
# Analysis of 2008 Title 24 Nonresidential Compliance Site Audits

Final Report

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# Executive Summary

## Background

This report describes a study for Southern California Edison (SCE), Pacific Gas & Electric (PG&E), Southern California Gas (SCG), and San Diego Gas & Electric (SDG&E) that builds on the earlier 2008 Title 24 evaluation and answers a number of research questions about measure-level compliance with Title 24. Cadmus previously evaluated electric and gas savings associated with 2008 Title 24 for the impact evaluation of the California investor-owned utilities (IOUs) Codes and Standards Program for program years 2010 through 2012. We collected detailed building characteristics data for 91 new commercial buildings following ASHRAE Level II audit guidelines. We focused data collection particularly on building measures covered by Title 24 that were expected, based on initial savings analyses, to have the highest impact on energy savings. These high-impact measures included lighting, sky-lighting, side-lighting, envelope insulation (mainly roof/attic insulation), cool roofs, HVAC efficiency, and direct digital control (DDC) to zone ventilation.

## Objectives

SCE developed a number of research questions based on the results of Cadmus' 2010-2012 program evaluation. While for the previous evaluation Cadmus addressed the impacts of the 2008 Title 24, for this study we investigated which building measures and other factors affected the degree of Title 24 compliance observed in the buildings included in the previous evaluation. The primary research questions are:

- What are the customer and commercial building characteristics of compliant versus non-compliant sampled buildings?
- What are the reasons some customers significantly exceeded new code requirements? For this question, Cadmus sought specific information about how the customer over-complied (e.g., use of LEDs, lower lighting power density through increased task lighting).

## Approach

To meet the objectives of this study, Cadmus performed the following key tasks:

- Identified and reviewed relevant literature on code compliance decision-making processes for commercial buildings
- Analyzed energy code compliance results for a sample of commercial buildings studied in 2010-2012 Codes and Standards Program evaluation
- Interviewed key decision-makers involved in commercial building energy efficiency and code compliance choices

## Summary of Findings

Interior lighting tended to over-comply when LED lighting was installed. Envelope tended to over-comply when continuous insulation was installed. Cool roof tended to over-comply when higher values were specified for aged solar reflectance (generally around 0.55 – 0.65) and emittance (generally around 0.75 – 0.88). HVAC efficiency tended to over-comply due to high-efficiency heat pumps, high-efficiency packaged variable air volume (VAV) systems, high-efficiency ductless mini-split systems, and fault detection and diagnostic credit.

Building type was the only significant driver of whole-building over-compliance. The following buildings may be good candidates to increase compliance overall:

- Auto care/maintenance
- Gas stations
- Research and laboratories
- Restaurants

Building type was the only characteristic driving over-compliance for interior lighting. The following buildings may present opportunities for increasing lighting compliance:

- Auto care/maintenance
- Gas stations
- High-bay or industrial
- Medical buildings
- Multifamily/group living
- Research and laboratories
- Restaurants

Envelope measures in the following building types tended to be under-compliant in terms of electricity:

- Gas stations
- Restaurants

Cool roof measures tended to over-comply.

HVAC efficiency tended to over-comply in terms of electricity compared to prescriptive requirements. We found that building type was the only characteristic that was associated with driving HVAC efficiency over-compliance. Of the 14 building types in the sample, all except auto care/maintenance buildings were associated with HVAC efficiency electricity over-compliance.

We found interior lighting, HVAC efficiency, and whole-building compliance to be highly correlated, implying that interior lighting and HVAC efficiency compliance are driving factors of whole-building electric compliance trends.

The interviewed individuals agreed that Title 24 HVAC system efficiency requirements are generally at the level that market practices will bear, while lighting requirements are less efficient than common market practice, given the affordability of LED lighting.

Although the owner has significant influence on the level of compliance with Title 24, building design professionals (architects, engineers, and Title 24 consultants) are the most important stakeholders in ensuring that the code requirements are explicitly addressed.

### *Recommendations*

Based on our findings from the literature review, data analysis and phone interviews, Cadmus suggests that the IOU program administrators consider the following recommendations.

Cadmus was unable to analyze electric and gas savings for certain measures due to insufficient data. Updating the sampling design to account for measures such as sky-lighting and side-lighting or DDC to zone, could increase sample sizes and improve analyses for these types of measures.

The greatest impact for improvement of electricity under-compliance can be obtained by directing efforts towards improving overall codes and standards compliance in gas station and restaurant building types. Additionally, classroom buildings, high-bay and industrial, medical buildings, multifamily/group living, museums, office buildings, and retail building types are also contributing to under-compliance of envelope performance; therefore, improving envelope compliance margins in these building types will improve electricity compliance margins and energy savings.

Establishing an energy performance target early in a project timeline is key to ensuring that the building performs well compared to Title 24. In general, the key stakeholder in establishing an early target is the owner or the owner/developer, although the occupants and the design professionals can also have a significant influence on those targets. We recommend engaging building owners early in a project timeline to help influence and improve compliance.

We recommend additional interviews with acceptance testing professionals on the specific issues they encounter, how they could be prevented, and how they are resolved. Contractors who are certified Mechanical or Lighting Acceptance Test Technicians would be a great resource while investigating this topic as they can provide an essential role in identifying noncompliance issues during the acceptance tests.

The energy analyst is another stakeholder who can provide an essential role in identifying noncompliance issues and helping to improve compliance. The energy analyst could be the design engineer, architect, or a third-party energy consultant. The California Association of Building Energy Consultants (CABEC) manages the Certified Energy Analyst (CEA) program. As part of a long-term goal for improving Title 24 compliance for the entire state, the IOU administrators might consider developing an incentive program that encourages or requires CEA involvement on new construction projects.

# Study Objectives and Background

## Objectives

Cadmus performed a study for the California investor owned utilities (IOUs) [Southern California Edison (SCE), Pacific Gas & Electric (PG&E), Southern California Gas (SCG), and San Diego Gas & Electric (SDG&E)] to answer a number of research questions about measure-level compliance with Title 24, California's building energy efficiency standards. SCE developed these questions based on the results of Cadmus' impact evaluation of the California investor-owned utilities (IOUs) Codes and Standards Program for program years 2010 through 2012. While for the previous evaluation Cadmus addressed the impacts of the 2008 Title 24, for this study we investigated which building measures and other factors affected the degree of Title 24 compliance observed in the buildings included in the previous evaluation.

The research questions to answer the study objectives and guide the research approach were:

- Primary research questions:
- What are the customer and commercial building characteristics of compliant versus non-compliant sampled buildings?
- What are the reasons some customers significantly exceeded new code requirements? For this question, Cadmus sought specific information about how the customer over-complied (e.g., use of LEDs, lower lighting power density through increased task lighting).
- Secondary research questions:
- Are there subgroups within the sample that had particular characteristics that led to over- or under-compliance?
- Are a few sample points driving the majority of over-compliance?
- Are there continued pockets of under-compliance for certain measures?
- Are a few sample points driving the majority of under-compliance? If so, what measures in which types of commercial buildings are causing the most effect?
- Is there any locational correlation with under- or over-compliance? If so, what regions or utility service territories tend to over- or under-comply?
- Was there under- or over-compliance with mandatory requirements?
    - In instances of under-compliance, how would overall compliance results change if mandatory requirements were fully complied with?

## Background

### Overview of Evaluation Approach

For the 2010-2012 program evaluation, Cadmus evaluated electric and gas savings associated with 2008 Title 24. We collected detailed building characteristics data for 91 new commercial buildings following ASHRAE Level II audit guidelines. We focused data collection particularly on building measures covered by Title 24 that were expected, based on initial savings analyses, to have the highest impact on energy savings. These high-impact measures included lighting, sky-lighting, side-lighting, envelope insulation (mainly roof/attic insulation), cool roofs, HVAC efficiency, and direct digital control (DDC) to zone ventilation.

Cadmus selected the buildings we analyzed in this study to represent the population of new buildings throughout California. The sample of 91 new commercial buildings in California was distributed as shown in Figure 1. We defined four distinct climate zones for this project, which are shown on the map.[1]

**Figure 1. Distribution of New Construction Sites Analyzed**


We created building energy simulations for each site and designed and performed automated parametric runs that compared the building as-built to the same building if built to just meet the 2008 Title 24.[2] Cadmus performed these analyses using a customized version of EnergyPro developed by EnergySoft for this project.

1 The four climate zones do not directly map to the 16 CEC climate zones. They are intended to generally represent the north and central coast, south coast, inland and Central Valley, and the southern desert areas.

2 For the impact evaluation, we also analyzed the building assuming it was built to meet the 2005 Title 24, but that analysis is not essential here (and therefore not included).

Compliance with code can be achieved and assessed in two basic ways: with reference to prescriptive requirements or based on energy consumption performance. For the prescriptive method, a yes/no value is assigned for a measure as installed. This method allows for a maximum value of 1.0 for full compliance and less than 1.0 for a proportion of complying measures. Alternatively, compliance can be based on the energy performance of a measure or group of measures.

Because the objective of this study was to assess energy impacts of over- and under-compliance, we used a compliance metric based on energy performance. This method allowed Cadmus to compare the energy consumption of a measure, set of measures, or whole building as-built to its energy consumption if it was to just meet the code. One way to present code compliance findings based on energy consumption is the energy compliance margin (eCM),[3] which is defined as:

**Equation 1**

$$Energy\ compliance\ margin = \frac{(Code\_compliant\ consumption - As\_built\ consumption)}{Code\_compliant\ consumption}$$

Where:

| | | |
|---|---|---|
| Code_compliant consumption | = | Energy consumption of measure or building that just meets code |
| As_built consumption | = | Energy consumption of measure or building as-built |

The eCM can be expressed as a fraction or percentage. For a measure or building that is more efficient than required by the code, the value is positive and the size of the value indicates how much better the efficiency is than code requires. If the measure or building is less efficient than the code requires, the eCM is negative.

If we define the energy compliance ratio (ECR) as one plus the eCM, then measures or buildings that are more efficient than code requires will have an ECR greater than one, and those that are less efficient than code requires will have an ECR less than one.

This report provides both building-level and measure-level results using energy consumption metrics. Whether the building took the performance-based path or prescriptive path to demonstrate compliance, we report measure-level savings relative to the prescriptive requirement for the measure. The prescriptive requirement provides a common reference point regardless of which compliance approach was taken. In the case of performance-based compliance, the efficiency of many measures can be traded off, and therefore there is no fixed minimum requirement they must meet.

We note that some of the high-impact measures in this report were also mandatory measures. Mandatory measures are those for which Title 24 establishes minimum efficiency requirements that

[3] We use the acronym eCM to avoid confusion with the usual use of ECM to designate energy conservation measure.

must be met regardless of whether a building complies with the code using a prescriptive or performance-based approach. In the case of a building using either the performance or prescriptive compliance approach, it is possible that our analysis would categorize a measure as under-complying if it just met the mandatory efficiency level and the prescriptive level were more efficient.[4]

## Summary of Evaluation Findings

For the 91 commercial buildings we analyzed, the simulation models comparing the high-impact measure performance led to the energy consumption values shown in Table 1. The table shows a comparison of the estimated total as-built energy consumption for all the buildings combined to the consumption of the buildings if the high impact measures had just met 2008 Title 24. For electricity, electricity demand, and natural gas (therms), the total as-built values were all less than the values required to just meet Title 24. The aggregated eCMs shown in the last column indicate that the energy savings ranged from 1% to 14% across this sample of buildings, depending on the energy consumption metric.

**Table 1. Performance-Based Compliance Results**

| Category | Type | Energy Consumption | | eCM |
|---|---|---|---|---|
| | | 2008 Code | As-Built | |
| Nonresidential New Construction (91 sites) | kWh | 22,847,342 | 19,886,535 | 13% |
| | kW* | 6,838 | 5,865 | 14% |
| | Therms | 193,601 | 191,551 | 1% |

* Cadmus calculate this demand based on the California Public Utility Commission (CPUC) definition.

Overall, at the measure level, the sampled new commercial buildings realized electricity savings across all measures except for envelope, as shown in Table 2. Based on the site data, interior lighting was responsible for 81% of all energy savings, followed by HVAC efficiency measures (14%) and cool roofs (6%). The building envelope measure was unique because, aggregated across all sites, envelopes were slightly less efficient than the 2008 Title 24 requirement.

4 We note that the compliance simulation software does not model some mandatory requirements, based on the assumption that the impact will be neutral or dependent on occupant behavior. The effect of occupancy sensors, for example, depends on the occupancy schedule, but the simulation assumes lighting is on during occupied periods. The model does not include the effect of such sensors in the baseline or as-built simulations.

**Table 2. New Construction Electric Savings by Measure Type**

| Measure | kWh Savings Relative to 2008 Title 24 |
|---|---|
| Sky-Lighting/Side-Lighting | 11,368 |
| Interior Lighting | 2,399,327 |
| Envelope | -35,945 |
| Cool Roof | 176,463 |
| DDC to Region | 832 |
| HVAC Efficiency | 408,762 |
| **Total** | **2,960,807** |

Cadmus found that 82 of the 91 buildings complied with the 2008 Title 24 lighting requirements. Daylighting savings came from side-lighting and sky-lighting. We calculated savings associated with daylighting by assessing the side-lit/sky-lit area, the effective aperture, the type of daylight sensor control, the number of lighting fixtures to which the daylight sensor is connected, and the wattage of the lighting fixtures.

Table 3 summarizes the compliance findings related to interior lighting for the sampled sites, by building type. Figure 2 shows measure-level savings for each of the four climate zones defined for this project.

**Table 3. Rates of Compliance with 2008 Title 24 Interior Lighting Code**

| Building Type | Count | Percentage of Sites in Compliance with 2008 Title 24 |
|---|---|---|
| Retail | 18 | 100.0% |
| Office Building | 14 | 92.9% |
| High-Bay or Industrial | 10 | 80.0% |
| Restaurant | 10 | 70.0% |
| Religious Facilities | 9 | 100.0% |
| Assembly | 7 | 100.0% |
| Gas Station | 5 | 60.0% |
| Athletic Facilities | 4 | 100.0% |
| Auto Care/Maintenance | 4 | 100.0% |
| Classroom Building | 2 | 100.0% |
| Medical Building | 2 | 100.0% |
| Multifamily/Group Living | 2 | 50.0% |
| Museum | 2 | 100.0% |
| Research and Laboratories | 2 | 100.0% |
| **Total** | **91** | **90.1%** |

Figure 2. New Construction Savings by Measure (Savings Relative to 2008 Title 24)

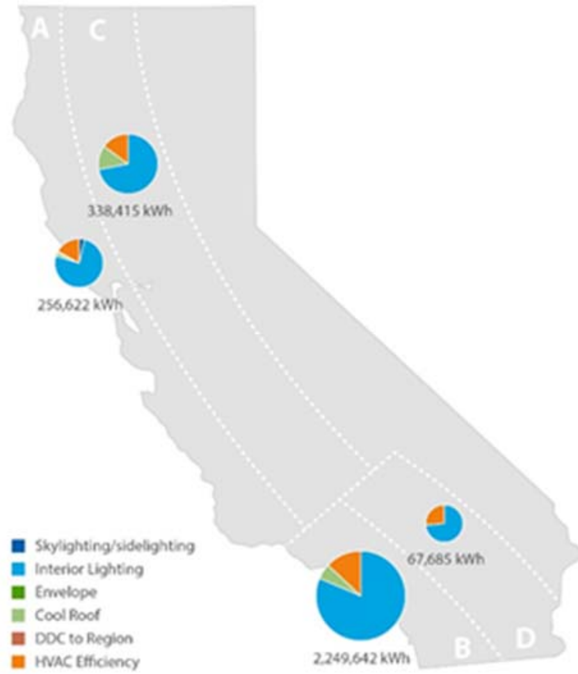


Table 4 shows the percentage of savings observed by building type. The weighted average electricity savings was 13.0% of the estimated consumption of buildings if built to just meet 2008 Title 24. The gas usage was decreased by 1.1% less than estimated if the buildings had just met 2008 Title 24.

Table 4. New Construction Savings by Building Types, Sampled Projects

| Building Type | Count | Percentage of 2008 Electric Consumption Saved | Percentage of 2008 Gas Consumption Saved |
|---|---|---|---|
| Retail | 18 | 13.9% | -0.4% |
| Office Building | 14 | 15.7% | 1.4% |
| High-Bay or Industrial | 10 | 5.5% | -27.5% |
| Restaurant | 10 | 2.9% | 1.3% |
| Religious Facilities | 9 | 14.2% | 3.4% |
| Assembly | 7 | 11.9% | 2.1% |
| Gas Station | 5 | 2.6% | -1.6% |
| Athletic Facilities | 4 | 7.1% | 7.9% |
| Auto Care/Maintenance | 4 | 5.3% | 0.8% |
| Classroom Building | 2 | 20.7% | 0.0% |
| Medical Building | 2 | 15.6% | -4.3% |
| Multifamily/Group Living | 2 | 5.7% | 14.2% |
| Museum | 2 | 15.9% | -46.1% |
| Research and Laboratories | 2 | 4.8% | -16.0% |
| **Total (Weighted Average)** | **91** | **13.0%** | **1.1%** |

## *Structure of Report*

To meet the objectives of this study, Cadmus performed the following key tasks:

- Identified and reviewed relevant literature on code compliance decision-making processes for commercial buildings
- Analyzed energy code compliance results for a sample of commercial buildings studied in 2010-2012 Codes and Standards Program evaluation.
- Interviewed key decision-makers involved in commercial building energy efficiency and code compliance choices

The following chapters discuss each of these tasks and our findings. The final chapters present our conclusions and recommendations.

# Literature Review

Cadmus performed a targeted literature review on code compliance decision-making to help answer the primary questions driving this research: which IOU nonresidential customer segments tend to over-comply and under-comply with Title 24 and why?

We focused our targeted literature review on studies specifically performed on the commercial building market in California and other studies that summarized reviews of broader literature. We used this latter category to identify potentially relevant literature on energy code compliance decision making.

Our review highlighted the importance of research on Title 24 code compliance in various customer segments, distinguished by the building type or geographic region, and the decision-making processes driving them. While there are many existing sources characterizing code compliance for a group of buildings, often after the buildings are completed and at the energy efficiency measure level, information on code compliance by customer segment and their decision-making processes is lacking.[5]

A summary of our relevant findings from this review is included below, while a full list of the references reviewed is provided in Appendix B. Sources Reviewed. These findings are organized by over-compliance and noncompliance.

## *Over-Compliance with Title 24*

Two consecutive commercial building market characterization studies for the Savings by Design (SBD)[6] Program, published in 2011 and 2014, highlight the historic SBD Program participation rates of various building types.[7,8] These market characterization studies estimated the historical SBD Program participation rates by dividing the floor space of SBD participants by the estimated program eligible floor space of commercial buildings. Historic SBD Program participation is an indicator (not a determinant) of over-compliance by building type since it is possible that some over-compliant buildings did not participate in the Program.

5 There is a substantial body of literature discussing individuals' energy efficiency decision-making and behavior, but these sources do not shed much light on the behavior of teams of individuals involved in the design and construction process in commercial buildings.

6 The IOU SBD Program targets the nonresidential new construction and major retrofits market. Project owner and design teams receive incentives separately for going above the minimum program efficiency standards (generally 10% better than Title 24).

7 Cadmus. *Commercial Building Market Characterization for Savings by Design Program*. Prepared for Southern California Edison. Study ID: SCE0312.01. June 20, 2011.

8 Navigant Consulting. *Savings By Design Market Potentials, Characterization and Best Practices Enhanced Program Participation Study.* Prepared for SCE, Pacific Gas and Electric (PG&E), and San Diego Gas and Electric (SDG&E). February 7, 2014.

The 2014 commercial building market characterization study for the SBD Program covered PG&E, SDG&E, and SCE service areas and estimated an average 14% participation rate for PG&E, 17% for SDG&E, and 13% for SCE between 2006-2012 across all building types. Table 5, Table 6, and Table 7 present historic SBD Program participation rates by building type for 2006-2012 for PG&E, SDG&E, and SCE, respectively.

**Table 5. PG&E Savings by Design Historic Participation Rate by Building Type (2006-2012)**

| Building Type | Historic Participation Rate |
|---|---:|
| Manufacturing Plants, Warehouses, Labs | 83% |
| Government Service Buildings | 37% |
| Miscellaneous Nonresidential Buildings | 36% |
| Hospitals and Other Health Treatment | 15% |
| Stores and Restaurants | 15% |
| Schools, Libraries, and Labs (nonmanufacturing) | 14% |
| Warehouses (excluding manufacturer owned) | 14% |
| Office and Bank Buildings | 7% |
| Religious Buildings | 3% |
| Amusement, Social, and Recreational Buildings | 1% |
| Hotels and Motels | 1% |
| Dormitories | 0% |
| Parking Garages and Automotive Services | 0% |
| **Total** | **14%** |

**Table 6. SDG&E Savings by Design Historic Participation Rate by Building Type (2006-2012)**

| Building Type | Historic Participation Rate |
|---|---:|
| Dormitories | 65% |
| Parking Garages and Automotive Services | 40% |
| Miscellaneous Nonresidential Buildings | 31% |
| Manufacturing Plants, Warehouses, Labs | 19% |
| Schools, Libraries, and Labs (nonmanufacturing) | 17% |
| Office and Bank Buildings | 16% |
| Government Service Buildings | 12% |
| Hospitals and Other Health Treatment | 12% |
| Amusement, Social, and Recreational Buildings | 10% |
| Religious Buildings | 6% |
| Stores and Restaurants | 6% |
| Warehouses (excluding manufacturer owned) | 3% |
| Hotels and Motels | 1% |
| **Total** | **17%** |

Table 7. SCE Savings by Design Historic Participation Rate by Building Type (2006-2012)

| Building Type | Historic Participation Rate |
|---|---|
| Manufacturing Plants, Warehouses, Labs | 37% |
| Miscellaneous Nonresidential Buildings | 34% |
| Warehouses (excluding manufacturer owned) | 25% |
| Office and Bank Buildings | 17% |
| Schools, Libraries, and Labs (nonmanufacturing) | 12% |
| Stores and Restaurants | 12% |
| Hospitals and Other Health Treatment | 10% |
| Hotels and Motels | 7% |
| Amusement, Social and Recreational Buildings | 1% |
| Government Service Buildings | 1% |
| Dormitories | 0% |
| Parking Garages and Automotive Services | 0% |
| Religious Buildings | 0% |
| **Total** | **13%** |

There are great differences in building type historic SBD Program participation rates among the three IOUs. For example, dormitories have a 65% historic participation rate in SDG&E territory, compared to almost 0% in PG&E and SCE territories. There are only two building types that are among the top five participating building types in all three IOU territories: miscellaneous nonresidential buildings and manufacturing plants/ warehouses/labs. Schools/libraries/labs (nonmanufacturing) are among the top five building types for SCE and SDG&E only. These variations suggest that building type is not a dominant factor leading to certain participation rates in the SBD Program (and over-compliance with Title 24).

The 2014 commercial building market characterization study highlights the project design and construction delivery process as a contributing factor to varying levels of compliance with Title 24. The study documented the decision-making flow charts and key decision points for Design-Bid-Build[9] and Design-Build,[10] two commonly used project design and construction delivery methods (Navigant 2014). The study suggests that larger projects with longer design and construction schedules (typically delivered as Design-Bid-Build) are best positioned for investing the time and effort required to investigate high-performing design alternatives. Smaller projects and those delivered as Design-Build

9 In Design-Bid-Build, the construction team is hired after the design team has developed the design, and the two entities have separate contracts with the owner. This project delivery method often leads to longer design and construction schedules but is preferred for public projects, since the owner is obligated to consider the construction cost as a factor in selecting the builder.

10 In Design-Build, the contractor or architect is the lead, and the owner hires a single entity for both the design and construction of the project. This project delivery method leads to shorted construction schedules and facilitates the coordination process between the design and construction teams.

have an accelerated design timeline and short decision-making windows, which makes them less likely to participate in the SBD Program or to over-comply with the code.

Regardless of project delivery method, establishing an early energy performance target is key to ensuring that the building project performs well compared to the Title 24 baseline. In general, the key stakeholder in establishing an early target is the owner or the owner/developer, though the occupants and the design professionals involved can have a high influence on those targets as well. All of these stakeholders can be motivated by high-performance building rating systems, recognition programs such as Leadership in Energy and Environmental Design (LEED), or (more recently) building energy use reporting and labeling programs. Utility costs are a major motivator for building projects that are owner-occupied. These buildings are often designed to higher energy performance standards than those that are built speculatively to lease to future occupants (who will pay for their own utility costs) or those that are built to sell (Cadmus 2011, Navigant 2014).

It is important to note that the design and construction industry is moving away from the traditional delivery models and contractual arrangements, and towards the Integrated Project Delivery method. Under this approach the owner, designer, and builder form a single business entity and deliver on their associated scopes of work, while sharing the losses and rewards of the final project result.[11,12] In general, this delivery model allows for higher levels of collaboration among principal project stakeholders (in addition to design consultants and construction trades) to achieve the project performance targets. For projects with improved energy performance targets, this delivery model is best suited to achieve those targets while keeping the design and construction costs under control.

## *Noncompliance with Title 24*

When reviewing measure-level compliance in available sources, we found that envelope prescriptive code compliance requirements are often traded off in performance-based code compliance with more efficient lighting and HVAC systems. This is often due to the project teams' desires to achieve a certain aesthetic for the building with high window to wall ratios. Some states intend to limit such tradeoffs in the future to maintain minimum envelope efficiency levels.[13] Lighting controls and HVAC installations and retrofits (mostly in small commercial buildings) have historically encountered installation quality

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[11] American Institute of Architects. *Integrated Project Delivery: A Guide*. 2007.

[12] Rocky Mountain Institute. *RMI: Using Contracting to Improve Building Project Delivery and Achieve Sustainable Goals*. 2013.

[13] Pacific Northwest National Laboratory. *Preserving Envelope Efficiency in Performance Based Code Compliance*. June 2015.

issues and noncompliance with Title 24, such that the California Energy Commission and the IOUs have focused on improving standards enforcement and strengthening licensure provisions.[14,15]

Prior Title 24 impact evaluations focused on evaluating compliance for measures that were expected to yield the greatest savings compared with the previous version of the code.[16] Cadmus also reviewed available literature listing enhancements required to improve compliance with building energy codes.[17, 18, 19, 20] These studies do not provide a view of the decision-making process related to Title 24 code compliance.

However, they confirm the common understanding that compliance is highly dependent on the measure (the actual requirements and their stringency or complexity), the building department (the local climate and the level of enforcement by the authorities having jurisdiction)[21], and the stakeholders involved (their motivations, decision-making process, and awareness).[22,23] Therefore, drivers for over-compliance and noncompliance may not be effectively understood if we focus on the variations in compliance among customer segments (building type or geographic region). These variations point to requirements, resources, and decision-making processes that are driving code compliance in different building types and local climates. This is why, in addition to investigating the relationships between customer segments

[14] Opinion Dynamics. *Indirect Impact Evaluation of the Statewide Energy Efficiency Education and Training Program. Volume I of IV: Final Report.* Study ID: CPU0014.01. Prepared for the California Public Utilities Commission Energy Division. March 2010.

[15] Donald Vial Center on Employment in the Green Economy. *California Workforce Education and Training Needs Assessment.* University of California, Berkeley. 2011.

[16] Cadmus. *Statewide Codes and Standards Program Impact Evaluation Report for Program Years 2010- 2012.* Prepared for the California Public Utilities Commission. October 2014.

[17] HMG. *SCE Codes & Standards Process and Market Assessment Study*. April 2009.

[18] Misuriello, Harry, S. Penney, M. Eldridge, and B. Foster. *Lessons Learned from Building Energy Code Compliance and Enforcement Evaluation Studies.* 2010.

[19] Meres, Ryan, J. Sigmon, M. DeWein, and K. Garrett. *Successful Strategies for Improving Compliance with Building Energy Codes.* 2012.

[20] DNV-GL. *Codes and Standards Compliance Improvement Program Years 2013-14 Process Evaluation Final Report.* Prepared for the California Public Utilities Commission. April 2016.

[21] Cadmus. *California Statewide Codes and Standards Compliance Enhancement Subprogram PY2010-2012 Pilot Process Evaluation*. Prepared for the California Public Utilities Commission. April 2014.

[22] Meres, Ryan, J. Sigmon, M. DeWein, and K. Garrett. *Successful Strategies for Improving Compliance with Building Energy Codes.* 2012.

[23] Quantec. *Statewide Codes and Standards Market Adoption and Noncompliance Rates Final Report*. CPUC Program No. 1134-04, SCE00224.01. 2007.

and whole-building or measure-level compliance as described in the next section, Cadmus performed a literature review and conducted interviews with owners and design professionals to better understand the drivers for code compliance.

# Data Analysis

## Research Questions

As part of Cadmus' evaluation of the IOUs' Codes and Standards Program for program years 2010 through 2012, we conducted site visits at sampled buildings to collect data on compliance in new nonresidential buildings. We used those data points in energy simulation models to compare as-built energy consumption to expected energy consumption (built-to-code). For the current study, we analyzed the data from the previous evaluation to answer the basic research questions presented in the first chapter of this report and listed again in Table 8.

**Table 8. Approaches Used to Answer Research Questions**

| Research Questions | Analysis Approach |
|---|---|
| Did particular groups of characteristics in commercial buildings lead to over- or under-compliance? | Cluster analysis to examine if any sub-groups exist in the data with certain characteristics. |
| Did under-compliance tend to occur for some measure types or building types, but not for others? If so, for which measures or types of commercial buildings did under-compliance occur more frequently? | Analysis of variance modeling and regression analysis to determine if any building types are associated with under-compliance. |
| Was either over- or under-compliance correlated with geographical location of buildings? If so, what regions tended to over- or under-comply? | Analysis of variance modeling and regression analysis to determine if any climate regions are associated with under-compliance. |
| Did a small number of observations drive compliance on average? If so, what were the characteristics of those corresponding buildings? | Various tests to find outliers and influential points in the data that could be driving compliance, including univariate methods, correlation between measures, and regression analysis. |

In this study, Cadmus examined eCMs and commercial building characteristics to determine if compliance with the 2008 Title 24 was correlated with building characteristics, location, and measure type. Cadmus examined the compliance margins of six measures: sky-lighting and side-lighting, interior lighting, envelope, cool roof, DDC to zone, and HVAC efficiency. We used quantitative analysis and data visualization to provide information on over- and under-compliance to answer the research questions shown in Table 8. This chapter provides details on the data, methodology, and results, then translates this information into conclusions that respond to each research question.

## Data

The 2010-2012 program year evaluation[24] dataset contained information on 91 buildings that included the following variables:

- ***Compliance margins:*** whole building, sky-lighting and side-lighting, interior lighting, envelope, cool roof, DDC to zone, and HVAC efficiency
- ***Building type:*** assembly, athletic facilities, auto care/maintenance, classroom buildings, gas station, high-bay or industrial, medical building, multifamily/group living, museum, office building, religious facilities, research and laboratories, restaurant, and retail
- ***Region:*** four climate regions defined for this project, indicated as A, B, C, and D
- ***Jurisdiction:*** rural and urban areas
- ***Utility:*** PG&E, SDG&E, and SCE
- ***Building size:*** square footage of the building floor area

Each building in the dataset included an energy compliance margin value for at least one measure. Table 9 shows an overview of the number of observations and range of the eCMs with respect to both electric and gas measures. All buildings in the sample use electricity; however, only 65 buildings in the sample use gas, resulting in different sample sizes for analysis between electricity and gas. Negative values of eCMs indicate that the as-built measure consumes more energy than it would if it just met the Title 24 prescriptive code requirement, and positive values of eCMs indicate that the measure is more efficient than the prescriptive requirement. The eCMs cannot exceed 100% (or 1.0), which would mean the measure (or building) contributed zero energy consumption to total usage.

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[24] The Cadmus Group and DNV GL. *Statewide Codes and Standards Program Impact Evaluation Report For Program Years 2010-2012.* August 2014. Available online: http://www.calmac.org/publications/CS%5FEvaluation%5FReport%5FFINAL%5F10052014%2D2.pdf

**Table 9. eCM Summary Statistics**

| Fuel Type | Statistic | Sky-Lighting and Side-Lighting | Interior Lighting | Envelope | Cool Roof | DDC to Zone | HVAC Efficiency | Whole Building |
|---|---|---|---|---|---|---|---|---|
| Electricity | Minimum | 0.2% | -21.0% | -12.8% | 0.2% | -0.9% | -2.2% | -22.0% |
| | 1st Quartile | N/A | 3.0% | -1.9% | 0.9% | ~0% | 0.9% | 4.2% |
| | Median | 1.6% | 7.6% | -0.5% | 2.2% | ~0% | 2.0% | 8.9% |
| | Mean | 2.6% | 7.6% | -0.6% | 2.9% | ~0% | 2.5% | 9.5% |
| | 3rd Quartile | N/A | 12.7% | 0.6% | 4.4% | 0.2% | 3.1% | 16.2% |
| | Maximum | 6.1% | 27.3% | 9.1% | 8.5% | 0.7% | 11.4% | 26.8% |
| | **Sample Size*** | **3** | **88** | **91** | **20** | **8** | **83** | **91** |
| Gas | Minimum | -2.4% | -20.0% | -98.8% | -63.4% | 1.1% | -227.5% | -176.9% |
| | 1st Quartile | N/A | -4.9% | -0.4% | -9.7% | 3.8% | ~0% | -7.0% |
| | Median | -0.5% | -2.7% | 0.8% | -5.0% | 4.1% | 0.5% | 0.1% |
| | Mean | -1.0% | -4.6% | 2.7% | -11.6% | 13.5% | -2.8% | -4.0% |
| | 3rd Quartile | N/A | -0.5% | 6.5% | -1.2% | 11.4% | 1.3% | 6.5% |
| | Maximum | -0.1% | ~0% | 96.2% | -0.1% | 59.1% | 53.9% | 96.1% |
| | **Sample Size*** | **3** | **8** | **62** | **16** | **7** | **58** | **65** |

* When sample sizes are small (n < 15) summary statistics and analysis may be misleading or inappropriate.

Note that for electricity (kWh), the sample sizes are very small for sky-lighting and side-lighting and for DDC to zone, as are the sample sizes for natural gas (therms) for sky-lighting and side-lighting, interior lighting, and DDC to zone; this limited Cadmus' ability to analyze these measures.

To better understand the data before further analysis, Cadmus created side-by-side boxplots[25] to visualize how compliance varied by measure. Boxplots show the trends of eCMs within measure type and building variables, which Cadmus compared to the results from quantitative analysis procedures to ensure the accuracy of findings. Figure 3 displays the distribution of the electricity eCMs, and Figure 4 provides the distribution of natural gas eCMs.

As shown in Figure 3, interior lighting, cool roof, sky-lighting and side-lighting, and HVAC efficiency measures tended to over-comply (that is, be more efficient than the prescriptive requirements) in terms of electricity consumption, while envelope measures tended to under-comply slightly compared with prescriptive requirements. There is a significant variance in the values for whole building electricity

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25 A boxplot separates the data into four quartiles. The "box" of the boxplot contains the middle 50% of the data, with the median noted by the bar inside the box. The "whiskers" of a boxplot are the lines that extend from either side of the box, and each contains approximately 25% of the data. Any points outside of the box and whiskers are outliers; note that all outliers should be examined further to determine if the values are reasonable. When Cadmus examined these outliers we determined these values are reasonable and should not be removed from the analysis.

energy compliance; however, most buildings over-comply based on the electricity compliance margin, resulting in savings beyond the level required by code.

**Figure 3. Distribution of Electricity eCMs by Measure**

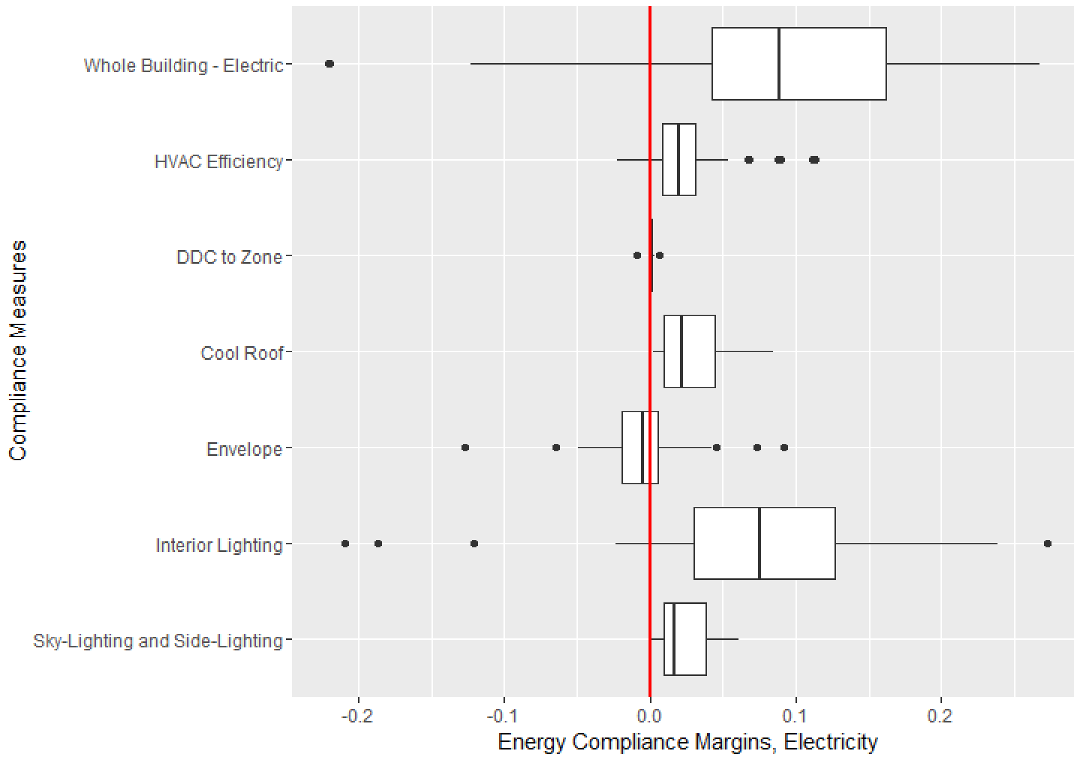
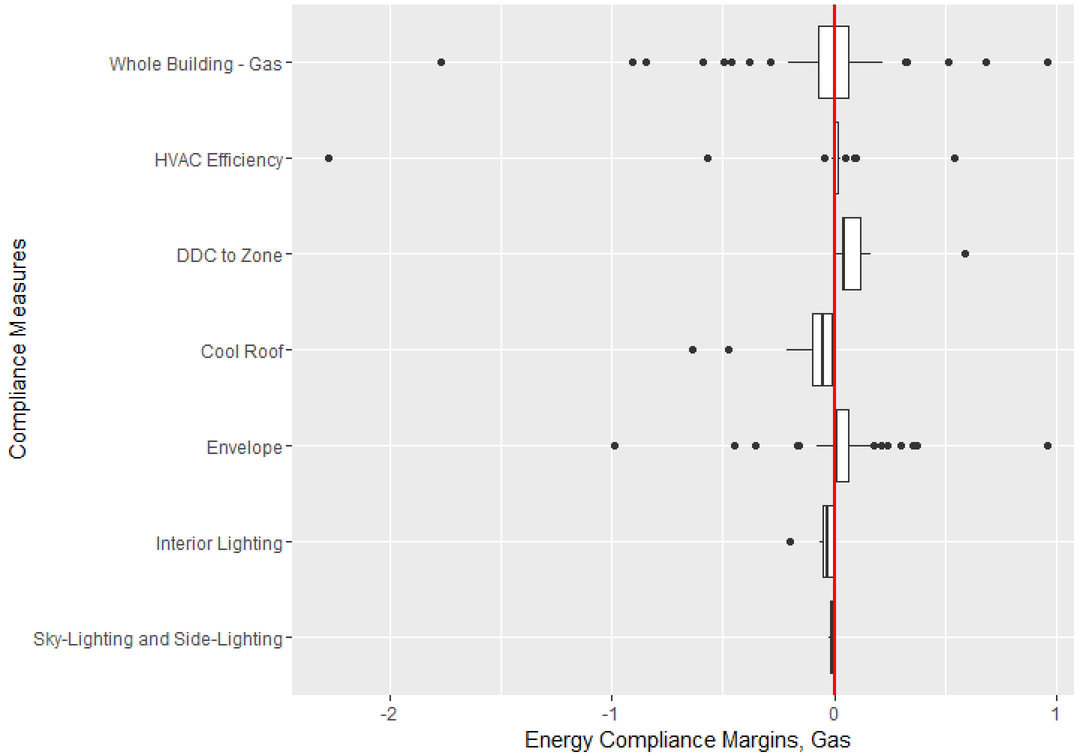



Figure 4 below shows that all DDC to zone measures in our sample were over-compliant in terms of gas consumption (that is, produce more savings than if they just met the Title 24 prescriptive requirements), whereas cool roof measures were all under-compliant. Envelope measures exhibited the largest variability in the eCMs. Whole building compliance for gas has a median of approximately zero with a large amount of variability in the data, producing a wide distribution. One observation has a whole building eCM less than -1, and one has an HVAC efficiency eCM of less than -1. These results indicate that the energy consumption associated with those measures are more than twice as large as expected if the measure or building exactly met the prescriptive requirement.

**Figure 4. Distribution of Natural Gas eCMs by Measure**




## Methodology

Cadmus used cluster analysis, data visualization, and regression analysis to determine the compliance margin trends for each measure. Prior to implementing these methods, we produced data summaries to understand the distribution of eCMs within sampled buildings across building characteristics. We applied the same methods to examine measures that affected electricity as we did for those that affected gas.

Cadmus used k-means cluster analysis[26] to determine if buildings with similar eCMs shared similar building characteristics (such as building size and type, climate region, jurisdiction, and utility). There are no rules about the sample size necessary for cluster analysis. Although large sample sizes are recommended, we can support smaller sample sizes using information about the variability in the data (if the data is less variable).[27] K-means clustering minimizes the within cluster variability while maximizing the between cluster variability. Using only buildings with complete data, we clustered

26 This method is described online: http://www.jmp.com/support/help/K-Means_Clustering.shtml

27 Dolnicar, Sara. *A Review of Unquestioned Standards in Using Cluster Analysis for Data-Driven Market Segmentation.* December 2002. Available online: http://ro.uow.edu.au/cgi/viewcontent.cgi?article=1286&context=commpapers

buildings with similar compliance margins, using an optimal number of clusters determined using cluster validation statistics.[28] Then we enumerated the building types, regions, jurisdictions, and utilities in each cluster to determine if buildings with similar compliance margins shared the same characteristics.

Next, due to the categorical nature of the explanatory variables, with the exception of building size, Cadmus used analysis of variance[29] (ANOVA) modeling and regression analysis to explore relationships between eCMs and building characteristics. We fit ANOVA models to estimate the overall effect of building characteristics on compliance margins for each measure. If the models indicated that any building characteristics drove compliance, we fit a regression model using that characteristic as a predictor of eCMs. From the regression results, Cadmus determined if certain characteristics had a significant relationship with over- or under-compliance. We used the same ANOVA and regression processes to analyze all measures; we present the models results for one measure below.

Finally, Cadmus used data visualization and statistical tests to determine whether particular sample points were associated with over- or under-compliance. Using only buildings with complete data to calculate correlation between measures, we produced boxplots, density plots, and scatterplots to identify unusual observations in the distribution of eCMs, both overall and in comparison to compliance for other measures. We used studentized residual plots and Cook's distance plots[30] to identify outliers and influential points in regression models, then examined the characteristics of buildings that could be driving over- or under-compliance. An outlier is an element of a data set that does not follow the trend of the rest of the data set. An influential point is an outlier that causes significant differences in the results of the data analysis depending on whether that point is included or excluded.

### Limitations

To perform the analyses described above, we required sufficient sample sizes and variation between the building characteristics of interest for each measure. For example, to fit an ANOVA or regression model to detect significant associations between eCMs and building types, we needed more observations for each measure than the number of building type categories (n=14); therefore, the minimum sample size required for modeling purposes was 15 observations. To obtain precision of coefficient estimates we needed a minimum of two samples per characteristic in the model to assess variability in the data.

For electricity, Cadmus determined there were sufficient sample sizes to perform analyses for interior lighting (n=88), envelope (n=91), HVAC efficiency (n=83), and whole building (n=91). We also found that there was a large enough sample size to perform analysis for cool roof measures (n=20), but acknowledge this is relatively small and may produce unreliable results. Cadmus included summary and

[28] This method is described online: http://artax.karlin.mff.cuni.cz/r-help/library/fpc/html/cluster.stats.html

[29] This method is described online: http://www.ma.utexas.edu/users/mks/384E06/3wayanovamodels.pdf

[30] Rawlings, John O., S.G. Pantula, and D.A. Dickey. *Applied Regression Analysis, A Research Tool*. Second Edition, 2001.

graphical information for sky-lighting and side-lighting (n=3) and DDC to zone (n=8), but due to small sample sizes we did not perform further statistical analyses.

For gas, Cadmus determined there was a sufficient sample size to perform analyses for envelope (n=61), HVAC efficiency (n=58), whole building (n=65). We also found that there was a large enough sample size to perform analysis for cool roof measures (n=16), but we acknowledge this is relatively small and may produce unreliable results. Cadmus included summary and graphical information for sky-lighting and side-lighting (n=3), interior lighting (n=9), and DDC to zone (n=8), but due to small sample sizes we did not perform further statistical analyses.

## Electricity Findings

Cadmus performed cluster analysis to determine if particular groups of characteristics in commercial buildings lead to over- or under-compliance, but found no evidence that groups of characteristics existed in the data for electricity eCMs. A more detailed description of the methods we employed is included in Appendix A. Additional Analysis and Results.

Cadmus used side-by-side boxplots to better understand the distribution of electricity eCMs for each measure by 14 building types, four climate regions, two jurisdictions, and three utilities for comparison with regression results to increase confidence in the results. Included in Appendix A are boxplots and sample size information for each building characteristic found to have a significant relationship with eCMs based on the ANOVA and regression results.

We fit ANOVA models for whole building, interior lighting, envelope, cool roof, and HVAC efficiency compliance measures. If characteristics were found to be driving compliance trends from the ANOVA results, we performed linear regression analysis on individual characteristics. Sky-lighting and side-lighting and DDC to zone measures had insufficient data for this analysis (n<10). We found no evidence of a significant relationship between building size and electricity eCMs for any measure after accounting for other characteristics in regression modeling. A more detailed description of building size analysis can be found in Appendix A. Additional Analysis and Results.

Cadmus performed correlation analysis for electricity eCMs to determine if any individual buildings or groups of buildings were driving the correlation between measures. For the correlation analysis, we used complete data from interior lighting, envelope, cool roof, and HVAC efficiency measures, as well as whole building compliance; this is presented graphically in Appendix A. Cadmus identified one influential point from envelope electricity eCMs which is detailed below in the Envelope eCM section.

### Whole Building

Cadmus found overall electricity energy savings to be greater than predicted for whole building compliance, implying that sites in our sample tended to over-comply with Title 24 requirements on average across measures. We performed ANOVA and regression analysis to obtain a better understanding of which characteristics of the whole building are driving the trend of over-compliance.

### *ANOVA Analysis*

Cadmus explored the relationship between building characteristics and eCMs by fitting ANOVA models and determining if any appeared to be driving compliance; the results are shown in Table 10.

**Table 10. ANOVA Results for Whole Building by Building Characteristics**

| Measure | Main Effects Characteristic | Degrees of Freedom | Sum of Squared Errors | Mean Squared Error | F-value | p-value |
|---|---|---|---|---|---|---|
| Whole Building | Building Type | 13 | 0.220 | 0.017 | 2.525 | 0.007* |
| | Climate Region | 3 | 0.000 | 0.000 | 0.018 | 0.997 |
| | Jurisdiction | 2 | 0.010 | 0.005 | 0.766 | 0.469 |
| | Utility | 1 | 0.005 | 0.005 | 0.747 | 0.390 |
| | Residuals[31] | 71 | 0.476 | 0.007 | - | - |

* This result is statistically significant at the 90% confidence level.

The ANOVA model for whole building electricity eCMs showed evidence that building type as a whole is driving the trend of over-compliance with a p-value of 0.007 (<0.10). We found no evidence of climate regions, jurisdictions, or utilities to be driving whole building over-compliance, as noted by the p-values greater than 0.10 (or 10%) at the 90% confidence level.

[31] The residual of an observed value is the difference between the observed value and the estimated value of the quantity of interest. The larger the residual degrees of freedom, the more precision we have in our calculations.

## *Regression Analysis*

Analyzing building types, Cadmus performed regression analysis to determine which individual building types had a significant relationship with whole building electricity eCMs; results are shown in Table 11.

**Table 11. Regression Results for Whole Building Electricity eCMs by Building Characteristics**

| Variable | Specific Characteristic | Estimate | Std. Error | t-value | p-value |
|---|---|---|---|---|---|
| Building Type | Assembly | 14.1% | 3.0% | 4.678 | <0.0001* |
| | Athletic Facilities | 10.1% | 4.0% | 2.522 | 0.014* |
| | Auto Care/Maintenance | 5.1% | 4.0% | 1.287 | 0.202 |
| | Classroom Building | 19.6% | 5.7% | 3.470 | 0.001* |
| | Gas Station | 0.8% | 3.6% | 0.224 | 0.823 |
| | High-Bay or Industrial | 6.1% | 2.5% | 2.410 | 0.018* |
| | Medical Building | 10.1% | 5.7% | 1.796 | 0.076* |
| | Multifamily/Group Living | 10.2% | 5.7% | 1.802 | 0.075* |
| | Museum | 15.9% | 5.7% | 2.808 | 0.006* |
| | Office Building | 9.8% | 2.1% | 4.601 | <0.0001* |
| | Religious Facilities | 11.8% | 2.7% | 4.430 | <0.0001* |
| | Research and Laboratories | 7.3% | 5.7% | 1.286 | 0.202 |
| | Restaurant | 1.2% | 2.5% | 0.461 | 0.646 |
| | Retail | 14.4% | 1.9% | 7.662 | <0.0001* |
| | **This model produces a residual standard error of 0.022 on 69 degrees of freedom[32] and an adjusted R-squared value of 0.585. This model accounts for approximately 59% of the variability in the data.** | | | | |

* These results are statistically significant at the 90% confidence level.

All building types over-comply on average with the code, as indicated by positive percentage estimates. The regression model for whole building provides evidence that assembly, athletic facilities, classroom buildings, high-bay or industrial, medical buildings, multifamily/group living, museums, office buildings, religious facilities, and retail building types are significantly associated with over-compliance, as noted by the positive percentage estimates and p-values less than 0.10 (or 10%) at the 90% confidence level. Side-by-side boxplots of whole building eCMs by building type can be found in Appendix A. Additional Analysis and Results for comparison and data visualization purposes.

## *Unusual Observation Analysis*

Cadmus created a studentized residual plot to identify outliers, as well as Cook's distance plots to identify influential points from the regression model of whole building compliance predicted by building type. We found no evidence of outliers or influential points from whole building electricity eCMs.

[32] The number of degrees of freedom is the number of values in the final model that are free to vary in order to calculate that model with a certain confidence and precision.

## Interior Lighting

Cadmus found overall electricity energy savings to be greater than predicted for interior lighting measures, implying that sites in our sample tended to over-comply with Title 24 interior lighting requirements. We performed ANOVA and regression analyses to better understand which building characteristics within interior lighting measures are driving the trend of over-compliance.

### *ANOVA Analysis*

Cadmus explored the relationship between building characteristics and interior lighting electricity eCMs by fitting ANOVA models and determining if any appeared to be driving compliance; the results are shown in Table 12.

**Table 12. ANOVA Results for Interior Lighting Electricity eCMs by Building Characteristics**

| Measure | Main Effects Characteristic | Degrees of Freedom | Sum of Squared Errors | Mean Squared Error | F-value | p-value |
|---|---|---|---|---|---|---|
| Interior Lighting | Building Type | 13 | 0.188 | 0.014 | 2.634 | 0.005* |
| | Climate Region | 3 | 0.003 | 0.001 | 0.178 | 0.911 |
| | Jurisdiction | 1 | 0.003 | 0.003 | 0.614 | 0.436 |
| | Utility | 3 | 0.012 | 0.004 | 0.717 | 0.545 |
| | Residuals | 67 | 0.368 | 0.005 | - | - |

* This result is statistically significant at the 90% confidence level.

The ANOVA model for interior lighting electricity eCMs showed evidence that building type as a whole is driving the trend of over-compliance with a p-value of 0.005 (<0.10). We found no evidence of climate regions, jurisdictions, or utilities to be driving interior lighting over-compliance, as noted by the p-values greater than 0.10 (or 10%) at the 90% confidence level.

### *Regression Analysis*

To analyze building type further, Cadmus performed linear regression analysis to determine which individual building types had a significant relationship with interior lighting electricity eCMs; the results are shown in Table 13.

**Table 13. Regression Results for Interior Lighting Electricity eCMs by Building Type**

| Variable | Specific Characteristic | Estimate | Std. Error | t-value | p-value |
|---|---|---|---|---|---|
| Building Type | Assembly | 11.2% | 2.7% | 4.106 | <0.0001* |
| | Athletic Facilities | 6.6% | 3.6% | 1.824 | 0.072* |
| | Auto Care/Maintenance | 1.8% | 3.6% | 0.495 | 0.622 |
| | Classroom Building | 6.4% | 5.1% | 3.219 | 0.002* |
| | Gas Station | 1.2% | 3.2% | 0.376 | 0.708 |
| | High-Bay or Industrial | 3.9% | 2.4% | 1.612 | 0.111 |
| | Medical Building | 4.0% | 5.1% | 0.781 | 0.437 |
| | Multifamily/Group Living | 6.4% | 5.1% | 1.255 | 0.213 |
| | Museum | 3.6% | 5.1% | 2.673 | 0.009* |
| | Office Building | 8.7% | 2.0% | 4.369 | <0.0001* |
| | Religious Facilities | 9.2% | 2.4% | 3.802 | <0.0001* |
| | Research and Laboratories | 3.5% | 5.1% | 0.694 | 0.490 |
| | Restaurant | 1.0% | 2.3% | 0.431 | 0.667 |
| | Retail | 3.3% | 1.8% | 7.597 | <0.0001* |
| | **This model produces a residual standard error of 0.072 on 74 degrees of freedom and an adjusted R-squared value of 0.579. This model accounts for approximately 58% of the variability in the data.** | | | | |

* These results are statistically significant at the 90% confidence level.

All building types over-comply on average with interior lighting codes and standards as seen by positive percentage estimates. The regression model for interior lighting provides evidence that assembly, athletic facilities, classroom buildings, museums, office buildings, religious facilities, and retail building types are significantly associated with over-compliance, as noted by the positive percentage estimates and p-values less than 0.10 (or 10%) at the 90% confidence level. Side-by-side boxplots of interior lighting eCMs by building type can be found in Appendix A. Additional Analysis and Results for comparison and data visualization purposes.

### *Unusual Observation Analysis*

Cadmus created a studentized residual plot to identify outliers, as well as Cook's distance plots to identify influential points from the regression model of interior lighting compliance predicted by building type. We found no evidence of outliers or influential points from interior lighting electricity eCMs.

### Envelope

Cadmus found overall electricity energy savings to be less than predicted for envelope measures, implying that sites in our sample tended to under-comply with Title 24 envelope requirements. We performed ANOVA and regression analysis to better understand which building characteristics are driving the trend of under-compliance of envelope measures.

### *ANOVA Analysis*

Cadmus explored the relationship between building characteristics and envelope electricity eCMs by fitting ANOVA models and determining if any appeared to be driving envelope compliance; the results are shown in Table 14.

**Table 14. ANOVA Results for Envelope Electricity eCMs by Building Characteristics**

| Measure | Main Effects Characteristic | Degrees of Freedom | Sum of Squared Errors | Mean Squared Error | F-value | p-value* |
|---|---|---|---|---|---|---|
| Envelope | Building Type | 13 | 0.010 | 0.001 | 1.057 | 0.410 |
| | Climate Region | 3 | 0.004 | 0.001 | 1.798 | 0.155 |
| | Jurisdiction | 1 | 0.000 | 0.000 | 0.04 | 0.842 |
| | Utility | 3 | 0.001 | 0.000 | 0.681 | 0.566 |
| | Residuals | 70 | 0.050 | 0.001 | - | - |

* None of the characteristics are statistically significant at the 90% confidence level.

ANOVA results show that none of the main effects of building characteristics are indicative of driving envelope under-compliance, as noted by the p-values greater than 0.10 (or 10%) at the 90% confidence level. However, since one objective of this analysis was to identify areas for improvement, Cadmus analyzed under-compliant measures in more detail to better understand where to allocate resources for future energy compliance enhancement.

### *Regression Analysis*

Cadmus analyzed the individual associations between building characteristics and envelope electricity eCMs through linear regression analysis to determine which individual characteristics had a statistically significant effect on the envelope electricity eCMs. Table 15 provides the results we obtained by fitting a regression model of envelope eCMs predicted by building type.

**Table 15. Regression Results for Envelope Compliance by Building Type**

| Variable | Specific Characteristic | Estimate | Std. Error | t-value | p-value |
|---|---|---|---|---|---|
| Building Type | Assembly | 0.8% | 1.0% | 0.779 | 0.438 |
| | Athletic Facilities | 0.8% | 1.3% | 0.574 | 0.568 |
| | Auto Care/Maintenance | 0.9% | 1.3% | 0.636 | 0.527 |
| | Classroom Building | -2.3% | 1.9% | -1.198 | 0.235 |
| | Gas Station | -2.9% | 1.2% | -2.390 | 0.019* |
| | High-Bay or Industrial | -1.3% | 0.8% | -1.576 | 0.119 |
| | Medical Building | -0.2% | 1.9% | -0.114 | 0.910 |
| | Multifamily/Group Living | -0.6% | 1.9% | -0.301 | 0.764 |
| | Museum | -1.8% | 1.9% | -0.932 | 0.354 |
| | Office Building | -0.2% | 0.7% | -0.283 | 0.778 |
| | Religious Facilities | 0.4% | 0.9% | 0.442 | 0.660 |
| | Research and Laboratories | 0.9% | 1.9% | 0.499 | 0.619 |
| | Restaurant | -1.7% | 0.8% | -1.959 | 0.054* |
| | Retail | -0.9% | 0.6% | -1.465 | 0.147 |
| | **This model produces a residual standard error of 0.027 on 77 degrees of freedom and an adjusted R-squared value of 0.047. This model accounts for approximately 4.7% of the variability in the data.** | | | | |

* These results are statistically significant at the 90% confidence level.

Gas station and restaurant building types are statistically significant predictors of envelope eCM under-compliance at the 90% confidence level. On average, gas stations under-comply by 2.9% and restaurants under-comply by 1.7% with Title 24 envelope requirements, as noted by negative percentage estimates and p-values less than 0.10 (or 10%) at the 90% confidence level. In addition to these building types, classroom buildings, high-bay or industrial, medical buildings, multifamily/group living, museums, office buildings, and retail building types under-comply on average with Title 24 envelope requirements, as seen by negative percentage estimates, but these are not statistically significant. Side-by-side boxplots of envelope eCMs by building type can be found in Appendix A. Additional Analysis and Results for comparison and data visualization purposes.

Table 16 provides the regression results for envelope electricity eCMs predicted by climate region. Climate region D is a statistically significant predictor of envelope eCM under-compliance at the 90% level; however, this region is represented in our sample by only four observations, and thus the results may be unreliable. On average, climate region D under-complies by 3.1% with Title 24 envelope requirements. In addition, all climate regions under-comply on average, which can be seen by negative percentage estimates, but these are not statistically significant. Side-by-side boxplots of envelope eCMs by climate region can be found in Appendix A. Additional Analysis and Results for comparison and data visualization purposes.

**Table 16. Regression Results for Envelope Compliance by Climate Region**

| Variable | Specific Region | Estimate | Std. Error | t-value | p-value |
|---|---|---|---|---|---|
| Climate Region | A | -0.8% | 0.7% | -1.222 | 0.225 |
| | B | -0.4% | 0.4% | -0.985 | 0.328 |
| | C | -0.5% | 0.5% | -0.956 | 0.342 |
| | D | -3.1% | 1.3% | -2.345 | 0.021* |
| | **This model produces a residual standard error of 0.027 on 87 degrees of freedom and an adjusted R-squared value of 0.051. This model accounts for approximately 5.1% of the variability in the data.** | | | | |

* This result is statistically significant at the 90% confidence level.

Cadmus performed regression analysis for envelope compliance margins predicted by jurisdiction and utilities, but they did not produce statistically significant results.

### *Unusual Observation Analysis*

From the correlation analysis we performed described previously, we observed one influential point from envelope electricity eCMs. Table 17 details one building identified by the correlation analysis that is highly influential on the correlation between measures.

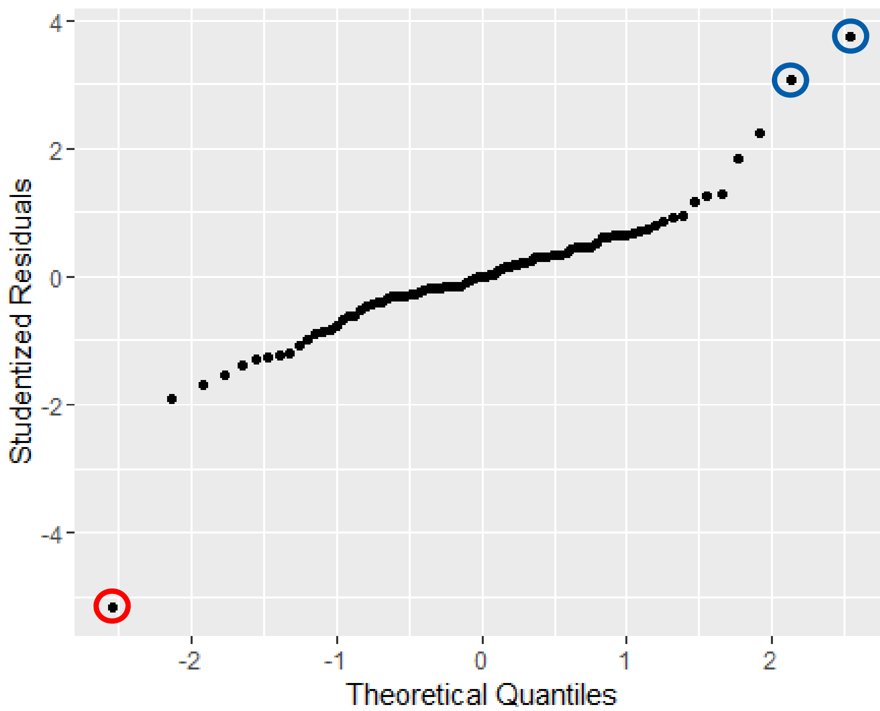
**Table 17. Electricity eCM Influential Point Characteristics**

| Measure | Compliance Margin | Building Type | Climate Region | Jurisdiction | Utility |
|---|---|---|---|---|---|
| Envelope | -12.8% | High-Bay or Industrial | B | Urban | SCE |

Cadmus researched the building that produced this influential point to ensure that this largely under-complying building was not a data collection error. We found that this building is a conditioned high-bay warehouse with U-0.18 metal walls and a U-0.12 metal roof, located in the Southern California City of Palmdale. The 2008 Title 24 prescriptive requirements for metal buildings are U-0.061 walls and a U-0.065 roof; therefore, we were able to determine that the actual building envelope fails to meet the prescriptive requirements by a wide margin. Additionally, we established that the whole building under-complied by a margin of approximately 73%.

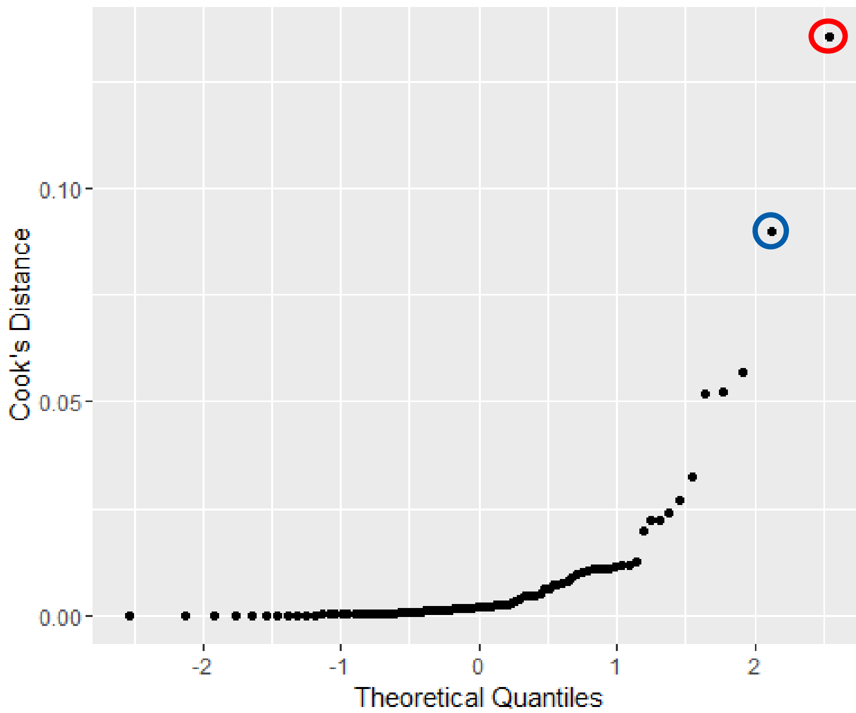
Cadmus produced studentized residual plots to identify outliers in envelope electricity eCMs regressed on building type; this is shown in Figure 5. In the studentized residual plot, the data points that do not follow the linearly increasing pattern are indicative of outliers. We identified potential outliers with blue circles, and identified the unusual observation found in envelope eCMs from the correlation analysis with a red circle, providing evidence of three potential envelope eCM outliers.

**Figure 5. Studentized Residual Plot for Envelope Electricity eCMs**



Cadmus produced Cook's distance plots to identify influential points in envelope eCMs regressed on building type, shown in Figure 6. In the Cook's distance plot, the data points that are largely different from zero tend to be considered influential points. We circled a potential influential point in blue, and circled the unusual observation found in envelope eCMs from the correlation analysis in red, providing evidence of two highly influential points in envelope eCMs.

**Figure 6. Cook's Distance Plot for Envelope Electricity eCMs**




Cadmus identified the point noted with red circles which is the same point outlined from the correlation analysis as influential with respect to correlation between measures and in the regression analysis. We acknowledge the high-bay or industrial building with a negative envelope electricity eCM as a potential driving factor of under-compliance in envelope eCMs.

## Cool Roof

Cadmus found overall electricity energy savings to be greater than predicted for cool roof measures, implying that sites in our sample tended to over-comply with Title 24 cool roof requirements. We performed ANOVA analysis to obtain a better understanding of which building characteristics within cool roof measures are driving the trend of over-compliance.

### *ANOVA Analysis*

Cadmus explored the relationship between building characteristics and eCMs by fitting ANOVA models and determining if any appeared to be driving compliance; this is shown in Table 18.

Table 18. ANOVA Results for Cool Roof Electricity eCMs by Building Characteristics

| Measure | Main Effects Characteristic* | Degrees of Freedom | Sum of Squared Errors | Mean Squared Error | F-value | p-value |
|---|---|---|---|---|---|---|
| Cool Roof | Building Type | 9 | 0.006 | 0.001 | 1.549 | 0.328 |
| | Climate Region | 2 | 0.001 | 0.000 | 0.557 | 0.605 |
| | Utility | 3 | 0.002 | 0.001 | 1.302 | 0.371 |
| | Residuals | 5 | 0.002 | 0.000 | - | - |

* Note that jurisdiction is not included in this model because there were no sites with cool roof measures located in rural jurisdictions.

The ANOVA model for cool roof electricity eCMs showed no evidence of any building characteristics driving over-compliance, as noted by the p-values greater than 0.10 (or 10%) at the 90% confidence level. Therefore, we had no evidence to perform regression or unusual observation analysis on any building characteristic.

## HVAC

Cadmus found overall electricity energy savings to be greater than predicted for HVAC efficiency measures, implying that sites in our sample tended to over-comply with Title 24 HVAC efficiency prescriptive requirements. We performed ANOVA and regression analysis to better understand which building characteristics within HVAC efficiency measures are driving the trend of over-compliance.

### *ANOVA Analysis*

We explored the relationship between building characteristics and HVAC efficiency electricity eCMs by fitting ANOVA models and determining if any appeared to be driving compliance (Table 19).

Table 19. ANOVA Results for HVAC Efficiency Electricity eCMs by Building Characteristics

| Measure | Main Effects Characteristic | Degrees of Freedom | Sum of Squared Errors | Mean Squared Error | F-value | p-value |
|---|---|---|---|---|---|---|
| HVAC Efficiency | Building Type | 13 | 0.013 | 0.001 | 1.868 | 0.052* |
| | Climate Region | 3 | 0.000 | 0.000 | 0.155 | 0.926 |
| | Jurisdiction | 1 | 0.000 | 0.000 | 0.005 | 0.947 |
| | Utility | 3 | 0.000 | 0.000 | 0.094 | 0.963 |
| | Residuals | 62 | 0.033 | 0.001 | - | - |

* This result is statistically significant at the 90% confidence level.

The ANOVA model for HVAC efficiency electricity eCMs showed evidence that building type as a whole is driving the trend of over-compliance with a p-value of 0.052 (<0.10). We found no evidence of climate regions, jurisdictions, or utilities to be driving HVAC efficiency over-compliance, as noted by the p-values greater than 0.10 (or 10%) at the 90% confidence level.

### *Regression Analysis*

To analyze building type further, Cadmus performed linear regression analysis to determine which individual building types had a significant relationship with HVAC efficiency electricity eCMs; the results are shown in Table 20.

**Table 20. Regression Results for HVAC Efficiency Electricity eCMs by Building Characteristics**

| Variable | Specific Characteristic | Estimate | Std. Error | t-value | p-value |
|---|---|---|---|---|---|
| Building Type | Assembly | 3.5% | 0.9% | 3.848 | <0.0001* |
| | Athletic Facilities | 2.8% | 1.1% | 2.540 | 0.013* |
| | Auto Care/Maintenance | 1.6% | 1.1% | 1.480 | 0.143 |
| | Classroom Building | 5.9% | 1.6% | 3.782 | <0.0001* |
| | Gas Station | 3.1% | 1.1% | 2.833 | 0.006* |
| | High-Bay or Industrial | 1.7% | 0.7% | 2.335 | 0.022* |
| | Medical Building | 7.0% | 1.6% | 4.448 | <0.0001* |
| | Multifamily/Group Living | 5.1% | 1.6% | 3.235 | 0.002* |
| | Museum | 4.5% | 1.6% | 2.857 | 0.006* |
| | Office Building | 1.5% | 0.6% | 2.454 | 0.017* |
| | Religious Facilities | 2.6% | 0.8% | 3.308 | 0.001* |
| | Research and Laboratories | 5.1% | 2.2% | 2.315 | 0.024* |
| | Restaurant | 1.8% | 0.7% | 2.455 | 0.017* |
| | Retail | 2.0% | 0.6% | 3.617 | 0.001* |
| | **This model produces a residual standard error of 0.022 on 69 degrees of freedom and an adjusted R-squared value of 0.585. This model accounts for approximately 59% of the variability in the data.** | | | | |

* These results are statistically significant at the 90% confidence level.

The regression model for HVAC efficiency provides evidence that all building types except auto care/maintenance are significantly associated with over-compliance, as noted by the positive percentage estimates and p-values less than 0.10 (or 10%) at the 90% confidence level. However, auto care/maintenance also over-complies on average with the HVAC efficiency prescriptive code, as seen by the positive percentage estimate. Side-by-side boxplots of HVAC efficiency eCMs by building type can be found in Appendix A. Additional Analysis and Results for comparison and data visualization purposes.

### *Unusual Observation Analysis*

Cadmus created a studentized residual plot to identify outliers, as well as Cook's distance plots to identify influential points from the regression model of HVAC efficiency compliance predicted by building type. We found no evidence of outliers or influential points from HVAC efficiency electricity eCMs.

## *Gas Findings*

Cadmus determined that cluster analysis was inappropriate for natural gas eCMs. A more detailed description of the methods we employed is included in Appendix A. Additional Analysis and Results.

We fit ANOVA models for whole building, envelope, cool roof, and HVAC efficiency compliance measures. If characteristics were found to be driving compliance trends from the ANOVA results, we performed linear regression analysis on individual characteristics. Sky-lighting and side-lighting, interior lighting, and DDC to zone measures had insufficient data for this analysis (n<10). We found no evidence of a significant relationship between building size and gas eCMs for any measure from regression results; details can be found in Appendix A. Additional Analysis and Results.

Cadmus performed correlation analysis for gas eCMs to determine if any individual buildings or groups of buildings were driving the correlation between measures. For the correlation analysis, we used complete data from envelope, cool roof, and HVAC efficiency measures, as well as whole building compliance (n=16), which is presented graphically in Appendix A. Cadmus identified three influential points from cool roof eCMs; the building characteristics of these influential points are outlined in Table 21. Note that the third influential point listed in the table below also appears to be an unusual observation in envelope eCMs.

**Table 21. Gas eCM Influential Point Characteristics**

| Cool Roof eCM | Envelope eCM | Building Type | Climate Region | Jurisdiction | Utility |
|---|---|---|---|---|---|
| -63.4% | 4.9% | High-Bay or Industrial | B | Urban | SDG&E |
| -47.7% | 13.7% | Retail | C | Urban | PG&E |
| -21.0% | -44.9% | High-Bay or Industrial | B | Urban | SCE |

Cadmus researched these largely under-complying buildings that produced the influential points to ensure they were not affected by data collection errors. We were able to determine that these building cool roof measures did fail to meet the prescriptive requirements and were not affected by data collection or recording errors.

## Whole Building

Cadmus found overall gas energy savings to be less than predicted for whole building compliance, implying that sites in our sample tended to under-comply with Title 24 requirements on average. The summary statistics from Table 9 above show that the average whole building gas savings was brought down by one drastically under-complying building. This site is of particular interest, so we outlined the building characteristics in Table 22 and performed a thorough review of the building details.

**Table 22. Whole Building Gas eCM Influential Point**

| Whole Building eCM | Envelope eCM | HVAC eCM | Building Type | Climate Region | Jurisdiction | Utility |
|---|---|---|---|---|---|---|
| -176.9% | -98.8% | 0.7% | Conditioned Warehouse | A | Urban | PG&E |

The building review produced a whole building value of -176.9% for this conditioned warehouse, which failed overall mainly due to the envelope gas eCMs. This site has 6-inch thick concrete walls with no insulation, and thus a wall insulation value of only R-1.2. From the review, Cadmus determined that this largely under-compliant building is affecting under-compliance for whole building gas eCMs. We then performed ANOVA analysis to investigate further if any building characteristics are driving the trend of whole building gas under-compliance.

### *ANOVA Analysis*

Cadmus explored the relationship between building characteristics and whole building gas eCMs by fitting ANOVA models and determining if any characteristics appeared to be driving compliance (Table 23).

**Table 23. ANOVA Results for Whole Building Gas eCMs by Building Characteristics**

| Measure | Main Effects Characteristic | Degrees of Freedom | Sum of Squared Errors | Mean Squared Error | F-value | p-value |
|---|---|---|---|---|---|---|
| Whole Building | Building Type | 12 | 0.535 | 0.045 | 0.313 | 0.984 |
| | Climate Region | 3 | 0.378 | 0.126 | 0.886 | 0.456 |
| | Jurisdiction | 2 | 0.487 | 0.244 | 1.714 | 0.191 |
| | Utility | 1 | 0.032 | 0.032 | 0.222 | 0.640 |
| | Residuals | 46 | 6.542 | 0.142 | - | - |

The ANOVA model for whole building gas eCMs showed no evidence of any building characteristics driving compliance, as noted by the p-values greater than 0.10 (or 10%) at the 90% confidence level, providing no evidence to perform regression analysis on any building characteristic.

### Envelope

Cadmus found overall gas energy savings to be greater than predicted for envelope measures, implying that sites in our sample tended to over-comply with Title 24 envelope requirements. We performed ANOVA analysis to obtain a better understanding of which building characteristics are driving envelope over-compliance.

### *ANOVA Analysis*

Cadmus explored the relationship between building characteristics and envelope gas eCMs by fitting ANOVA models and determining if any characteristics appeared to be driving compliance (Table 24).

**Table 24. ANOVA Results for Envelope Gas eCMs by Building Characteristics**

| Measure | Main Effects Characteristic | Degrees of Freedom | Sum of Squared Errors | Mean Squared Error | F-value | p-value |
|---|---|---|---|---|---|---|
| Envelope | Building Type | 13 | 0.242 | 0.019 | 0.415 | 0.957 |
| | Climate Region | 3 | 0.186 | 0.062 | 1.386 | 0.257 |
| | Jurisdiction | 1 | 0.005 | 0.005 | 0.116 | 0.735 |
| | Utility | 3 | 0.138 | 0.069 | 1.539 | 0.224 |
| | Residuals | 51 | 2.327 | 0.045 | - | - |

The ANOVA model for envelope gas eCMs showed no evidence of any building characteristics driving compliance, as noted by the p-values greater than 0.10 (or 10%) at the 90% confidence level, providing no evidence to perform regression analysis on any building characteristic.

### Cool Roof

Cadmus found overall gas energy savings to be less than predicted for cool roof measures, implying that sites in our sample tended to under-comply with Title 24 cool roof requirements on average. We performed ANOVA analysis to obtain a better understanding of which building characteristics are driving cool roof under-compliance.

#### *ANOVA Analysis*

Cadmus explored the relationship between building characteristics and cool roof gas eCMs by fitting ANOVA models and determining if any appeared to be driving compliance; the results are shown in Table 25.

**Table 25. ANOVA Results for Cool Roof Gas eCMs by Building Characteristics**

| Measure | Main Effects Characteristic* | Degrees of Freedom | Sum of Squared Errors | Mean Squared Error | F-value | p-value |
|---|---|---|---|---|---|---|
| Cool Roof | Building Type | 7 | 0.175 | 0.025 | 0.461 | 0.825 |
| | Climate Region | 2 | 0.025 | 0.012 | 0.228 | 0.806 |
| | Utility | 2 | 0.082 | 0.041 | 0.761 | 0.525 |
| | Residuals | 4 | 0.216 | 0.054 | - | - |

* The jurisdiction building characteristic is not included in this model because there were no buildings with cool roof eCMs in a rural jurisdiction.

The ANOVA model for cool roof gas eCMs showed no evidence of any building characteristics driving compliance, as noted by the p-values greater than 0.10 (or 10%) at the 90% confidence level, providing no evidence to perform regression analysis on any building characteristic.

### HVAC Efficiency

Cadmus found overall gas energy savings to be less than predicted for HVAC efficiency measures, implying that sites in our sample tended to under-comply with Title 24 prescriptive HVAC requirements on average. The summary statistics in Table 9 show that the average HVAC efficiency gas savings was dragged down by one drastically under-complying building. This building is a driving factor of the overall under-compliance for HVAC efficiency gas eCMs. This site is of particular interest; therefore, we identified the building characteristics (shown in Table 26) and performed a thorough review of the building details.

**Table 26. HVAC Efficiency Gas eCM Influential Point**

| Whole Building eCM | Envelope eCM | HVAC eCM | Building Type | Climate Region | Jurisdiction | Utility |
|---|---|---|---|---|---|---|
| -19.7% | 35.6% | -227.5% | High-Bay or Industrial | B | Urban | SDG&E |

From the building review, we found that the HVAC efficiency value of -227.5% results from a small denominator in a division calculation driving the large negative value shown in Equation 2.

**Equation 2**

$$\frac{-17.8\ annual\ gas\ savings}{7.83\ measure\ level\ baseline\ gas} x\ 100\% \ = \ -227\%$$

This site is located in San Diego and experiences a mild climate with minimal heating demand. The heat source is mainly electric heat pumps; thus the building has very minimal gas consumption. The baseline is insignificant at only 7.8 therms and the savings is a trivial -17.8 therms. In addition, it is unclear why a site with electric heat pumps would have both an electric and gas baseline. This appears to be an anomaly.

We then performed ANOVA analysis to determine if any building characteristics are driving HVAC efficiency under-compliance.

### *ANOVA Analysis*

Cadmus explored the relationship between building characteristics and HVAC efficiency gas eCMs by fitting ANOVA models and determining if any appeared to be driving compliance (Table 27).

**Table 27. ANOVA Results for HVAC Efficiency Gas eCMs by Building Characteristics**

| Measure | Main Effects Characteristic | Degrees of Freedom | Sum of Squared Errors | Mean Squared Error | F-value | p-value* |
|---|---|---|---|---|---|---|
| HVAC Efficiency | Building Type | 12 | 0.377 | 0.031 | 0.238 | 0.995 |
| | Climate Region | 3 | 0.096 | 0.032 | 0.243 | 0.866 |
| | Jurisdiction | 1 | - | 0.000 | 0.002 | 0.967 |
| | Utility | 2 | 0.157 | 0.079 | 0.595 | 0.557 |
| | Residuals | 39 | 5.156 | 0.132 | - | - |

* Note that no characteristics are statistically significant at the 90% confidence level.

The ANOVA model for HVAC efficiency gas eCMs showed no evidence of any building characteristics driving compliance, as noted by the p-values greater than 0.10 (or 10%) at the 90% confidence level, providing no evidence to perform regression analysis on any building characteristic.

## Decision-Maker Interviews

The purpose of the decision-maker interviews was to supplement the findings of the data analysis by highlighting the decision-making processes, market practices, and stakeholder motivators that affect Title 24 compliance.

Cadmus developed an interview guide,[33] which included questions about Title 24 compliance modeling and documentation work flows, design practices, and technologies that make it challenging or easy to meet the Title 24 requirements and reasons why some buildings over-comply while others may not comply.

We referred to some of the high-level findings of the data analysis in our interviews. For example, envelope insulation performance among the sampled buildings was, on average, slightly less efficient than the Title 24 prescriptive envelope requirements with an electricity eCM average of -0.6%. HVAC system efficiency and interior lighting were, on average, more efficient than the Title 24 prescriptive requirements, with eCMs of 2.5%, and 7.6%, respectively. We used the interview responses to gain additional insight into these patterns of over-compliance and noncompliance.

We anticipated that, given the passage of time, either we may not be able to reach the individuals involved in the design and construction of the buildings sampled for the 2010-2012 evaluation, or they would not recall decision-making processes or market practices specific to the 2008 Title 24 standards. Therefore, we asked about current market practices and decision-making processes in interviews but included an additional question on whether these practices and processes have changed in the past few years.

Cadmus randomly selected 30 buildings from the 2010-2012 evaluation sampled buildings and called owners/developers, design professionals (architect or engineers), and Title 24 consultants listed on the project documentation. We were able to reach five individuals involved in the sampled building projects, plus two individuals who had replaced the original professionals in charge of the sampled building project. We supplemented these interviews with two interviews with design and construction professionals recruited from an IOU Title 24 focus group meeting held in SoCalGas Anaheim Energy Center on November 15, 2016. Table 28 shows the detailed count of interviewees.

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33 The interview guide is provided in Appendix C. Decision-Maker Interview Guide.

Table 28. Detailed Count of the Interviewed Decision-Makers

| Stakeholder Type | Number of Interviewees Involved in Sampled Building Project | Number of Interviewees Not Involved in Sampled Building Project | Total Number of Interviewees |
|---|---|---|---|
| Owner/developer | 2 | - | 2 |
| Architect | 2 | - | 2 |
| Mechanical Engineer | 1 | - | 1 |
| Mechanical Engineer and Title 24 Energy Analyst | 1 | 2 | 3 |
| Title 24 Energy Analyst and Certified California Advanced Lighting Control Training Program (CALCTP) Acceptance Testing Professional | - | 1 | 1 |
| **Total** | **6** | **3** | **9** |

We used the interview guide to lead the conversation and asked follow-up questions where appropriate. We limited the interviews to 30 minutes and therefore, focused on the most relevant questions to the interviewee's role on the project or design discipline. When responses could be classified into groups, we included the number of responses in each category. Otherwise, we brought interview findings together to describe a general process or market practice. It is important to note that due to the limited number of interviews, the findings are not representative of overall market practice and decision-making processes.

We have summarized the interview results in three sections:

- Decision-Making Processes that Lead to Over- or Under-Compliance
- Motivating Factors for Over- or Under-Compliance
- Customer and Building Characteristics of Over- and Under-Compliant Buildings

## *Decision-Making Processes that Lead to Over- or Under-Compliance*

Five out of nine owners and design professionals interviewed stated that they perform their first complete evaluation of a project's compliance against Title 24 during the design development phase[34] or earlier. One Title 24 energy analyst stated that he performs the first building energy compliance analysis during design development for green building projects. Otherwise he does not review projects until the

34 Schematic design, design development, and construction documents are three distinct phases identified in most new construction or major retrofit project milestones. The project design is further refined as it progresses through each phase. The architect and engineers provide detailed information and specifications in the construction documents phase such that the building project can be priced and built. In tenant improvement or small retrofit projects, these phases are condensed into one or two phases total.

construction documents phase. Two other Title 24 energy analysts expressed frustration that the first time they review projects for compliance with Title 24 is typically after the mid-point of the construction documents phase or prior to permit submittal (and thus not soon enough). One owner stated that he does not need to evaluate building energy compliance because they are already incorporated in the plans (presumably by the design professionals involved) and therefore did not speak to the specific timing of such evaluations (see Table 29).

**Table 29. Timing of the First Title 24 Building Compliance Check or Performance Evaluation**

| Response | Number |
|---|---|
| During Early Planning Reviews | 1 |
| During Schematic Design | 1 |
| During Design Development | 3 |
| During Design Development for Green Buildings and After 50% Construction Documents for Others | 1 |
| After 50% Construction Documents | 1 |
| Before Permit Submittal or Building Inspection | 1 |
| No Answer | 1 |
| **Total** | **9** |

One architect explained that by the time the engineers review the project for Title 24 compliance for the first time, some of the most critical architectural design decisions that greatly impact the building energy performance (e.g. the building massing, orientation, and glazing area) have already been made to satisfy earlier planning reviews and stakeholder approvals. Another architect stated that on projects pursuing green building certification they perform iterative reviews of a building project's compliance against Title 24 starting in the schematic design phase. It is Cadmus's understanding that the reason why some owners and developers do not invest in building energy modeling or compliance checks earlier than design development, is their perception that detailed design information is needed for this effort.

When Title 24 energy analysts evaluate the energy performance of a project design during the design development phase or earlier, they incorporate assumptions about the detailed characteristics of envelope, fenestration, mechanical equipment, building controls, and lighting systems. Two out of four interviewees who responded said that if the design does not pass the first performance compliance check, the envelope insulation and fenestration values are the first two aspects of the building design to be altered. These individuals further explained they assume that mechanical, plumbing, and electrical design will eventually meet or exceed prescriptive compliance requirements based on past experience, which is not necessarily true for envelope insulation and fenestration values. One out of four interviewees said that it depends on the building, and he will try to find which measures will have the highest impact on the project performance. The remaining respondent listed mechanical controls and economizers as the aspect of the design that is most likely altered early in the design (see Table 30).

**Table 30. Building Design Aspect that is Most Likely Altered if the Building Fails its First Title 24 Compliance Evaluation During Design Development**

| Response | Number |
|---|---|
| Envelope insulation and fenestration energy performance values | 2 |
| Mechanical controls and economizers | 1 |
| It depends on the most impactful energy efficiency measure | 1 |
| No response* | 5 |
| **Total** | **9** |

* Cadmus asked this question when interviewees indicated that they perform their first compliance review during design development.

The fact that envelope performance is subject to this scrutiny was a surprise since we had found that envelope had a lower eCM when compared to the HVAC system and lighting efficiency. We had thus concluded that, on average, envelope does not receive the level of scrutiny that may be typical for electrical, lighting, or mechanical systems. One Title 24 energy analyst further explained that, while the fenestration characteristics are required in the compliance model and are closely examined, the actual performance characteristics of the project glazing or the National Fenestration Rating Council (NFRC)[35] rating of the fenestration products are often not included in the construction documents or they are not coordinated with the building compliance model. The fenestration product performance specifications are confirmed after mid-construction when fenestration products are purchased. If the glazing characteristics do not match the values assumed in the Title 24 compliance model or the prescriptive standards, the compliance model often is not updated during construction to reflect these values. If the actual glazing characteristics are worse than the values in the compliance model, then the compliance margin could decrease enough that the project fails to comply overall.[36]

Title 24 energy analysts re-evaluate the building project's performance against Title 24 around mid-construction documents phase; from that point on, they may re-evaluate the building each time new design information that may impact building energy performance becomes available. The energy analysts perform one final major update when the construction documents are approximately 90% complete. At this point, the energy analysts focus their changes on fine-tuning the compliance model.

When asked if changes during construction are reflected in the compliance model or documentation, two interviewees said yes, three said rarely, one was not sure, and one said it depends on how extensive

[35] NFRC is the supervisory entity responsible for administering the country's certification program for fenestration products. NFRC ratings are available for windows, doors, and skylight products. Under the NFRC's program, the U-factor, solar heat gain coefficient, and visible transmittance of fenestration products are independently tested, certified, and labeled.

[36] Unlike site-built and field-fabricated fenestration products, NFRC-rated products are not subject to Section 110.6(a) envelope acceptance testing requirements of the 2013 Title 24 standards.

the changes are (see Table 31). Failing to revise the compliance model or documentation with updated design or construction specifications is an apparent path for noncompliance. Though the acceptance testing requirements of Title 24 are meant to limit discrepancies between the building as-built and as-documented for compliance, the lighting acceptance testing professional indicated it is not uncommon for buildings to fail the acceptance tests. He recommended further interviews with acceptance testing professionals on the specific issues they encounter, how they could be prevented, and how they are resolved.

**Table 31. Are Changes During Construction Reflected in the Title 24 Compliance Model or Documentation**

| Response | Number |
|---|---|
| Yes | 2 |
| Perhaps (depending on how extensive the changes are) | 1 |
| Rarely | 3 |
| Not Sure | 1 |
| No response | 2 |
| **Total** | **9** |

Five out of six interviewees who responded said they were not surprised by the high-level findings of our data review. In reaction to Cadmus' average envelope under-compliance observation, the interviewees said the envelope prescriptive requirements are fairly strict. One of the architects emphasized that energy performance is one among many of the factors that architects need to consider in their design, which include stakeholders' preferences, the surrounding environment and limitations of the site, etc. As an example, he cites, "*… when the prescriptive requirements sets a limit of 40% on the west elevation glazing, this sets us up for a very limiting architectural conversation*."

On the other hand, due to the potentially catastrophic cost impacts of an HVAC redesign, mechanical engineers are very conservative with their design and go above and beyond the Title 24 energy standards prescriptive requirements. While this over-compliance can be explained by design decisions on the part of mechanical engineers, it appears that LED technology selection and availability is the main driver for lighting over-compliance. As one Title 24 energy analyst put it, "*I always count on lighting to make up the difference* [between the desired building energy compliance or performance level and the performance achievable based on mechanical and envelope design improvements alone]."

When asked how they have changed their approach to showing compliance or exceeding Title 24 in their projects in recent years, three of the interviewees said their approach has not changed. Two of the interviewees said they aim for higher performance right from the beginning and get started on the analysis earlier so they can better inform and influence the building design process. One interviewee said his conversations with the architects have become much more important. Three interviewees did not know or did not respond.

**Table 32. Changes Made in Title 24 Compliance Approach in Response to Increased Code Stringency**

| Response | Number |
|---|---|
| No change | 3 |
| Aim for higher performance from project start and perform analysis earlier | 2 |
| Prioritize the discussion with architects | 1 |
| No response | 3 |
| **Total** | **9** |

## *Motivating Factors for Over- or Under-Compliance*

Seven of eight interviewees who responded agreed that owners are the most important stakeholders in determining the level of compliance with Title 24. One owner (incidentally, a project manager from a city capital improvements department) argued that the city building department or the authority having jurisdiction is the most important stakeholder. [37]

**Table 33. Who is the Most Important Stakeholder to Determine Level of Title 24 Compliance**

| Response | Number |
|---|---|
| Building owner | 7 |
| City building department or the authority having jurisdiction | 1 |
| No response | 1 |
| **Total** | **9** |

All eight respondents said that while owners can demand a certain level of energy performance, they have limited control when it comes to actually making sure those demands materialize. The design professionals translate the owners' demands into project plans and specifications that must meet the Title 24 requirements. For this reason, the interviewed owners deflected the responsibility to the design professionals for ensuring the Title 24 requirements are explicitly addressed. One of the owners said, "*… the energy standards are in the plans*. [The owners] *don't give it much thought. The architects do*." Similarly, one architect said his design is informed by compliance input from engineers (which loosely refers to the Title 24 energy analyst that is often part of the mechanical, electrical, and plumbing team or hired by them). Therefore, it appears that the responsibility for ensuring the requirements are explicitly addressed in the design is the engineer's responsibility.

[37] The limitation of authorities having jurisdiction, specifically in enforcing the energy code requirements, have been extensively documented in the literature and were anecdotally confirmed in our interviews. Refer to the Literature Review section of this report for references to articles reviewed as part of this effort about the role of the authority having jurisdiction and their limitations when it comes to enforcing the energy code.

All nine interviewees agreed that controlling project construction costs is the most important motive for owners in targeting a certain level of compliance with Title 24. While owners do not set out to under-comply with Title 24, the acceptance testing professional stated that he often sees noncompliant projects, in which the owner (with the general contractor's input) decided to cut project costs without the input of the design professionals or the Title 24 energy analysts.[38] One of the owners expressed frustration with the retrofit threshold, above which a lighting retrofit project needs to go through the permitting and code compliance process. He said building owners with small retrofit projects may not comply with the code by failing to apply for a construction permit. None of the buildings sampled for the 2010-2012 evaluation fell in this category since they were all permitted.

The interviews confirmed what Cadmus found in the literature review regarding green building certification and recognition programs being a strong motivator for exceeding Title 24 requirements. However, those certification and recognition programs are appealing for larger or flagship projects. On small projects, the biggest motivation is often limiting operating costs. One mechanical engineer/Title 24 analyst interviewed stated that: "*Except when they desire green building certification, most of our clients do not plan on exceeding Title 24. I have yet to see* [project design] *requirements from an owner that says: 'exceed Title 24 requirements.'*"

## Customer and Building Characteristics of Over- and Under-Compliant Buildings

Seven interviewees responded to questions about whether the building type and geographic location affect the level of compliance with Title 24. All agreed that geographic location was a factor that affected compliance, and only one out of seven thought that building type was not an important factor in the level of compliance. The prescriptive envelope insulation criteria in Section 140.3 of 2013 Title 24, for example, are more stringent for inland climate zones 10-16. Therefore, the geographic location of the project can impact how easy or challenging it is to exceed the Title 24 requirements.

One Title 24 analyst pointed to building construction type as an important factor in determining the level of compliance with Title 24. He pointed to the prescriptive exterior wall insulation requirements in Section 140.3 of 2013 Title 24 that are particularly challenging to meet for metal-framed buildings, saying, "*The builders do not want to hang stucco on tall buildings more than an inch or two off the metal framing* [to accommodate continuous insulation]*, as the fasteners are not strong enough* [to hold the stucco in-place] *and this leads to poor construction.*"

[38] This comment was in specific reference to occupancy sensors required by Title 24. The acceptance testing professional has found during acceptance testing that some projects do not install all the sensors required in an effort to cut costs.

Another Title 24 analyst pointed to the fenestration performance requirements that are challenging to meet in retail buildings, indicating that retailers prefer single pane clear glass, which does not have a good thermal performance.

The HVAC fan power consumption limits in Section 140.4(c) are challenging in retail, dining, and other high-density occupancies because of the low fan power requirements for VAV systems as the standard for buildings over 1 story or 10,000ft$^2$. The code also requires constant air volume and high filtration requirements for medical office buildings, specifically OSHPD 3 occupancies. This combination makes it nearly impossible to pursue a performance approach compliance path for these buildings, and prescriptive compliance path is also challenging. On the other hand, these requirements are easy to exceed in warehouses where the ventilation airflow requirements are lower. One interviewee said that while there is an economizer trade-off table for comfort cooling systems in Section 140.4(e), the economizer requirements in Section 140.9 of Title 24 2013 do not provide an efficiency trade-off alternative and can be very challenging to meet in certain situations.

In our interview calls to the owners and design professionals involved in the 2010-2012 evaluation sampled buildings, we realized another factor that may affect over- and under-compliance. In the case of restaurants, gas stations, and auto care/maintenance buildings, building type is also a proxy for building project size. We were not able to conduct the interview with the owners and professionals involved in these building projects as they either did not return our calls or refused to participate in the interviews. We did, however, realize that these projects are owned and designed by small businesses. The businesses did not have a website, or the limited website had not been updated recently. The phone directories listed only a few staff names. In one case, a building engineer contacted for a potential interview requested compensation for his time in order to agree to be interviewed. Smaller businesses may not have the resources required for a thorough investigation of the Title 24 requirements or the continuous education needed to keep up on the changing requirements of the code.

# Conclusions

## *Building Characteristics and Code Compliance*

Cadmus performed data analysis to answer the research questions of this project. The conclusions from that effort are described here.

Note that some measures comply with electric requirements but not gas requirements and vice versa. The Title 24 performance approach does not have separate maximum energy use thresholds for gas and electric. Gas and electric are both rolled into the Time Dependent Valuation (TDV) energy budgets for the standard design building and the proposed design building as a combined kBtu. Our custom version of EnergyPro reported both kWh and therms (standard design and proposed design) so we could analyze these separately.

### Building Characteristics and Whole-Building or Measure Code Compliance

To answer questions about the relationship between building characteristics and code compliance, we conducted several analyses examining compliance at the whole-building level and by measure. The examined building characteristics included building type, climate region, jurisdiction (urban or rural), electric utility, and building size.

With regard to specific details about how the customers over-complied, Cadmus reviewed the site visit notes, data collection forms, and building energy simulations for the sites with highly over-complying measures. Interior lighting tended to over-comply when LED lighting was installed. Envelope tended to over-comply when continuous insulation was installed. Cool roof tended to over-comply when higher values were specified for aged solar reflectance (generally around 0.55 – 0.65) and emittance (generally around 0.75 – 0.88). HVAC efficiency tended to over-comply due to high-efficiency heat pumps, high-efficiency packaged variable air volume (VAV) systems, high-efficiency ductless mini-split systems, and fault detection and diagnostic credit.

This research and report are based on the earlier 2008 Title 24 evaluation. Since then, the 2013 and 2016 versions have taken effect, each one more stringent than the last. The results of this research would certainly change if the baseline used the 2013 or 2016 standard rather than the 2008 standard. In most cases, these particular sites would likely not meet the newer standards at the whole-building level. However, at the measure level we expect a number of these findings would still be valid if using a newer standard as the baseline. For example, interior lighting would still over-comply when LED lighting was installed as LED lighting is not yet the prescriptive baseline. Envelope would still over-comply when continuous insulation was installed as continuous insulation is not yet the prescriptive baseline. The HVAC economizer fault detection and diagnostic credit is now a mandatory requirement as of the 2013 standards, so that is no longer a pathway to over-compliance.

### *Electricity Compliance Margins*

Cadmus performed ANOVA analysis on whole-building, interior lighting, envelope, cool roof, and HVAC efficiency electricity eCMs and regression analysis on any building characteristics found to be driving compliance trends from the ANOVA analysis.

#### Whole Building

Our analysis showed that building type was the only significant driver of whole-building over-compliance, based on results from ANOVA modeling. Analyzing this further, we found that the following building types were associated with whole-building electricity over-compliance:

- Assembly
- Athletic facilities
- Classroom buildings
- High-bay or industrial
- Medical offices (not including hospitals)
- Multifamily/group living
- Museums
- Office buildings
- Religious facilities
- Retail

The following buildings may be good candidates to increase compliance overall because they did not exhibit a statistically significant relationship between building type and whole-building electricity over-compliance:

- Auto care/maintenance
- Gas stations
- Research and laboratories
- Restaurants

However, we found no evidence of any specific observations driving these results.

#### Interior Lighting

Our analysis also showed that building type was the only characteristic driving over-compliance for interior lighting based on results from ANOVA modeling. Analyzing this further, we found that interior lighting in the following building types tended to be over-compliant in terms of electricity:

- Assembly
- Athletic facilities
- Classroom buildings
- Museum

- Office buildings
- Religious facilities
- Retail

The following buildings may present opportunities for increasing lighting compliance because they did not exhibit a statistically significant relationship between building type and lighting electricity over-compliance:

- Auto care/maintenance
- Gas stations
- High-bay or industrial
- Medical buildings
- Multifamily/group living
- Research and laboratories
- Restaurants

However, we found no evidence of any specific observations driving these results.

### Envelope

Unlike the findings for whole-building and lighting compliance, we found envelope was under-complying (relative to the prescriptive requirements) and no building characteristics, including building type, were driving under-compliance. We did find, however, that envelope measures in the following building types tended to be under-compliant in terms of electricity:

- Gas stations
- Restaurants

These results, and those for whole-building and lighting compliance, suggest that gas stations and restaurants may be good candidates for efforts to increase code compliance. We also found that climate region D tended to be under-compliant in terms of envelope electricity.

From analyzing results for individual observations, we found that one building was influential in the envelope electricity under-compliance. The building had walls and a roof that were significantly less efficient than required to meet the Title 24 prescriptive requirements.

### Cool Roof

Cadmus found cool roof measures tended to over-comply, but ANOVA modeling provided no evidence of any building characteristics driving over-compliance.

### HVAC Efficiency

Cadmus found HVAC efficiency tended to over-comply in terms of electricity compared to prescriptive requirements. We found that building type was the only characteristic that was associated with driving

HVAC efficiency over-compliance, based on results from ANOVA modeling. Analyzing this further, we found that the following building types were associated with HVAC efficiency electricity over-compliance:

- Assembly
- Athletic facilities
- Classroom buildings
- Gas stations
- High-bay or industrial
- Medical
- Multifamily/group living
- Museums
- Office buildings
- Religious facilities
- Research and laboratories
- Restaurants
- Retail

Auto care/maintenance buildings were the only buildings that did not exhibit a statistically significant relationship between building type and HVAC efficiency electricity over-compliance.

#### *Gas Compliance Margins*

Cadmus performed ANOVA analysis on whole-building, envelope, cool roof, and HVAC efficiency gas eCMs, which provided no evidence of any building characteristic driving compliance trends for any measure and, thus, provided no evidence to perform regression analysis for individual characteristics.

### Relationships among Compliance Levels

We analyzed correlations after removing influential observations to determine more representative underlying correlations. Cadmus identified one point in envelope electricity eCMs that was influencing the correlation between measures and the results from envelope ANOVA and regression analyses. After removing this point, we found interior lighting, HVAC efficiency, and whole-building compliance to be highly correlated, implying that interior lighting and HVAC efficiency compliance are driving factors of whole-building electric compliance trends.

In the cool roof gas eCM analysis, we identified three influential points, one of which was also identified as an outlier in envelope gas eCMs. When we removed these observations, we found envelope, cool roof, and whole-building compliance to be highly correlated, implying that envelope and cool roof compliance are driving factors of whole-building gas compliance trends.

### Mandatory Measure Compliance

To address a key secondary research question—*In instances of under-compliance, how would overall compliance results change if mandatory requirements were fully complied with?*—Cadmus proposed to review the mandatory measures it found noncompliant in the under-complying sites and estimate the effect if they complied. However, due to resource constraints, data collection during the 2010-2012 evaluation prioritized Title 24 changes that significantly impacted energy consumption and mandatory measures either did not change or were expected to have only a minor effect on energy consumption. Furthermore, the Title 24 code compliance software does not directly provide information on the savings impacts of some mandatory measures. Even if it did, we do not believe that the compliance results would have been significantly different than those reported in the study. For these reasons, this research project could not provide detailed analysis of these measures.

## Decision-making and Code Compliance

Cadmus performed nine interviews with building owners and design professionals about their current motivation, work flows, and decision-making factors that affect compliance with Title 24. The interviews provided insight into why envelope insulation electric compliance margin was, on average, below Title 24 prescriptive baselines and lower than lighting and HVAC system efficiency electric compliance margins in our review of sampled buildings. Building architectural design is developed and refined ahead of the mechanical, electrical/lighting, and plumbing systems, and energy performance is one of many considerations in early stages of the architectural design. Under the performance compliance path, envelope prescriptive requirements are traded off with more efficient mechanical and lighting systems. The interviewed individuals agreed that Title 24 HVAC system efficiency requirements are generally at the level that market practices will bear, while lighting requirements are less efficient than common market practice, given the affordability of LED lighting.

Although the owner has significant influence on the level of compliance with Title 24, building design professionals (architects, engineers, and Title 24 consultants) are the most important stakeholders in ensuring that the code requirements are explicitly addressed in the building design and construction. The acceptance testing professional had observed that construction documents sometimes do not explicitly address Title 24 requirements. Another mechanical engineer and Title 24 energy analyst observed this is also true for fenestration products, where detailed energy performance characteristics of fenestration products become available much later in the construction phase of the project. Even when construction documents address code requirements, changes during construction may not be reflected in the compliance model or documentation. So the as-built building may not comply with certain requirements, while the as-documented building does appear to comply.

The interviewees indicated a general perception that buildings in temperate climates of the state have an easier time exceeding Title 24 requirements, while those in more extreme climates need to be built to more stringent requirements, thus making it harder to exceed the code requirements. The interviewees also indicated that building type is an important factor due to ventilation requirements, the predominance of steel frame construction, and the prevalence of highly glazed design in certain building types. While making interview calls, we found that restaurants, gas stations, and auto care/maintenance buildings were often developed and designed by smaller organizations, which may not have the resources for a thorough investigation of Title 24 requirements or the continuous education needed to keep up with the changing code requirements.

# Recommendations

Based on our findings from the literature review, data analysis and phone interviews, Cadmus suggests that the program administrators consider the following recommendations.

## Recommendations Related to Electric Savings

Envelope performance showed consistent under-compliance with Title 24. After analyzing specific characteristics, the greatest impact for improvement of under-compliance can be obtained by directing compliance improvement efforts towards gas station and restaurant building types. Additionally, classroom buildings, high-bay and industrial, medical buildings, multifamily/group living, museums, office buildings, and retail building types are also contributing to under-compliance of envelope performance; therefore, efforts can be focused on these building types to improve eCMs and energy savings.

## Recommendations Related to Electric and Gas Savings

Cadmus was unable to analyze electric and gas savings for certain measures due to insufficient data. Updating the sampling design to account for measures such as sky-lighting and side-lighting or DDC to zone, could increase sample sizes and improve analyses for these types of measures. A stratified sampling design with measures of interest as the strata is one approach to ensuring that this type of data offers a large enough sample size of buildings with these measures.

Establishing an energy performance target early in a project timeline is key to ensuring that the building performs well compared to Title 24. In general, the key stakeholder in establishing an early target is the owner or the owner/developer, although the occupants and the design professionals can also have a significant influence on those targets. We recommend that efforts to improve code compliance address how to engage building owners early in a project timeline to help influence and improve compliance.

Smaller design companies may not have the resources for a thorough investigation of Title 24 requirements or the continuous education needed to keep up with the changing code requirements. Targeting these smaller organizations with education and outreach is a good opportunity for IOU code compliance improvement efforts.

Failing to revise the compliance model or documentation with updated design or construction specifications is an apparent path for noncompliance. Although the acceptance requirements are intended to help limit discrepancies between the building as-built and as-documented for compliance, the lighting acceptance testing professional indicated it is not uncommon for buildings to fail the acceptance tests. We recommend additional interviews with acceptance testing professionals on the specific issues they encounter, how they could be prevented, and how they are resolved. Contractors who are certified Mechanical or Lighting Acceptance Test Technicians would be a great resource while investigating this topic as they can provide an essential role in identifying noncompliance issues during the acceptance tests. The Nonresidential Data Registry is a database where certified Acceptance Test

Technicians will upload acceptance test results. It is still in development as of December 2016 and is expected to be available sometime in 2017. The forms will be publicly available and will thus be a good resource for technician contact information, building characteristics, and acceptance test results.

The energy analyst is another stakeholder who can provide an essential role in identifying noncompliance issues and helping to improve compliance. The energy analyst could be the design engineer, architect, or a third-party energy consultant. The California Association of Building Energy Consultants (CABEC) manages the Certified Energy Analyst (CEA) program. As part of a long-term goal for improving Title 24 compliance for the entire state, the IOU administrators might consider developing an incentive program that encourages or requires CEA involvement on new construction projects.

# Appendix A. Additional Analysis and Results

## Building Size Regression Analysis

To examine whether building size affected compliance margins, Cadmus used building size as a predictor for electricity and gas eCMs for each measure. After accounting for other characteristics in regression modeling, such as building type, we determined there is no evidence of a significant relationship between building size and eCMs for any measure; results are shown below in Table 34.

**Table 34. Regression Results - eCMs Predicted by Building Size**

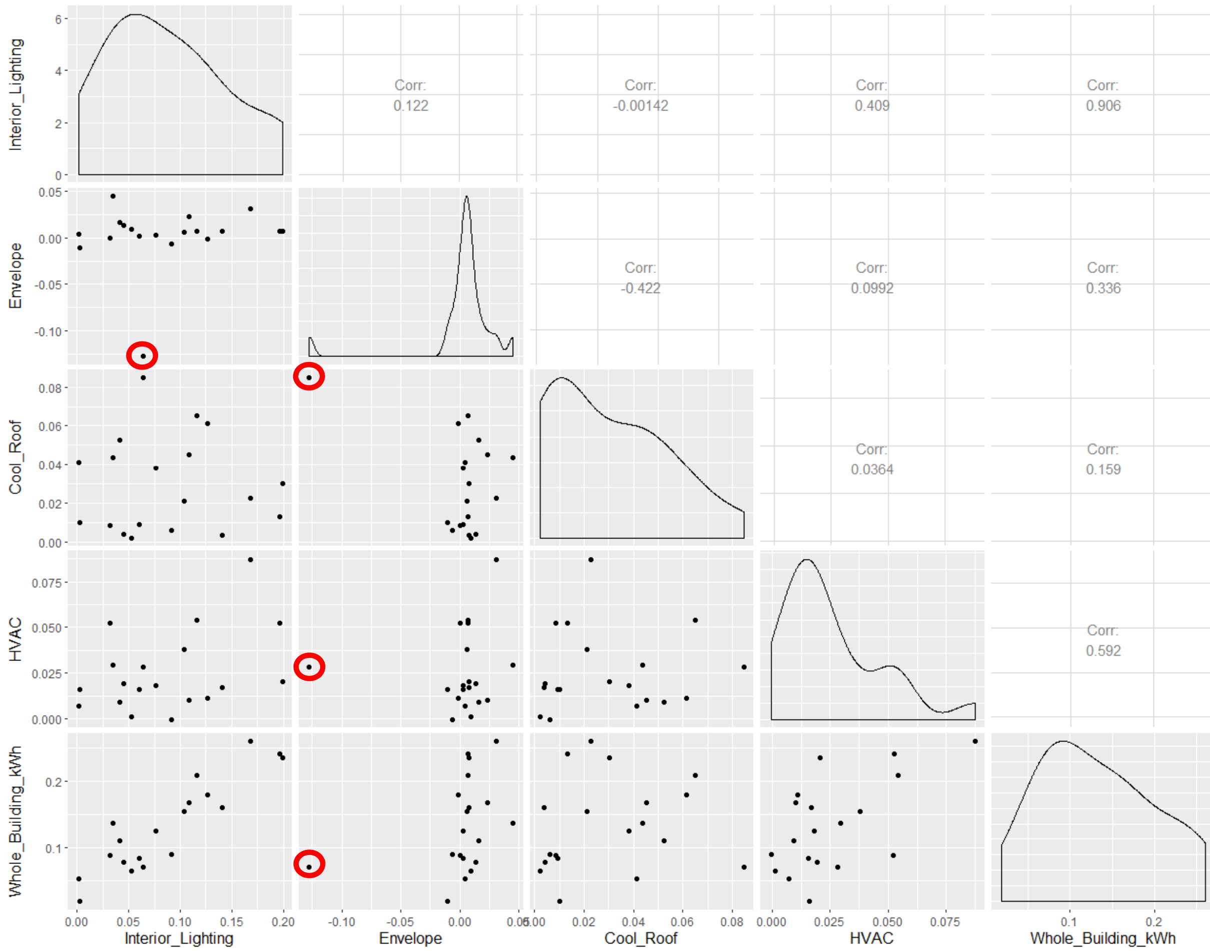
| Energy Type | Measure | p-value |
|---|---|---|
| Electricity | Whole Building | 0.195 |
| | Interior Lighting | 0.195 |
| | Envelope | 0.761 |
| | Cool Roof | 0.915 |
| | HVAC Efficiency | 0.945 |
| Gas | Whole Building | 0.795 |
| | Envelope | 0.586 |
| | Cool Roof | 0.905 |
| | HVAC Efficiency | 0.908 |

## Electricity Findings

### Correlation Analysis for Influential Points

Figure 7 shows density plots of univariate measures on the diagonal, with scatterplots of the correlation between measures in the lower half of the figure, and the correlation coefficients—which are measures of the strength of the linearity between two variables—in the upper half of the figure, mirroring their respective scatterplots. Cadmus used these plots to identify possible outliers or influential points in the data.

**Figure 7. Univariate Density and Bivariate Correlation Plot, Electricity**




Cadmus identified one influential point from envelope compliance, circled in red in Figure 7. Table 17 from the Electricity Findings report section presents building and locational characteristics for this observation. This sample point significantly affected the correlation between envelope and other measures, with a major effect on the relationship between envelope and cool roof measures. Table 35 shows the correlation between compliance measures after removing the influential point.

**Table 35. Correlation Between Electricity Compliance Measures**

| Measure | Interior Lighting | Envelope | Cool Roof | HVAC Efficiency | Whole Building |
|---|---|---|---|---|---|
| Interior Lighting | 1 | 0.094 | 0.060 | 0.414 | 0.911 |
| Envelope | | 1 | 0.265 | 0.327 | 0.370 |
| Cool Roof | | | 1 | 0.026 | 0.339 |
| HVAC Efficiency | | | | 1 | 0.613 |
| Whole Building | | | | | 1 |

Cadmus found a correlation coefficient of 0.41 between interior lighting and HVAC efficiency compliance after removing the influential point. This indicates a moderately strong positive relationship between the two measures, meaning that as interior lighting electricity eCMs increase, HVAC efficiency eCMs will also tend to increase. We found a correlation coefficient of 0.91 between whole building and interior lighting and a correlation coefficient of 0.61 between whole building and HVAC efficiency. These indicate very strong positive relationships of whole building compliance with interior lighting and HVAC efficiency, implying that over-compliance of interior lighting or HVAC electricity eCMs tend to drive whole building electricity eCMs to over-comply.

## Summary Statistics by Building Characteristics

This section includes tables of sample sizes by building characteristics for each regression model presented in the body of the report, along with boxplots for every regression model presented in the body of the report. Cadmus compared the regression estimates of compliance margins to the boxplots to ensure accuracy of the results. Including the sample sizes is imperative for the regression analysis procedure because although a building type might show statistical significance, if it is only represented by two observations, the results may not represent the population of that building type.

### *Whole Building*

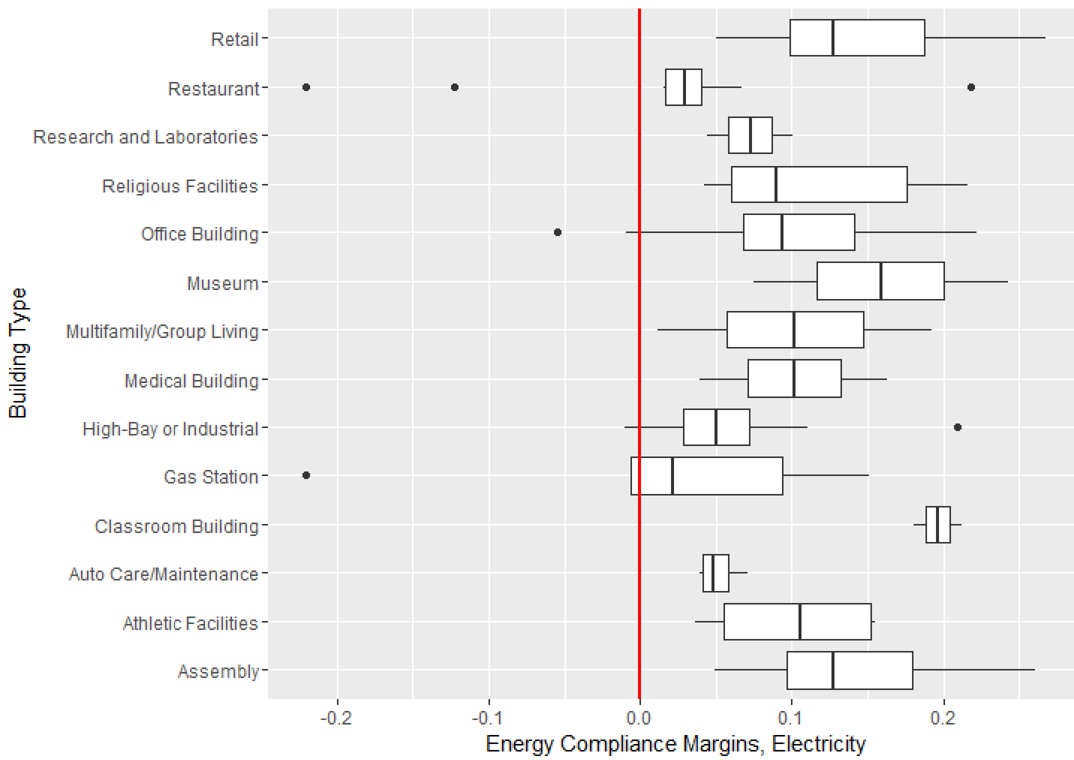
Cadmus performed regression analysis using building type as a predictor of whole building compliance. Table 36 provides the sample sizes used in the regression analysis.

**Table 36. Sample Sizes by Building Type – Whole Building**

| Building Type | Sample Size |
|---|---|
| Assembly | 7 |
| Athletic Facilities | 4 |
| Auto Care/Maintenance | 4 |
| Classroom Building | 2 |
| Gas Station | 5 |
| High-Bay or Industrial | 10 |
| Medical Building | 2 |
| Multifamily/Group Living | 2 |
| Museum | 2 |
| Office Building | 14 |
| Religious Facilities | 9 |
| Research and Laboratories | 2 |
| Restaurant | 10 |
| Retail | 18 |
| **Total** | **91** |

Figure 8 shows the distribution of whole building eCMs within each building type.

### Figure 8. Whole Building eCMs by Building Type



### *Interior Lighting*

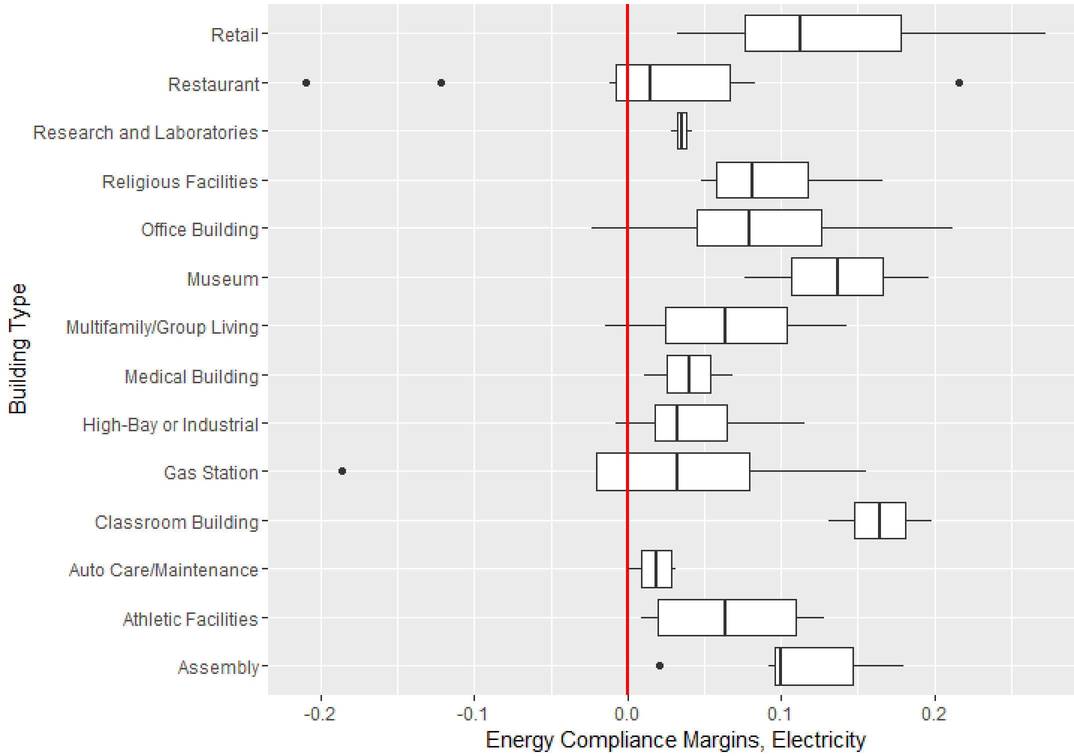
Cadmus performed regression analysis using building type as a predictor of interior lighting compliance. Table 37 provides the sample sizes used in the regression analysis.

**Table 37. Sample Sizes by Building Type – Interior Lighting**

| Building Type | Sample Size |
|---|---:|
| Assembly | 7 |
| Athletic Facilities | 4 |
| Auto Care/Maintenance | 4 |
| Classroom Building | 2 |
| Gas Station | 5 |
| High-Bay or Industrial | 9 |
| Medical Building | 2 |
| Multifamily/Group Living | 2 |
| Museum | 2 |
| Office Building | 13 |
| Religious Facilities | 9 |
| Research and Laboratories | 2 |
| Restaurant | 10 |
| Retail | 17 |
| **Total** | **88** |

Figure 9 shows the distribution of interior lighting eCMs within each building type.

**Figure 9. Interior Lighting eCMs by Building Type**



### *Envelope*

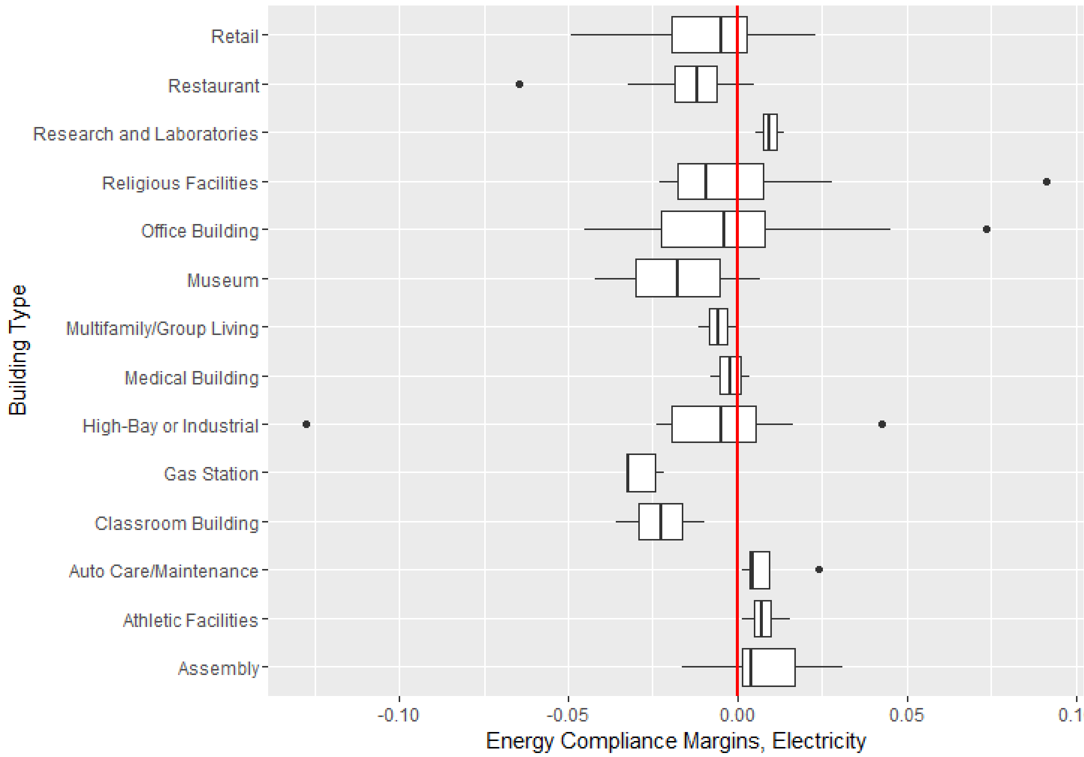
Cadmus performed regression analysis with building type predicting envelope eCMs. Table 38 provides sample sizes used in the analysis.

**Table 38. Sample Sizes by Building Type – Envelope**

| Building Type | Sample Size |
|---|---|
| Assembly | 7 |
| Athletic Facilities | 4 |
| Auto Care/Maintenance | 4 |
| Classroom Building | 2 |
| Gas Station | 5 |
| High-Bay or Industrial | 10 |
| Medical Building | 2 |
| Multifamily/Group Living | 2 |
| Museum | 2 |
| Office Building | 14 |
| Religious Facilities | 9 |
| Research and Laboratories | 2 |
| Restaurant | 10 |
| Retail | 18 |
| **Total** | **91** |

Figure 10 shows the distribution of envelope eCMs within each building type.

**Figure 10. Envelope Electricity eCMs by Building Type**



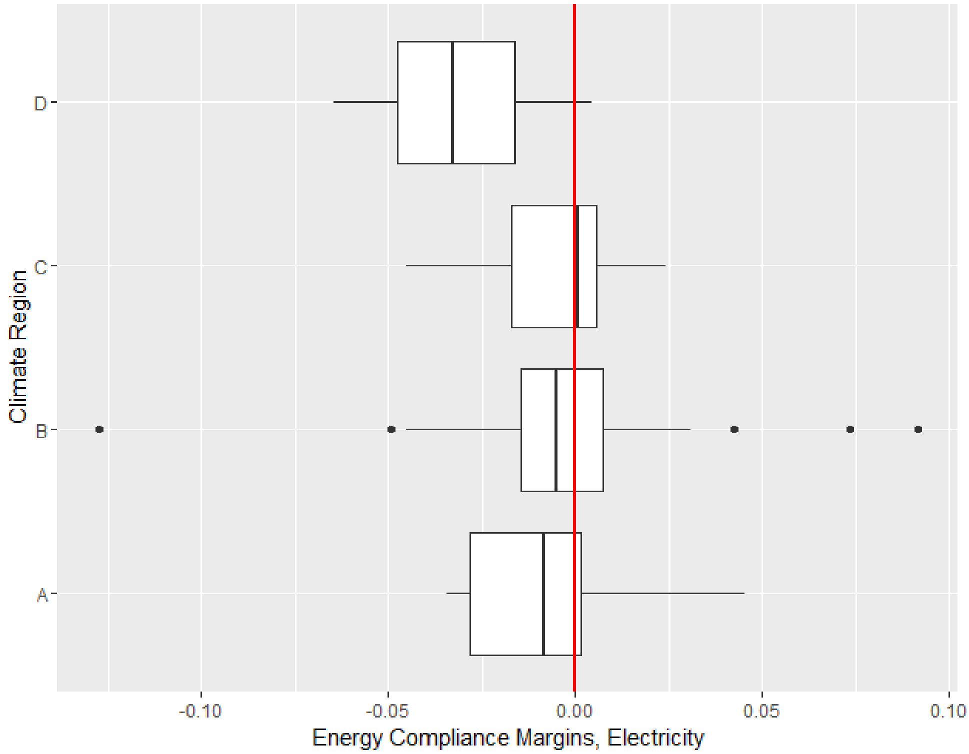

We also performed regression analysis using climate region as a predictor of envelope compliance. Table 39 provides the sample sizes used in the regression analysis.

**Table 39. Sample Sizes by Climate Region – Envelope**

| Building Type | Sample Size |
|---|---|
| A | 15 |
| B | 48 |
| C | 24 |
| D | 4 |
| **Total** | **91** |

Figure 11 shows the distribution of envelope eCMs within each climate region.

**Figure 11. Envelope Electricity eCMs by Climate Region**



### *HVAC Efficiency*

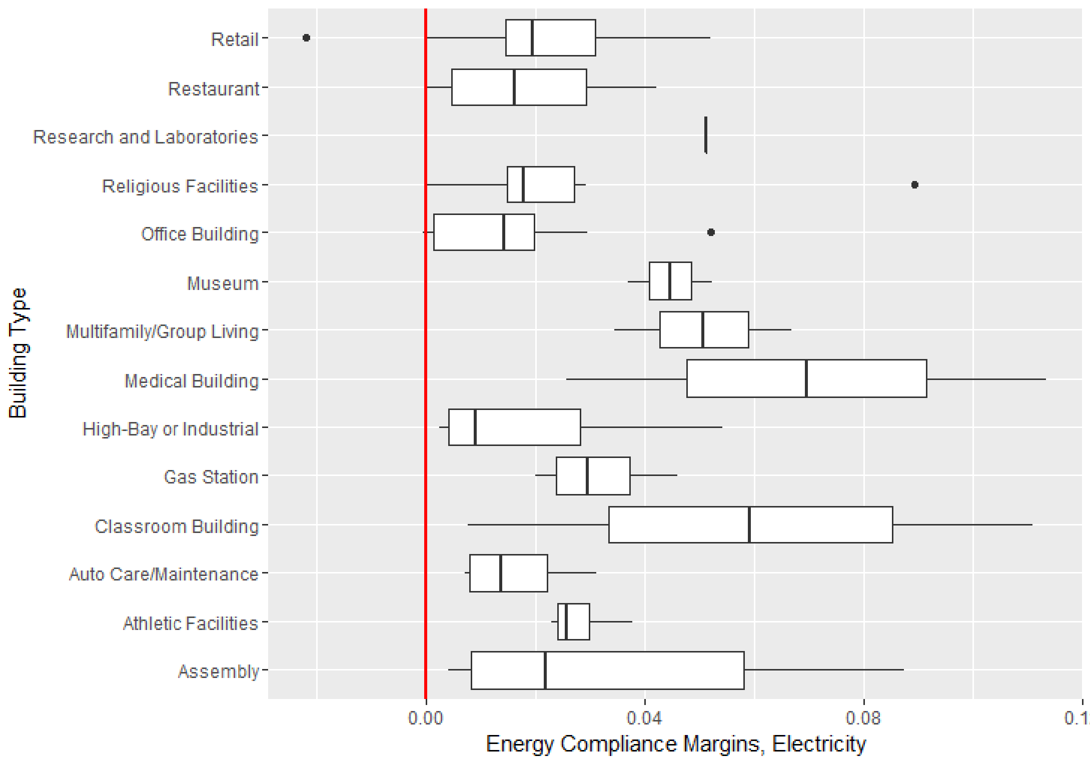
Cadmus performed regression analysis using building type as a predictor of HVAC efficiency compliance. Table 40 provides the sample sizes used in the regression analysis.

**Table 40. Sample Sizes by Building Type – HVAC Efficiency**

| Building Type | Sample Size |
|---|---:|
| Assembly | 6 |
| Athletic Facilities | 4 |
| Auto Care/Maintenance | 4 |
| Classroom Building | 2 |
| Gas Station | 4 |
| High-Bay or Industrial | 9 |
| Medical Building | 2 |
| Multifamily/Group Living | 2 |
| Museum | 2 |
| Office Building | 14 |
| Religious Facilities | 8 |
| Research and Laboratories | 1 |
| Restaurant | 9 |
| Retail | 16 |
| **Total** | **91** |

Figure 12 shows the distribution of HVAC efficiency eCMs within each building type.

**Figure 12. HVAC Efficiency eCMs by Building Type**




## *Gas Findings*

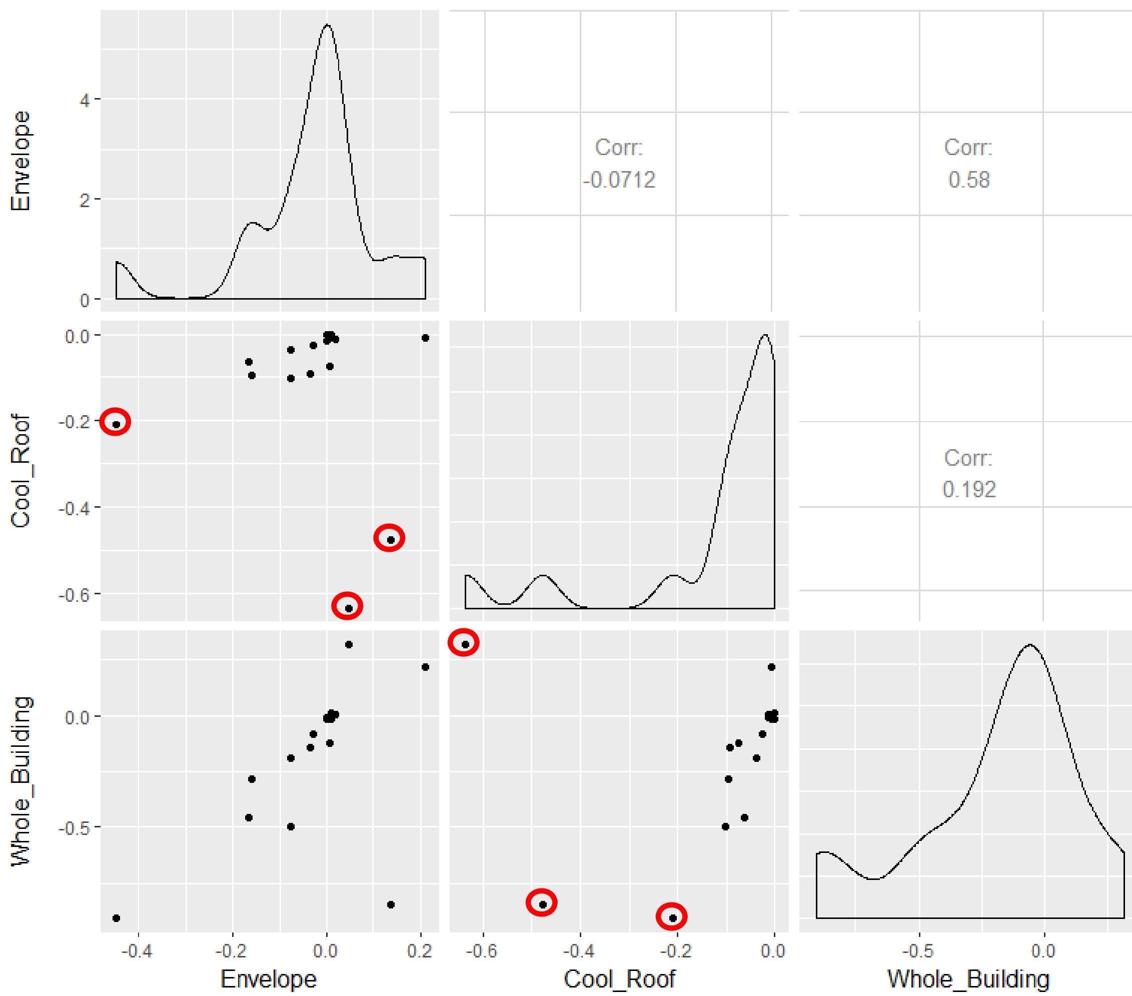
### Cluster Analysis

K-means cluster analysis was assessed for natural gas eCMs using complete data for envelope, HVAC efficiency, and whole building compliance. Cadmus established that based on the small sample size (n=57) along with the large amount of variability in the natural gas eCM data, that k-means cluster analysis was inappropriate and could produce misleading results.

### Unusual Observation Analysis

When performing univariate and correlation analysis for gas, Cadmus found one outlier in the univariate case for envelope measures, and potential outliers in the univariate case for cool roof measures. We found that with respect to correlation between measures, there appear to be three highly influential points, as circled in red in Figure 13.

Figure 13. Correlation Plot for Gas eCMs




Cadmus identified three influential points from cool roof eCMs. The building characteristics of these influential points are outlined in the body of the report in Table 21. Cadmus calculated the correlation between envelope and cool roof measures after removal of these points; results shown in Table 41. We found a moderately strong, positive correlation between envelope and cool roof eCMs. If gas eCMs for envelope increase, eCMs for cool roof increase as well. Similarly, we found strong positive relationships between whole building compliance and both envelope and cool roof compliance measures, meaning that as envelope or cool roof eCMs increase, whole building compliance will tend to increase.

Table 41. Correlation Between Measures, Gas

| Measure | Envelope | Cool Roof | Whole Building |
|---|---|---|---|
| Envelope | 1 | 0.60 | 0.86 |
| Cool Roof | | 1 | 0.78 |
| Whole Building | | | 1 |

# Appendix B. Sources Reviewed


American Institute of Architects. *AIA Contract Documents: Contract Relationship Diagrams*. October 2015.

American Institute of Architects. *Integrated Project Delivery: A Guide*. 2007.

Cadmus. *California Statewide Codes and Standards Compliance Enhancement Subprogram PY2010-2012 Pilot Process Evaluation*. Prepared for the California Public Utilities Commission. April 2014.

Cadmus. *Commercial Building Market Characterization for Savings by Design Program*. Prepared for Southern California Edison. Study ID: SCE0312.01. June 20, 2011.

Cadmus. *Statewide Codes and Standards Program Impact Evaluation Report for Program Years 2010-2012*. Prepared for the California Public Utilities Commission. October 2014.

DNV-GL. *Codes and Standards Compliance Improvement Program Years 2013-14 Process Evaluation Final Report*. Prepared for the California Public Utilities Commission. April 2016.

Donald Vial Center on Employment in the Green Economy. *California Workforce Education and Training Needs Assessment.* University of California, Berkeley. 2011.

Heschong Mahone Group (HMG). *SCE Codes & Standards Process and Market Assessment Study*. April 2009.

Meres, Ryan, J. Sigmon, M. DeWein, and K. Garrett. *Successful Strategies for Improving Compliance with Building Energy Codes.* 2012.

Misuriello, Harry, S. Penney, M. Eldridge, and B. Foster. *Lessons Learned from Building Energy Code Compliance and Enforcement Evaluation Studies*. 2010.

Navigant Consulting. *Savings By Design Market Potentials, Characterization and Best Practices Enhanced Program Participation Study*. Prepared for Southern California Edison, Pacific Gas and Electric, and San Diego Gas and Electric. February 7, 2014.

Navigant Consulting. *Measure, Application, Segment, Industry (MASI): Integrated Design for New Construction Buildings.* Prepared for Southern California Edison. February 18, 2015.

Opinion Dynamics. *Indirect Impact Evaluation of the Statewide Energy Efficiency Education and Training Program. Volume I of IV: Final Report.* Study ID: CPU0014.01. Prepared for the California Public Utilities Commission Energy Division. March 2010.

Opinion Dynamics. *2013-2014 Statewide WE&T Program: Program Theory and Logic Model Update; Centergies Data Needs; And Critical WE&T Data Needs.* CALMAC Study ID SDG0278.01. June 2014.

Pacific Northwest National Laboratory. *Commercial Building Energy Code Compliance Literature Review*. February 2016.

Pacific Northwest National Laboratory. P*reserving Envelope Efficiency in Performance Based Code Compliance*. June 2015.

Quantec. *Statewide Codes and Standards Market Adoption and Noncompliance Rates Final Report.* CPUC Program No. 1134-04, SCE00224.01. 2007.

Rocky Mountain Institute. *RMI: Using Contracting to Improve Building Project Delivery and Achieve Sustainable Goals*. 2013.

# Appendix C. Decision-Maker Interview Guide

### 2008 Title 24 Nonresidential Compliance Stakeholder Interview Guide

| Researchable Questions | Category Title | Question #s |
|---|---|---|
| • Background Information | Background Information | A1 - A3 |
| • What are the decision-making processes that lead to over or under compliance?<br>• What types of requirements lead to under or over compliance? | Performance Evaluation Process | B1 - B9 |
| • What are the customer and building characteristics of noncompliant and compliant buildings?<br>• What are the reasons that some customers significantly exceeded new code requirements? | Customer and Building Characteristics | C1- C6 |

**Objective:** The purpose of the stakeholder interviews is to complement the findings of a detailed review of the data Cadmus collected for 91 sampled buildings as part of the 2010-2012 Title 24 codes and standards impact evaluation for the CPUC. The interviews will highlight the decision-making process and motivations affecting Title 24 compliance, and focus on gaining insight beyond the data review. The questions in this interview guide do not refer to the performance of a specific building, but refer to the performance of sampled buildings on average.

Cadmus will use this interview guide to ask interviewees about current market practices and decision-making processes. Assuming that these practices and processes have remained the same as those for the 2010-2012 evaluation sampled buildings, we will use the interview responses to explain patterns we have found in the data. Additionally, we are seeking market insights or indications that respond to the project's researchable questions (see table above).

**Audience:** The stakeholders selected for this study are owners/developers, design professionals (architect or engineers), Title 24 consultants involved in code compliance decision-making, analysis, and documentation.

**Sample Methodology:** The interviewees sample frame includes stakeholders involved in the design and construction of 30 nonresidential buildings randomly selected from the 2010-2012 evaluation sample and stakeholders recruited from the IOU Title 24 focus group meeting held in Southern California on November 15, 2016. Cadmus will attempt to contact everyone on the sample frame until we have reached between eight to 10 stakeholders with the following targeted distribution: two owners/developers, two architects, and four mechanical/electrical/plumbing/Title 24 consultants. We may interview multiple stakeholders involved in the same project.

We pulled the following variables from the sampled list of projects:

- **[FIRST NAME]**

- **[LAST NAME]**
- **[BUSINESS NAME]**
- **[ROLE IN 2010-2012 EVALUATION SAMLED PROJECT OR N/A IF NOT APPLICABLE]**
- **[PROJECT BUILDING NAME]**
- **[PROJECT LOCATION (CITY)]**

## *Scheduling*

Hello,

May I please speak with ***[FIRST NAME] [LAST NAME] [IF APPLICABLE:*** or the person who is most knowledgeable about the ***[PROJECT BUILDING NAME]*** located in ***[PROJECT LOCATION (CITY)]***?

My name is ______ from Cadmus. I am calling on behalf of California's Investor Owned Utilities. They asked us to conduct interviews with owners, building design professionals, and consultants to understand your experience in evaluating performance against Title 24.

We are calling you because ***[CHOOSE APPLICABLE:*** (you participated in the IOUs Title 24 focus group and agreed to participate in these interviews) ***OR*** (you played a role in a project permitted under Title 24 2008 that Cadmus visited as part of a larger evaluation of the code's energy savings)***]***.

Do you have a detailed knowledge of Title 24 and the process of evaluating building project compliance with Title 24?

***[IF YES]*** The interview will take about 15 minutes. Shall we begin now or should I call back another time?

***[IF NO, THANK AND TERMINATE.]***

***[IF ANOTHER TIME, RECORD SCHEDULED INTERVIEW TIME]***

Respondent name:______________________________________________________________

Respondent phone: _____________________________________________________________

Interview date: ________________________________ Interviewer: ____________________

## Interview

Hello,

This is ______. I am calling for our scheduled interview. Is this still a good time?

Thank you for making the time to speak with us. As previously mentioned, Cadmus is conducting short phone interviews to better understand building design decisions and practices that affect building energy compliance with the nonresidential requirements of Title 24 Part 6 (California's Building Energy Efficiency Standards). We will refer to Title 24 Part 6 briefly as Title 24 and focus on new construction or major retrofit nonresidential projects.

We will refer to findings from our review of 91 buildings permitted under 2008 Title 24. However, most of our questions are general. They are not restricted to 2008 Title 24, a particular building, or a specific timeframe.

### A. Background Information

A1. What is your current position/role at ***[BUSINESS NAME]***?

A2. [If applicable] What was your role in the design and construction of ***[PROJECT BUILDING NAME]?***

A3. Please describe your usual role in the process of evaluating building energy compliance with Title 24:

### B. Performance Evaluation Process

First, I would like to learn about how you evaluate performance compared with Title 24.

B1. Who are the key decision-makers in making sure that Title 24 requirements are explicitly addressed in a typical building design project?

B2. At what point in the design process is the building project performance against Title 24 first evaluated?

1. If the evaluation shows that the design does not comply, what aspect of the design is most likely altered to bring the building into compliance with Title 24 at this point?

B3. Do you typically re-evaluate the building project performance against Title 24 again at some later stage in the project?

1. If so, at what stage in the project does this occur?
2. If the evaluation shows that the building does not comply, what aspect of the design is most likely altered to bring the building into compliance with Title 24?

B4. When changes are made to the design or building systems during construction, are these typically reflected in the Title 24 compliance model or documentation?

B5. The following three questions are in reference to our review of 91 nonresidential buildings permitted under 2008 Title 24.

B6. In our review, we found that envelope insulation performance was, on average, about as efficient as or less efficient than the Title 24 prescriptive envelope requirements.

1. Is this a typical level of performance in your experience?
2. What design decisions or technology selections usually make it challenging/easy to comply with the Title 24 envelope insulation requirements?
3. Does the project building type affect the level of envelope insulation performance?
4. Does the project building's local climate affect the level of envelope insulation performance?

B7. In our review, we found that building HVAC systems were, on average, more efficient than the Title 24 prescriptive HVAC system efficiency requirements.

1. Is this a typical level of performance in your experience?
2. What design decisions or technology selections usually make it challenging/easy to comply with the Title 24 HVAC system efficiency requirements?
3. Does the project building type affect the level of HVAC system efficiency?
4. Does the project building's local climate affect the level of HVAC system efficiency?

B8. In our review, we found that interior lighting performance was, on average, more efficient than the Title 24 2008 prescriptive interior lighting requirements (if necessary, under complete building area method).

1. Is this a typical level of performance in your experience?
2. What design decisions or technology selections usually make it challenging/easy to comply with the Title 24 interior lighting requirements?
3. Does the project building type affect the level of interior lighting efficiency?
4. Does the project building's local climate affect the level of interior lighting efficiency?

B9. Are you aware of other areas in the 2013 Title 24, where the requirements are typically easy to exceed or hard to meet?

1. If so, which areas are easy to exceed and which are less stringent than the prescriptive requirements and why?

B10. Are there any mandatory requirements that are difficult to meet for a specific building type?

B10a. ***[IF YES]*** What are those mandatory requirements and for what building type?
If necessary, example mandatory measures:
Mandatory requirements for space-conditioning equipment efficiency
… for multi-level occupant sensing
… for daylighting control devices
… for ventilation minimum flows
… for demand controlled ventilation

… for automatic demand shed controls
… nonresidential mechanical system acceptance tests

## C. *Customer and Building Characteristics*

Next, I would like to explore the impact of customer and building characteristics on energy code compliance decision-making.

C1. Does the local climate of a building affect the targeted level of energy performance compared with Title 24? (for example, coastal vs. inland, northern vs. southern vs. central California)

C1b. *[IF YES]* Please explain how local building climate affects decisions about meeting Title 24.

C2. In your experience, which building types tend to over-comply the most; that is, beat Title 24 by the highest margin? Please explain why these building types are likely to over-comply. ***[LIST BUILDING TYPES IF NECESSARY]***

1. Retail
2. Office Building
3. High-bay or Industrial
4. Restaurant
5. Religious Facilities
6. Assembly
7. Gas Station
8. Athletic Facilities
9. Auto Care/Maintenance
10. Classrooms or schools
11. Medical Building including hospitals
12. Multifamily/Group Living
13. Museum
14. Research and Laboratories

C3. Does whether the owner ultimately occupies the building affect the level of energy performance compared with Title 24?

C3c. *[IF YES]* How and why?

C4. Aside from pursuing green building certification, what are the reasons that some owners/developers significantly exceed Title 24 energy code requirements?

C5. Aside from an effort to keep project costs down, what are the reasons that some owners/developers barely comply with Title 24 energy code requirements?

C6. As Title 24 has become more stringent since the 2008 version, how have you changed your approach to showing compliance or exceeding the performance level in your projects?

That concludes our interview. Thank you again for sharing your time today.