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Proposed Updates to Equipment Power Densities and Schedules in the 2028 Energy Code Nonresidential and Multifamily Alternative Calculation Method (NRMFACM) Reference Manual

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Executive Summary

Plug loads (also called receptacle loads) and operational schedules can significantly impact energy consumption estimates calculated using whole-building energy simulation programs. The plug load is the energy consumed by all appliances or electronic devices that are plugged into a receptacle or receptacle outlet. While plug loads are not regulated by the California Energy Code, the impacts of plug loads are critically important. When appliances or electronic devices, such as computers or monitors, operate in a space, they can heat the air around them. These heat gains associated with plug loads directly affect the heating and cooling loads of a building, the energy consumption and peak electrical demand for these systems, and sizing and performance of solar photovoltaic and battery storage systems.

In the context of energy code compliance analysis, plug loads are represented as a plug-load intensity of watts per square foot and a fractional schedule that represents how the load varies throughout the day (with variations for weekdays, weekends, holidays, and other seasonal variations).

Updates to the plug loads are proposed for 10 space types; updates to the plug load schedules are proposed for six function groups and one new schedule function group is proposed for hotel/motel rooms. Also, updates are proposed to refrigeration loads in two space types. The proposed updates account for advances in equipment technology and consider the most recent available research.

The result of updating these values leads to an up-to-date representation of building performance with some changes in simulated site energy and long-term system cost (LSC) for the nonresidential and multifamily building prototype models. The simulations for most of the building prototypes show that the changes will have minimal impacts on compliance outcomes and the relative impacts of different types of efficiency measures. However, the changes to the office prototype simulations result in reductions to heating, cooling, and fan energy and long-term system cost; therefore, heating, ventilating and air conditioning measures may contribute less toward compliance for office buildings if the proposed changes are adopted. Also, solar photovoltaic systems of a particular size may generate a greater portion of the total building electric energy consumption.

The forthcoming 2028 update to weather files, prototypes, plug loads, and the long-term system cost and source energy metrics will only apply to nonresidential building types.

Introduction

Whole-building energy simulation software is used for several important purposes in developing and implementing the California Energy Code. During the Energy Code update, simulations are used to analyze energy efficiency measures. After the code updates are adopted, simulations are performed by compliance software tools that evaluate if a proposed building design complies with the performance standards of the Energy Code.

Plug loads (also called receptacle loads) and operational schedules significantly affect energy consumption estimates calculated using whole-building energy simulation software. While plug loads are not regulated by the energy code, the effects of plug loads are critically important. Heat gains associated with plug loads directly impact the heating and cooling loads of a building, the energy consumption and peak electrical demand for these systems, and sizing and performance of solar photovoltaic and battery storage systems.

To properly capture the performance of heating and cooling systems, and the effects of efficiency measures for these systems, the magnitude of plug loads and the ways that they vary during occupied and unoccupied periods must be carefully considered. If the loads are too high, cooling energy and the effect of efficiency measures for cooling can be overestimated; if the loads are too low, the same is true for heating.

Some energy simulation protocols, such as the ASHRAE 90.1 Performance Rating Method, allow energy modelers to customize the inputs for plug loads and schedules based on their knowledge of the anticipated operation of a building project. However, for California's Building Energy Code compliance (CBECC) software, these inputs are *prescribed*, meaning that they are defined by the code and may not be edited. The prescribed values for plug loads are defined in the *Nonresidential and Multifamily Alternative Calculation Method (NRMFACM) Reference Manual* (plug loads in Appendix 5.4A, and schedules in Appendix 5.4B).

One of the reasons for using prescribed values for these inputs is that the operation of a building is likely to change over the lifetime of that building. Using customized inputs may make sense for the initial occupants of a building, but those inputs are likely to change for future occupants. Because these values affect heating, ventilating and air conditioning (HVAC) performance and the relative importance of building envelope performance, they will also affect the compliance of a building with the code. By using prescribed inputs, compliance is based on the project design and is not driven by operation.

The prescribed values in the NRMFACM are intended to represent "typical" operation for compliance projects and code development activities. However, the current values for operational schedules and plug loads in the NRMFMACM have not been updated for several code cycles and do not capture recent improvements in equipment efficiency, and studies focused on usage patterns. The analysis presented in this report proposes updating the values for a subset of prescribed values for use in the 2028 energy code cycle. This report includes the proposed updates, the method for the updates, and an evaluation of the anticipated effects on energy simulation results using the new values.

Proposed Updates

This section includes the proposed updated values for plug load equipment power density (EPD) and operational schedules associated with plug loads. The tables and figures show the newly proposed values compared to the values in the current NRMFACM manual (2025 version).

Proposed Updates to Equipment Power Density Values

Equipment power density values are specified in the NRMFACM for each space type. Updated values are proposed for ten (10) space types. These space types were selected as discussed in the section **Prioritization Approach**. The proposed values are shown in Table 1.

Table 1: Proposed New EPD Values, by Space Type

Space Type	Current EPD[1] (W/ft^2)	Proposed EPD (W/ft^2)
Office Area (>250 square feet)	1.5	0.7
Office Area (<250 square feet)	1.5	0.7
Kitchen/Food Preparation Area	1.5	1.5[2]
Kitchenette or Residential Kitchen	1.0	1.0[3]
Retail Sales Area (Grocery Sales)	1.0	0.4[4]
Retail Sales Area (Retail Merchandise Sales)	1.0	0.4
Retail Sales Area (Fitting Room)	1.0	0.4
High-Rise Residential Living Spaces	- [5]	Reduced by 3.5%
Hotel/Motel Guest Room	0.5	0.5[6]
Classroom, Lecture, Training, Vocational Areas[7]	1.0	0.8

[1] From 2025 NRMFACM Reference Manual, Appendix 5.4A

[2] No change proposed to EPD value; however, changes to how the cooking equipment loads are accounted for in compliance analysis are recommended as discussed in Appendix A, in the section **Kitchen/Food Preparation Area**.

[3] No change proposed to EPD value at this time. There is data that suggests the loads could be increased; however, anecdotal evidence indicates that, for compliance analysis, kitchenettes are often included in a larger thermal zone with schedules that do not align with the intermittent usage of kitchenette equipment. Further study is recommended.

[4] In addition to the proposed change of EPD value, additional changes to how refrigeration loads are applied to this space type are proposed as discussed in Appendix A, in the section **Retail Sales Area (Grocery Sales) - Refrigeration Loads**.

[5] Plug loads in High-rise residential living spaces are treated differently than in other space types. The overall value is proposed to be reduced by 3.5%. More details are provided in Appendix C**.**

[6] No change proposed to EPD value in the NRMFACM; however, changes to how the value is used in compliance analysis are recommended as discussed in Appendix A, in the section **Hotel/Motel Guest Room**. It is also recommended to update the refrigeration load associated with this space type.

[7] The proposed reduction of EPD value only applies to K-8 schools. It is proposed that a new space type "Classroom (K-8 school)" be added and that the existing space type be used for other schools.

Proposed Updates to Equipment Schedules

Equipment operational schedules are specified in the NRMFACM for each “function group,” which roughly corresponds to building type. Function groups and the ways they are used in the compliance analysis simulation are described in the section **Methodology for Updating Schedule Values**. Updated schedules are proposed for six function groups:

- Office
- Warehouse
- Restaurant
- Retail
- School
- Assembly

One new function group is proposed:

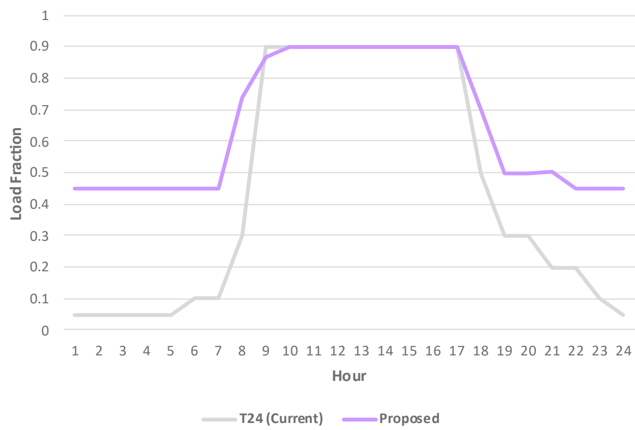
- Hotel Living

These function groups were selected as discussed in the section **Prioritization Approach**. The proposed schedules are presented below.

Proposed Updates to Office Schedules

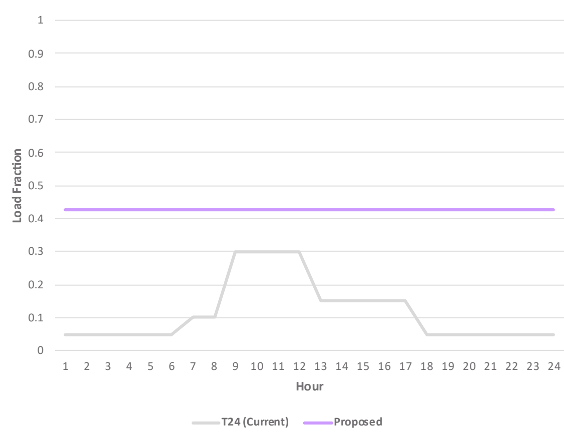
The analysis of office schedules indicated that the unoccupied period receptacle load fraction in office buildings is significantly higher than in the current NRMFACM schedules. Therefore, an increase in load fraction during this period is proposed for all days (weekdays, Saturday, Sunday). The weekend schedules are proposed to remain flat at this increased base load fraction. The proposed updates are shown below in Figure 1 through Figure 3.

Figure 1: Proposed Update to Office Receptacle Schedule (Weekday)



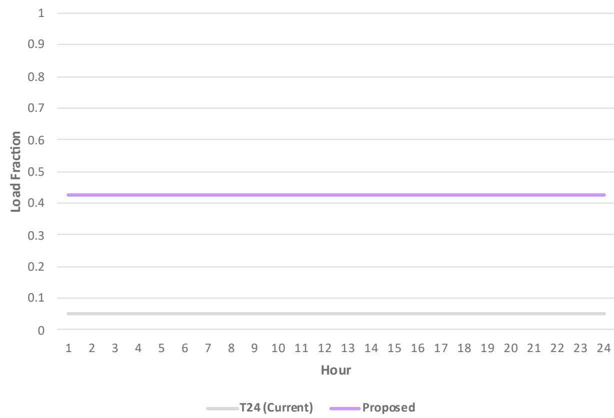
	Hour																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T24 (Current)	0.05	0.05	0.05	0.05	0.05	0.10	0.10	0.30	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.50	0.30	0.30	0.20	0.20	0.10	0.05
Proposed	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.74	0.87	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.70	0.50	0.50	0.50	0.45	0.45	0.45

Figure 2: Proposed Update to Office Receptacle Schedule (Saturday)



	Hour																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T24 (Current)	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.10	0.30	0.30	0.30	0.30	0.15	0.15	0.15	0.15	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Proposed	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43

Figure 3: Proposed Update to Office Receptacle Schedule (Sunday)

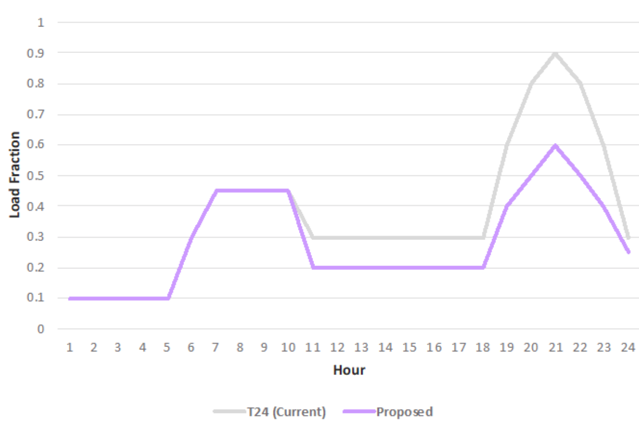


	Hour																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T24 (Current)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Proposed	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43

Proposed Addition of New Hotel Living Schedules

The current NRMFACM does not have a dedicated function group for hotel living spaces (guestrooms). Hotel living spaces currently use the “Residential Living” function group. However, the analysis of the schedule datasets indicated that occupancy and usage of hotel guest rooms differs from that of a multifamily residential space. Therefore, a new “Hotel Living” schedule function group is proposed. Figure 4 shows how the new Hotel Living receptacle schedules (“Proposed”) differ from the current Residential Living receptacle schedules (“T24 (Current)”). The proposed schedules consist of a lower daytime base load, and a lower second peak in the evening. Note that the new Hotel Living schedule is proposed to be the same for weekdays, Saturday, and Sunday.

Figure 4: Proposed Hotel Living Receptacle Schedule (All Days)



	Hour																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T24 (Current)	0.10	0.10	0.10	0.10	0.10	0.30	0.45	0.45	0.45	0.45	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.60	0.80	0.90	0.80	0.60	0.30
Proposed	0.10	0.10	0.10	0.10	0.10	0.30	0.45	0.45	0.45	0.45	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.40	0.50	0.60	0.50	0.40	0.25

A new refrigeration schedule is also proposed for this space type to account for the presence of refrigerators in guest rooms. This schedule is proposed to be a constant 0.9 load fraction. More details on refrigeration loads in guest rooms are described in Appendix A, section **Hotel/Motel - Refrigeration**.

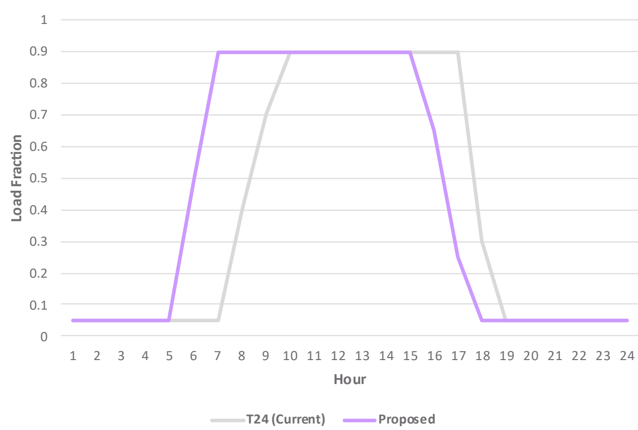
Other Residential Living schedules (e.g. occupancy, lighting, HVAC) will be aligned with the proposed new Hotel Living schedule function group.

The forthcoming 2028 update to weather files, prototypes, plug loads and the LSC and source energy metrics will only apply to nonresidential building types.

Proposed Updates to Warehouse Schedules

The analysis of warehouse schedules indicated that, on weekdays, warehouses tend to begin operating earlier in the day, and end operating earlier than the current NRMFACM schedules. Therefore, a shift in the schedule is proposed as shown in Figure 5. No changes are proposed to the Saturday or Sunday schedules.

Figure 5: Proposed Update to Warehouse Receptacle Schedule (Weekday)



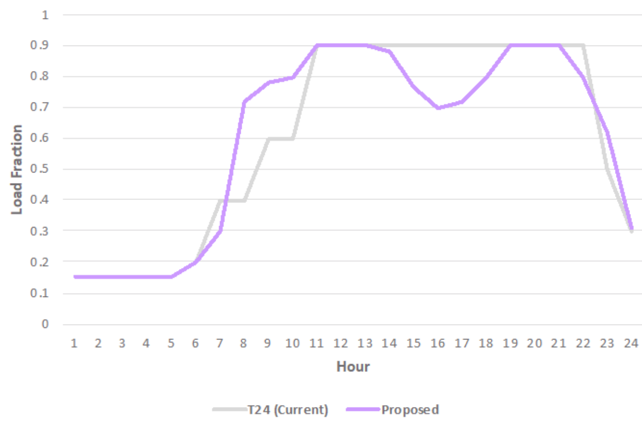
	Hour																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T24 (Current)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.40	0.70	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.30	0.05	0.05	0.05	0.05	0.05	0.05
Proposed	0.05	0.05	0.05	0.05	0.05	0.50	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.65	0.25	0.05	0.05	0.05	0.05	0.05	0.05	0.05

Other warehouse schedules (e.g. occupancy, lighting, HVAC) will be aligned with the proposed shift in operating hours.

Proposed Updates to Restaurant Schedules

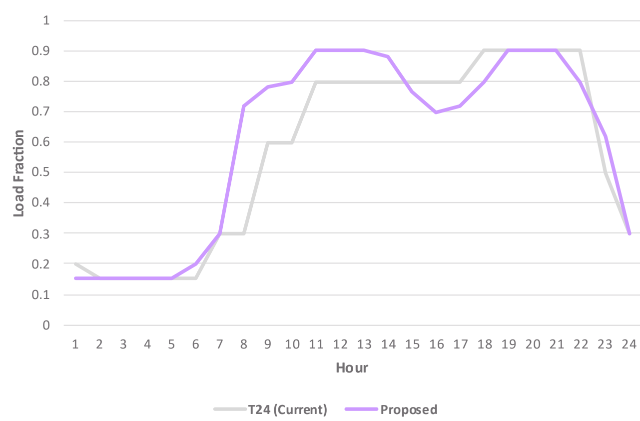
The analysis of restaurant schedules led to two proposed changes in the plug load shape: a quicker ramp-up period in the morning to account for restaurants with morning service, and a reduction in equipment use during the afternoon period between lunch and dinner as shown in Figure 6. The proposed schedules will be used for all days (weekdays, Saturday, and Sunday) instead of having a reduction of loads on the weekend as in the current NRMFACM schedules.

Figure 6: Proposed Update to Restaurant Receptacle Schedule (Weekday)



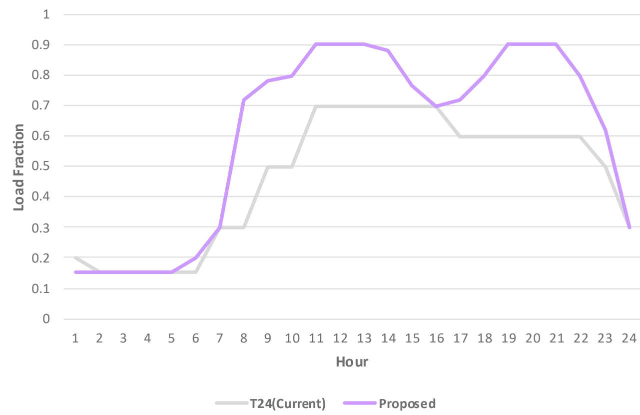
	Hour																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T24 (Current)	0.15	0.15	0.15	0.15	0.15	0.20	0.40	0.40	0.60	0.60	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.50	0.30
Proposed	0.15	0.15	0.15	0.15	0.15	0.20	0.30	0.72	0.78	0.80	0.90	0.90	0.90	0.88	0.77	0.70	0.72	0.80	0.90	0.90	0.90	0.80	0.62	0.30

Figure 7: Proposed Update to Restaurant Receptacle Schedule (Saturday)



	Hour																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T24 (Current)	0.20	0.15	0.15	0.15	0.15	0.15	0.30	0.30	0.60	0.60	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.90	0.90	0.90	0.90	0.90	0.50	0.30
Proposed	0.15	0.15	0.15	0.15	0.15	0.20	0.30	0.72	0.78	0.80	0.90	0.90	0.90	0.88	0.77	0.70	0.72	0.80	0.90	0.90	0.90	0.80	0.62	0.30

Figure 8: Proposed Update to Restaurant Receptacle Schedule (Sunday)

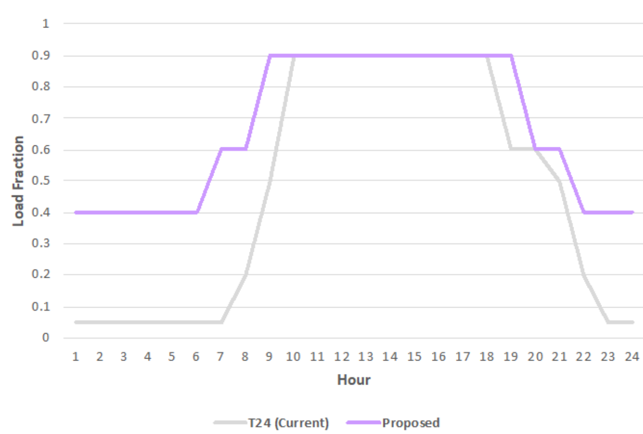


	Hour																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T24 (Current)	0.20	0.15	0.15	0.15	0.15	0.15	0.30	0.30	0.50	0.50	0.70	0.70	0.70	0.70	0.70	0.70	0.60	0.60	0.60	0.60	0.60	0.60	0.50	0.30
Proposed	0.15	0.15	0.15	0.15	0.15	0.20	0.30	0.72	0.78	0.80	0.90	0.90	0.90	0.88	0.77	0.70	0.72	0.80	0.90	0.90	0.90	0.80	0.62	0.30

Proposed Updates to Retail Schedules

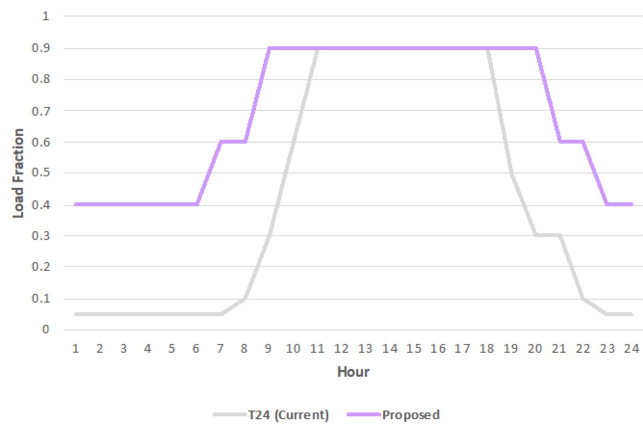
The analysis of retail schedules indicated that the baseline receptacle load fraction during unoccupied periods is significantly higher than in the current NRMFACM schedules. Therefore, an increase in load fraction during this period is proposed for all days (weekdays, Saturday, and Sunday). Additional adjustments are proposed to the Sunday schedule. The current schedule has reduced hours of operation on Sunday, and this is retained in the new schedule; however, the peak during occupied hours is increased to match the weekday and Saturday peak. This is based on the expectation that, while hours may be reduced, equipment usage is similar during the occupied periods. The proposed updates are shown below in Figure 9 through Figure 11.

Figure 9: Proposed Update to Retail Receptacle Schedule (Weekday)



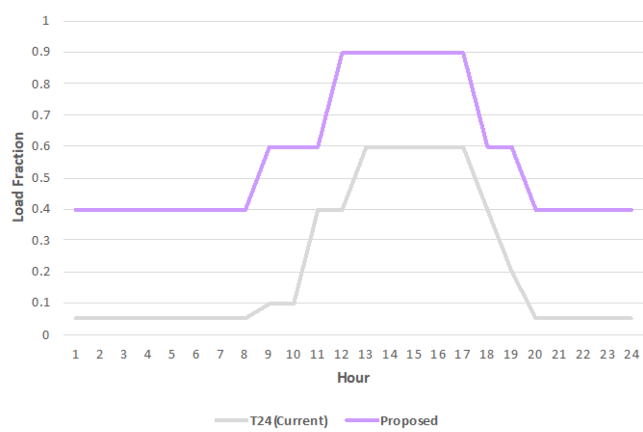
	Hour																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T24 (Current)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.20	0.50	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.60	0.60	0.50	0.20	0.05	0.05
Proposed	0.40	0.40	0.40	0.40	0.40	0.40	0.60	0.60	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.60	0.60	0.40	0.40	0.40

Figure 10: Proposed Update to Retail Receptacle Schedule (Saturday)



	Hour																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T24 (Current)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.30	0.60	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.50	0.30	0.30	0.10	0.05	0.05
Proposed	0.40	0.40	0.40	0.40	0.40	0.40	0.60	0.60	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.60	0.60	0.40	0.40

Figure 11: Proposed Update to Retail Receptacle Schedule (Sunday)



	Hour																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
T24 (Current)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.10	0.40	0.40	0.60	0.60	0.60	0.60	0.60	0.40	0.20	0.05	0.05	0.05	0.05	0.05
Proposed	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.60	0.60	0.60	0.90	0.90	0.90	0.90	0.90	0.90	0.60	0.60	0.40	0.40	0.40	0.40	0.40

Proposed Updates to School Schedules

Substantial updates to modeling schedules are proposed for elementary/middle schools (Kindergarten–8th grade) and high schools (grades 9–12). The analysis to date has focused on updating occupancy schedules and adding new variants of the occupancy schedules. The current proposal is to develop individual schedule sets to account for the different occupancy patterns in different space types:

- Classrooms & Library
- Offices & Other

- Multipurpose Room
- Kitchen

These schedules will also account for the unique annual operation of a school building including features like reduced use in the summer, half days and early release days, summer classes, and evening events.

This effort is ongoing and will be documented in a separate report. After the occupancy schedules are finalized, new load schedules (e.g., lighting, receptacle, HVAC) will be developed to align with the new occupancy patterns.

Proposed Updates to Assembly Schedules

Significant updates are proposed to modeling schedules for assembly buildings. To address the wide variety of operation of different types of assembly buildings, CEC staff proposes to add several new types of assembly schedules to replace the single assembly schedule currently included in the NRMFACM. The analysis to date has focused on creating new occupancy schedules for different assembly types:

- Motion Picture & Performance
- Museum and Library
- Religious Worship
- Convention Center
- Exercise, Fitness and Gymnasium

This effort is ongoing and will be documented in a separate report. After the occupancy schedules are finalized, new load schedules (e.g., lighting, receptacle, HVAC) will be developed to align with the new occupancy patterns.

Methodology for Updating Values

This section describes the rationale used to determine which EPDs and equipment schedules to update, and the processes to develop the newly proposed values.

Current NRMFACM Values

The prescribed values for plug loads are defined in the Nonresidential and Multifamily Alternative Calculation Method (NRMFACM) Reference Manual (plug loads in Appendix 5.4A, and schedules in Appendix 5.4B).

The current values for operational schedules and plug loads in the NRMFACM were largely derived from the COMNET Modeling Guidelines ("COMNET").[8] COMNET was originally published in 2011; the values have been used in the NRMFACM starting with the 2013 Energy Code and have not undergone any updates since then with the exception of miscellaneous electrical loads for residential spaces (updated in 2016 for low-rise residential and 2019 for high-rise residential).

Some of the assumptions in COMNET were derived from older data sources. The COMNET schedules were based on the ANSI/ASHRAE/IESNA Standard 90.1-2007 User's Manual, Table G-E. For building types not included in the User's Manual, schedules were based on the 2005 Nonresidential ACM Manual, Table N2-9.

The COMNET plug load assumptions were developed using a methodology described in the COMNET Plug Loads Technical Support Document (TSD).[9] The plug load values were based on information from the 2003 Commercial Buildings Energy Consumption Survey (CBECS).[10]

Prioritization Approach

The NRMFACM defines EPD values for 83 space types and schedules for 13 function groups. This project's scope did not allow for every space type and schedule to be updated, so the analysis focused on updating values for space types and building types that would be most impactful.

Prioritization of Function Groups for Schedule Updates

The prioritization of updates to the schedule function groups was based on an analysis of projected statewide construction forecast data, and statewide impact analysis data. The forecast data is a projection of the total anticipated new construction square footage, by building type. The impact analysis uses the forecast data and simulation analysis to project total energy consumption by building type and broken down by energy end use.

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[8] COMNET. 2025. *Legacy Modeling Guidelines.* https://www.comnet.org/legacy-modeling-guidelines

[9] COMNET. 2015. *Plug Loads Technical Support Document (TSD)*. https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.comnet.org/sites/default/files/pdfs/150928_plug_loads_tsd.pdf&ved=2ahUKEwjM0caZm_KOAxVUyOYEHTHDOs8QFnoECBwQAQ&usg=AOvVaw1LtWIoxhuHuUCqiyw4C98v

[10] U.S. Energy Information Agency (EIA). 2003. *Commercial Buildings Energy Consumption Survey (CBECS)*. https://www.eia.gov/consumption/commercial/data/2003/

This data was analyzed to determine which building types accounted for the highest projected statewide plug load energy consumption, as shown in Table 2. Additional analysis was performed to determine which building types had the highest percentage of statewide plug load energy consumption, as shown in Table 3.

Table 2: Statewide Energy Consumption Forecast, Ordered by Electric Plug Load Energy

Building Type	Forecasted Construction Area (Millions sf)	Total Statewide Energy Consumption (GWh)	Statewide Energy Consumption – Electric Plug Loads (GWh)	Elec Plug Loads Energy (% of Total)
High-rise Multifamily	29.8	182.7	**43.9**	24.1%
Office	9.1	81.5	**38.7**	47.5%
Warehouse	41.4	183.1	**24.4**	13.3%
Hotel	4.7	59.8	**14.0**	23.5%
School	7.1	57.7	**13.6**	23.7%
Hospital	2.9	79.5	**10.5**	13.3%
Retail	3.1	29.8	**9.6**	32.4%
Laboratory	1.8	94.3	**8.4**	8.9%
Assembly	2.7	36.6	**7.5**	20.4%
Restaurant	0.7	52.2	**3.4**	6.6%
Parking Garage	24.6	7.89	**0.0**	0.0%

Table 3: Statewide Energy Consumption Forecast, Ordered by Electric Plug Load Percentage of Total Energy

Building Type	Forecasted Construction Area (Millions sf)	Total Statewide Energy Consumption (GWh)	Statewide Energy Consumption – Electric Plug Loads (GWh)	Elec Plug Loads Energy (% of Total)
Office	9.1	81.5	38.7	**47.5%**
Retail	3.1	29.8	9.6	**32.4%**

High-rise Multifamily	29.8	182.7	43.9	**24.1%**
School	7.1	57.7	13.6	**23.7%**
Hotel	4.7	59.8	14.0	**23.5%**
Assembly	2.7	36.6	7.5	**20.4%**
Warehouse	41.4	183.1	24.4	**13.3%**
Hospital	2.9	79.5	10.5	**13.3%**
Laboratory	1.9	94.3	8.4	**8.9%**
Restaurant	0.7	52.2	3.4	**6.6%**
Parking Garage	24.6	7.9	0.0	**0.0%**

This analysis identified several building types where plug load energy is the most impactful statewide, and/or where plug loads make up a significant portion of a building's energy consumption and therefore were candidates to be updated. The building types initially considered for prioritization included:

- High-rise Multifamily
- Office
- Warehouse
- Hotel
- School
- Retail
- Hospital
- Laboratory
- Assembly
- Restaurant

These building types were reviewed as follows.

The assembly building was not among the most impactful, however it was included for consideration because the assembly schedules in the NRMFACM are known to be problematic for certain types of assembly uses. The NRMFACM assembly schedules assume the building is primarily used during the weekdays during daytime which may be appropriate for assembly spaces in a convention center but is not appropriate for some assembly types such as religious worship spaces, or buildings where occupants are in the building at nighttime such as a theater.

The restaurant building was not among the most impactful in terms of plug loads, but when also considering loads from cooking equipment, it was among the most impactful in terms of both statewide electricity and natural gas energy consumption.

The hospital and laboratory buildings were removed from consideration because their design is highly specialized, and the team decided that these buildings should be evaluated in the future when additional subject matter experts could assist with the analysis and vetting.

Finally, the high-rise multifamily building was removed because no data sources were available that were more up to date and at the same level of detail than those used in developing the current NRMFACM schedules.

The remaining prioritized building types were then mapped to the NRMFACM Function Groups as shown in Table 4.

Table 4: Mapping of Building Types and NRMFACM Function Groups

Building Type	NRMFACM Function Group(s)
Office	Office
Warehouse	Warehouse
Hotel	Residential Living, Residential Common
School	School
Assembly	Assembly
Restaurant	Restaurant
Retail	Retail

Final List of Schedule Function Groups Evaluated

The final list of schedule function groups selected from the prioritization effort was:

- Office
- Hotel Living
- Hotel Common
- School
- Restaurant
- Retail
- Assembly (multiple types)

The process for developing proposed updates to these schedules is discussed in the section **Methodology for Updating Schedule Values**.

Prioritization of Space Types for EPD Updates

The prioritization of updates to the EPD values was based on three criteria:

1. Analysis of data sources to determine how prevalent space types are across multiple building types ("frequency analysis")
2. How much variation is seen between the current NRMFACM EPD values and other data sources ("differential analysis")
3. Space type is present in the building types where plug/process loads have the highest statewide impacts (as discussed above in the section **Prioritization of Function Groups for Schedule Updates**)

The frequency analysis was performed by reviewing multiple data sources (see the section **Data Sources Evaluated for Updating Values**) and identifying how frequently each space type appears in prototype models for different building types. The data source most heavily relied upon for this analysis was the report and supporting dataset from the Pacific Northwest National Laboratory. The space types that appeared most frequently across multiple building types were:

- Office
- Kitchen/Food Preparation areas
- Corridor
- Lobby
- Restroom
- Storage
- Electrical/Mechanical Rooms
- Stairwell

The differential analysis was performed by comparing the plug load EPD values in the NRMFACM to values in the other datasets. Table 5 shows the average difference between the NRMFACM value and the other datasets for the space types that had the highest average difference.

Table 5: Average Difference[11] in EPD Values Between NRMFACM and Other Datasets

Space Type	Average EPD Difference (W/sf)
Pharmacy Area	4.40
Laundry Area	2.60
Laboratory, Scientific	1.23
Library (Reading Area)	1.10
Museum Area (Exhibition/Display)	1.07
Healthcare Facility and Hospitals (Exam/Treatment Room)	0.93
Office Area (>250 square feet), Office Area (<250 square feet)	0.82
Kitchen/ Food Preparation Area	0.74
Audience Seating Area	0.55
Classroom, Lecture, Training, Vocational Areas	0.38
Retail Sales Area (Grocery Sales, Retail Merchandise Sales, Fitting Room)	0.34

The frequency analysis and differential analyses identified several space types as candidates to be updated. Spaces that had a high frequency but did not have significant differences from other datasets were removed from consideration. These space types included corridor, lobby, restroom, storage, and stairwell.

All the space types were also reviewed to determine if they were likely to appear in building types with plug loads that accounted for high statewide energy consumption projections, and if not, they were removed from consideration. These space types included library, museum, and audience seating area. High-rise residential living spaces were added to the list of space types to be considered for updates because of the very high projected construction.

[11] Note: all space types shown in this table had a larger NRMFACM value for EPD compared to other datasets.

Healthcare and laboratory spaces were also removed from consideration, again because their design is highly specialized, and the team decided that these space types should be evaluated in the future when additional subject matter experts could assist with the analysis and vetting.

Final List of Space Types Evaluated for EPD Updates

The final list of space types selected from the prioritization effort was:

- Office Area (>250 square feet)
- Office Area (<250 square feet)
- Kitchen/Food Preparation Area
- Kitchenette or Residential Kitchen
- Retail Sales Area (Grocery Sales)
- Retail Sales Area (Retail Merchandise Sales)
- Retail Sales Area (Fitting Room)
- High-Rise Residential Living Spaces
- Hotel/Motel Guest Room
- Classroom, Lecture, Training, Vocational Areas

The process for developing proposed updates to these EPD values is discussed in the section **Methodology for Updating Equipment Power Density Values**.

Data Sources Evaluated for Updating Values

The following is a summary of the primary data sources evaluated for the proposed updates. Some updates relied upon additional data sources and are noted as applicable in the appendices of this report.

Pacific Northwest National Laboratory Paper on Internal Loads and Load Schedules

Title: *A New Database of Building-Space-Specific Internal Loads and Load Schedules for Performance Based Code Compliance Modeling of Commercial Buildings*.[12]

[12] Pacific Northwest National Laboratory (PNNL). 2024. *A New Database of Building-Space-Specific Internal Loads and Load Schedules for Performance Based Code Compliance Modeling of Commercial Buildings*. https://link.springer.com/article/10.1007/s12273-024-1111-z

This 2024 paper by the Pacific Northwest National Laboratory (PNNL) focuses on approaches to update modeling assumptions for internal gains and schedules. The paper highlights a limitation in current approaches — namely that they are not specific enough to cover the wide range of operation across building types. For example, current modeling assumptions for office spaces are used across offices in all building types even though offices may be used very differently across different building types (e.g. office building vs. hospital vs. warehouse).

The paper presents a methodology for creating new assumptions for each space type that is specific to its building type. The process starts by mapping the master list of all space types (that are used by current energy codes and standards) to each building type to determine which space types should be present in each building type.

Next, a bottom-up approach is used to determine the appropriate input assumptions for each space type. For example, this process may involve determining what specific pieces of plug load equipment are likely to be present in each space type and adding up the wattages to determine the appropriate input value. This approach is likely to result in different values depending on the building type in which the space type is in.

An approach to developing schedules is also detailed in the paper. The paper notes that many codes rely on building-level schedules (e.g., in an office building, most space types will use the "office" operational schedules). However, this may not be appropriate due to the diversity of how different spaces are used within a single building type, and the diversity of how a specific space type is used in different building types. The paper proposes a method to use space-specific schedules instead.

The authors of the paper pursued the approaches and developed a set of new internal gain and schedule assumptions. Internal gains were based largely on ASHRAE data sources, and schedules were based on a detailed United Kingdom database ("NCM database"). The newly developed values are publicly available on a project GitHub repository.[13]

The paper also includes technical analysis demonstrating the variance of simulation results using the more detailed assumptions created vs. the older less-specific assumptions.

Commercial Building Sector Stock Model (ComStock)

ComStock is a project that has been developed and maintained by the National Renewable Energy Laboratory (NREL) since 2016. The fundamental goal of the project is to provide a complete picture of

[13] https://github.com/pnnl/COMNET

the energy consumption across the US building stock on a sub-hourly level. There are many different applications for the project, but NREL's main use case is to evaluate building-level efficiency and electrification measures and their impact on the entire U.S. commercial building stock.

ComStock is made up of approximately 350,000 OpenStudio building energy models that, in aggregate, represent the U.S. commercial building stock as it was in 2018. This serves as the "baseline" for evaluating energy efficiency and electrification measures. The ComStock models are based on the DOE prototype models by PNNL. The project studied many different public and private data sets to determine all the configurations of building characteristics that were needed to represent the national commercial building stock using the 15 prototype building models.

The Plug and Process Loads values in the ComStock models retain the original assumptions in the DOE prototype models. ComStock models representing the California building stock also rely on inputs from the California Public Utilities Commission's Database of Energy Efficiency Resources (CPUC DEER) prototype models. Plug load schedules are based on the U.S. Department of Energy (DOE) and DEER prototypes as well. For select building types, modifications were made to the plug load values and schedules as part of a large end-use submetering data study during the End Use Load Profile (EULP) project that served as a large-scale calibration and validation study of the ComStock models.[14] Of particular relevance to this report, food service, mercantile, education, and office plug load schedules were revised based on the EULP project.

All of the OpenStudio models are publicly available online so the inputs could be reviewed. Additionally, the results are available in both a web viewer and spreadsheet data.[15]

ASHRAE 90.1 Prototype Building Models

The Prototype Building Models are a set of standardized building models developed by the U.S. Department of Energy (DOE) to support the development and analysis of building energy codes and standards. These models represent a wide range of commercial building types and are used to simulate energy performance and evaluate the impact of various design choices and technologies. Their primary use case is for research and development of energy codes, including the development of Building Performance Factors (BPFs) for use with the Performance Rating Method of ASHRAE 90.1. Additionally, they are often used for other purposes such as early-stage design analysis and evaluation of new technologies.

[14] https://www2.nrel.gov/buildings/end-use-load-profiles

[15] https://comstock.nrel.gov/page/datasets

The prototype models include 16 commercial building types in 19 climate locations (16 United States, 3 international), all of which are publicly available for download.[16] Input data is summarized in a "scorecard" (spreadsheet).[17] The plug load values used in the prototype models do not always map directly to a single space type – for example, the office prototype models use simple core/perimeter zoning and the plug load inputs are meant to represent combined values for various space types that may be in these larger zones such as office spaces, corridors, conference rooms, and other space types. Schedules are modeled at the building level.

2022 California Commercial End-Use Survey (CEUS)

The California Commercial End-Use Survey[18] conducted by the California Energy Commission Energy Assessments Division, Demand Analysis Branch consists of data from over 24,000 commercial buildings in California, collected via on-site surveys and inspections from 2018 through 2022. The data was collected for 12 building types with information about floor area, fuel shares of major equipment, electric and natural gas energy consumption, weather-normalized hourly whole-building load profiles, and penetrations or saturations of equipment.

The data is provided at the building-type level, and information is not available for individual space types within each building type. No building schedule data is available, but load profiles are available for each building type. For some of the building types, the analysis team was able to apply disaggregation techniques to estimate operational schedules.

2019 Residential Appliance Saturation Study (RASS)

The California Residential Appliance Saturation Study[19] conducted by the California Energy Commission Energy Assessments Division, Demand Analysis Branch is a comprehensive study of residential sector energy use. Data was collected by surveys of ~300,000 homes covering a range of utility service areas, climate regions, home types, and energy consumption levels.

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[16] https://www.energycodes.gov/prototype-building-models

[17] https://www.energycodes.gov/sites/default/files/2023-10/PNNL_Prototype_Scorecards.xlsx

[18] https://www.energy.ca.gov/publications/2023/2022-california-commercial-end-use-survey-ceus-final-report

[19] https://www.energy.ca.gov/data-reports/surveys/2019-residential-appliance-saturation-study

The overall trend of RASS data between the 2009 version (used in the 2016 Codes and Standards Enhancement (CASE) team's analysis of residential plug loads[20]) and the 2019 version of the study showed an overall 3.5% decrease in residential plug loads. This trend was identified as a key data point for recommended updates to the CBECC multifamily plug load assumptions.

Methodology for Updating Equipment Power Density Values

A bottom-up approach was used to develop updated EPD values. The approach consisted of the following steps:

1. Estimate a total area applicable for each space type.
2. Estimate the types and quantities of electrical plug load equipment present in the space type.
3. Determine the power load for each piece of equipment. Sources for this data included DOE technical support documents for Appliance Efficiency Standards proceedings, the Energy Star commercial equipment calculator,[21] and additional literature and online research.
4. If a type of equipment may be present in some buildings, but not in all, then its prevalence was estimated by determining the percentage of buildings where it may be present. This was used to weight the contribution of the equipment's power towards the total EPD.

The equation is represented as:

$$Space\ EPD = \frac{\sum_i (Load_i \times N_i \times F_i)}{Area}$$

Where:

- $Load_i$ is the power load for a single piece of equipment of type i.
- N_i is the quantity of the equipment of type i.
- F_i is the assumed frequency of the equipment of type i, expressed as a fraction of buildings in which the equipment may be present.
- $Area$ is the assumed area for the space type analyzed.

[20] Codes and Standards Enhancement Initiative (CASE). 2016. Plug Loads and Lighting Modeling. Measure Number: 2016-RES-ACM-D. https://t24stakeholder.wpengine.com/wp-content/uploads/2017/10/2016_CASE-Report_Plug-Loads-and-Lighting-Modeling.pdf

[21] https://www.energystar.gov/buildings/save_energy_commercial_buildings

Detailed analysis and calculations for each space type are included in Appendix A.

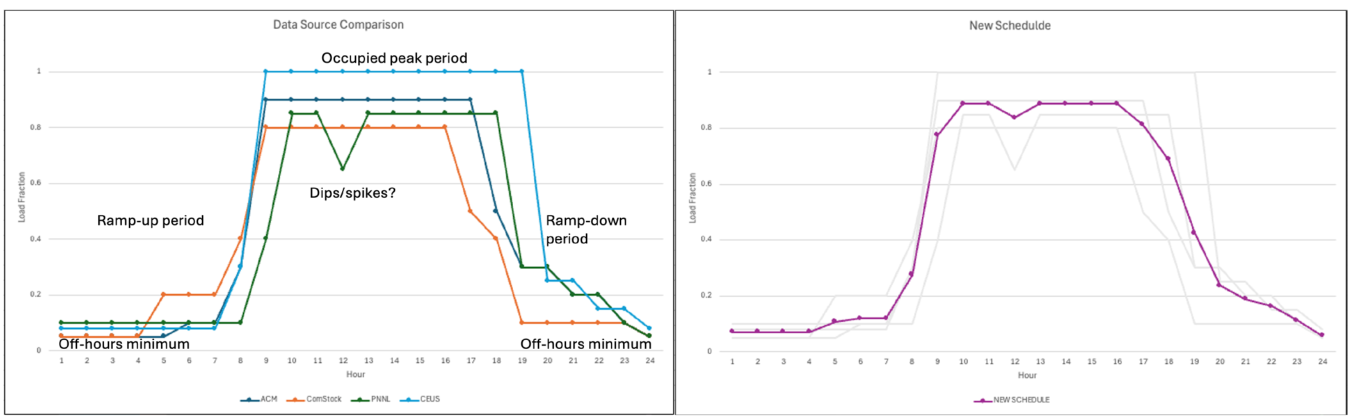
Methodology for Updating Schedule Values

A comparative approach was used to develop updated schedule values. The approach consisted of generating plots of the current NRMFACM schedules, along with plots of schedules from the other data sources with relevant data available. All of the plots were reviewed together, and several segments of the plots were analyzed to determine:

- Values during unoccupied periods
- If a ramping up or ramping down period occurs, when it occurs, and its duration
- The peak value, when it is reached, and when it ends
- Whether any dips or spikes occur during occupied periods

The team's subject matter experts then determined if any of these segments should be adjusted from the current values by looking for common trends across multiple datasets, and applying engineering judgment. An example of this approach is illustrated below in Figure 12.

Figure 12: Schedule Update Methodology



The updated operational schedules are proposed to be specified in the NRMFACM for each "function group" which roughly corresponds to building type.[22]

Details for the function-group-specific analysis are included in Appendix B.

Analysis and Comparison of Energy and LSC Impacts Between New and Previous Datasets

Building simulation analysis was performed to analyze the impacts of the proposed changes to plug load EPD values and schedules. The analysis was performed by utilizing prototype energy models for each of the building types impacted by the proposed changes:

- Medium Office
- Small Hotel
- Restaurant
- Retail
- Warehouse[23]
- Mid-rise Multifamily[23]
- Large School[24]
- Assembly[24]

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[22] Care must be taken by compliance analysts to ensure that they understand how the schedules are used in the compliance software. When performing a compliance analysis, the schedules are not applied at the individual space level but rather are determined by the compliance software based on the "predominant" space type per thermal zone or building floor. A predominant schedule group is determined by assigning the function group schedules associated with the space function having the largest area within the thermal zone or building floor. As a hypothetical example, suppose a warehouse building has warehouse spaces and a supervisor's office at the ground floor, and an additional small upper floor with office space. In this scenario, the ground floor would use the warehouse schedules for both the warehouse and office space, while the upper floor would use the office schedules. This concept is explained in more detail in the NRMFACM, Section 2.3.3 "Space Use Classification Considerations." Also note that some space types (e.g., corridors, restrooms, and others as noted in the NRMFACM Appendix 5.4A) do not count towards the predominant schedule group determinations.

[23] Results for this prototype were still under development at the time of writing this report.

[24] Results for this prototype are included in the memo titled "Proposed 2028 Energy Code Cycle Building Prototype Updates," https://efiling.energy.ca.gov/GetDocument.aspx?tn=265691&DocumentContentId=102542.

The prototypes were analyzed in each of the 16 California climate zones. Results for three climate zones are presented in this report to represent the impacts across a range of climate conditions (climate zones 3, 9, and 12).

The analysis process compared the simulation results from the prototype models using the current values for EPD and schedules in the 2025 NRMFACM Reference Manual Appendices (labeled as "Current" in the charts and tables) to alternative versions of the prototypes using the new proposed values for EPD and schedules (labeled as "Proposed" in the charts and tables).

Simulation results for the LSC metric were analyzed to determine how the proposed changes may impact compliance. Charts and tables were developed to present the LSC impacts, specifically for regulated end uses.

Simulation results for site energy were also analyzed to determine how the proposed changes impact the energy balance for each building. Charts were developed to show the magnitude in change for site energy end-uses impacted by the proposed changes.

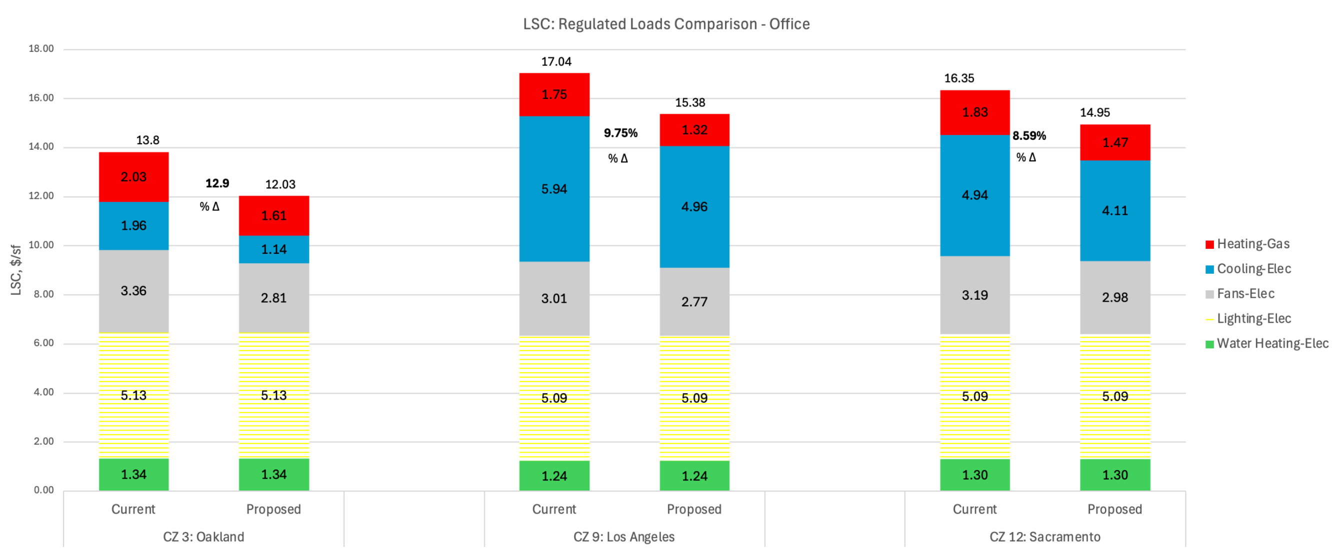
Results for each prototype are presented in Appendix D. Most prototypes experienced relatively small changes to overall LSC (+/- 1-3%) with the exception of the office prototype which is evaluated here in more detail.

Impacts for the Medium Office Prototype

The proposed reduction of EPD and increase in the schedule load fraction during unoccupied hours resulted in decreases for cooling, heating, and fan site energy and LSC.

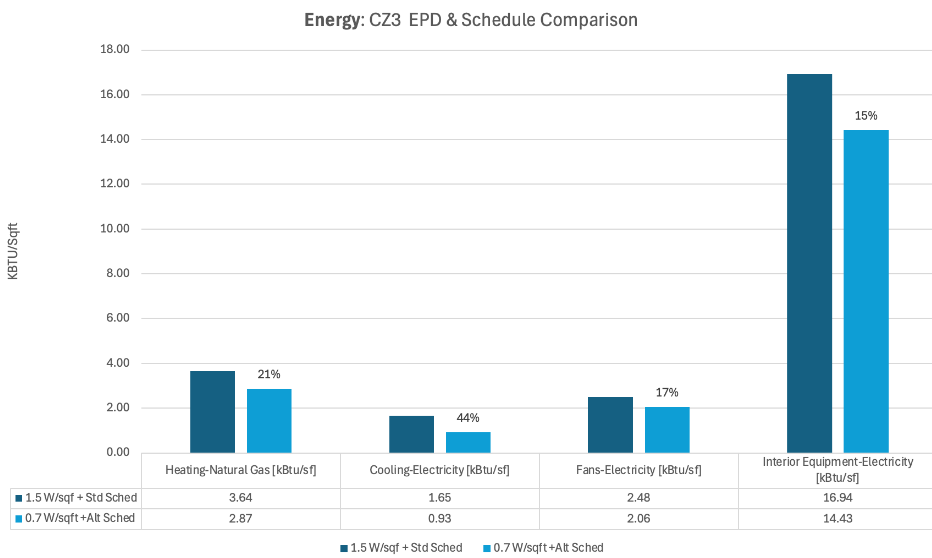
Figure 13 shows an overall decrease in LSC by approximately 10% in each climate zone.

Figure 13: Office - Impacts of Proposed Changes on LSC



The end uses that are impacted by the proposed changes include the plug loads (interior equipment), and the HVAC end uses (Heating, Cooling, Fans). Figure 14 through Figure 16 show how each of these end uses is impacted by the proposed changes. The upper portion of the figure shows site energy for each end use and the lower portion shows LSC. In each chart, side-by-side bars compare results from simulations using the current NRMFACM values (left bar) to the proposed new values (right bar). The percentage above the right bar indicates the percent change between the two simulations for each end use.

Figure 14: Office (CZ3) – Impact of Proposed Changes on Site Energy and LSC



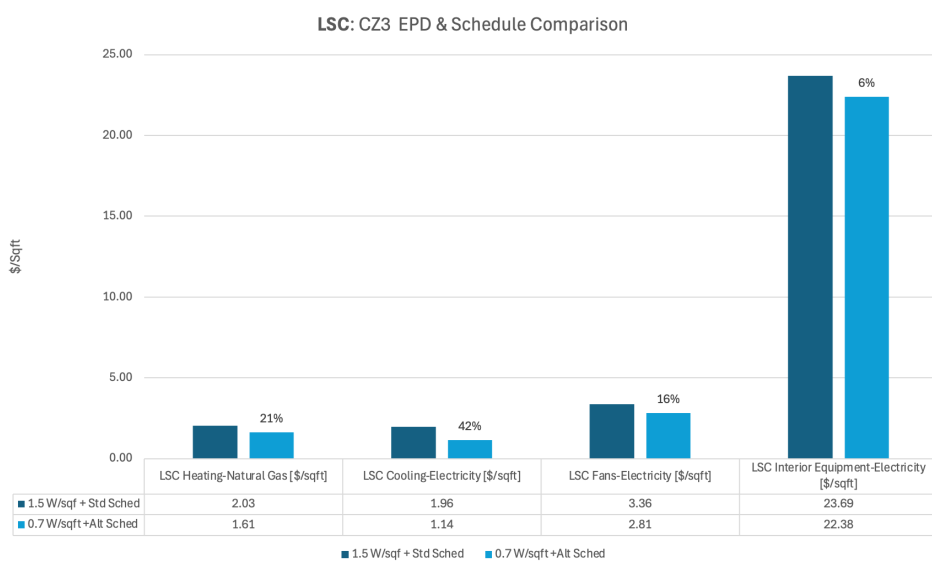
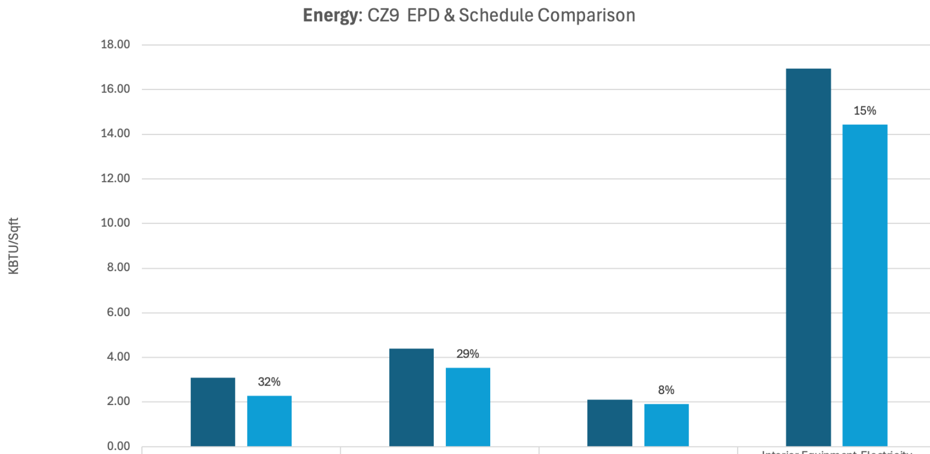
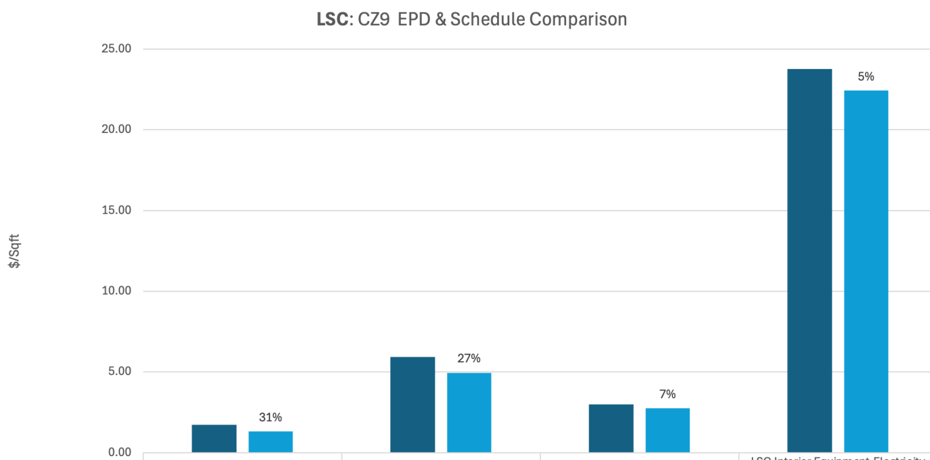


Figure 15: Office (CZ9) – Impact of Proposed Changes on Site Energy and LSC



	Heating-Natural Gas [kBtu/sf]	Cooling-Electricity [kBtu/sf]	Fans-Electricity [kBtu/sf]	Interior Equipment-Electricity [kBtu/sf]
1.5 W/sqf + Std Sched	3.09	4.39	2.12	16.94
0.7 W/sqft +Alt Sched	2.29	3.54	1.92	14.43

■ 1.5 W/sqf + Std Sched ■ 0.7 W/sqft +Alt Sched



	LSC Heating-Natural Gas [$/sqft]	LSC Cooling-Electricity [$/sqft]	LSC Fans-Electricity [$/sqft]	LSC Interior Equipment-Electricity [$/sqft]
1.5 W/sqf + Std Sched	1.75	5.94	3.01	23.78
0.7 W/sqft +Alt Sched	1.32	4.96	2.77	22.44

■ 1.5 W/sqf + Std Sched ■ 0.7 W/sqft +Alt Sched

Figure 16: Office (CZ12) – Impact of Proposed Changes on Site Energy and LSC

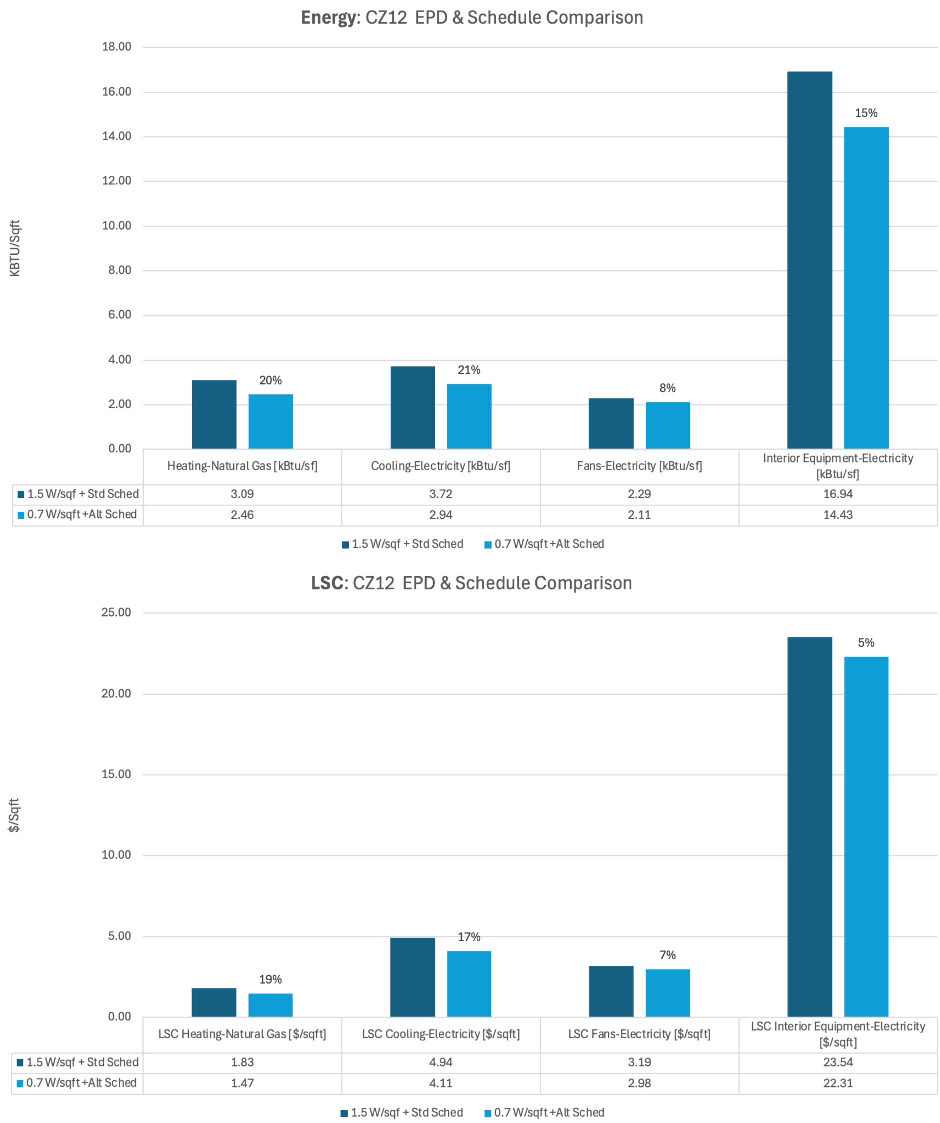


Table 6 shows how each regulated end use contributes to the LSC total for the current NRMFACM values compared to the proposed values. This table illustrates how compliance may be impacted by the proposed changes:

- Heating, cooling, and fan energy in the proposed simulations make up smaller percentages of the regulated LSC compared to the simulations using current NRMFACM values. Therefore, HVAC measures may contribute less towards compliance if the proposed changes are adopted.
- Lighting and water heating make up larger percentages of the regulated LSC compared to the current NRMFACM values. Therefore, lighting and water heating measures may contribute more towards compliance if the proposed changes are adopted.

Table 6: Office – Impacts of Proposed Changes to LSC by End Use, Percentage of Total Regulated LSC

Climate Zone	Current or Proposed	Water Heating-Elec	Lighting-Elec	Fans-Elec	Cooling-Elec	Heating-Gas	Total % Change
CZ 3: Oakland	Current	9.7%	37.1%	24.3%	14.2%	14.7%	12.96%
CZ 3: Oakland	Proposed	11.1%	42.6%	23.3%	9.5%	13.4%	12.96%
CZ 9: Los Angeles	Current	7.3%	29.9%	17.7%	34.9%	10.3%	9.75%
CZ 9: Los Angeles	Proposed	8.1%	33.1%	18.0%	32.3%	8.6%	9.75%
CZ 12: Sacramento	Current	8.0%	31.1%	19.5%	30.2%	11.2%	8.59%
CZ 12: Sacramento	Proposed	8.7%	34.0%	19.9%	27.5%	9.9%	8.59%

Conclusions and Considerations for Future Work

The updates presented in this report are recommended to be used during the 2028 energy code update cycle. The assumptions used to update the plug load EPD values and schedules have been carefully documented to facilitate future updates as equipment efficiency and usage changes. The proposed values result in better alignment with recent studies.

The result of updating these values leads to an up-to-date representation of building performance causing some changes in simulated site energy and LSC for the relevant nonresidential and multifamily building prototype models. The simulations for most of the building prototypes show that the changes will have minimal impacts on compliance outcomes and the relative impacts of different types of efficiency measures. However, the changes to the office result in reductions to heating, cooling, and fan energy and LSC. Therefore, HVAC measures may contribute less towards compliance for office buildings if the proposed changes are adopted.

During the course of this effort, several opportunities for future study have been identified:

- As noted, schedules and equipment loads for hospitals and laboratories were not included in the analysis. The report concludes that additional stakeholders should be engaged to support updating these values.

- This report includes recommendations for changes to the Warehouse plug load schedule by shifting its operation earlier in the day. The other schedules (e.g., occupancy, lighting, HVAC) will need to be aligned with this proposed change.
- This report recommends adding a new schedule function group for "Hotel Living" and proposes a plug load schedule. The other schedules (e.g., occupancy, lighting, HVAC) will also need to be created to ensure that the new schedule function group is complete and can be used in the compliance software.
- The analysis of the kitchen space loads focused on revising the loads associated with cooking equipment. However, the research process also suggests that non-cooking equipment loads may be higher than the current NRMFACM values, so these should be studied further.
- The analysis of the kitchenette space loads suggest that plug load values may be higher than the current NRMFACM values, but further input is needed from stakeholders on how these spaces are represented in compliance models.
- This report describes the prioritization process used to select space types and function groups to update. Future analysis could be pursued to update additional values not included in this initial study.
- As noted, schedules for school and assembly buildings are being updated as part of a related effort and these updates will be presented in a separate report.

The forthcoming 2028 update to weather files, prototypes, plug loads and the LSC and source energy metrics will only apply to nonresidential building types.

Glossary

Term	Definition
Alternative calculation methods (ACM)	Compliance software, or alternative component packages, or exceptional methods approved by the Energy Commission under Section 10-109 of the Energy Code. ACMs are also referred to as Compliance Software.
CBECS	The Commercial Buildings Energy Consumption Survey (CBECS) is a national sample survey that collects information on the stock of U.S. commercial buildings, including their energy-related building characteristics and energy usage data (consumption and expenditures).
Climate zone	The Energy Commission has established typical weather data, prescriptive packages, and energy budgets for 16 geographic areas of California, called climate zones, as specified in the Energy Code.
COMNET	COMNET provides resources for standardized energy modeling for buildings. The program is managed by the Pacific Northwest National Laboratory on behalf of the United States Department of Energy.
Energy budget	Maximum energy consumption that a proposed building, or portion of a building, can be designed to consume, calculated using Commission-approved compliance software as specified by Section 10-109 of the Energy Code and the Alternative Calculation Method Reference Manual. The energy budget for newly constructed buildings is expressed in terms of the Long-Term System Cost (LSC) and Source Energy. The energy budget for additions and alterations is expressed in terms of LSC.
Long-term system cost	CEC-projected present value of costs to California's energy system over a period of 30 years. LSC does not represent a prediction of individual utility bills.
Plug load / receptacle load	Energy consumed by any appliances or electronic devices that are plugged into a receptacle or receptacle outlet. Plug loads are not related to general lighting, heating, ventilation, cooling, and water heating, domestic and service water system, renewable power, information technology equipment, computer room electronic equipment, and electric vehicle charging.

APPENDIX A:
Plug Load Update Analysis Details

This appendix contains analysis details for the proposed plug load EPD updates. Plug loads for each space type were developed using the bottom-up approach described in the section **Methodology for Updating Equipment Power Density Values** except as otherwise indicated.

Office (<250 square feet)

Table 7: Equipment Assumptions for Office (<250 square feet)

Equipment	Qty	Frequency	Power Draw (W/unit)	Total Watts
Phones	2	50%	4	4
Computers/ Desktops	1	100%	39	39
Laptops	1	100%	12	12
Printers	1	25%	22	6
Laptop docking station	1	50%	49	25
Screens/monitors	2	100%	25	50
Task lighting	2	100%	2	4
Misc at workstation	2	20%	2.5	1
Total (W)				140
EPD (W/SF)				**0.70**

Note: Analysis assumes office area of 200 square feet.

Office (>250 square feet)

Table 8: Equipment Assumptions for Office (>250 square feet)

Equipment	Qty	Frequency	Power Draw (W/unit)	Total Watts
Phones	4	50%	4	8
Computers/ Desktops	2	100%	39	78
Laptops	2	100%	12	24
Printers	1	25%	22	11

Laptop docking station	2	50%	49	49
Screens/monitors	4	100%	25	100
Task lighting	4	100%	2	8
Misc at workstation	4	20%	2.5	2
Total (W)				280
EPD (W/SF)				**0.70**

Note: Analysis assumes office area of 400 square feet.

Kitchen/Food Preparation Area

No updates are proposed to the receptacle EPD value (1.5 W/ft^2) for this space type. However, updates to the default values for "Gas Equipment" and "Elec. Equipment" are recommended to better represent the loads associated with kitchen cooking equipment.

Currently, these values for cooking equipment loads are not prescribed like the EPD values but rather a default value is provided that may be overridden by users of the compliance software. The NRMFACM, Appendix 5.4A currently specifies a default value of 17.5 Btu/h-ft^2 of gas equipment load for this space type and a default value of 0 W/ft^2 of electrical equipment load. If a building is specified as "all electric" in the compliance software, then this gas load is converted to an electrical load.

While these values are user editable, these are default values that are not displayed to the user and this report recommends that a more transparent approach be provided to allow users to specify cooking equipment loads, see Figure 17 for an example input interface. The recommended approach consists of providing an additional input screen in the compliance software to allow users to specify the type and quantity of various appliances and whether they are served by gas or electricity, and the software can calculate the loads accordingly based on built-in assumptions for load per appliance. The software could add additional reports for these cooking appliances if desirable as well. Analysis performed to date has determined loads per appliance, typical quantities, and prevalence of gas vs. electric appliances and this analysis could be used to pre-populate inputs in the software.

Figure 17: Mockup of Kitchen Cooking Appliance Inputs for CBECC

Equipment	Gas	qty	Electric	qty
Griddle	☑	1	☐	0
Fryer	☐	0	☑	1
Oven	☑	1	☐	0
Cook Top/Range (6 burner)	☑	1	☐	0
Steam Cooker	☐	0	☑	1
Load	**xxxxx BTU/h-ft2**		**yyyyyy W/ft2**	

Kitchenette or Residential Kitchen

No change is proposed to the EPD value (1.0 W/ft2) at this time. There is data that suggests the loads could be increased; however, anecdotal evidence indicates that, for compliance analysis, kitchenettes are often included in a larger thermal zone with schedules that do not align with the intermittent usage of kitchenette equipment. Further study is recommended.

Analysis performed to date represents work in progress and is presented below for future reference.

Table 9: Equipment Assumptions for Kitchenette

Equipment	Qty	Frequency	Power Draw (W/unit)	Total Watts
Drip Coffee Maker	1	100%	88	88
Refrigerator	1	100%	121	121
Toaster Oven	1	100%	198	198
Microwave	1	100%	88	88
Total (W)				495
EPD (W/SF)				**3.1**

Note: Analysis assumes kitchenette area of 160 square feet.

Retail Sales Area

The NRMFACM has three retail sales area space types: Retail Sales Area (Grocery Sales), Retail Sales Area (Retail Merchandise Sales), and Retail Sales Area (Fitting Room). These space types are based on the prescriptive lighting power allowance table in the Energy Code. This report recommends that the plug load EPD in all of these spaces be reduced from 1.0 W/ft^2 to 0.4 W/ft^2. Unlike the other space types, this recommendation was based on a top-down analysis by reviewing several alternative data sources to determine if an alternative value was more commonly specified. The data sources reviewed did not include sufficient data to evaluate using the bottom-up approach.

The top-down analysis summary is provided below and shows that most data sources specify lower values than the NRMFACM values. As such, a reduction in retail space EPD is warranted for simulation purposes.

Table 10: Retail Plug Load EPD Top-Down Analysis

Data Source	EPD (W/ft^2)
Energy Code NRMFACM	1.00
AEDG - Small Retail (2006)	0.40
AEDG - General Merchandise (2009)	0.20 – 0.70
AEDG - Medium and Big Box Retail (2013)	0.40 – 0.70
ASHRAE 90.1 Appendix C	0.30
ASHRAE 90.1 User Manual	0.25
COMNET	0.55 – 0.82
DOE Reference Building - Retail Stand Alone	0.30
DOE Reference Building - Retail Strip Mall	0.40
ASHRAE 90.1 Prototype - Retail Stand Alone	0.30
ASHRAE 90.1 Prototype - Retail Strip Mall	0.40
ComStock - Retail Stand Alone	0.20
ComStock - Retail Strip Mall	0.40
DEER - Retail Sales and Wholesale Showroom	1.00

Retail Sales Area (Grocery Sales) - Refrigeration Loads

The space type Retail Sales Area (Grocery Sales) includes refrigeration loads in addition to plug loads. These refrigeration loads represent the commercial refrigeration equipment for food product merchandising. Currently, the NRMFACM specifies a non-editable prescribed refrigeration load of 5.0 W/ft^2 applied to an entire space within the Grocery Sales function. However, research indicates that modeled thermal zones in grocery sales areas may include some area with commercial refrigeration equipment and some area without. In this case, the refrigeration loads would be overestimated. For operating schedules, the refrigeration load is assigned a 90% fractional multiplier for all hours in the NRMFACM; this means the operating load of the refrigeration equipment is 4.5 W/ft^2.

This report recommends that modifications be made to the compliance software to allow users to specify a fraction of the modeled space that includes refrigerators and/or freezers. This fraction would be used by the software to calculate a total refrigeration load for the space. For example, if a space of 1000 ft^2 has a fraction of 0.5 for the area with refrigerators or freezers, then the total refrigeration load would be calculated as 1000 ft2 x 5.0 W/ft^2 x 0.5 = 2500 W. Note that walk-in refrigerators (coolers) or freezers should not be included in this fraction, as a modeler would be expected to use the more appropriate Refrigerated Storage space function.

Another consideration with the current refrigeration equipment modeling in the compliance software is that the entire load is within the space. In other words, it is currently assumed in the NRMFACM that all refrigeration equipment is self-contained with all heat being rejected within the space. However, many systems have remote condensing units that discharge heat from the refrigerated cases to the ambient air. In this scenario, the systems will consume energy but not add heat to the space.[25] Therefore, another recommended modification to the compliance software is to include an additional input that allows the user to specify the percentage the refrigeration equipment that is served by remote condensing units and will not add heat to the space. The software would then adjust the load to the space accordingly. The energy consumption of the system would not be reduced by these inputs – only the thermal loads.

To evaluate the 5.0 W/ft^2 assumption used for Grocery Sales areas, previous research along with current efficiency regulations for commercial refrigeration equipment was used. In particular, the assumptions for two prototype energy models were reviewed: the first is the supermarket prototype model included in the DOE Commercial Reference Buildings with the second being the underlying model used for the Advanced Energy Design Guide for Grocery Stores (AEDG). Both of these models rely on previous DOE research evaluating energy savings related to commercial refrigeration equipment. For a typical 45,000 ft^2 supermarket, the table below details the assumptions for a typical refrigeration equipment design—these assumptions form the basis of the supermarket prototype from the DOE Commercial Reference Buildings.

[25] In fact, equipment with remote condensers would actually remove heat from the space; however, this effect cannot be modeled with the current W/ft^2 refrigeration load implementation. Accounting for the actual interaction of refrigeration equipment with both the indoor and outdoor environments would require a significant change in how these loads are modeled in CBECC.

Table 11: DOE Supermarket Prototype Commercial Refrigeration Equipment

Temperature Designation	Item	Quantity per Store	Load[1] per ft or per ft^2	Total Load[1] (mBtu/hr)
Medium	Multideck Meat Cases	120 ft	1500 Btu/hr/ft	180
	Other Multideck Cases	260 ft	1500 Btu/hr/ft	390
	Meat Walk-In Coolers	400 ft^2	60 Btu/hr ft^2	26
	Other Walk-In Coolers	2,600 ft^2	60 Btu/hr/ft^2	154
			Total	750
Low	Reach-In Cases	268 ft	560	150
	Single-Level Open Cases	128 ft	550	70
	Walk-In Freezers	1,000 ft^2	80 Btu/hr/ft^2	80
			Total	300

The AEDG prototype model adapted the refrigeration equipment assumptions but modified them to fit a revised building geometry with additional space types. The AEDG assumptions were used as the basis of the evaluation for this report. These assumptions are broken down in the table below:

Table 12: AEDG Grocery Store Prototype Model Commercial Refrigeration Equipment

Zone Name	Case/Walk-in Type	Case Length	Number of Units	Total Length or Area
Sales	Island Single Deck Meat	12 ft (3.66 m)	13.9	167 ft (50.9 m)
Sales	Multi-Deck Dairy/Deli	12 ft (3.66 m)	14.3	172 ft (52.4 m)
Sales	Vertical Frozen Food with Doors	15 ft (4.57 m)	15.6	234 ft (71.3 m)
Sales	Island Single Deck Ice Cream	12 ft (3.66 m)	12	36 ft (11.0 m)
Sales	Walk-In Cooler (Medium Temperature)	N/A	2	2,545 ft^2 (236.4 m^2)
Sales	Walk-In Freezer (Low Temperature)	N/A	1	691 ft^2 (64.2 m^2)
Produce	Multi-Deck Dairy/Deli	12 ft (3.66 m)	8.8	106 ft (32.3 m)
Deli	Multi-Deck Dairy/Deli	12 ft (3.66 m)	1.1	13.2 ft (4.0 m)
Deli	Walk-In Cooler (Medium Temperature)	N/A	1	115 ft^2 (10.7 m^2)
Bakery	Walk-In Cooler (Medium Temperature)	N/A	1	57 ft^2 (5.3 m^2)

To determine the load for each piece of equipment (excluding the walk-in coolers and freezers as noted above), the federal efficiency regulations found in 10 CFR 431 Subpart C were used. These efficiency requirements have also been adopted as part of the Appliance Efficiency Standards in California's Title 20 (CCR, Title 20, Section 1605). For all of the equipment defined above, the Maximum Daily Energy Consumption (MDEC) in kWh allowed by regulations is a function of the equipment's Total Display Area (TDA). In short, the TDA represents the two-dimension viewable area of the display merchandiser. The MDEC can be converted into a peak space load assuming a constant load over a 24-hour period and dividing by the NRMFACM 90% hourly fractional multiplier.

The tables below detail the MDEC calculations and the conversion from MDEC into the NRMFACM W/ft^2 assumption. Assumptions required to calculate the TDA were based on reviews of manufacturer literature for typical equipment dimensions. The DOE MDEC calculations take the form of a simple linear equation with the slope and intercept of the equation represented by the “MDEC Mult.” and “MDEC Adder” in the table below, respectively.

Table 13: Refrigeration Equipment Load Calculations

Zone Name	**Area [ft²]**	**Refrigerated Case** (excluding walk-ins)	**Temp. Class**	**Equipment Configuration**	**Equipment Class**
Main & Perimeter Sales	24,727	island single deck meat	Medium	Horizontal	HZO, SC, M
Main & Perimeter Sales	24,727	multi-deck dairy/deli	Medium	Vertical	VOP, SC, M
Main & Perimeter Sales	24,727	vertical frozen food with doors	Low	Vertical	VCT, SC, L
Main & Perimeter Sales	24,727	island single deck ice cream	Low	Horizontal	HCT, SC, I
Produce	7,657	multi-deck dairy/deli	Medium	Vertical	VOP, SC, M
Deli	2,419	multi-deck dairy/deli	Medium	Vertical	VOP, SC, M
Bakery	2,250	-	-	-	-
BOH	7,951	-	-	-	-
Grocery Sales	**37,053**	**-**	**-**	**-**	**-**
Total Bldg	45,004	-	-	-	-

Table 14: Refrigeration Equipment Load Calculations, continued

Zone Name	Unit Length (ft)	Display H or W (ft)	# of Units	Unit TDA (ft^2)	MDEC Mult.	MDEC Adder	Total MDEC (kWh)	Hourly Mult.	Peak W/sf
Main & Perimeter Sales	12	2.90	14	34.75	0.72	5.55	425	0.9	4.8
Main & Perimeter Sales	12	5.58	14	67.00	1.69	4.71	1690	0.9	4.8
Main & Perimeter Sales	15	5.00	16	75.00	0.29	2.95	385	0.9	4.8
Main & Perimeter Sales	12	2.79	3	33.50	0.56	0.43	58	0.9	4.8
Produce	12	5.58	9	67.00	1.69	4.71	1042	0.9	6.3
Deli	12	5.58	1	67.00	1.69	4.71	130	0.9	2.5
Bakery	-	-	-	-	-	-	-	-	-
BOH	-	-	-	-	-	-	-	-	-
Grocery Sales	**-**	**-**					**3730**	**0.9**	**4.7**
Total Bldg	-	-					3730	0.9	3.8

To obtain the space equipment load on a W/ft^2 basis, the total equipment load was divided by the grocery sales area of the prototype model. The resultant peak refrigerant load was approximately 4.7 W/ft^2. Based on this result, it is reasonable to leave the current 5.0 W/ft^2 assumption in the NRMFACM for refrigeration loads in Grocery Sales area.

Multifamily Residential Living Spaces

Plug loads in residential living spaces are modeled following a different methodology from other space types; they are modeled according to the NRMFACM Appendix E: Plug Loads and Lighting Modeling. For most appliances, the values are in “Table 2: Algorithms for Plug Load and Lighting Annual Energy Use”. This table includes a load for each appliance (titled ‘intercept’) and an adjustment factor (titled ‘slope’) that modifies the appliance energy use by the number of bedrooms. The intercept corresponds to the base appliance energy use with zero bedrooms (studio apartment) and the slope indicates a fixed rate of increase per additional bedroom.

The following values are proposed as modifications to the values currently in "Appendix E Table 2" (only modified values are shown).

Table 15: Proposed Modifications to Appendix E, Table 2

End Use	Intercept (base use-0 bedrooms)	Slope (adjustment per bedroom)
Refrigerator	303 kWh	25 kWh
Set Top Boxes	Omitted	Omitted
MELs	990 kWh	346 kWh

For appliances associated with hot water use, load information is provided in "Table 4: Multi-family Dwelling Unit Algorithm for Dishwasher, Clothes Washer, and Clothes Dryer Annual Energy Use". This table includes specific annual energy use based on each possible number of bedrooms. The ratio of energy use to number of bedrooms is not linear. For these appliances, the ratio of energy use from the base case value to the value for additional bedrooms was kept constant with the ratios in the original table.

Table 16: Proposed Modifications to Appliances in Appendix E, Table 4

Bedrooms per Unit	Electric Clothes Dryer (kWh, Annual)
0	321
1	341
2	482
3	474
4	573
5+	521

A comprehensive summary of the analysis performed to make these proposed edits is provided in Appendix C.

The forthcoming 2028 update to weather files, prototypes, plug loads and the LSC and source energy metrics will only apply to nonresidential building types.

Hotel/Motel Guest Room

Currently, Hotel/Motel Guest Room spaces utilize the plug load calculations for residential living spaces. However, this representation does not account for the differences in hotel/motel room occupancy and equipment usage. Therefore, this report recommends to remove the link to the residential calculations and use a simple 0.5 W/ft^2 value derived from a bottom-up analysis, presented below. The NRMFACM currently lists a value of 0.5 W/ft^2, but this value has not been used in recent versions of compliance software due to the link to residential calculations, so the proposed change will revert to using the NRMFACM value.

Table 17: Equipment Assumptions for Hotel/Motel Guest Room

Equipment	Qty	Frequency	Power Draw (W/unit)	Total Watts
Television, 50 in	1	100%	77	77
Desk Lamp	1	80%	10	8
Bed Lamps	2	100%	10	20
Floor Lamp	1	100%	30	30
Laptop (plug-in)	1	25%	65	16.25
Total (W)				151.25
EPD (W/SF)				**0.46**

Note: Analysis assumes guest room area of 330 square feet.

Hotel/Motel - Refrigeration

Another proposed change is to add a refrigeration load to this space type.[26] The value for the load was derived using the same calculation approach as for the plug loads, with one additional factor, “Prevalence.” The prevalence value represents the percentage of hotel rooms that have a full-size refrigerator rather than a mini-fridge. The prevalence values used in the table are based on an analysis

[26] Note that the current multifamily load used for hotel/motel guest rooms does include refrigeration as a “process electric load.” However, as noted above, the assumptions used for multifamily analysis include several appliances that are not appropriate for hotel/motel guest rooms. Therefore, the proposal is to specify refrigeration as a standalone prescribed value (refrigeration load) for this space type.

of the fraction of hotel area in California for long-term stay hotels compared to short-term stay hotels with the long-term hotels having a full-sized refrigerator and the short-term hotels having a mini-fridge at the frequency levels specified.[27]

Like other space types, this report expects this refrigeration load will operate with a constant 0.9 load fraction schedule. This schedule is proposed to be added to the "Hotel Living" schedule function group.

Table 18: Refrigeration Load Calculation for Hotel/Motel Guest Room

Equipment	Qty	Prevalence	Frequency	Power Draw (W/unit)	Total Watts
Full Fridge	1	18%	90%	167	27.0
Mini Fridge	1	82%	60%	27	13.3
Total (W)					40.3
EPD (W/SF)					**0.12**

The forthcoming 2028 update to weather files, prototypes, plug loads and the LSC and source energy metrics will only apply to nonresidential building types.

Classroom (K-8 School)

The CEC proposes to add a new space type for classrooms in K-8 schools. All other classrooms should continue to use the EPD values for Classroom, Lecture, Training, Vocational Areas.

The equipment types and quantities for the bottom-up analysis presented below is based on extensive discussions between staff of the Energy Commission, the California Division of the State Architect (DSA), and considering the Los Angeles Unified School District (LAUSD) equipment list.

[27] Estimates for prevalence of short-term vs. long-term stay hotels are based on an analysis of total floor area of lodging buildings in California (approximately 491,000 ksf according to 2022 CEUS, and approximately 321,300 ksf according to Dodge 2023 data), online literature search to determine the approximate number of extended stay hotels in California (between 1,200 to 1,500 properties), and online search to determine the average size of extended stay hotels (approximately 50,000 sf). Using the Dodge data and lower estimate of the number of properties led to an estimate of 12% prevalence of extended stay hotels. Using the CEUS data and higher estimate of the number of properties led to an estimate of 23% prevalence of extended stay hotels. An average value of 18% was used for the analysis.

Table 19: Equipment Assumptions for Classroom (K-8 School)

Equipment	Qty	Frequency	Power Draw (W/unit)	Total Watts
Telephone	1	100%	4.2	4.2
Laptop (plug-in)	1	100%	65	65
Projector	1	100%	376	376
Document Camera	1	100%	13	13
Device Charging Station	2	100%	200	400
Total (W)				858.2
EPD (W/SF)				**0.86**

Note: Analysis assumes classroom area of 1000 square feet.

APPENDIX B:
Schedule Update Analysis Details

This appendix contains analysis details for the proposed plug load schedule updates. Revised schedules for each space function were developed using a comparative approach described in the section **Methodology for Updating Schedule Values**. For each revised schedule, two charts are presented below — on the left, the comparative chart plots the relevant schedules from all of the data sources used in the analysis; on the right, the proposed new schedule is plotted with the current NRMFACM schedule to clearly show the proposed modifications.

The primary data sources used for this analysis (as listed in the chart legends) include:

- **Title 24 (Current)**: Title 24 schedules from the NRMFACM Manual, Appendix 5.4B.
- **PNNL**: Input data from the PNNL GitHub repository supporting the 2024 paper described in the section **Data Sources Evaluated for Updating Values**
- **ComStock Output**: End-use load profile data from ComStock simulation outputs
- **ComStock Input**: Input data from Comstock energy models
- **ASHRAE**: Input data from the ASHRAE 90.1 Prototype Models[28]
- **DOE:** Input data from the DOE Commercial Reference Building models[29]

Additional data sources were used for specific space functions and are noted in the following sections as applicable.

Office

Most of the data sources reviewed indicated that the baseline receptacle load fraction during unoccupied periods is significantly higher than in the current NRMFACM schedules. Therefore, an increase in load fraction during this period is proposed for all days (weekdays, Saturday, Sunday). The weekend schedules are proposed to remain flat at this increased base load fraction.

The Office schedule analysis included review of two additional data sources:

- **Existing Building Data**: Field-collected data from office buildings in Sunnyvale and San Francisco.

[28] https://www.energycodes.gov/prototype-building-models
[29] https://www.energy.gov/eere/buildings/commercial-reference-buildings

- **NBI**: New Buildings Institute & Portland Energy Conservation, Inc. (PECI). (2013). Methodology for reporting commercial office plug load energy use. California Energy Commission, Public Interest Energy Research program.

Figure 18: Analysis and Proposed Updates to Office Receptacle Schedule (Weekdays)

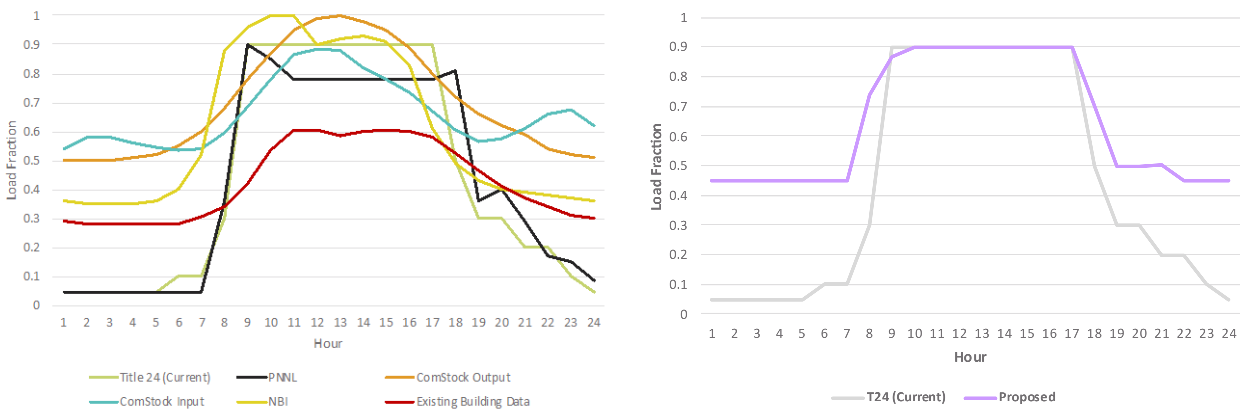
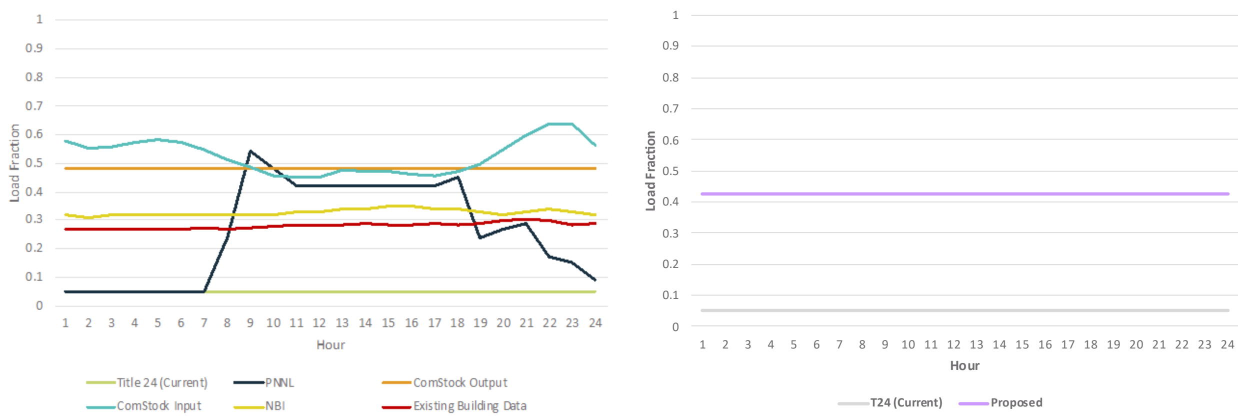


Figure 19: Analysis and Proposed Updates to Office Receptacle Schedule (Saturday)

Figure 20: Analysis and Proposed Updates to Office Receptacle Schedule (Sunday)



Hotel Living (proposed schedule function group)

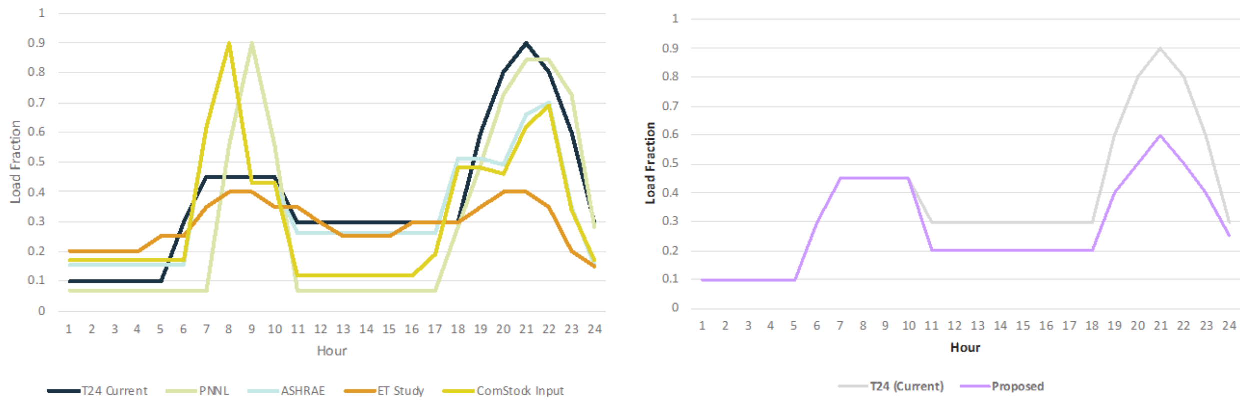
The current NRMFACM does not have a dedicated function group for hotel living spaces. Hotel living spaces currently use the “Residential Living” function group. However, the analysis of the schedule datasets indicated that occupancy and usage of hotel guest rooms differs from that of a multifamily residential space. Therefore, a new “Hotel Living” schedule function group is proposed. Compared to the Residential Living schedule, it consists of a lower daytime base load, and a lower second peak in the evening. The new Hotel Living schedule is proposed to be the same for weekdays, Saturday, and Sunday.

The Hotel Living schedule analysis included review of one additional data source:

- **ET Study**: Frey, Don and J. Arent 2010. Occupancy-Based Guestroom Controls Study, PG&E Emerging Technologies Program, Application Assessment Report #0825.[30]

[30] https://etcc-ca.com/sites/default/files/OLD/images/pge_hrc_occ_sens_rpt-_final_042610-2.pdf

Figure 21: Analysis and Proposed Updates to Hotel Living Receptacle Schedule (All days)

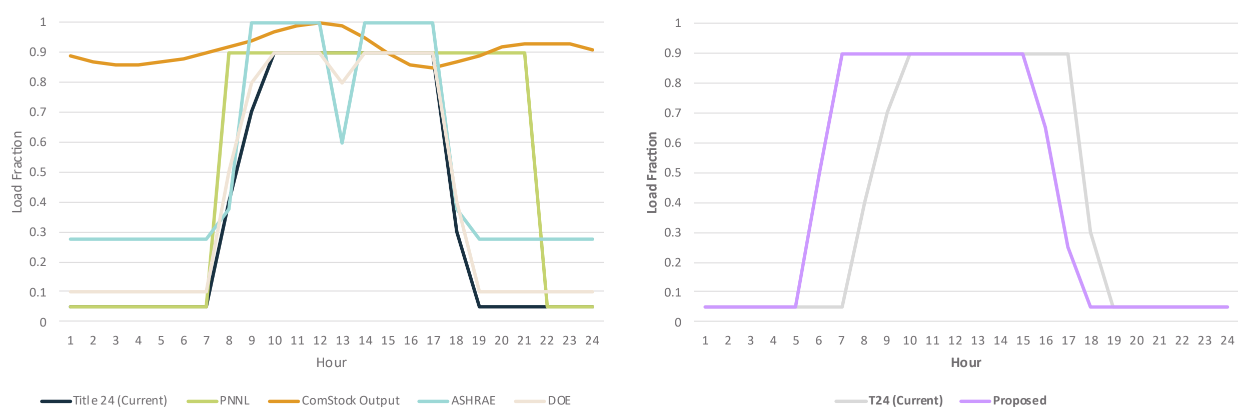


The forthcoming 2028 update to weather files, prototypes, plug loads and the LSC and source energy metrics will only apply to nonresidential building types.

Warehouse

The current NRMFACM schedules are in reasonably close alignment with many of the other data sets. The analysis of CEUS data indicated that, on weekdays, warehouses tend to operate for approximately 12 hours. The decision to shift the schedule to begin operating earlier in the day and end operating earlier than the current NRMFACM schedules was based on engineering judgement. No changes are proposed to the Saturday or Sunday schedules.

Figure 22: Analysis and Proposed Updates to Warehouse Schedule (Weekdays)



Restaurant

The analysis of restaurant schedules led to two proposed changes in the plug load shape: a quicker ramp-up period in the morning to account for restaurants with morning service, and a reduction in equipment use during the afternoon period between lunch and. It is proposed that this schedule be used for all days (weekdays, Saturday, and Sunday) instead of a reduction of loads on the weekend as in the current NRMFACM schedules.

Figure 23: Analysis and Proposed Updates to Restaurant Receptacle Schedule (Weekday)

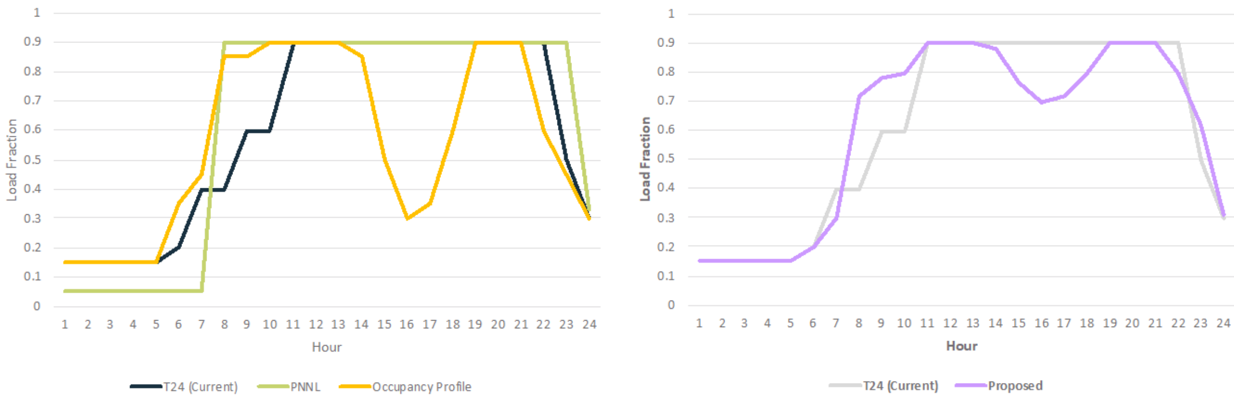


Figure 24: Analysis and Proposed Updates to Restaurant Receptacle Schedule (Saturday)

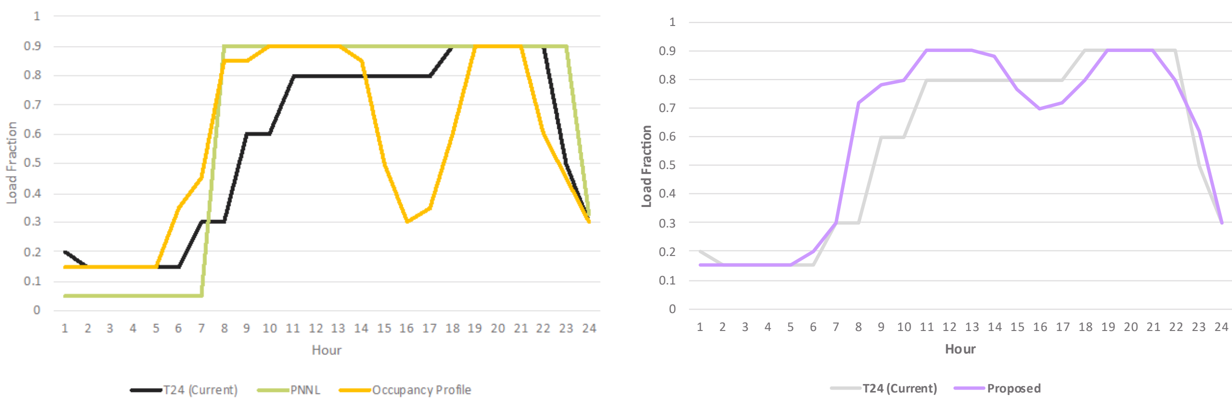
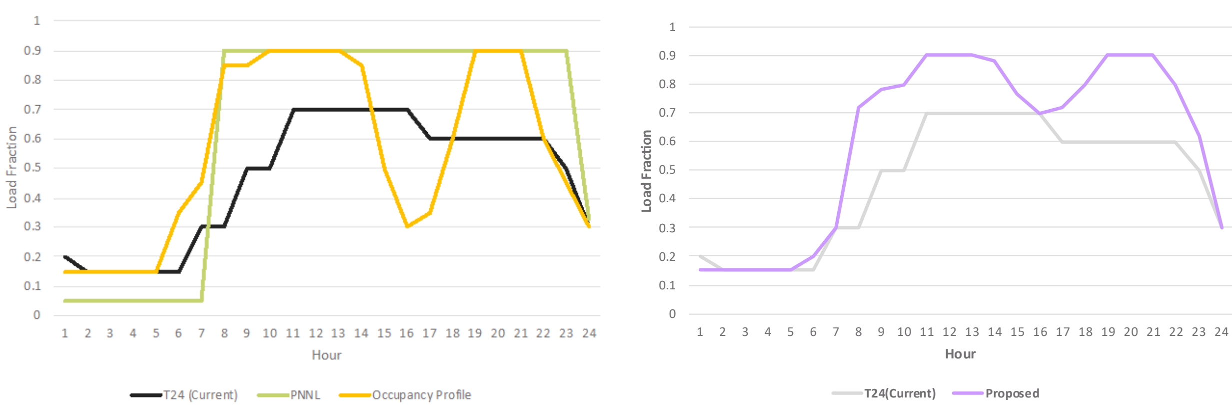


Figure 25: Analysis and Proposed Updates to Restaurant Receptacle Schedule (Sunday)



Retail

The analysis of retail schedules indicated that the baseline receptacle load fraction during unoccupied periods is significantly higher than in the current NRMFACM schedules. Therefore, an increase in load fraction during this period is proposed for all days (weekdays, Saturday, Sunday). Additional adjustments are proposed to the Sunday schedule. The current schedule has reduced hours of operation on Sunday, and this is retained in the new schedule; however, the peak during occupied hours is increased to match the weekday and Saturday peak. This is based on the expectation that, while hours may be reduced, equipment usage is similar during the occupied periods.

Figure 26: Analysis and Proposed Updates to Retail Receptacle Schedule (Weekday)

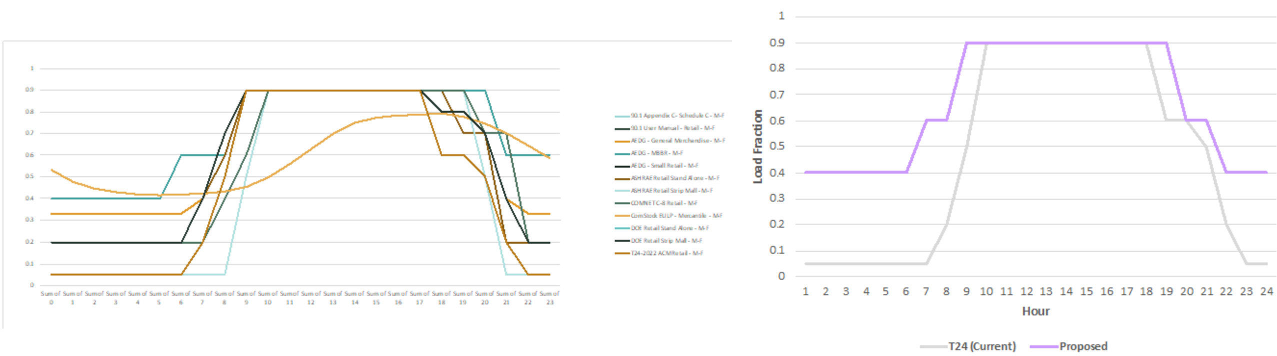


Figure 27: Analysis and Proposed Updates to Retail Receptacle Schedule (Saturday)

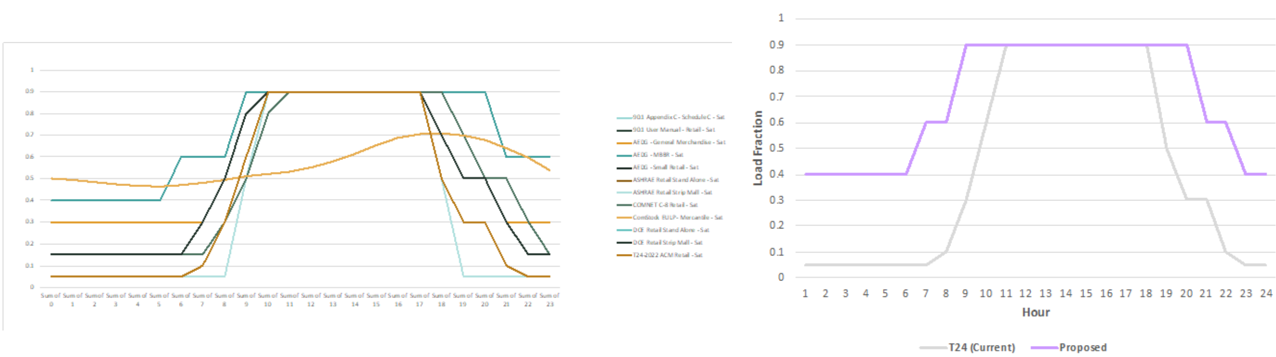
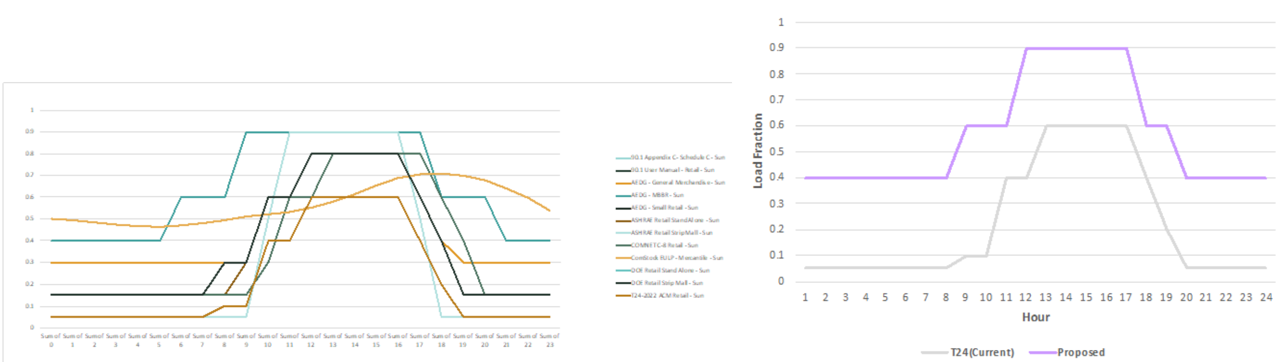


Figure 28: Analysis and Proposed Updates to Retail Receptacle Schedule (Sunday)



APPENDIX C:
Multifamily Living Space Analysis Details

This appendix provides a detailed summary of the analysis of multifamily living space plug loads and schedules, and the process used to make the proposed updates. The goal of this analysis was to determine whether recent plug load analysis in the multifamily sector suggests that modifications to current assumptions in CBECC should be implemented.

Based on this analysis, the following recommendations are proposed for adjustments to the multifamily plug loads in CBECC. Comparisons and evaluations are discussed in subsequent sections.

The forthcoming 2028 update to weather files, prototypes, plug loads and the LSC and source energy metrics will only apply to nonresidential building types.

Recommendations

- Overall plug load values should be reduced by 3.5% to reflect data trends in the most recent RASS data set compared to previous analyses. (The overall decrease is calibrated to 3.5% by increasing miscellaneous electric loads (MELs) to offset significant efficiency improvements in major appliances like refrigerators.)
- Major appliance loads (refrigerator, dryer) should be revised downward based on newer federal appliance standards.
- Set top boxes currently included in the CBECC protocol represent an obsolete technology and should be removed from the appliance list.
- Generally, MELs should be increased to reflect new appliances commonly seen in residential settings, such as gaming consoles, device chargers, etc. (The overall increase matches the balance of load available in a 3.5% total plug load decrease.)
- No change is proposed for individual appliance schedules because no new field data has been collected on which to base behavioral changes since the last analysis in 2016.

The specific values proposed as modifications to current CBECC appliance values are provided at the end of this appendix.

Current Basis for CBECC Multifamily Plug Loads

CEC multifamily plug load calculation protocols were most recently updated in 2016 based on an extensive Plug Loads and Lighting Modeling research project conducted by the Codes and Standards Enhancement (CASE) team (see sources at end). The values generated by this report were incorporated into the CBECC-COM calculations, and remain the basis of multifamily plug load calculations in the current version. The values include both total estimated annual residential appliance and plug loads, and a derivation of anticipated daily schedules which drive the daily patterns of expected plug load consumption. The values include a factor that modifies plug load assumptions based on the number of bedrooms per individual living unit.

The report included an extensive evaluation of the available data on multifamily plug loads, including some of the sources evaluated in this report. The CASE report analysis highlighted that much of the data evaluated was from single-family residences, and this single-family data was used to apply the data to multifamily buildings.

Daily Schedules (load shape)

The CASE report identified three resources upon which the appliance and plug load daily schedules were based; a Florida metering analysis from 2009, the 2015 Northwest Energy Efficiency Alliance (NEEA) Residential Building Stock Assessment (RBSA) study from the Pacific Northwest, and the CEC Title 24 Water Heating ruleset. These three resources were used to generate hourly use patterns for all of the appliances included in the multifamily plug load calculations, as indicated in the table below.

Table 20: Data Sources for Appliance Hourly Energy Use Patterns

End Use	Data Source
Refrigerators and Freezers	PDR[1]
Dishwashers	CEC HWH ruleset
Clothes washers	CEC HWH ruleset
Clothes dryers	CEC HWH ruleset[1]
Ovens and cooktops	PDR
Televisions	PDR
Set-top boxes	NEEA RBSA
Computers and monitors	NEEA RBSA
Exterior lighting	NEEA RBSA
Interior and garage lighting	Existing hourly schedule (HMG 1999)
Residual MELs	Existing hourly schedule (BA HSP 2009)

The Florida PDR study included interval metering for single-family residences, from which daily appliance load shapes were derived. NEEA's RBSA study included device-level submetering which provided load shapes for individual appliances. For hot water consumption appliances (dishwashing and laundry) the goal of the analysis was to keep appliance load shapes consistent with CEC Title 24 hot water use schedules, which remained the basis of the load shapes for these appliances.

This brief narrative of the CASE study approach is provided here to emphasize that a relatively extensive analysis of plug loads was undertaken in 2016, as described in a report that became the basis for current plug load assumptions in CBECC-COM. In addition to developing a set of recommendations for plug load values, the report included several key recommendations paraphrased here:

- Better plug load estimates would require the use of more recent plug load data than was available at the time of the report's analysis.
- A broad RBSA-type study in California with end use metering and appliance submetering should be conducted to identify more recent and more California-specific plug load use patterns.
- More detail about miscellaneous electrical loads (MELs) is needed to understand recent changes and trends in plug load behavior and components.
- Field data should be collected on occupant use patterns that can inform appliance and MEL daily use pattern assessment.
- A more detailed analysis focused specifically on multifamily residential energy use patterns is needed. (The current data is focused on single family.)
- More data should be collected on the relationship between the number of bedrooms and the number of occupants in residential building types to better assess plug load use patterns.

Almost none of the work recommended above has been undertaken since the publication of the CASE report. However, two of the data sources (RASS and RBSA) have released new versions of their data since that time. Unfortunately, the updated RBSA study did not include appliance submetering, so no additional basis for modifications to appliance daily load shapes was provided in this study. The new RASS data results are discussed below.

Comparison of Plug Load Studies

To assess overall estimates of multifamily plug loads compared to CBECC, several data sources were compared. These included:

- CBECC
- COMNET
- RASS
- LEED for Multifamily
- RECS (U.S. Energy Information Administration, Residential Energy Consumption Survey)
- PNNL prototypes

Divergent Calculation Protocols

Comparisons among different plug load calculation protocols are made challenging by the wide variety of approaches deployed for assessing plug loads. Broadly, the approaches vary from estimates of total annual energy use for individual appliances to hourly estimates for each appliance, to total plug load power per square foot assumptions with a daily use schedule. Modifiers such as number of occupants, bedrooms, or appliance density add additional variability to the calculations. In addition, each protocol identifies a different set of appliances that make up the total appliance load, and different energy values for similar appliances, making it difficult to compare individual appliance loads independently from the full calculation.

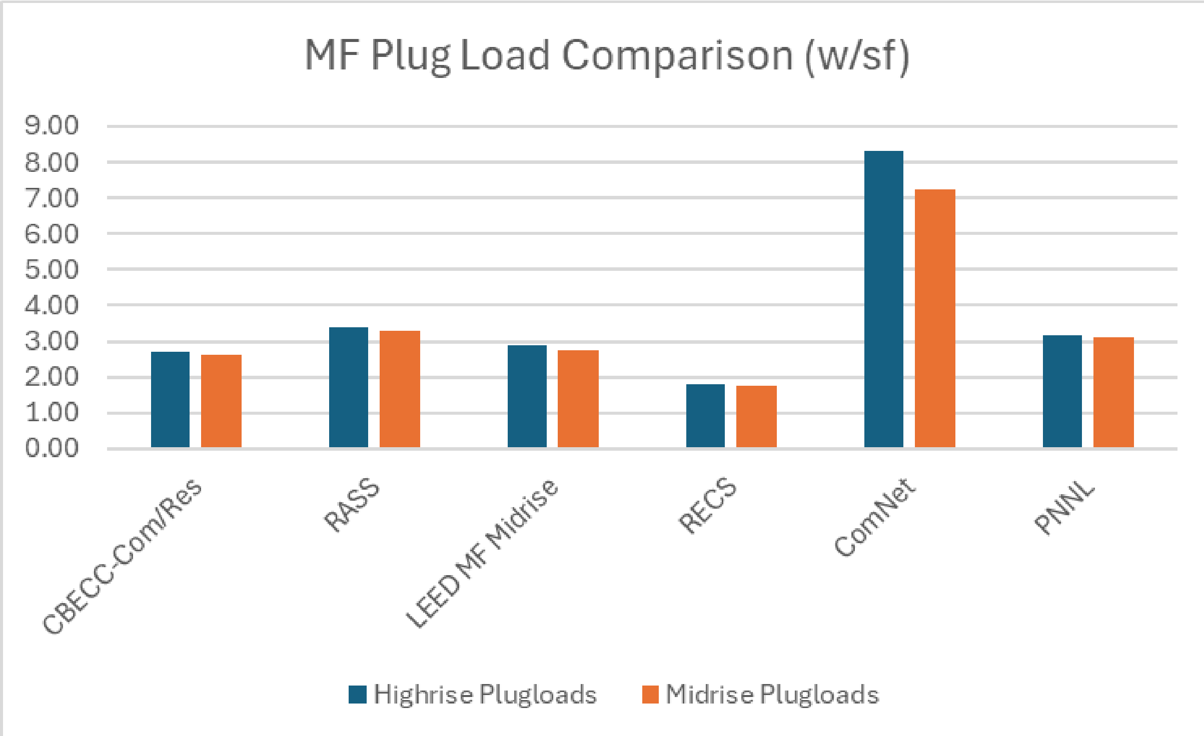
The table below shows a comparison of the different set of appliances used by different standards to develop a complete multifamily plug load estimate. (Though not shown here, note that none of the appliances indicated have the same energy use value among any of the different protocols.)

Table 21: Appliances included in various standards

	Refrigerator	Oven	Cooktop	TV	Set-top boxes	PCs	Dishwasher	Clothes Washer	Dryer	Room AC	2nd refrig	Freezer	Home office	Microwave	MEL
CBECC	■	■	■	■	■	■	■	■	■						■
RASS	■	■		■		■	■	■	■	■	■	■	■	■	■
LEED	■		■				■	■	■						■
RECS	■	■					■	■	■					■	■

To generate a rough comparison among the different approaches the plug load values for each data source were incorporated into the PNNL mid-rise and high-rise building prototypes as a way to compare the total predicted plug loads implied by each data source or standard. Because many of the protocols did not include common area plug load calculations, we excluded common areas from the analysis. All protocols were applied to both the mid-rise and high-rise prototypes, and normalized per square foot. The results of this evaluation are shown in the figure below.

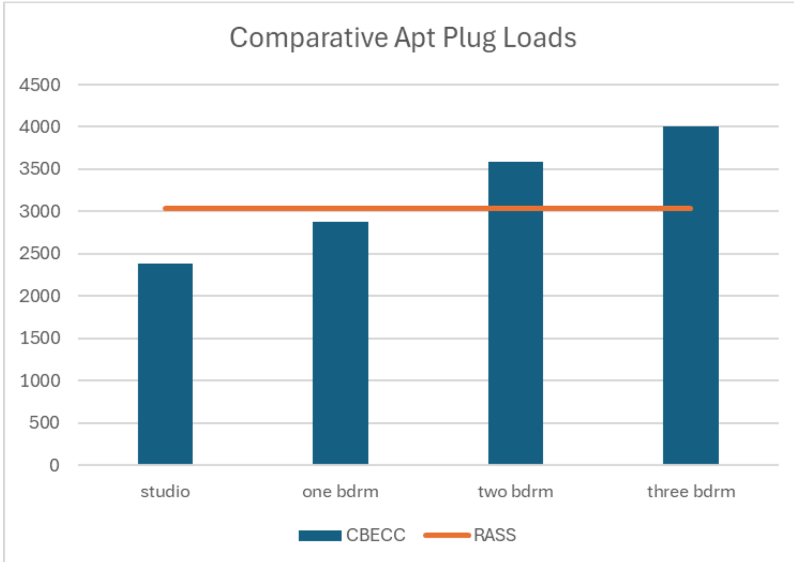
Figure 29: Comparison of plug loads from different standards applied to PNNL prototypes



The results of this comparison were highly variable and did not lead to a strong consensus on a recommended approach to plug load modifications in CBECC. (Though the COMNET data is clearly an outlier.)

It should also be noted that RASS and RECS data were gathered from single-family housing and extrapolated to multifamily installations. This adds significant uncertainty to the comparison since CBECC and LEED protocols include specific values based on number of bedrooms. This impact can be visualized in the figure below, which shows the variability of multifamily plug loads by number of bedrooms for CBECC (which accounts for number of bedrooms) and RASS (which does not). At the same time, it can be seen that the RASS data aligns well with an average of the number of bedrooms used in CBECC.

Figure 30: Comparing plug loads from RASS 2019 with CBECC by number of bedrooms



Residential Appliance Saturation Study (RASS)

The RASS study targets California residences and represents a more recent data set for this analysis. The overall trend of RASS data between the 2009 version (used in the CASE analysis) and the 2019 version of the study showed an overall 3.5% decrease in residential plug loads. This trend was identified as a key data point for recommended updates to the CBECC multifamily plug load assumptions.

Federal Appliance Standards

In CBECC two major appliances, refrigerators and dryers, represent the largest appliance loads in multifamily apartments. The efficiency of these appliances has been improving, and current federal appliance standards now show improvements of over 30% for each of these appliances compared to previous CBECC values. (see sources below) For this reason, one of the recommendations of this analysis is to reduce the anticipated load of these appliances to match current federal efficiency standards.

At the same time, various studies indicate a general increase in the range of miscellaneous appliances contributing to residential plug loads, including gaming consoles, charging devices, mobility devices (scooters, e-bikes), etc. Data on actual energy use for these devices in homes is lacking, but the trends are well-documented.

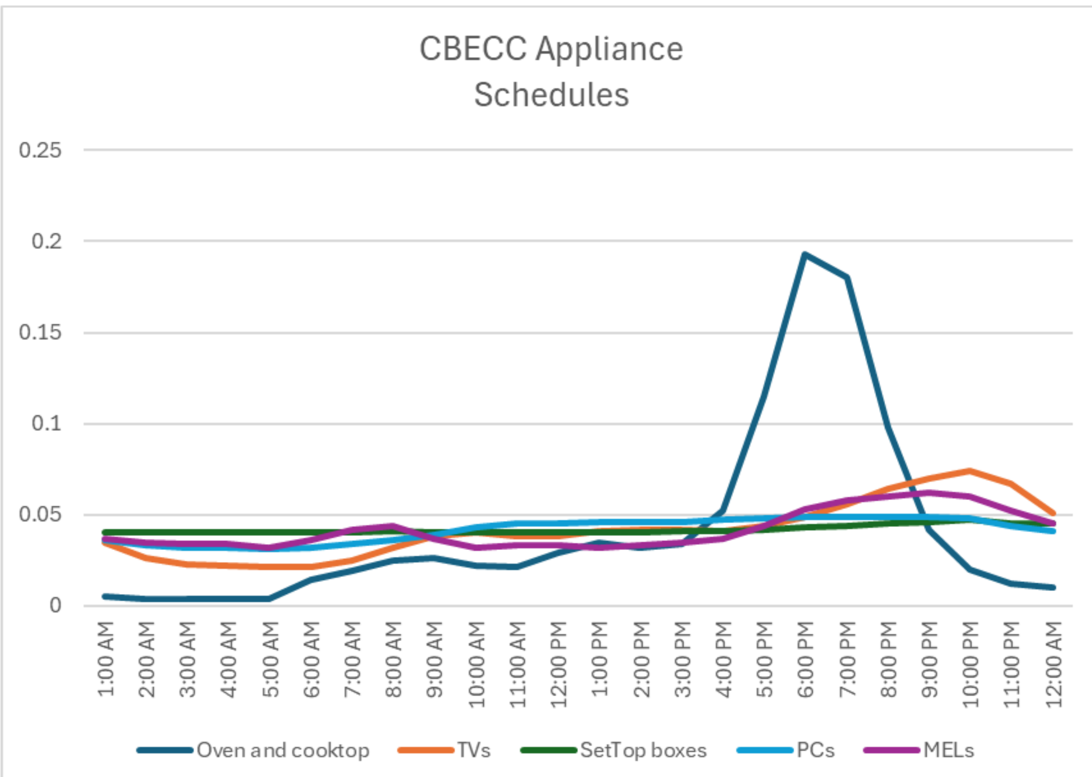
Taken together, these two trends led to the basis of the plug load changes recommended in this analysis.

Daily Load Profiles

In CBECC, daily load profiles are applied to the total energy use for each appliance to determine the daily distribution of plug load energy use. As discussed above, these load profiles were generated from metered data in two studies evaluated for the 2016 plug load analysis. Since the publication of the 2016 analysis, additional appliance load shape data has not been collected, so there is no updated data to use as a basis for proposed changes to current CBECC daily load profiles. For this reason no changes to daily load profiles are recommended by this report.

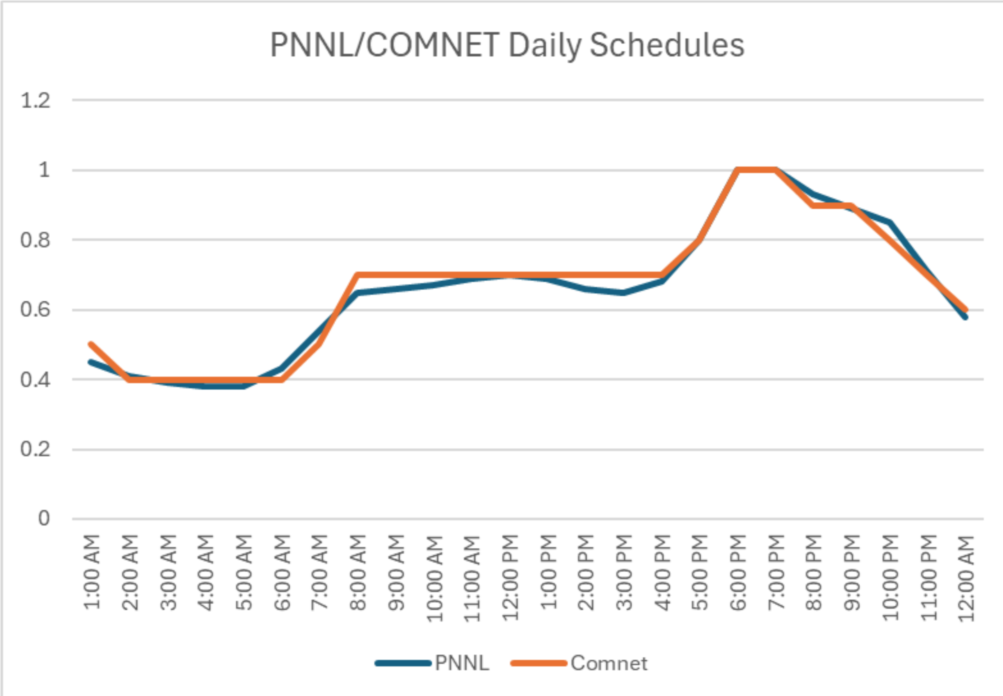
For comparison, the figure below shows the daily load profiles used for appliances by CBECC currently. Note that these profiles do not include hot water-related appliances (laundry and dishwashers) which follow the CEC hot water use schedule.

Figure 31: CBECC Appliance Daily Schedules



Two of the protocols reviewed in this analysis included a different methodology for calculating daily plug loads. The PNNL and COMNET protocols used a uniform daily load shape and an overall plug load power density to derive daily loads. The daily load shape for these two protocols is virtually identical, as shown in the figure below. This daily load profile is significantly different from the load shape used by CBECC.

Figure 32: Daily load schedules for PNNL prototypes and COMNET



The LEED, RASS, and RECS protocols did not specify daily load profiles, and instead provided an annual energy use number for each appliance without any daily/hourly modifiers.

Summary of Changes to Appliance Values

The appliance energy use valued in CBECC are located in two NRMFACM tables in Appendix E: Plug Loads and Lighting Modeling.

For most appliances, the values are in "Table 2: Algorithms for Plug Load and Lighting Annual Energy Use". This table includes a load for each appliance (titled 'intercept') and an adjustment factor (titled 'slope') that modifies the appliance energy use by the number of bedrooms. The intercept corresponds to the base appliance energy use with zero bedrooms (studio apartment) and the slope indicates a fixed rate of increase per additional bedroom.

The following values are proposed as modifications to the values currently in "Appendix E Table 2" (only modified values are shown)

End Use	Intercept (base use-0 bedrooms)	Slope (adjustment per bedroom)
Refrigerator	303 kWh	25 kWh
Set Top Boxes	Omitted	Omitted

MELs	990 kWh	346 kWh

For appliances associated with hot water use, load information is provided in "Table 4: Multi-family Dwelling Unit Algorithm for Dishwasher, Clothes Washer, and Clothes Dryer Annual Energy Use". This table includes specific annual energy use based on each possible number of bedrooms. The ratio of energy use to number of bedrooms is not linear. For these appliances, the ratio of energy use from the base case value to the value for additional bedrooms was kept constant with the ratios in the original table.

Bedrooms per Unit	Electric Clothes Dryer (kWh, Annual)
0	321
1	341
2	482
3	474
4	573
5+	521

Appendix C Sources

California Energy Commission. (2010). *Residential Appliance Saturation Study*. In *California Energy Demand 2010-2020: Adopted Forecast* (Vol. 2, pp. 2-1 to 2-50). Retrieved from https://www.energy.ca.gov/2010publications/CEC-200-2010-004/CEC-200-2010-004-V2.PDF

Rubin, E., Young, D., Hietpas, M., Zakarian, A., & Nguyen, P. (2016). *Plug Loads and Lighting Modeling*. California Statewide Codes and Standards Enhancement (CASE) Program. Retrieved from https://title24stakeholders.com/wp-content/uploads/2017/10/2016_CASE-Report_Plug-Loads-and-Lighting-Modeling.pdf.

Northwest Energy Efficiency Alliance (NEEA). (2024). *2022 Residential Building Stock Assessment - Methods Report*. Retrieved from https://neea.org/img/documents/2022-Residential-Building-Stock-Assessment-Methods-Report.pdf.

Northwest Energy Efficiency Alliance (NEEA). (2024). *2022 Residential Building Stock Assessment - Findings Report*. Retrieved from https://neea.org/img/documents/2022-Residential-Building-Stock-Assessment.pdf.

Federal Appliance Standards

- Refrigerators: https://downloads.regulations.gov/EERE-2017-BT-STD-0003-0108/content.pdf
- Clothes Dryers: https://downloads.regulations.gov/EERE-2014-BT-STD-0058-0059/content.pdf

APPENDIX D:
Energy and LSC Impact Analysis Details

This appendix contains the results of building simulation analysis quantifying the impact of the proposed EPD and schedule changes on site energy and LSC. The simulation approach is described in the section **Analysis and Comparison of Energy and LSC Impacts Between New and Previous Datasets**, along with a detailed review of the impacts on the office prototype. The results from the other prototypes are discussed below.

Impacts to the Small Hotel Prototype

The proposed changes for the hotel analysis included a new guest room plug load schedule, reverting the EPD value in guest rooms to a single value (removing the connection to the residential inputs), and adding a small refrigeration load to the guest rooms.

These proposed changes result in an increase in heating energy and decrease in cooling energy. The overall impact to LSC for regulated loads is less than 2% in CZ3, and less than 1% in CZ9 and CZ12. In this building type, the prototype analysis shows that heating measures will have a slightly larger impact, and cooling measures will have a slightly lesser impact on compliance results. The impact of other regulated end uses remains level.

Figure 33: Hotel - Impacts of Proposed Changes to LSC

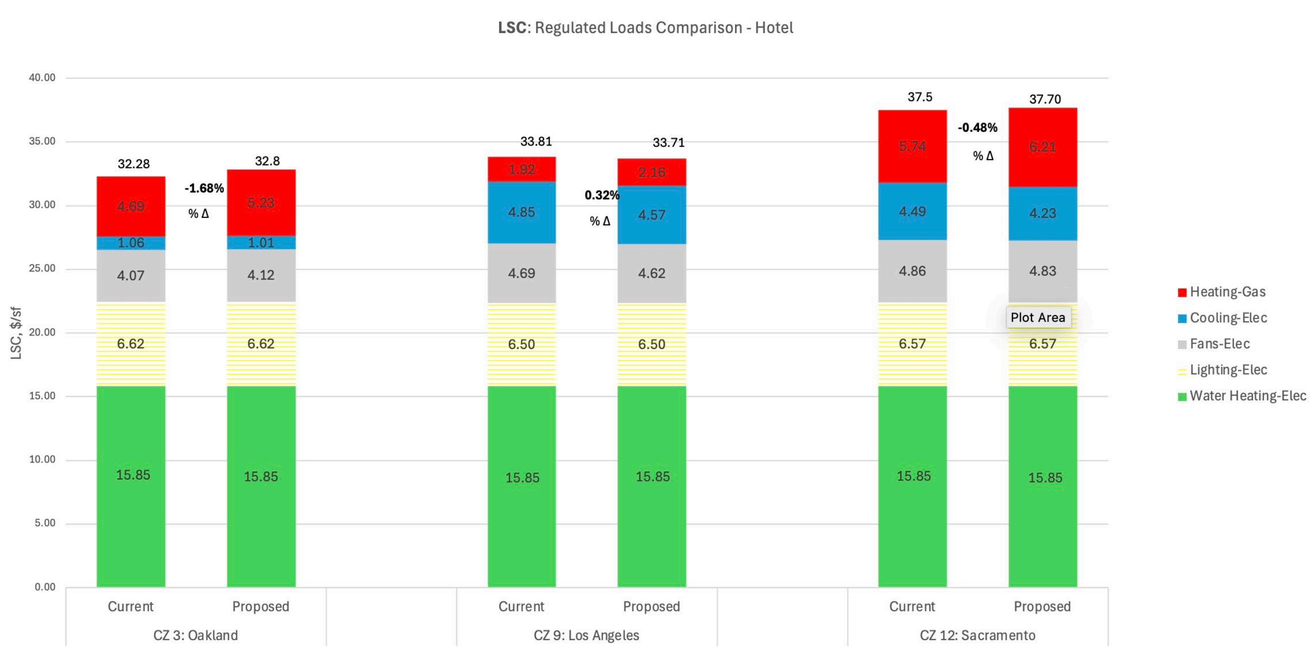
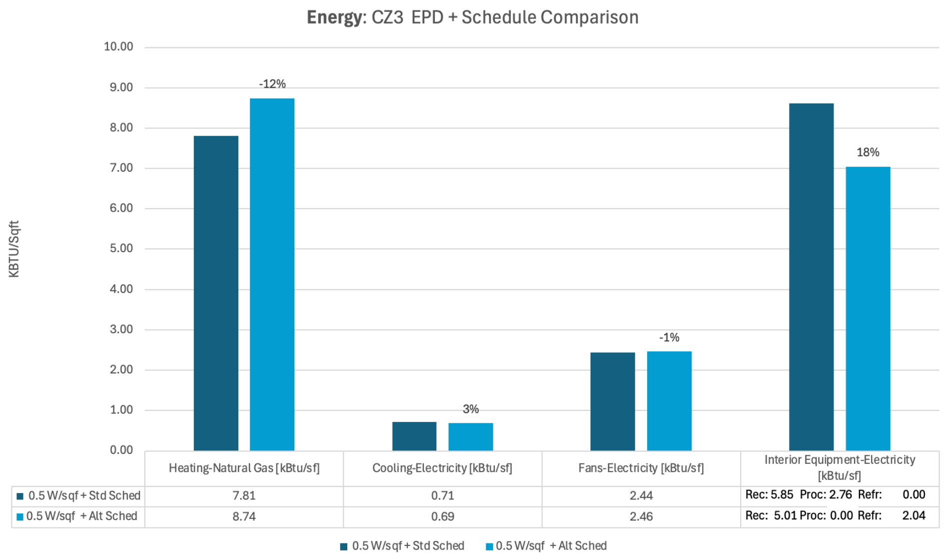


Figure 34: Hotel (CZ3) – Impact of Proposed Changes to Site Energy and LSC



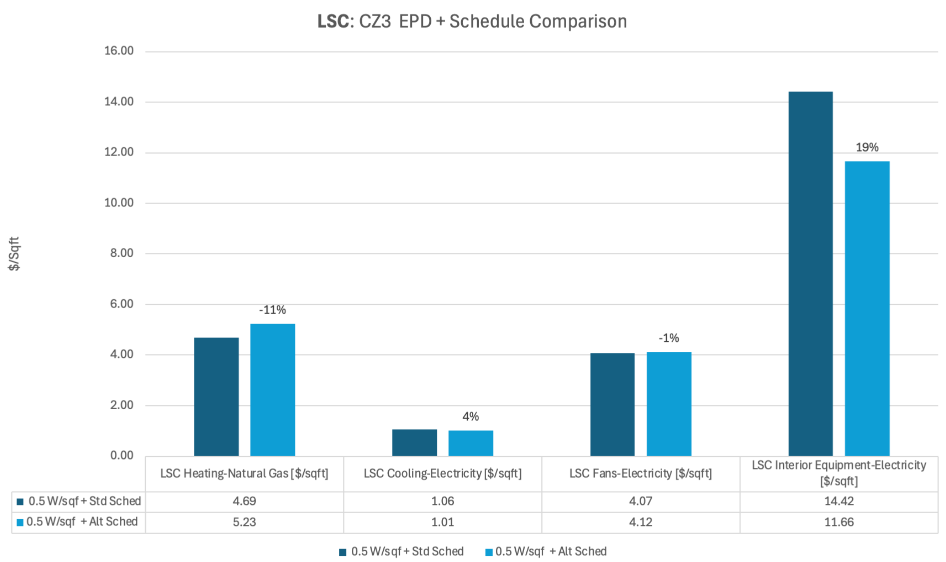
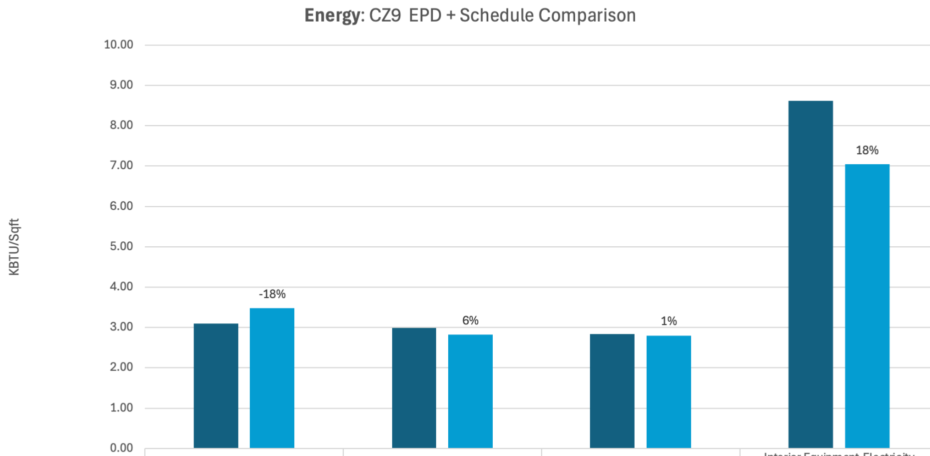
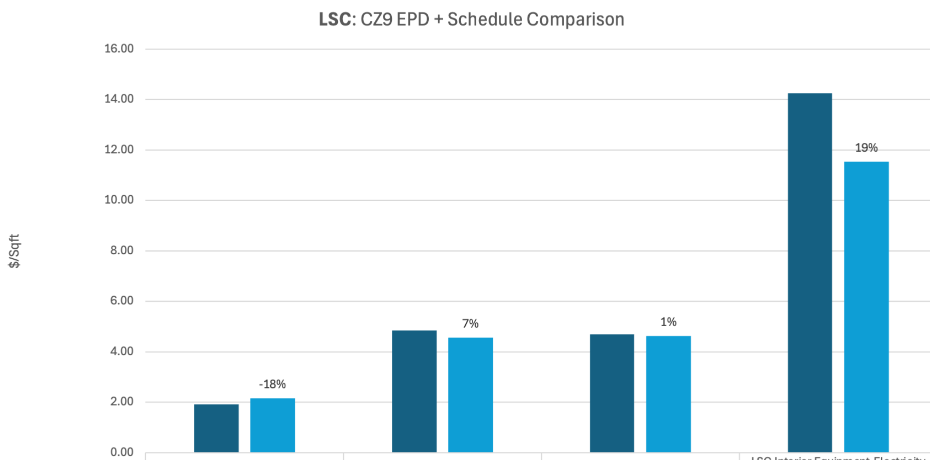


Figure 35: Hotel (CZ9) – Impact of Proposed Changes to Site Energy and LSC



	Heating-Natural Gas [kBtu/sf]	Cooling-Electricity [kBtu/sf]	Fans-Electricity [kBtu/sf]	Interior Equipment-Electricity [kBtu/sf]
0.5 W/sqf + Std Sched	3.09	2.99	2.84	Rec: 5.85 Proc: 2.76 Refr: 0.00
0.5 W/sqf + Alt Sched	3.48	2.83	2.80	Rec: 5.01 Proc: 0.00 Refr: 2.04

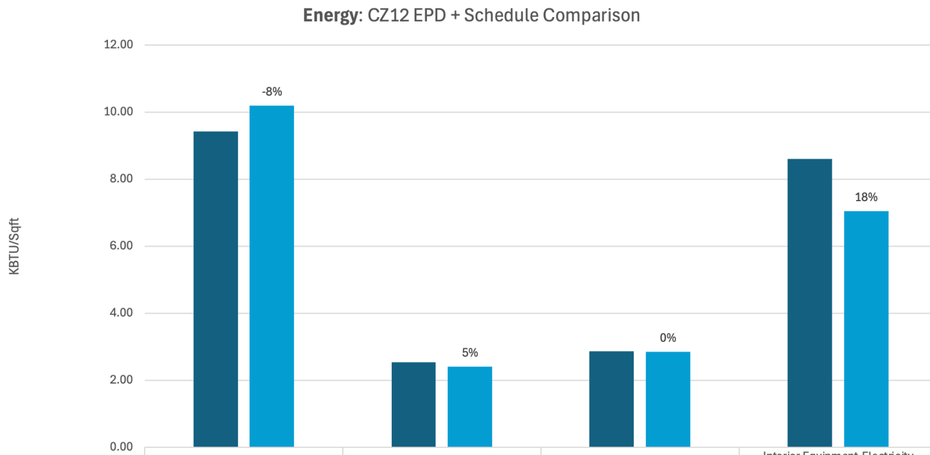
■ 0.5 W/sqf + Std Sched ■ 0.5 W/sqf + Alt Sched



	LSC Heating-Natural Gas [$/sqft]	LSC Cooling-Electricity [$/sqft]	LSC Fans-Electricity [$/sqft]	LSC Interior Equipment-Electricity [$/sqft]
0.5 W/sqf + Std Sched	1.92	4.85	4.69	14.25
0.5 W/sqf + Alt Sched	2.16	4.57	4.62	11.53

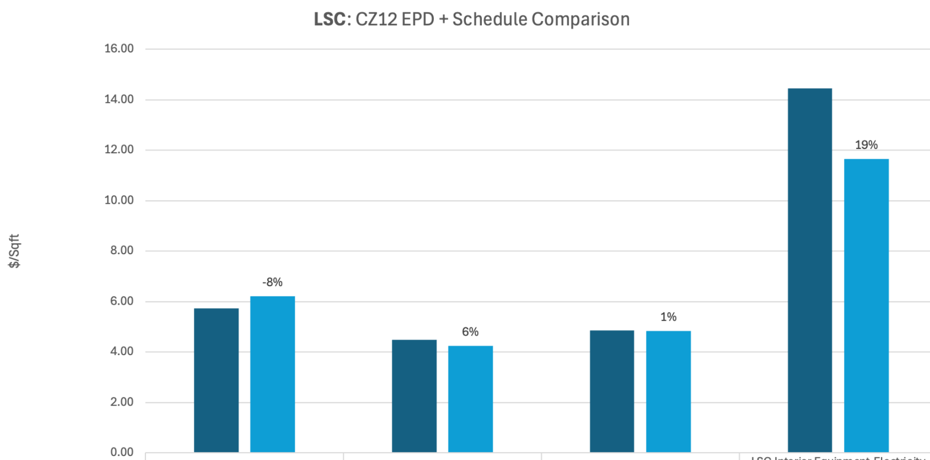
■ 0.5 W/sqf + Std Sched ■ 0.5 W/sqf + Alt Sched

Figure 36: Hotel (CZ12) – Impact of Proposed Changes to Site Energy and LSC



	Heating-Natural Gas [kBtu/sf]	Cooling-Electricity [kBtu/sf]	Fans-Electricity [kBtu/sf]	Interior Equipment-Electricity [kBtu/sf]
0.5 W/sqf + Std Sched	9.42	2.55	2.87	Rec: 5.85 Proc: 2.76 Refr: 0.00
0.5 W/sqf + Alt Sched	10.20	2.41	2.86	Rec: 5.01 Proc: 0.00 Refr: 2.04

■ 0.5 W/sqf + Std Sched ■ 0.5 W/sqf + Alt Sched



	LSC Heating-Natural Gas [$/sqft]	LSC Cooling-Electricity [$/sqft]	LSC Fans-Electricity [$/sqft]	LSC Interior Equipment-Electricity [$/sqft]
0.5 W/sqf + Std Sched	5.74	4.49	4.86	14.46
0.5 W/sqf + Alt Sched	6.21	4.23	4.83	11.66

■ 0.5 W/sqf + Std Sched ■ 0.5 W/sqf + Alt Sched

Table 22: Hotel – Impacts of Proposed Changes to LSC by End Use, Percent of Total Regulated LSC

Climate Zone	Current or Proposed	Water Heating-Elec	Lighting-Elec	Fans-Elec	Cooling-Elec	Heating-Gas	Total % Change
CZ 3: Oakland	Current	49.1%	20.5%	12.6%	3.3%	14.5%	-1.68%
CZ 3: Oakland	Proposed	48.3%	20.2%	12.5%	3.1%	15.9%	-1.68%
CZ 9: Los Angeles	Current	46.9%	19.2%	13.9%	14.4%	5.7%	0.32%
CZ 9: Los Angeles	Proposed	47.0%	19.3%	13.7%	13.5%	6.4%	0.32%
CZ 12: Sacramento	Current	42.2%	17.5%	13.0%	12.0%	15.3%	-0.48%
CZ 12: Sacramento	Proposed	42.0%	17.4%	12.8%	11.2%	16.5%	-0.48%

Impacts to the Restaurant Prototype

The proposed change to the restaurant schedule was used in the analysis to calculate the impacts on site energy and LSC. No EPD changes were proposed for the kitchen/food prep area. Changes are proposed to the calculation approach for kitchen equipment loads in the compliance software, but not a specific wattage value. Therefore, the analysis below only accounts for changes to the restaurant schedule.

The analysis shows that the proposed change does not lead to significant impacts on compliance results for the restaurant prototype with the change in total regulated LSC less than 1% in each climate zone. The relative importance of each regulated end use does not change significantly – cooling LSC as a percentage of total LSC increases by a fraction of a percent while heating decreases by a fraction of a percent.

Figure 37: Restaurant - Impacts of Proposed Changes to LSC

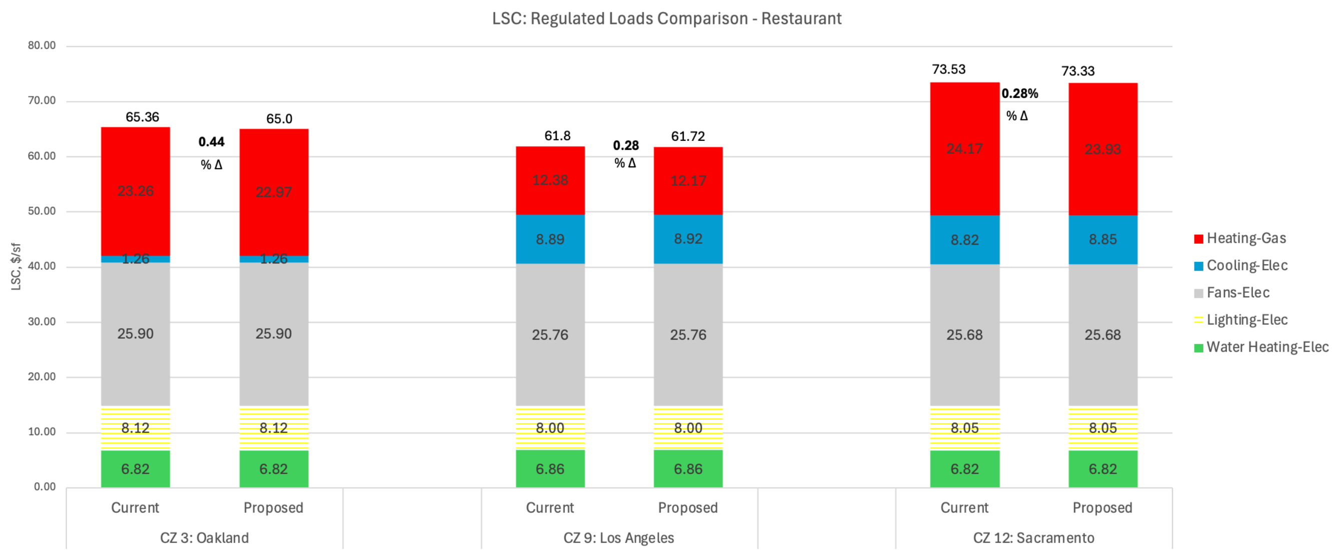
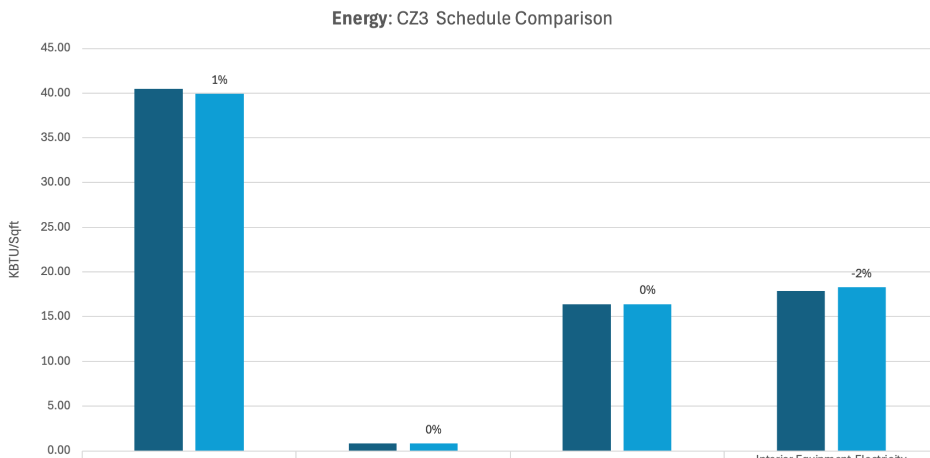
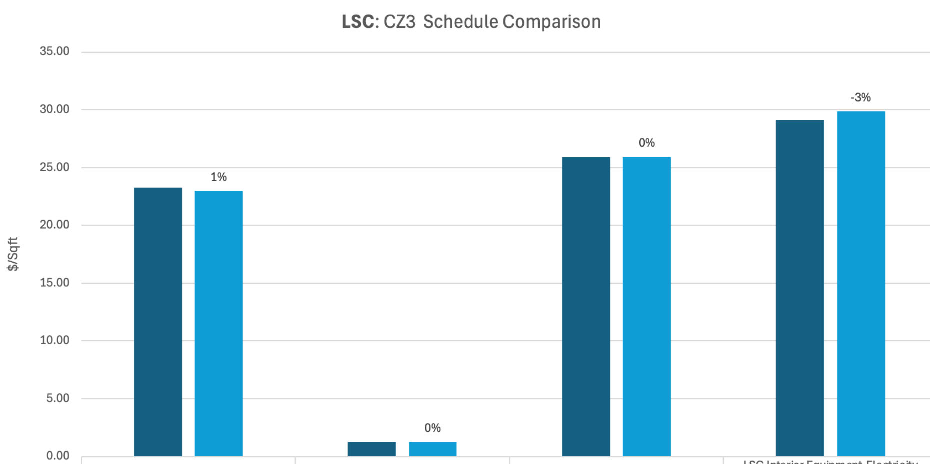


Figure 38: Restaurant (CZ3) – Impact of Proposed Changes to Site Energy and LSC



	Heating-Natural Gas [kBtu/sf]	Cooling-Electricity [kBtu/sf]	Fans-Electricity [kBtu/sf]	Interior Equipment-Electricity [kBtu/sf]
Std Sched	40.46	0.81	16.40	17.84
Alt Sched	39.93	0.80	16.40	18.28

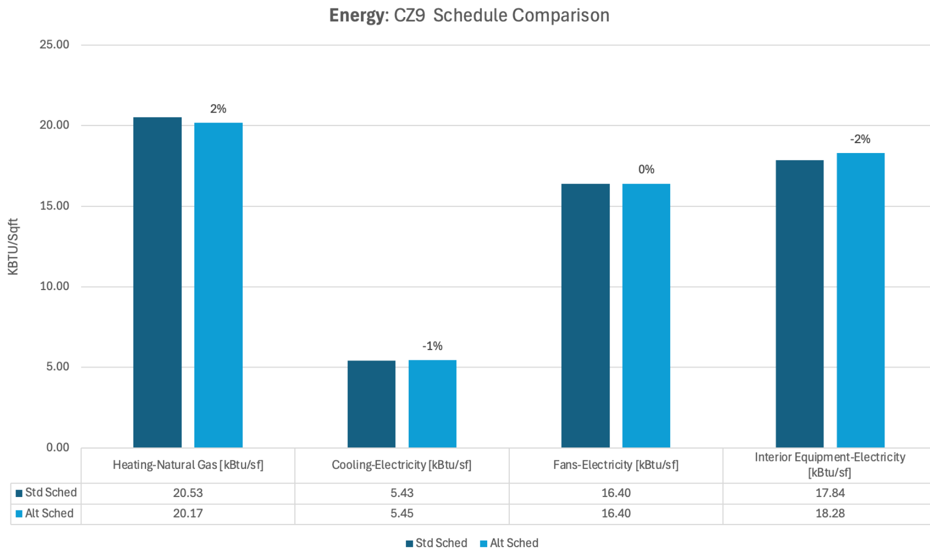
■ Std Sched ■ Alt Sched



	LSC Heating-Natural Gas [$/sqft]	LSC Cooling-Electricity [$/sqft]	LSC Fans-Electricity [$/sqft]	LSC Interior Equipment-Electricity [$/sqft]
Std Sched	23.26	1.26	25.90	29.09
Alt Sched	22.97	1.26	25.90	29.85

■ Std Sched ■ Alt Sched

Figure 39: Restaurant (CZ9) – Impact of Proposed Changes to Site Energy and LSC



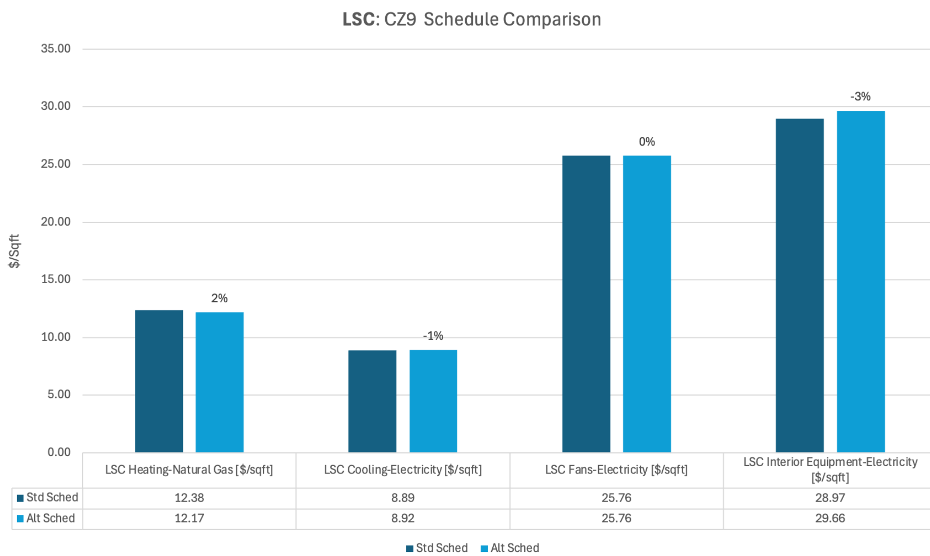
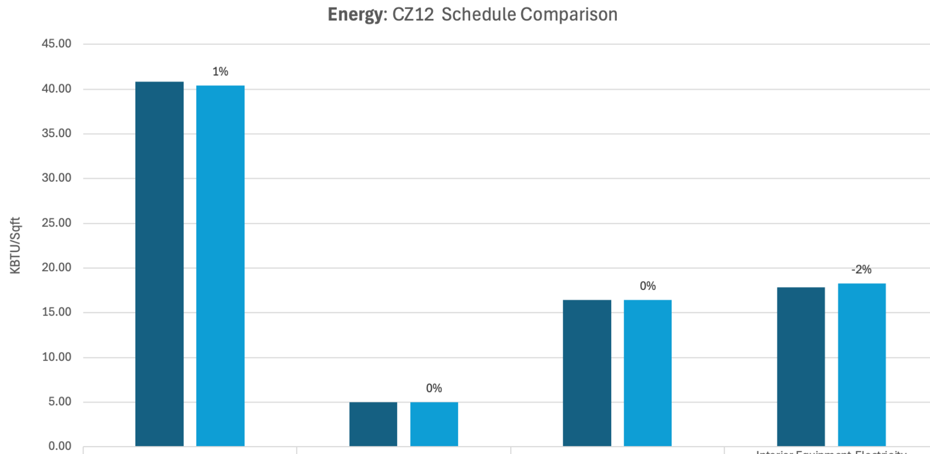
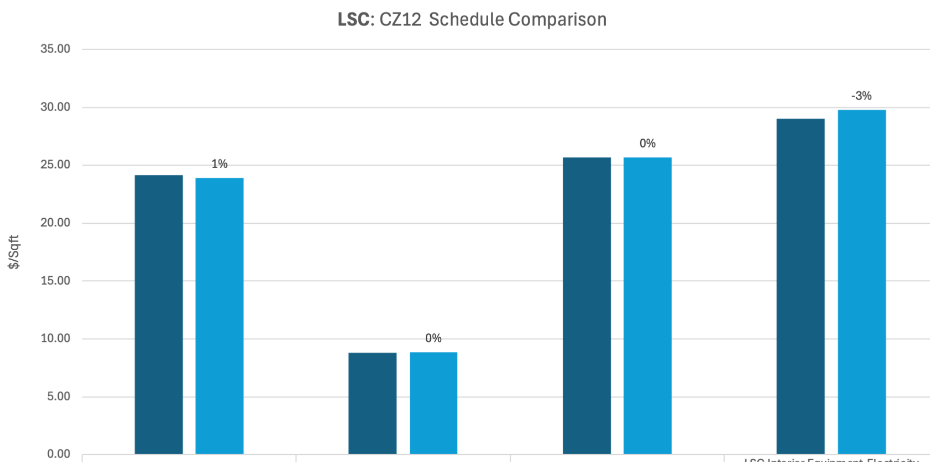


Figure 40: Restaurant (CZ12) – Impact of Proposed Changes to Site Energy and LSC



	Heating-Natural Gas [kBtu/sf]	Cooling-Electricity [kBtu/sf]	Fans-Electricity [kBtu/sf]	Interior Equipment-Electricity [kBtu/sf]
Std Sched	40.84	4.96	16.40	17.84
Alt Sched	40.40	4.97	16.40	18.28

■ Std Sched ■ Alt Sched



	LSC Heating-Natural Gas [$/sqft]	LSC Cooling-Electricity [$/sqft]	LSC Fans-Electricity [$/sqft]	LSC Interior Equipment-Electricity [$/sqft]
Std Sched	24.17	8.82	25.68	29.04
Alt Sched	23.93	8.85	25.68	29.79

■ Std Sched ■ Alt Sched

Table 23: Restaurant – Impacts of Proposed Changes to LSC by End Use, Percentage of Total Regulated LSC

Climate Zone	Current or Proposed	Water Heating-Elec	Lighting-Elec	Fans-Elec	Cooling-Elec	Heating-Gas	Total % Change
CZ 3: Oakland	Current	10.4%	12.4%	39.6%	1.9%	35.6%	0.44%
CZ 3: Oakland	Proposed	10.5%	12.5%	39.8%	1.9%	35.3%	0.44%
CZ 9: Los Angeles	Current	11.1%	12.9%	41.6%	14.4%	20.0%	0.28%
CZ 9: Los Angeles	Proposed	11.1%	13.0%	41.7%	14.5%	19.7%	0.28%
CZ 12: Sacramento	Current	9.3%	10.9%	34.9%	12.0%	32.9%	0.28%
CZ 12: Sacramento	Proposed	9.3%	11.0%	35.0%	12.1%	32.6%	0.28%

Impacts to the Retail Prototype

The proposed changes to the retail schedule and retail sales area EPD were used in the analysis to calculate the impacts on energy and LSC. As discussed in previous sections of this report, the proposed schedule changes have a higher load fraction during unoccupied periods, and the EPD is proposed to be reduced. The retail prototype does not include refrigerated sales area, so the analysis below represents the performance of a non-grocery retail store.

The analysis shows that the proposed changes do not lead to significant impacts on compliance results for the retail prototype with the change in total regulated LSC less than 1% in CZ 3 and CZ12. The proposed changes in CZ9 result in a decrease of approximately 4% LSC.

The relative importance of each regulated end use changes by a small margin – cooling LSC as a percentage of total LSC decreases by approximately 2% percent while heating increases by the same amount.

Figure 41: Retail - Impacts of Proposed Changes to LSC

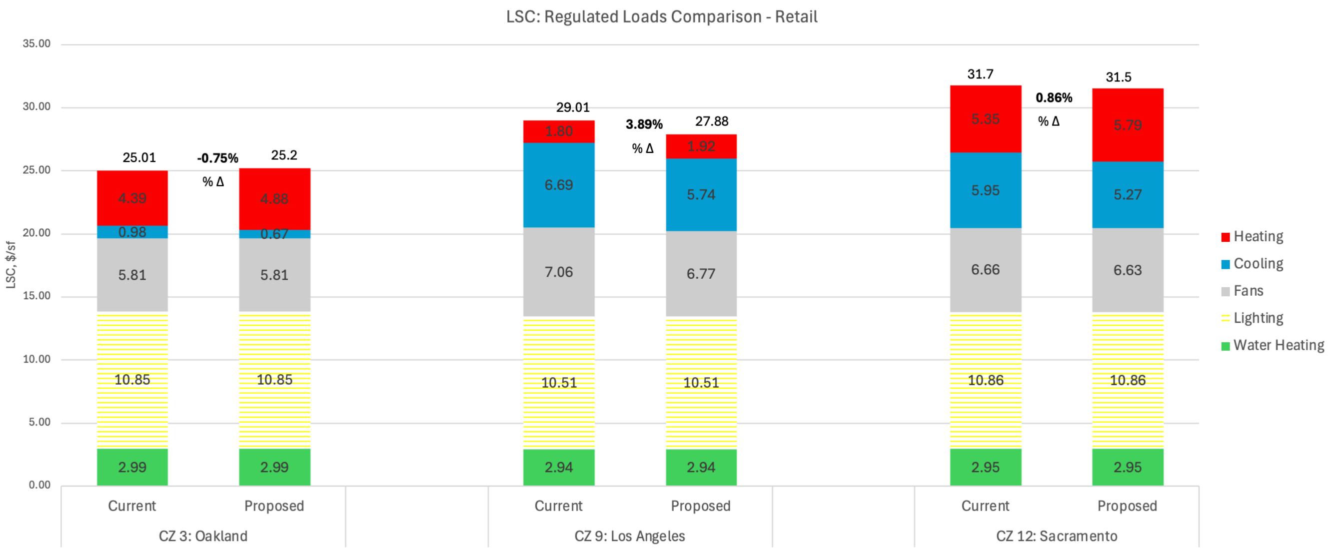
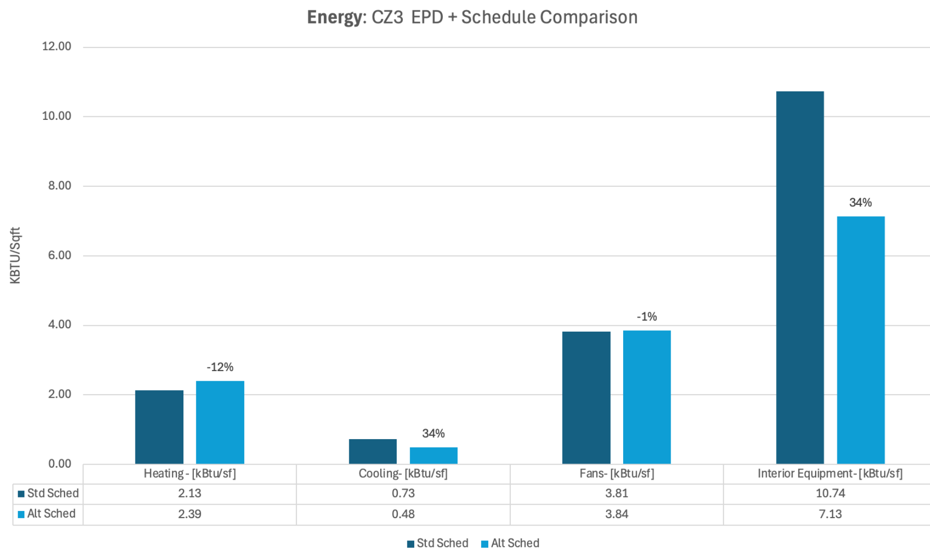
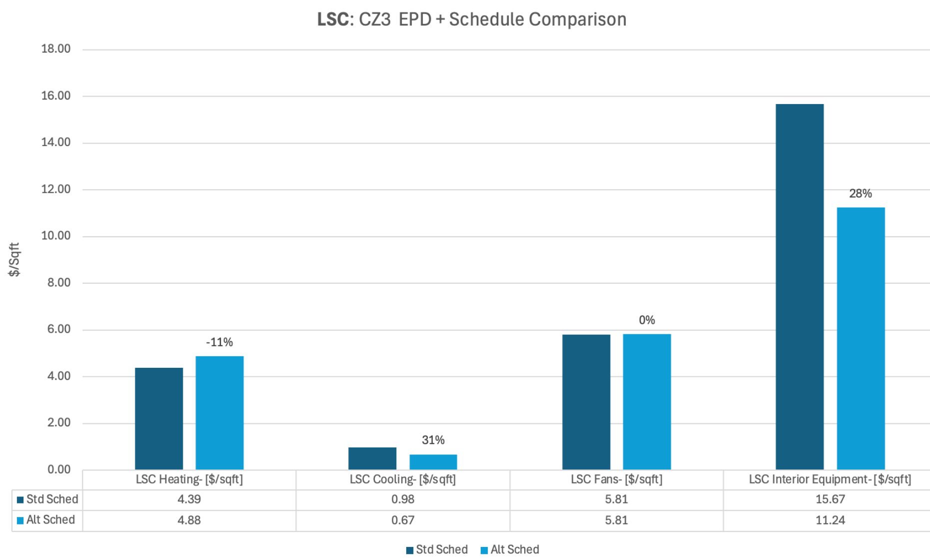


Figure 42: Retail (CZ3) – Impact of Proposed Changes to Site Energy and LSC

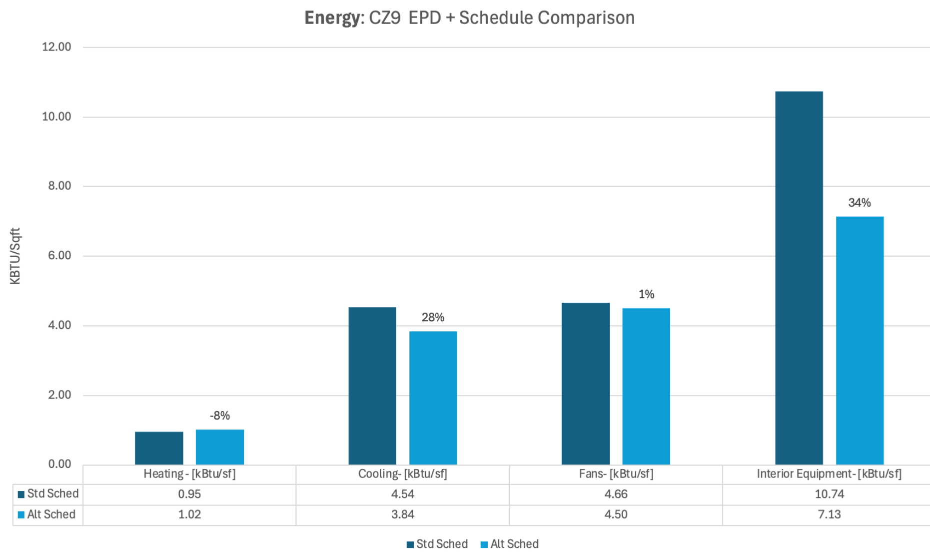


	Heating - [kBtu/sf]	Cooling- [kBtu/sf]	Fans- [kBtu/sf]	Interior Equipment- [kBtu/sf]
Std Sched	2.13	0.73	3.81	10.74
Alt Sched	2.39	0.48	3.84	7.13



	LSC Heating- [$/sqft]	LSC Cooling- [$/sqft]	LSC Fans- [$/sqft]	LSC Interior Equipment- [$/sqft]
Std Sched	4.39	0.98	5.81	15.67
Alt Sched	4.88	0.67	5.81	11.24

Figure 43: Retail (CZ9) – Impact of Proposed Changes to Site Energy and LSC



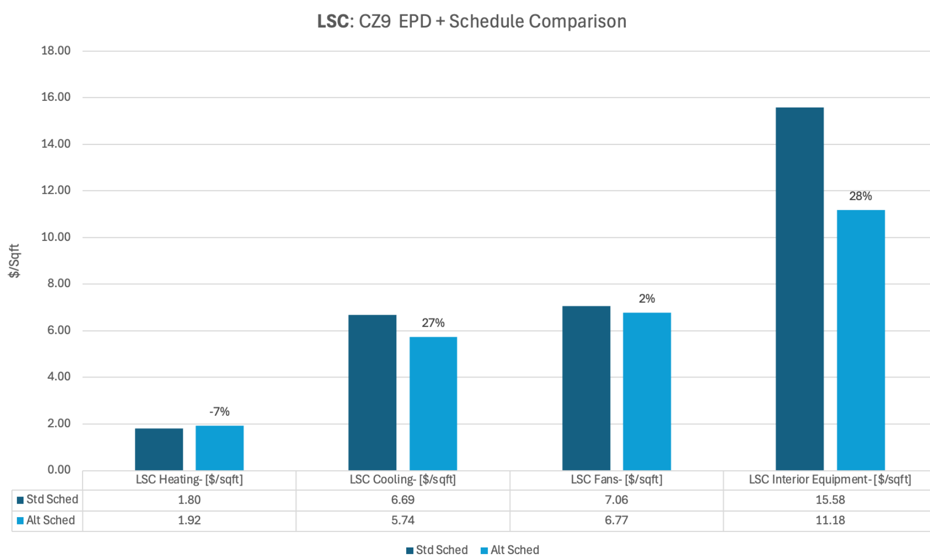
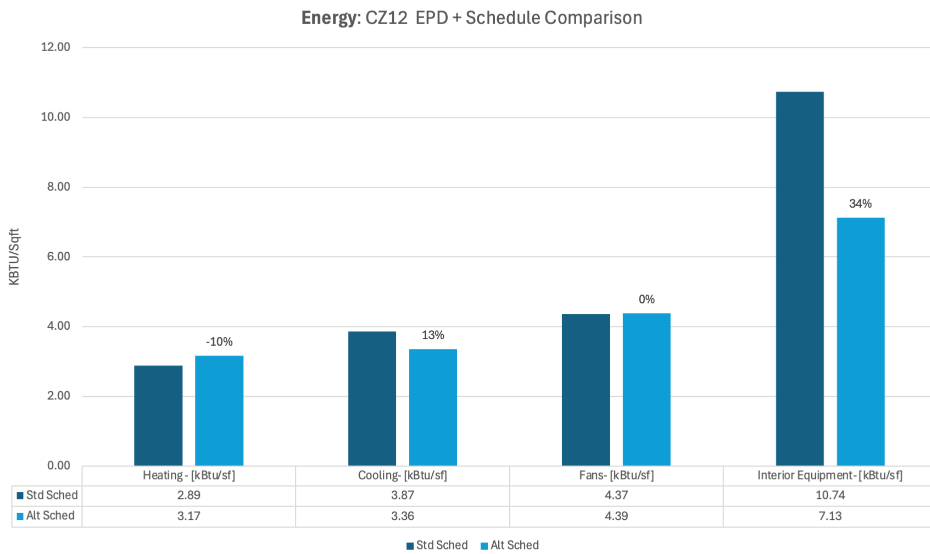
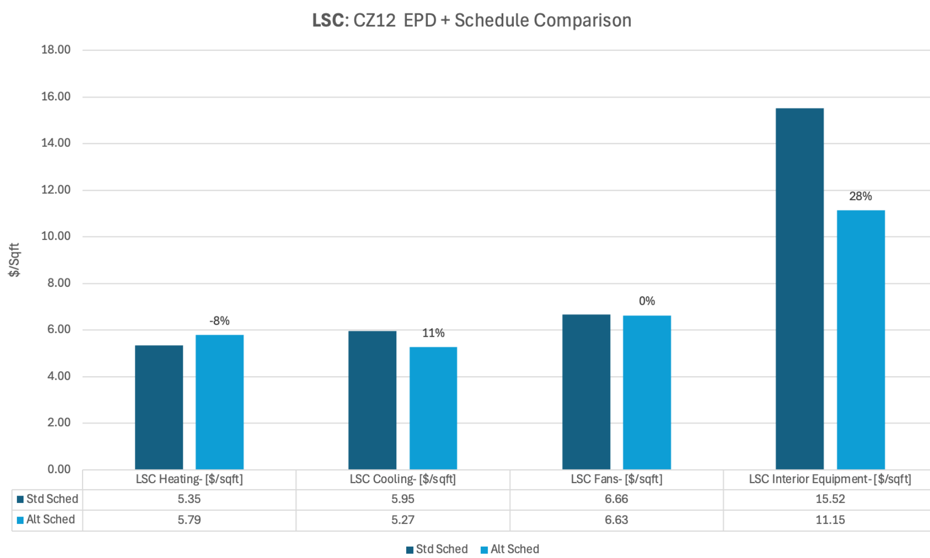


Figure 44: Retail (CZ12) – Impact of Proposed Changes to Site Energy and LSC



	Heating - [kBtu/sf]	Cooling- [kBtu/sf]	Fans- [kBtu/sf]	Interior Equipment- [kBtu/sf]
Std Sched	2.89	3.87	4.37	10.74
Alt Sched	3.17	3.36	4.39	7.13



	LSC Heating- [$/sqft]	LSC Cooling- [$/sqft]	LSC Fans- [$/sqft]	LSC Interior Equipment- [$/sqft]
Std Sched	5.35	5.95	6.66	15.52
Alt Sched	5.79	5.27	6.63	11.15

Table 24: Retail – Impacts of Proposed Changes to LSC by End Use, Percent of Total Regulated LSC

Climate Zone	Current or Proposed	Water Heating -Elec	Lighting -Elec	Fans- Elec	Cooling -Elec	Heating -Gas	Total % Change
CZ 3: Oakland	Current	11.9%	43.4%	23.2%	3.9%	17.5%	-0.75%
CZ 3: Oakland	Proposed	11.9%	43.0%	23.1%	2.7%	19.4%	-0.75%
CZ 9: Los Angeles	Current	10.2%	36.2%	24.4%	23.1%	6.2%	3.89%
CZ 9: Los Angeles	Proposed	10.6%	37.7%	24.3%	20.6%	6.9%	3.89%
CZ 12: Sacramento	Current	9.3%	34.2%	21.0%	18.7%	16.8%	0.86%
CZ 12: Sacramento	Proposed	9.4%	34.5%	21.1%	16.7%	18.4%	0.86%

Impacts to the Warehouse Prototype

Analysis of the warehouse prototype was still under development at the time of writing this report.

Impacts to the Mid-rise Multifamily Prototype

Analysis of the mid-rise multifamily prototype was still under development at the time of writing this report.