What Was the Real Energy Impact of the 2008 Title 24 Energy Code?

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ABSTRACT

This paper presents results from the impact evaluation of the California statewide Codes and Standards Program (the Program) for program years 2010 through 2012. The evaluation was conducted for the California Public Utilities Commission (CPUC). The Program implemented jointly by PG&E, SDG&E, SCE, and SCG provides technical, cost, and market studies that support the adoption of standards by the California Energy Commission (CEC) and the federal government. The evaluation covered energy, demand, and natural gas impacts during the period 2010 through 2012 from the adoption of the Title 24 building codes. Commission staff and technical advisors provided oversight and input to the research.

Cadmus evaluated electric and gas savings associated with California's building energy code, the 2008 Title 24. We collected detailed primary data related to building parameters and characteristics for 91 nonresidential new construction sites following ASHRAE Level II audit guidelines. Measurement of compliance for high-impact Title 24 building code requirements was a high priority for this evaluation. The overall sample design for the field research included five distinct climate regions and selection of jurisdictions using a proportional-to-size method within each region.

We created building energy simulations for each site using EnergyPro, the most common energy simulation software package for verifying and documenting compliance with the 2008 Title 24 code. We also created customized performance reports and isolated the energy effects of the high-impact measures by performing automatic parametric runs comparing the as-built model with the 2008 Title 24 and 2005 Title 24 baseline models at a measure level.

Overview

Cadmus evaluated electric and gas savings associated with the 2008 Title 24 energy code. We collected detailed primary data related to building parameters and characteristics for 91 nonresidential new construction sites following ASHRAE Level II audit guidelines. Measurement of compliance for high-impact Title 24 building code requirements was a high priority for this evaluation. We created building energy simulations for each site using EnergyPro, the most common simulation software package for verifying and documenting code compliance with the 2008 Title 24 energy code. As the initial step of this process, we worked closely with EnergySoft, the company that developed EnergyPro, to create a customized performance report that included energy consumption for different end uses (lighting, heating, cooling, fan, and water heating). Through this analysis, we also isolated the high-impact measures (lighting, sky-lighting, side-lighting, envelope insulation, cool roof, HVAC efficiency and HVAC direct digital controls (DDC) by performing automatic parametric runs that compared the as-built model with the 2008 Title 24 and 2005 Title 24 baseline models at a measure level. These measures were those for which the 2008 Title 24 code became more stringent compared to the 2005 Title 24 code, resulting in a significant impact on the energy consumption of the building.

Compliance with code can be achieved and assessed in two basic ways: with reference to prescriptive requirements or based on energy consumption performance. The prescriptive method assigns a yes/no value for a measure as installed. This method allows for a maximum value of 1.0 for full compliance and could have values less than 1.0 based on the proportion of complying measures. Alternatively, compliance can be based on the performance of a measure or group of measures in terms of energy consumption. This method compares 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. Using an appropriate metric, compliance using a performance measure can exceed 1.0 in cases where the as-built measures consume less energy than if they or the building had just met code. One way to present code compliance findings based on energy consumption is the compliance margin, defined as follows:

$$\text{Compliance margin} = \frac{(\text{Code} - \text{compliant consumption} - \text{As} - \text{built consumption})}{\text{Code} - \text{compliant consumption}}$$

Where:

Code-compliant consumption = energy consumption of a measure or building that just meets code, and
As-built consumption = energy consumption of a measure or building as built.

The compliance margin 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 indicates how much better the efficiency is than the code requires. If the measure or building is less efficient than the code requires, the value is negative.

For nonresidential new construction projects, simulation models provided energy consumption values that we used to determine the Title 24 compliance and the compliance margins shown in Table 1.

Table 1. Performance-based compliance results*

Category	Type	Energy consumption		Compliance margin
		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%

* In the 2010–2012 evaluation[1], we reported compliance at the building level based on the ratio of energy consumption of the building, if it just met code, divided by the energy consumption of the building as built.

[1] See "Statewide Codes and Standards Program, Impact Evaluation Report For Program Years 2010-2012" prepared for California Public Utilities Commission: http://www.calmac.org/publications/CS_Evaluation_Report_FINAL_10052014-2.pdf

Sampling

The overall sample design for the field research included five distinct climate regions[2] and selection of jurisdictions using a proportional-to-size method within each region. Based on statistical testing, we found the new construction sample to be representative of the overall population for new construction. Also, we post-weighted results to ensure representativeness. This allowed us to apply the evaluation results to statewide construction activity. Data purchased from market research firms such as McGraw Hill Construction (MHC).

Data Collection

Through our analysis, we determined whether the measures met the 2008 Title 24 code requirements and how much more or less efficient they were than the requirements. We performed the following three steps to assess compliance of each site:

- Researched all available building department documents related to the plan review and permitting process, including:
    - Architectural, electrical, and mechanical drawings;
    - Construction details and specification books;
    - Title 24 documentation (envelope, lighting, and mechanical); and
    - Cool roof rating certification.
- Conducted site visits to physically verify the building's parameters and characteristics to use in the whole-building energy modeling, including:
    - Building configuration, footprint dimensions, orientation, and area of each activity type (square footage);
    - Construction material type;
    - Envelope characteristics;
    - HVAC equipment and distribution-system specifications (type, quantities, and efficiency rating);
    - Envelope insulation material and thickness (R-value);
    - Window glazing specifications (U-value and SHGC) and surface areas; and
    - Lighting densities and control types.
- Interviewed staff familiar with the facility to confirm current occupancy or facility use and other items significantly impacting facility energy consumption. To maintain consistency across sites and assess compliance in accordance with the code-modeling requirements, we used EnergyPro's default schedules for each commercial building.

Analysis

Cadmus used a customized performance report produced by EnergyPro that included energy consumption for different end uses (lighting, heating, cooling, fan, and water heating). This report also isolated high-impact measures that we wanted to analyze by performing automatic parametric runs that compared the as-built model with the 2008 Title 24 and 2005

[2] Based on analysis of the California Energy Commission's 16 climate zones.

Title 24 baseline models at a measure level. For the sampled buildings, we calculated the energy savings in two ways: by taking the difference between the modeled energy use of each building as built and (1) if built to just meet the 2008 code and (2) if built to just meet the 2005 code. We disaggregated the measure-level savings for measures for which the 2008 Title 24 code was considerably more stringent than the 2005 Title 24 code and would have significantly impacted the energy consumption of the building. The measures included the following:

- Lighting (complete building, area category, and tailored methods);
- Sky-lighting;
- Side-lighting;
- Envelope insulation;
- Cool roof;
- HVAC efficiency; and
- DDC to zone (five measures).

Through these evaluation efforts, Cadmus analyzed the 91 new commercial buildings in California that are distributed as shown in Figure 1.

Figure 1. Distribution of new construction sites analyzed[3]

[3] See "Statewide Codes and Standards Program, Impact Evaluation Report For Program Years 2010-2012" prepared for California Public Utilities Commission: http://www.calmac.org/publications/CS_Evaluation_Report_FINAL_10052014-2.pdf

California's Title 24 commercial building code regulates the intensity of installed lighting in commercial spaces by placing limits on the lighting power density (LPD), which is the total wattage of lighting installed per square foot of lit area. Cadmus applied the following most relevant compliance methods to the savings per lighting load estimated for the projects:[4]

- **Complete building method.** The complete building method may be used when more than 90% of a building is given over to a specific area type; in this case, the entire building is treated as a single unit and an LPD cap relevant to that specific space type is applied.
- **Area category method.** The area category method is used to provide differing LPD caps according to the function of each space within a building. Trade-offs between these area-specific allowances are permitted by Title 24, although not between conditioned and unconditioned spaces, allotments of which must be separate. An overall maximum lighting allowance is awarded based on the sum of allowances for all areas within the building.
- **Tailored method**. The tailored method is used as an alternative to the area category method, typically (although not necessarily) when significant ornamental lighting is installed. This method is the most customized, and adjusts standard LPD allowances on the basis of lamp positioning and other critical factors.

Under all compliance methods, fixtures may be subject to a power adjustment factor (PAF) that reduces the effective installed wattage because of skylights or lighting controls.

In 2008, Title 24 underwent an extensive revision, with adjustments made to the allowable LPDs for all compliance methods. The code introduced new categories of activity areas and made adjustments to special allowances relating to lighting controls and other considerations. In our code-compliance analyses involving lighting, Cadmus modeled the site with the installed lighting power observed by Cadmus staff on-site. We also compared the energy consumption to the site using the lighting allowances permitted by the 2005 and 2008 Title 24 codes through one of the compliance methods discussed above.

Among the critical inputs for these models were the various area functions within a site as well as the square footage of each function. Under the area category method, these room or zone functions determine the maximum allowable lighting power for that space.

Similarly, for the complete building method, a site-wide lighting power allowance is determined based on the building's primary function (e.g., a restaurant or an office).

To be in compliance with Title 24, as stipulated in the 2005 and 2008 Title 24 codes, the cumulative wattage of installed lighting at a site cannot exceed an overall lighting allowance determined using the LPDs specified above. To determine the overall amount of permissible installed lighting, the square footage of each zone is multiplied by the zone's code-required LPD; these products are then summed across all zones within the building. Under the complete building method, all spaces within a site are treated as a single zone.

$$Allowed\ Lighting\ (W) = \sum_{All\ zones} area_{zone} \times LPD_{zone}$$

[4] A whole-building performance-based path also can be taken in the case of new construction.

A PAF may be applied to lights operating with certain controls (e.g., occupancy sensors, dimming switches) within certain area types, and in areas with sky-lighting or side-lighting under certain daylighting controls. The effective wattage of the controlled fixture may then be determined by subtracting the product of the PAF and the nameplate controlled wattage from the installed wattage.

Cadmus found that 82 of the 91 buildings analyzed met the 2008 Title 24 lighting code requirements. Daylighting savings came from side-lighting (vertical fenestration) 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. EnergyPro requires that daylight sensor control information, along with the physical skylight or sidelight (window or door) 'child' component, be assigned to the correct 'parent' component (wall or roof) within the space. The sky-lit and/or side-lit area within each space is assigned upstream at the space parameter level. Daylighting savings are calculated only if there is a daylight sensor assigned for controlling lighting fixtures within the space that has side-lighting or sky-lighting. In the evaluation process, we discovered several projects in which skylights were installed; however, daylighting savings could not be claimed because daylight sensors were not installed. This lack of controls precludes the fixtures' capabilities of automatically dimming down when ample daylighting is available. Table 2 summarizes the compliance findings for interior lighting.

Table 2. Rates of compliance with 2008 Title 24 interior lighting code[5]

Building type	Count	Percentage of sites in compliance with 2008 code
Retail	18	100%
Office building	14	93%
High-bay or industrial	10	80%
Restaurant	10	70%
Religious facilities	9	100%
Assembly	7	100%
Gas station	5	60%
Athletic facilities	4	100%
Auto care/maintenance	4	100%
Classroom building	2	100%
Medical building	2	100%
Multifamily/group living	2	50%
Museum	2	100%
Research and laboratories	2	100%
Total	91	90%

[5] See "Statewide Codes and Standards Program, Impact Evaluation Report For Program Years 2010-2012" prepared for California Public Utilities Commission: http://www.calmac.org/publications/CS_Evaluation_Report_FINAL_10052014-2.pdf

Savings Results

Overall, at the measure level, the sampled new construction sites realized electric savings across all areas of building characteristics except for envelope measures, as shown in Table 3.

Table 3. New construction electric savings by measure type

Measure	kWh savings relative to 2008 code
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

As shown in Figure 2, the cool roof savings are higher in the Central Valley and Southern regions of the state due to the climatic conditions and cooling load being significantly higher than other regions. Also, savings associated with sky/side-lighting were only observed in few sampled sites --happened to be in the Central Coast region-- as most sites either did not have this measure, or the controls were not effectively wired to photo sensors to adjust the lighting levels accordingly and in an automatic way.

Figure 2 presents measure-level savings for each climate zone.

Savings relative to 2008 code

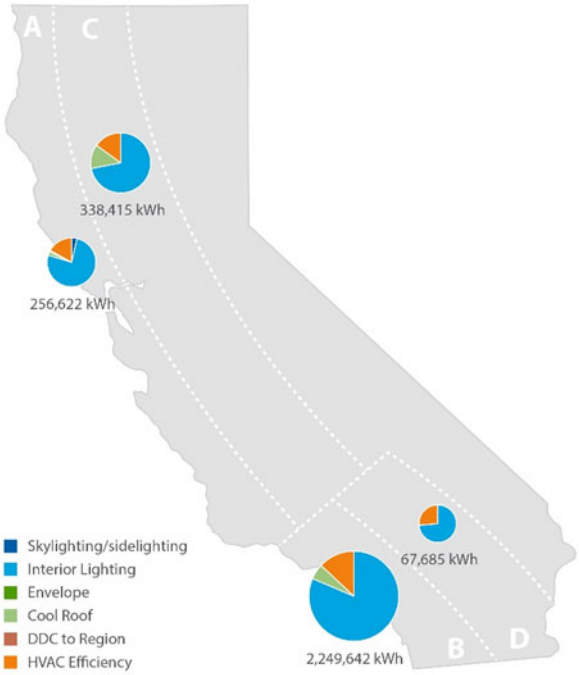

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Table 4 presents the overall savings compared to the 2005 and 2008 Title 24 codes. For all measures at the 91 newly constructed sites, Cadmus found that the sites analyzed saved 3,917 MWh relative to baseline 2005 Title 24 code buildings and 2,961 MWh relative to the 2008 Title 24 code, as shown in Table 4. While lighting improvements often result in an increase in gas consumption because of higher heating loads, other site improvements resulted in overall gas savings of 13,267 Therms relative to the 2005 code and 2,050 Therms relative to the 2008 code. Energy and demand savings decrease from the 2005 Title 24 to the 2008 Title 24 energy code as the 2008 version of the code became more stringent and hence a higher baseline to estimate the savings against.

Table 4. Overall savings for new construction sites

Savings type	Overall consumption			Savings	
	As-built	Minimally compliant with 2005 Title 24 code	Minimally compliant with 2008 Title 24 code	Savings relative to 2005 Title 24 code	Savings relative to 2008 Title 24 code
Electric energy (kWh)	19,886,535	23,803,195	22,847,342	3,916,660	2,960,807
Demand (kW)	5,865	7,265	6,838	1,399	972
Gas energy (Therms)	191,551	204,817	193,601	13,267	2,050

Table 5 shows the percentage of savings observed: approximately 16.5% of their electric consumption relative to the 2005 code and 13.0% of their electric consumption relative to the 2008 code. Gas use decreased by 6.5% relative to the 2005 Title 24 code, but by only 1.1% relative to the 2008 Title 24 code.

Table 5. New construction savings by building types, sampled projects

Building type	Count	Percentage of 2005 electric consumption saved	Percentage of 2008 electric consumption saved	Percent of 2005 gas consumption saved	Percentage of 2008 gas consumption saved
Retail	18	17.7%	13.9%	2.8%	-0.4%
Office building	14	20.4%	15.7%	4.6%	1.4%
High-bay or industrial	10	8.9%	5.5%	-1.2%	-27.5%
Restaurant	10	5.9%	2.9%	4.1%	1.3%
Religious facilities	9	15.8%	14.2%	4.0%	3.4%
Assembly	7	12.8%	11.9%	5.8%	2.1%
Gas station	5	5.9%	2.6%	3.4%	-1.6%
Athletic facilities	4	7.9%	7.1%	22.0%	7.9%
Auto care/maintenance	4	14.2%	5.3%	3.5%	0.8%
Classroom building	2	21.8%	20.7%	0.0%	0.0%
Medical building	2	17.3%	15.6%	7.0%	-4.3%
Multifamily/group	2	6.6%	5.7%	14.9%	14.2%

Living					
Museum	2	17.7%	15.9%	12.8%	-46.1%
Research and laboratories	2	6.1%	4.8%	-4.5%	-16.0%
Total	91	16.5%	13.0%	6.5%	1.1%

Conclusions

Cadmus estimated the total potential Title 24 savings at 3,656 GWh, 844.9 MW and 4.3 MTherms (based on construction data for 2010-2012). For new construction sites, measurement of compliance for high impact Title 24 building codes was a high priority for this evaluation. Measures that significantly impacted the energy consumption of the building included the following:

- Lighting (complete building, area category, and tailored methods);
- Sky-lighting;
- Side-lighting;
- Envelope insulation;
- Cool roof;
- HVAC efficiency; and
- DDC to zone (five measures).

Based on the site data, lighting systems were responsible for 81% of all energy savings, followed by HVAC efficiency measures (14%) and cool roofs (6%). The building envelope was unique because, aggregated across all sites, envelopes were slightly less efficient than the 2008 Title 24 code required.

Reference

Statewide Codes and Standards Program, Impact Evaluation Report For Program Years 2010-2012" prepared for California Public Utilities Commission: http://www.calmac.org/publications/CS_Evaluation_Report_FINAL_10052014-2.pdf