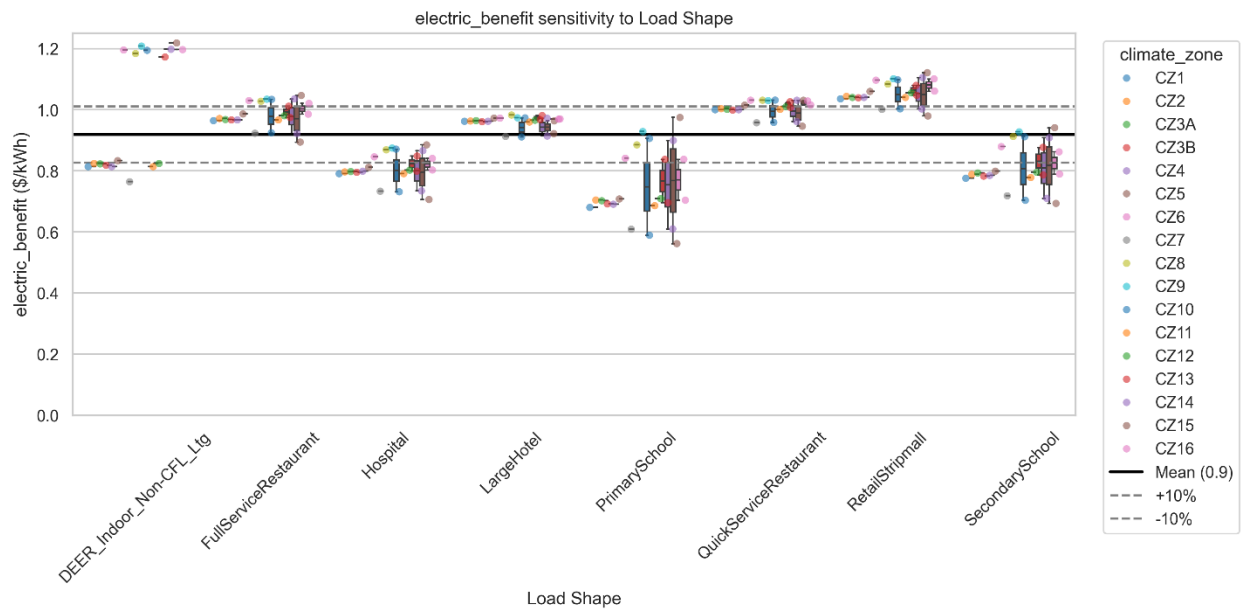


Figure 182: Unit electric benefits of impact profile vs. building location and building type.

Appendix E: Grouping Description

The creation of groupings to be used in this analysis is for demonstration purposes only. The groups can be created more rigorously if this concept is adopted. An example of this grouping is demonstrated in the Cal TF presentation from 10/24/2024:

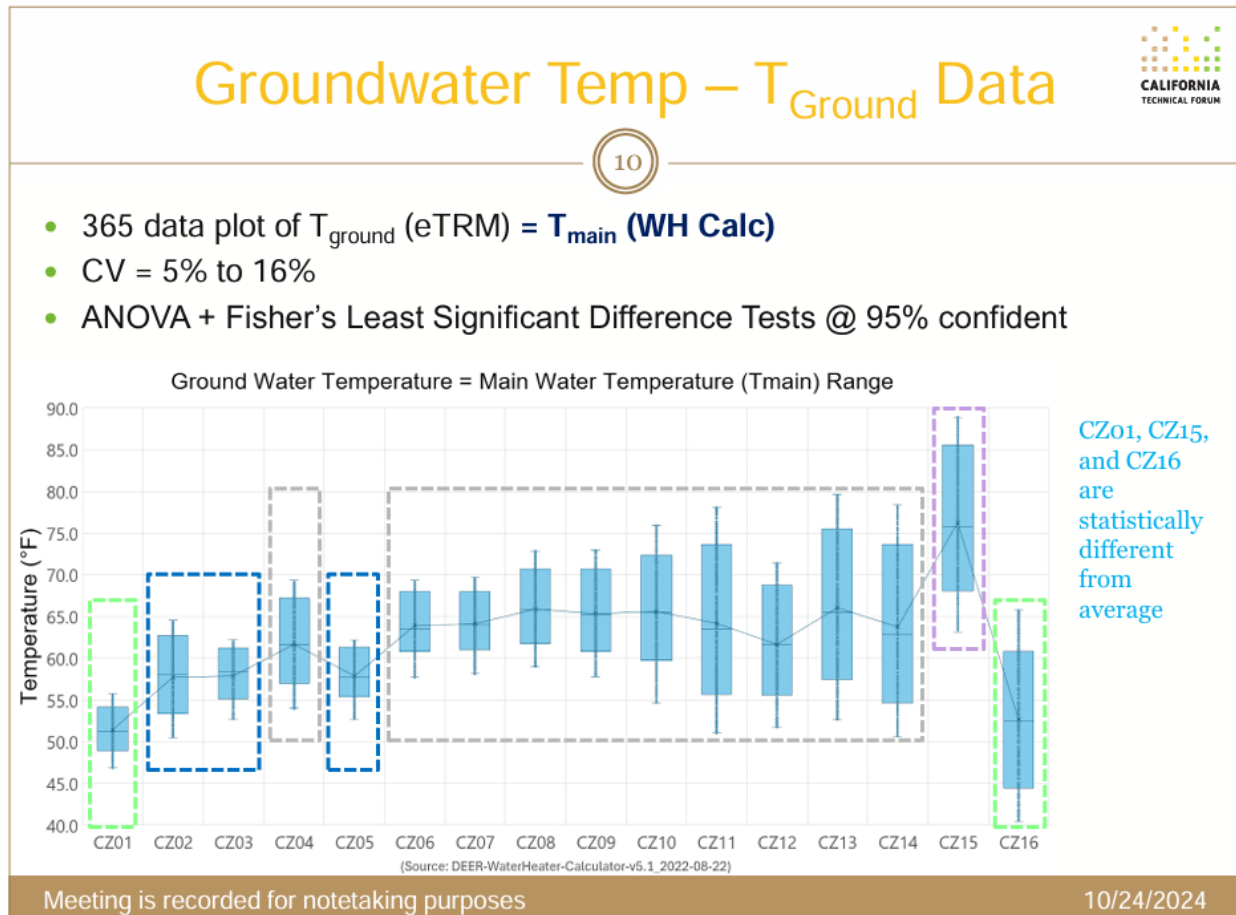


Figure 183: Illustration¹⁵ of groundwater grouping that could be adopted.

In a similar way, groupings can be established for both building type and building location based upon a physical characteristic of the data (e.g., heating and cooling degree days, hours of operations, hour of operation that align with critical avoided cost days, etc.).

For this analysis, groupings have been chosen by the relative association to the unit electric benefit value. These values from commercial HVAC MPs were sorted, and four groups of similar types were assembled in the following way.

¹⁵ Source: Cal TF Meeting 10/2024, Measure Permutation Streamlining, pg 10 of 37.

Table 32: Grouping example used for building types.

Category	BT
Cat 1	Rt3
	RtL
	Gro
	RtS
Cat 2	MLI
	ESe
Cat 3	Nrs
	Asm
	Hsp
	SCn
	EPr
	ECC
	OfL
	Mtl
	EUn
	Htl
	OfS
Cat 4	ERC
	RFF
	MBT
	RSD

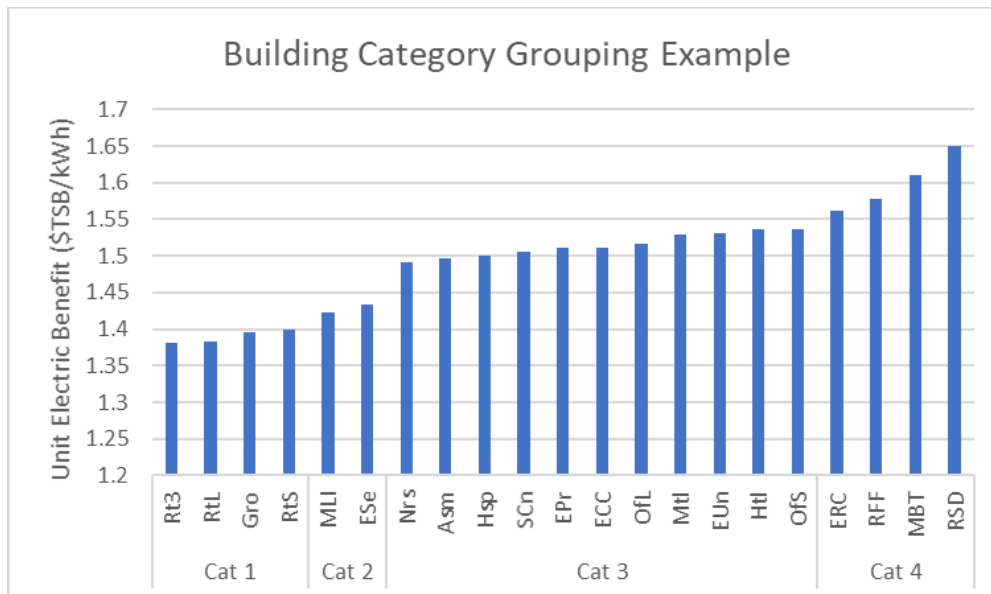


Figure 184: Example of how groupings could be established for building type using unit electric benefits.

Table 33: Grouping example used for building locations.

Category	CZ
Loc1	CZ7
	CZ5
	CZ3A
	CZ3B
	CZ1
	CZ4
	CZ2
	CZ6
Loc2	CZ8
	CZ9
	CZ12
	CZ11
Loc3	CZ16
	CZ10
Loc4	CZ15
	CZ14
	CZ13

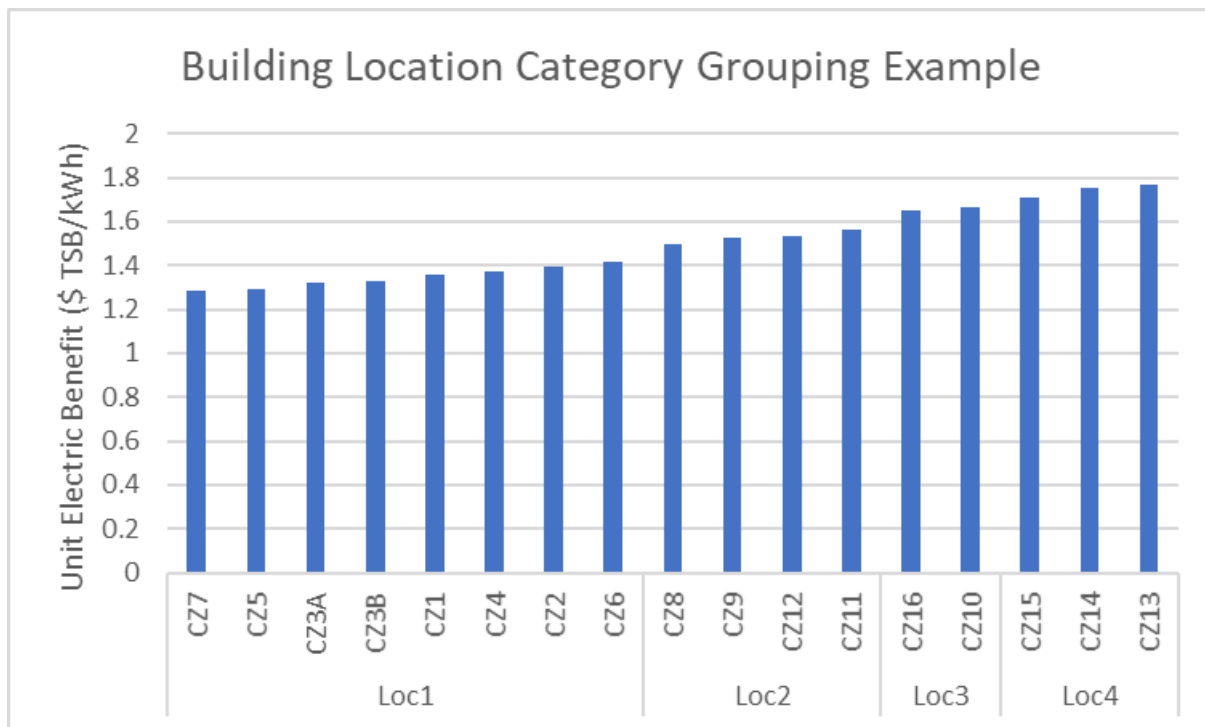


Figure 185: Example of how groupings could be established for building location using unit electric benefits.