STATE OF CALIFORNIA EDMUND G. BROWN JR., *Governor*

PUBLIC UTILITIES COMMISSION
505 VAN NESS AVENUE
SAN FRANCISCO, CA 94102-3298

August 4, 2017

Codes & Standards Impact Evaluation

Dear Interested parties:

The primary purpose of the codes & standards impact evaluation is to determine the energy savings credit given to investor owned utilities (IOUs) for the advocacy work in promoting building codes and standards. The evaluation of the IOUs codes & standards program showed net program savings (i.e., the credit given to utilities for their role in developing a new California building code) of **96% of what the IOUs reports for electricity savings**.

The protocol[1] for evaluating codes and standards is as follows:

1. Define *potential* credit - the delta between the prior standard just meeting code to the new standard just meeting code
2. Adjust potential credit for non-compliance of standards
3. Adjust attribution to IOU advocacy efforts by reducing the credit by the amount of normally occurring market adoption
4. Finally, a panel of experts then decides how much of the savings should be attributed to the IOUs advocacy efforts to get the *net program savings*

This report modifies the previous evaluation method to avoid giving credit to IOUs for savings due to buildings implementing measures that result in energy savings that surpass what is required just to meet code. This will be accomplished by limiting the potential credit to no more 100% of new code requirements.

Sincerely,

Peter Biermayer
Regulatory Analyst

[1] Ref.: California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals, April 2006, p. 94

"In order to comply with the Evaluation Protocol, the evaluation contractor must estimate non-compliance across the technologies being assessed and adjust the anticipated savings for the net non-compliance rate over time. "

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CONSULTANT REPORT

California Statewide Codes and Standards Program Impact Evaluation Phase Two, Volume Two: 2013 Title 24

Work Order: ED_D_CS_1
CALMAC Study ID: CPU0170.01
June 23, 2017

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Acknowledgments

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We wish to acknowledge the critical contribution of two groups of experts to the evaluation. The first group of four experts, knowledgeable about Codes and Standards Program adoption processes, served on an independent panel that determined attribution for each standard evaluated. The second group of industry experts estimated naturally occurring market adoption and engaged with their fellow experts to produce a consensus estimate for each standard.

Many other individuals answered our calls and e-mails as we searched for information on the product mix, market volumes, compliance, and other evaluation inputs. The evaluation results have been considerably strengthened by the help we received.

Finally, we appreciate the comments and questions from other groups and individuals who, although not closely involved in the process, still took an interest in this evaluation.

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Abstract

This report presents results from the impact evaluation of the California Statewide Codes and Standards (C&S) Program for the C&S program years 2013 through 2015. The evaluation was conducted for the California Public Utilities Commission. Pacific Gas and Electric (PG&E), Southern California Edison (SCE), San Diego Gas and Electric (SDG&E), and Southern California Gas (SCG) jointly implemented the C&S program, providing technical, cost, and market studies to support adoption of standards by the California Energy Commission and the federal government. Volume Two covers the evaluation of energy, demand, and natural gas impacts stemming from the adoption of the 2013 Title 24 building energy code. The impacts for the 2013 Title 24 are estimated for the 18 months between the effective date, July 1, 2014, and the end of 2015. The impacts of the 2005 Title 24 and the 2008 Title 24 continue through 2013-2015 and are included as impacts of previously evaluated standards.

The evaluation methodology followed the California protocol. First, the evaluation team estimated potential savings that would result if all construction projects met the Title 24 code. Next, the team adjusted for the observed energy savings based on primary research to determine gross savings. The team followed this by determining net savings by adjusting—with the help of industry experts—for naturally occurring market adoption of energy-efficient units. To determine the Program’s net savings, a panel of independent experts developed an attribution adjustment to account for the Program’s effect on standard adoption. Finally, the team allocated net savings to investor-owned utilities (IOUs) based on their share of California’s electricity and gas sales.

Keywords: impact evaluation, 2013 Title 24

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Executive Summary

Introduction

California's Title 24 building codes set energy performance specifications that new buildings and alteration projects must meet. Because they eliminate low-efficiency construction practices from the market, Title 24 is an important component for reducing energy consumption.

Starting in the late 1990s, California's investor-owned utilities (IOUs) have taken a significant role in researching, proposing, and promoting efficiency standards through what has become the statewide utility Codes and Standards Program (the Program). Each IOU has a codes and standards (C&S) program. These individual programs provide a place within each utility for funding program activities and recording the C&S savings claimed in the IOU energy efficiency portfolios.

Scope

The purpose of this impact evaluation is to validate or correct the IOUs estimates of energy savings attributable to their advocacy of codes and standards. Many of the tables in this report compare the energy savings the IOUs estimated and the results as determined by the contactor and author of this report. The columns labeled "net program" show the energy savings attributed to IOU advocacy after adjusting the potential savings for compliance, normal market adoption and attribution to the IOUs.

The evaluation scope includes two broad categories of efficiency regulations: appliance standards and building codes. The report is organized into volumes that correspond to these two categories. Volume Two, this document, includes evaluation methods and findings for the 2013 Title 24 building codes. Volume One includes descriptions of the evaluation and findings for Title 20 and federal appliance standards.

We present the IOU estimated savings from the 2013 Title 24 building codes in Table ES-1. The savings are separated into three major construction categories. Nonresidential Alterations (NRA) describes renovation of existing space, Nonresidential New Construction (NRNC) includes new buildings and additions that add to the building area, and the Residential category includes new construction and alterations for single family and low-rise multifamily homes. Table ES-1 shows the IOUs estimates on energy and demand savings credit they claim for their advocacy efforts. The net program values in Table ES-1 represent the savings just for the energy use in the service territories of the IOUs. This is 71% of the total statewide savings. Because the changes in Title 24 affect the entire state, other tables include the energy savings statewide attributed to the IOUs involvement in implementing a new building code, including service territories of non-IOU utilities.

Table ES-1. IOU Estimate of Total Energy and Demand Savings for 2013-2015*

Total Savings for 2013–2015	GWh		MW		MMTherms***	
Category	Potential	IOU Share of Net Program**	Potential	IOU Share of Net Program	Potential	IOU Share of Net Program
Nonresidential Alterations (NRA)	1,226.1	417.4	320.7	106.9	1.73	-0.63
Nonresidential New Construction (NRNC)	382.3	152.8	56.1	21.4	4.27	2.63
Residential	29.0	10.0	34.0	11.7	2.04	1.18
Total	**1,637.3**	**580.2**	**410.8**	**140.0**	**8.05**	**3.19**

*Values may not sum exactly due to rounding.

**All report values are statewide unless otherwise noted. IOU Share of Net Program refers to attributable net program savings allocated to the IOUs' service areas.

***MMTherms equals millions of therms.

Findings

Terminology

Throughout the report we refer to savings in terms that are generally analogous to other resource programs. Potential savings are based on the estimated unit energy savings and the number of those units (new buildings, alteration projects, or products) entering the market each year.

In this and previous Title 24 evaluations, unit savings values are computed as the difference in energy consumption between a building or measure that just meets the new 2013 Title 24 code and a baseline building or measure that just meets the previous 2008 Title 24 code.

We apply an energy savings adjustment factor (ESAF) to potential savings to derive gross energy savings. This factor captures the percent of the energy saving potential that has been realized in the market.

Net savings result from adjusting the gross savings for the percent of the market that would have adopted the measure without the code. We determine net program savings by applying an attribution score that credits the statewide C&S program. We allocated net program savings to each utility based on share of the statewide energy market (for electricity or gas).

Electricity Savings

Table ES-2 summarizes electric energy savings (in GWh) from the 2013 Title 24 standards. The table's last row compares total evaluated savings to the IOU Estimate. As shown, evaluated net program savings accounted for 81% of the IOU Estimate.

Table ES-2. Evaluated vs. IOU Estimate: 2013–2015 PY 2013 Title 24 Electricity Savings (GWh)*

GWh	IOU Estimated Savings				Evaluated Savings			
	Potential	Gross	Net	Net Program	Potential	Gross	Net	Net Program
NRA	1,226.1	1,017.6	738.9	582.9	1,029.9	922.9	718.5	425.6
NRNC	382.3	317.3	262.0	213.4	403.7	351.7	313.2	213.0
Residential	29.0	24.0	19.2	14.0	50.4	32.1	21.3	14.6
2013-2015 Total	**1,637.3**	**1,359.0**	**1,020.1**	**810.3**	**1,484.0**	**1,306.8**	**1,053.0**	**653.1**
Evaluated/IOU Estimated					**91%**	**96%**	**103%**	**81%**

*Values may not sum exactly due to rounding.

Demand Reduction

Table ES-3 presents findings for 2013 Title 24 demand savings. The last row compares evaluated savings to the IOU Estimate. Evaluated net program demand savings accounted for 59% of the IOU Estimate.

Table ES-3. Evaluated vs. IOU Estimate: 2013–2015 PY 2013 Title 24 Demand Savings (MW)*

MW	IOU Estimated Savings				Evaluated Savings			
	Potential	Gross	Net	Net Program	Potential	Gross	Net	Net Program
NRA	320.7	266.2	192.9	149.3	178.8	156.0	118.7	61.6
NRNC	56.1	46.5	36.7	29.9	65.1	53.6	48.9	32.5
Residential	34.0	28.3	22.6	16.3	60.2	46.1	30.4	20.8
2013-2015 Total	**410.8**	**340.9**	**252.2**	**195.6**	**304.1**	**255.7**	**198.0**	**114.9**
Evaluated/IOU Estimated					**74%**	**75%**	**79%**	**59%**

*Values may not sum exactly due to rounding.

Gas Savings

Table ES-4 presents findings for gas savings from the 2013 Title 24 standards when including Interactive Effects (IEs).[2] Negative gas values indicate that reduced electric energy consumption for an end-use such as lighting means that more gas heating will be required. Evaluated net gas savings accounted for 119% of the IOU Estimate.

2 The impact of each standard includes primary (direct) savings and secondary savings described as interactive effects (IEs). Specifically, IEs include negative gas savings due to increased heating when electric energy is saved indoors and positive electric IEs due to reduced cooling.

Table ES-4. Evaluated vs. IOU Estimate: 2013-2015 PY 2013 Title 24 Gas Savings Including Interactive Effects (MMTherms) *

MMTherms	IOU Estimated Savings				Evaluated Savings			
	Potential	Gross	Net	Net Program	Potential	Gross	Net	Net Program
NRA	1.73	1.44	1.03	-0.64	1.83	1.36	0.87	-0.31
NRNC	4.27	3.54	3.34	2.66	5.25	4.45	4.33	2.74
Residential	2.04	1.70	1.53	1.19	2.70	2.36	1.86	1.40
2013-2015 Total	**8.05**	**6.68**	**5.90**	**3.22**	**9.77**	**8.17**	**7.07**	**3.83**
Evaluated/IOU Estimated					**121%**	**122%**	**120%**	**119%**

*Values may not sum exactly due to rounding.

Table ES-5 presents findings for gas savings from the 2013 Title 24 standards when IEs are excluded. Under this scenario, evaluated net gas savings accounted for 107% of the IOU Estimate.

Table ES-5. Evaluated vs. IOU Estimate: 2013-2015 PY 2013 Title 24 Gas Savings Excluding Interactive Effects (MMTherms) *

MMTherms	IOU Estimated Savings				Evaluated Savings			
	Potential	Gross	Net	Net Program	Potential	Gross	Net	Net Program
NRA	3.46	2.87	2.07	0.24	3.18	2.59	1.87	0.31
NRNC	4.59	3.81	3.59	2.87	5.56	4.71	4.55	2.91
Residential	2.09	1.73	1.56	1.22	2.78	2.36	1.86	1.40
2013-2015 Total	**10.14**	**8.42**	**7.21**	**4.32**	**11.52**	**9.66**	**8.29**	**4.62**
Evaluated/IOU Estimated					**114%**	**115%**	**115%**	**107%**

*Values may not sum exactly due to rounding.

Conclusions and Recommendations: Code Savings Estimation

Conclusion: A weakness in the individual code/measure approach is the lack of a method for taking into account interactions among requirements. The whole building approach using simulations implicitly accounts for interactions and was used to the extent possible in this evaluation. The IOUs have relied on the analyses conducted for the California Energy Commission (CEC) to estimate whole building code savings. Improvements in documentation and thoroughness are needed.

Recommendation: Future C&S Program evaluations should rely primarily on whole building analyses to evaluate Title 24 savings. To support this, we recommend that the IOUs, CPUC, and CEC collaborate to develop an approach designed to quantify statewide Title 24 savings using a consistent building simulation approach. We recommend that the program evaluation focus on verifying the inputs, assumptions, and outputs of these simulations and updating them as needed. We recommend that the IOUs document the whole building analyses.

Conclusion: Although the impact estimation would be most efficient and accurate using a whole building analysis, studies of individual code requirements and measures are useful. These analyses provide insights into what measures are expected to have the largest impacts and they inform efforts to improve code compliance.

Recommendation: We recommend that the IOUs continue to document estimated savings and their activities supporting each of the code changes incorporated in each Title 24 update. We also recommend that the IOUs research ways to assess and account for interactions among the individual code changes to increase the consistency with the whole building estimates.

Conclusion: The data collected and estimated on unit savings and construction/alterations during the evaluation can provide a solid basis for estimating the potential savings accurately. With sufficiently large samples and accurate market data, the evaluators could develop an independent estimate of potential savings that could replace an IOU estimate of the potential.

Recommendation: We recommend that the CPUC examine the feasibility and resource requirements needed to rely on the evaluation to estimate the potential Title 24 savings as an alternative to using an estimate provided by the IOUs based on CEC analyses.

Conclusion: For this evaluation, we estimated code energy savings in two ways: (1) comparing the as-built building to the 2008 Title 24 requirements and (2) limiting the as-built building to being no more efficient than required by the 2013 code and comparing the limited values to the 2008 Title 24 requirements. The first approach treats the baseline as the 2008 Title 24 and allows all efficiency improvements over the 2013 Title 24 to contribute to the savings. The second approach also uses the 2008 Title 24 baseline, but assumes that any efficiency improvements over the 2013 Title 24 occur for reasons other than the new code so they do not contribute to program savings. The ESAF factor takes into account the savings of buildings, whether they meet the 2013 Title 24 or not. For the current evaluation, we used a slightly different approach for the appliance standards. Unit savings for appliances are based on the difference between the baseline and new standard efficiencies, but the compliance adjustment just accounts for the proportion of products that meet the new standard.

Recommendation: We recommend that the CPUC continue research on the most appropriate and consistent way to define the baseline, unit savings, and compliance, and examine opportunities to align the evaluation methods used to determine the impacts of both codes and standards.

Conclusion: Acquisition of accurate data on building construction and alterations has been a challenge for each of the C&S Program evaluations. This has been especially problematic for commercial buildings, while the Construction Industry Research Board (CIRB) data provide a fairly reliable estimate of residential new construction. Residential alterations also continue to be difficult to estimate accurately. These data are important for evaluating the Title 24 impacts, but they are critical for all projections of building energy use, such as demand forecasts.

Recommendation: We recommend that the CPUC consider researching diverse sources of building construction and alterations data and collaborating with the CEC in its efforts to improve data for the building sector in response to recent legislation requiring significant increases in building energy savings.

Conclusion: Our efforts to recruit homes to include in this evaluation were most successful when we worked with the building industry, particularly large builders.

Recommendation: We recommend that future evaluations focus on recruiting builders to provide access to homes for purposes of assessing construction practices. We also recommend that the CPUC consider conducting research on the housing market to determine the distribution of construction among large, medium, and small builders to use that information to fill any gaps. We also recommend that future evaluations investigate similar industry sources to provide improved access to commercial buildings for analyses of their construction characteristics.

Conclusion: One challenge faced by the evaluation was identifying buildings that were constructed under the 2013 Title 24. This was especially true for nonresidential buildings, which typically take longer to construct than residential buildings. The lag between when a new code is effective and buildings are constructed under it is important for two reasons. First, it affects the number of buildings available for estimating compliance. In the case of nonresidential buildings, this is particularly problematic as the relatively long time required for construction limits the pool of buildings available to study and tends to increase the proportion of smaller commercial buildings. Second, the savings estimation depends on adjustments to the construction volume based on the length of time required to construct buildings. Based on some limited empirical data, we made assumptions in this analysis about the typical time lag between the code effective date and construction completion.

Recommendation: The CPUC and IOUs should consider conducting both secondary and primary research to establish improved estimates of the lag between code-effective date and construction completion for both residential and commercial buildings. Any such study should address the variation in the lag by building type and market factors, such as construction downturns.

Recommendation: The CPUC should examine ways to develop sufficiently accurate code compliance estimates in the near-term, but plan to true-up the estimates by allowing sufficient time to pass to collect accurate date on code compliance. This is especially true for commercial buildings, which may take longer than a year to complete. The CPUC should consider supplementing the current evaluation of non-residential new construction Title 24 impacts with additional data collection and analysis now that additional buildings have been constructed under the 2013 Title 24.

Conclusions and Recommendations: Compliance Issues

Conclusion: Compliance of residential buildings with the 2013 Title 24, as measured with the ESAF, is considerably lower than it was when residential compliance was last evaluated for the 2005 Title 24. In that evaluation, the average ESAF exceeded 100%, indicating that, on average, new homes were more efficient than required by the code.

Recommendation: We recommend that the CPUC consider conducting a study with builders and other industry members to understand why compliance has declined with the new code and what types of steps could be taken to improve compliance.

Conclusion: Compliance with some specific code requirements was relatively poor. Examples include the installation of demand-control valves in homes with residential hot water recirculation pumps. Another example was common failure to meet the mandatory daylighting control requirements in commercial buildings, particularly in alterations, and incorrect calculations.

Recommendation: We recommend that the IOUs and CEC target compliance improvement efforts on those code requirements for which the evaluation found relatively poor compliance. The IOUs could conduct additional research to identify specific code requirements that are not being commonly met and use the findings to inform their compliance improvement activities.

Conclusions and Recommendations: Special Investigations

Conclusion: We conducted two special studies as part of this evaluation to address the potential impacts of noncompliance with specific code mandatory requirements in the 2013 Title 24. One requirement was for daylighting controls in commercial building spaces and the other was application of the proper lighting Power Adjustment Factor (PAF) in association with controls. We assessed the level of compliance with the daylighting control requirements and the impacts, and we calculated the theoretical effect of improper application of the PAF requirements. Our analyses showed that the energy impacts of both types of measures were very small, on the order of 1% of building consumption.

Recommendation: We recommend that the CPUC minimize the efforts dedicated to analyzing similar requirements, but include them in future evaluations to the extent that evaluation scopes permit.

1. Overview of Evaluation Approach

This is the second of two volumes that report on Cadmus' impact evaluation of the investor-owned utilities' (IOUs') California Statewide Codes and Standards (C&S) Program. The first volume focused on appliance standards and this volume focuses on the impact of the 2013 Title 24 building energy codes.

The evaluation project reflects the major construction categories identified by the IOUs in their estimate of C&S program savings. Specifically, the categories include:

- Nonresidential Alteration (NRA). This category includes most construction projects in existing buildings that do not add floor area (square footage) to the structure.
- Nonresidential New Construction (NRNC). This category includes new buildings and projects that add floor area to existing buildings.
- Residential. This category includes both Residential New Construction (RNC) and Residential Alterations (RA). The residential code requirements apply to unattached single-family homes and low-rise (less than four-story) multifamily buildings.

In Cadmus' experience, savings from building codes are sometimes estimated based on the energy consumption of whole (new) buildings and sometimes based on the energy consumption of specific measures within a new building or construction project. The IOUs used both approaches in their estimates of energy and demand savings from the 2013 Title 24. In these estimates, the sum of savings from individual measures is greater than the estimated savings from whole building categories. The IOUs took the whole building estimates for residential and nonresidential construction directly from the California Energy Commission's (CEC) analysis of the 2013 Title 24 codes[3].

We asked the IOUs for clarification and they provided a memo[4] that confirmed that the whole building savings and some of the measure level estimates were redundant. We also learned that they regard the whole building approach as more accurate than individual measure estimates since the whole building approach accounts for interactions between the various measures.

Cadmus agrees that whole building simulation is a better approach to estimating savings for new construction than summing estimates of savings from individual measures in isolation. Accordingly, our strategy in this evaluation is to use a whole building approach to determine energy savings from the NRNC and RNC categories and then to reconcile the measure findings to the building totals as much as possible.

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[3] CEC. (Consultant Report) *Impact Analysis: California's 2013 Building Efficiency Standards.* CEC-400-2013-008. July 2013. Available online: http://www.energy.ca.gov/2013publications/CEC-400-2013-008/CEC-400-2013-008.pdf

[4] The memo, 2013 Title 24 Savings – Whole Building and Individual Measure Savings, October 26, 2016, was authored by Yanda Zhang. It was provided by Mary Andersen of PG&E on behalf of the statewide program.

In addition to the primary impact evaluation, our approach included investigation of two related topics:

- **Nonresidential mandatory measure: Daylighting/Standard B43**. We identified this standard as one for which the IOUs identified substantial potential savings but that our primary analysis approach (building energy simulation) would not address. For this reason, Cadmus did a manual analysis that included 90% of the nonresidential sites we visited. The analysis and results are described in section 2.2.5.
- **Power Adjustment Factors (PAFs)**. In response to extensive discussion of the application and impact of PAFs, Cadmus analyzed five new construction sites to determine the difference in lighting energy and whole building energy use between two scenarios. In the first scenario, the model includes no PAF credits, while in the alternative scenario, the model includes the allowed PAF credits for each applicable light fixture. Analysis and results are described in section 2.2.6.

1.1. Report Structure

In general, the evaluation scope includes two broad categories of efficiency regulations: appliance standards and building codes. In the first Phase, we evaluated Title 20 and Federal Appliance standards that became effective in 2013 and 2014. The Phase Two report is organized into volumes that correspond to the two categories. Volume Two, this document, includes evaluation methods and findings for the 2013 Title 24 Building Codes. Volume One includes descriptions of the evaluation and findings for Title 20 and federal appliance standards (including those evaluated in Phase One of the project). This two-volume approach was suggested by the California Public Utilities Commission (CPUC) staff and was agreed to by the project management team. The reasons for organizing the report into two volumes include:

- Differences in evaluation methods used and results reported for appliance standards and building codes: For appliance standards, each product category is evaluated independently. The primary difference in methods and reported results is the use of a whole-building approach to evaluate new construction. In this case, a group of standards are evaluated in terms of their collective effect on new building energy consumption.
- Document length and level of detail: In the 2010–2012 evaluation, the effort to keep the report to a manageable length of roughly 100 pages meant that much of the descriptive detail was included in the report appendices. The two-volume approach allows much more of the evaluation to be documented in the main report rather than in the appendices.

To avoid redundancy, some material is included in only one volume, although it applies equally to evaluation of both appliance standards and building codes. These sections include:

- Descriptions of the C&S program (Volume One)
- Overview of the evaluation approach (Volume One)
- Uncertainty analysis (Volume Two)

1.2. Protocol

In each C&S program evaluation, the evaluation team applies the California Evaluation Protocols with documented modifications during the evaluation process.[5] Figure 1 presents a flowchart of the evaluation process Cadmus used for the current evaluation (in addition to the 2006–2008 and 2010–2012 program year evaluations).

Figure 1. C&S Advocacy Program Evaluation Protocol

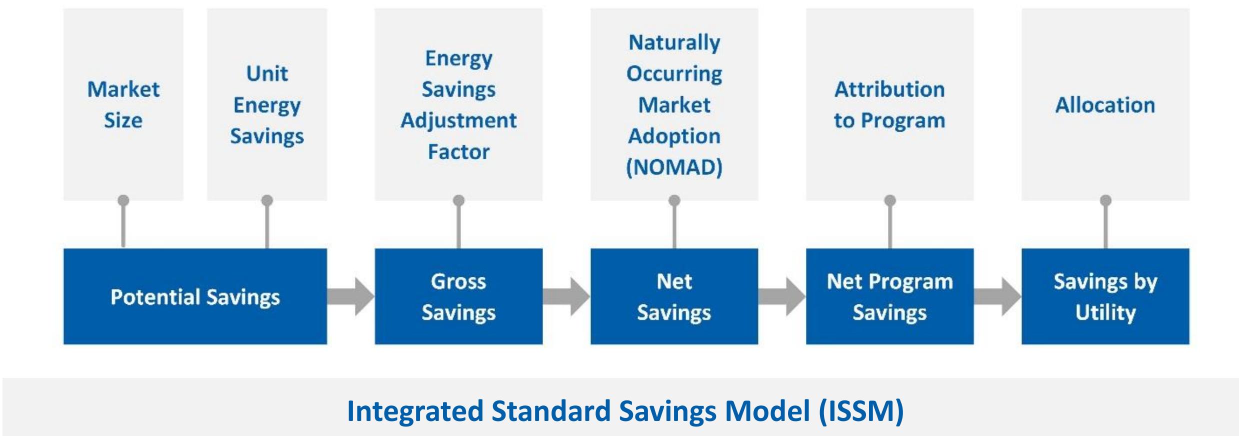


Figure 1 shows the major factors used to determine savings under the protocol. We based the potential energy savings attributable to the C&S program on the estimated unit energy savings and the number of those units (new buildings, alteration projects, or products entering the market) each year.

In this and previous Title 24 evaluations, the unit savings values used to determine potential are computed as the difference in energy consumption between a building or measure that just meets the new 2013 Title 24 code and a baseline building or measure that just meets the previous 2008 Title 24 code.

We applied the compliance adjustment to potential savings to derive gross energy savings. Net savings result from adjusting the gross savings by the NOMAD of measures or appliances meeting the code or standard that would have occurred in the absence of the code or standard. We determined the net program savings that are credited to the statewide C&S program by applying an attribution score. We then allocated to each utility these net savings attributable to the program, based on each utility's share of the statewide energy market (for electricity or gas).

We implemented the analysis using the Integrated Standards Savings Model (ISSM)—developed by the evaluators specifically for the previous C&S program evaluations and modified for this evaluation—that incorporates all the input data from the evaluation, measurement, and verification (EM&V) activities.

[5] Hall, Nick, J. Roth, C. Best (TecMarket Works). *California Energy Efficiency Evaluation Protocols.* Prepared for the California Public Utilities Commission. 2006.

Modifications made for this evaluation are described in Section 2.3. To help ensure transparency, the evaluation team implemented the model in an Excel workbook. The IOUs use a similar model to calculate their estimate of C&S program savings.

1.2.1. Adjustments to Determine Gross Savings

As shown in Figure 1, the value used to calculate gross savings relative to potential savings is typically referred to as the "compliance adjustment factor" (CAF) or "compliance rate." These terms are used throughout Volume One of this report in our evaluation of appliance standards. For building codes, however, Cadmus and the project management team have identified the word "compliance" as somewhat problematic because of differences in definitions used by various stakeholders. For this reason, we use the term "energy savings adjustment factor" (ESAF) throughout Volume Two of the report to identify this value in the context of Title 24 evaluation. Because this is an evaluation of energy and demand impacts, our focus is on the energy performance of construction projects rather than the evaluation of strict conformance to regulatory requirements.

Unbounded versus Bounded ESAF Values

When the energy consumption of a specific building, project, or measure is between the value required by the old code and the new code, the ESAF value is between zero and one (or 0% and 100%). From an energy performance perspective, however, it is possible for a building, project, or measure to consume less energy, or be more efficient, than the level established by the current Title 24 code. In this case, the ESAF value would be greater than one (or greater than 100%). We note that the energy consumption can also be greater than the level established by the previous code, in which case the ESAF value would be negative (or less than 0%).

When no constraints are placed on the ESAF values for specific sites, we refer to the resulting statewide values as unbounded ESAFs. Per CPUC direction, we also computed statewide ESAF values with the constraint that site-level ESAF values are limited to a maximum of 100%. For any site where the calculated ESAF value is greater than 100%, the value is set to be equal to 100%. The CPUC requested analyses limiting the ESAF to 100% for the following reasons. First, there is no empirical basis for attributing performance more efficient than the code requires to adoption of the code. Second, the calculation of unit savings assumes the baseline is the prior code; however, it could be defined as the typical efficiency level of buildings built under the prior code. In this case, if the baseline were more efficient than required by the prior code, then the unit savings of buildings built under the new code would be smaller than if the savings were based on the prior code. When site-level values are constrained in this way, we refer to the resulting statewide values as "bounded ESAFs."

1.3. Scope for 2013–2015 Impact Evaluation: 2013 Title 24 Building Codes

The three major categories of Title 24 building codes within the evaluation scope and the IOU estimated savings for each are summarized in Table 1.

Table 1. Evaluation Scope for 2013 Title 24 Standard Categories, IOU Estimated Savings

Reference	Description	Effective Date	2013-2015 Potential Savings (GWh)	2013-2015 Potential Savings (MMtherms)*
B34-B42	NRA	7/1/2014	1,226.1	1.73
B46-B54, B57, B64-B82	NRNC	7/1/2014	382.3	4.27
B83, B93-B100	Residential	7/1/2014	29.0	2.04
Total			**1,637.3**	**8.05**

* MMtherms = millions of therms

1.4. IOU Estimate of Savings During 2013–2015

For each major construction category, Cadmus provides complete lists of the items the IOUs included in the estimated savings for the statewide program in Table 2, Table 3, and Table 5. Although most of these items correspond to specific sections of the Title 24 regulations, there are some significant exceptions, which we identify below.

We note that each of the nine NRA items listed in Table 2 correspond to specific sections of the Title 24 code. Potential savings are estimates provided by the IOUs. Checkmarks in Table 2 and subsequent tables denote whether we evaluated that protocol parameter for a particular standard. For attribution, a check mark denotes that the standard was scored by either the panel or Cadmus staff. For parameters with no checkmark, we most often use the parameter values provided by the IOUs with their estimate of savings.

Table 2. Evaluation Scope for 2013 Title 24 NRA Standards, IOU Estimated Savings

Standard	Description	Effective Date	2013–2015 Potential Savings GWh	2013–2015 Potential Savings MMtherms	Potential	Compliance	NOMAD	Attribution
Std B34	Lighting-Alts.-New Measures	7/1/2014	333.1	(1.94)	✓	✓	✓	✓
Std B35	Lighting-Alts.-Existing Measures	7/1/2014	476.1	(1.34)	✓	✓	✓	✓
Std B36	Lighting-Egress Lighting Control	7/1/2014	124.6	-	✓	✓	✓	✓
Std B37	Lighting-MF Building Corridors	7/1/2014	8.5	(0.03)	✓	✓	✓	✓
Std B38	Lighting-Hotel Corridors	7/1/2014	3.1	(0.01)	✓	✓	✓	✓
Std B39	Lighting-Warehouses, Libraries	7/1/2014	90.7	(0.34)	✓	✓	✓	✓
Std B40	Envelope-Cool Roofs	7/1/2014	26.6	(0.15)			✓	✓
Std B41	HVAC-Equipment Efficiency	7/1/2014	144.4	5.55	✓		✓	✓
Std B42	Process-Air Compressors	7/1/2014	19.1	-			✓	✓
Total NRA Potential Savings			**1,226.1**	**1.73**				

* MMtherms = millions of therms

We provide a complete list of the NRNC line items included in the IOUs' savings estimate in Table 3. We requested clarification regarding the whole building standard (B82), which the IOUs provided in a memo received on September 26, 2016[6]. In this memo, the IOUs stated that the whole building savings estimate includes interactive effects, whereas individual standard line items do not. The memo identified the source of the whole building energy savings as the California Energy Commission's (CEC's) 2013 Title 24 Impact Analysis[7]. The memo also identified the specific standards that are included in the whole building analysis and provided the following statement: "If whole building savings are used, savings from the corresponding individual measures should be excluded in assessing the overall 2013 Title 24 energy impact."

In Table 3, we present the total IOU estimated potential savings for the NRNC category. As directed by CPUC staff, our study evaluated savings from a whole building perspective and for individual standards. Our approach to this issue, the methods we used, and our findings are included in the relevant sections throughout this report.

Table 3. Evaluation Scope for 2013 Title 24 NRNC Standards, IOU Estimated Savings

Standard	Description	Effective Date	2013–2015 Potential Savings GWh*	2013-2015 Potential Savings MMtherms*	Potential	Compliance	NOMAD	Attribution
StdB46	Lighting-Egress Lighting Control	4/1/2015	16.9	-	✓	✓	✓	
StdB47	Lighting-MF Building Corridors	4/1/2015	3.6	(0.0)		✓	✓	
StdB48	Lighting-Hotel Corridors	4/1/2015	0.6	(0.0)		✓	✓	
StdB49	Lighting-Warehouses, Libraries	4/1/2015	20.2	(0.1)	✓	✓	✓	
StdB50	Lighting-Parking Garage	4/1/2015	18.4	-	✓	✓	✓	✓
StdB51	Lighting-Controllable Lighting	4/1/2015	50.4	(0.2)	✓	✓	✓	✓
StdB52	Lighting-DR Lighting Controls	4/1/2015	0.5	(0.0)		✓		
StdB53	Lighting-Outdoor Controls	4/1/2015	5.9	-		✓		✓
StdB54	Lighting-Office Plug Load Control	4/1/2015	11.5	(0.0)	✓	✓	✓	✓
StdB64	HVAC-Garage Exhaust	4/1/2015	9.3	-		✓	✓	
StdB65	HVAC-Laboratory Exhaust	4/1/2015	38.3	1.5	✓	✓	✓	✓
StdB66	HVAC-Small ECM Motor	4/1/2015	37.1	-	✓	✓	✓	✓
StdB67	HVAC-Water, Space Heat ACM	4/1/2015	0.1	0.2		✓		
StdB68	HVAC-Cooling Towers Water	4/1/2015	0.2	-		✓		
StdB69	HVAC-Occt. Control Smart T'stats.	4/1/2015	0.1	-		✓		

6 The memo, 2013 Title 24 Savings – Whole Building and Individual Measure Savings, October 26, 2016, was authored by Yanda Zhang. It was provided by Mary Andersen of PG&E on behalf of the statewide program.

7 CEC. (Consultant Report) *Impact Analysis: California's 2013 Building Efficiency Standards.* CEC-400-2013-008. July 2013. Available online: http://www.energy.ca.gov/2013publications/CEC-400-2013-008/CEC-400-2013-008.pdf

Standard	Description	Effective Date	2013–2015 Potential Savings GWh*	2013-2015 Potential Savings MMtherms*	Potential	Compliance	NOMAD	Attribution
StdB70	HVAC-Low-Temp Radiant Cooling	4/1/2015	-	-				
StdB71	HVAC-Evap Cooling Credit	4/1/2015	-	-				
StdB72	HVAC-Outside Air	4/1/2015	-	-				
StdB73	HVAC-Acceptance Reqmts.	4/1/2015	0.8	-		✓		
StdB74	Refrigeration-Warehouse	4/1/2015	0.7	-		✓		
StdB75	Refrigeration-Supermarket	4/1/2015	12.1	1.3	✓	✓	✓	✓
StdB76	Process-Process Boilers	4/1/2015	0.5	0.7		✓		
StdB77	Process-Air Compressors	4/1/2015	7.1	-		✓		✓
StdB78	Process-Data Centers	4/1/2015	18.5	-	✓	✓	✓	✓
StdB79	DHW-Hotel DHW Control, Solar	4/1/2015	-	-				
StdB80	DHW-Solar Water Heating	4/1/2015	0.8	0.2		✓		
StdB81	Solar-Solar Ready	4/1/2015	8.5	-		✓	✓	✓
StdB82	Whole Building	4/1/2015	120.3	0.7	✓	✓	✓	✓
Total NRNC Potential Savings			**382.3**	**4.27**				

* MMtherms = millions of therms

Table 4 presents the IOU estimates of potential savings from the individual standards that are included in the whole building standard B82. Because we are using the whole building analysis results to define potential savings, we have excluded these standards from the NRNC total. This approach has been reviewed with CPUC staff and with representatives of the statewide program.

These individual estimates are redundant with the whole building estimate given for standard B82. We note that the whole building estimate of about 120 GWh is less than the 287 GWh sum of the individual measures due to interaction between these measures when they are installed simultaneously in new construction.

Table 4. Measure Level Savings for NRNC Standards Superseded by Whole Building Analysis, IOU Estimated Savings

Standard	Description	Effective Date	2013–2015 Potential Savings GWh*	2013-2015 Potential Savings MMtherms*	Potential	Compliance	NOMAD	Attribution
StdB43	Lighting-Daylighting	4/1/2015	70.3	(0.3)	✓	✓	✓	✓
StdB44	Lighting-Indoor Lighting Controls	4/1/2015	6.8	(0.0)		✓		
StdB45	Lighting-Retail	4/1/2015	37.7	(0.1)	✓	✓	✓	
StdB55	Envelope-Cool Roofs	4/1/2015	4.1	(0.0)		✓		
StdB56	Envelope-Fenestration	4/1/2015	57.4	(0.1)	✓	✓	✓	✓
StdB57	HVAC Controls, Economizers	4/1/2015	45.8	-	✓	✓	✓	✓

Standard	Description	Effective Date	2013–2015 Potential Savings GWh*	2013-2015 Potential Savings MMtherms*	Potential	Compliance	NOMAD	Attribution
StdB58	HVAC-Fan Control & Economizers	4/1/2015	22.6	(0.0)	✓	✓	✓	✓
StdB59	HVAC-Reduced Reheat	4/1/2015	0.0	0.1		✓		
StdB60	HVAC-Guest Room OC Controls	4/1/2015	3.0	-		✓		
StdB61	HVAC-Kitchen Ventilation	4/1/2015	20.2	0.2	✓	✓	✓	✓
StdB62	HVAC-Commercial Boilers	4/1/2015	0.3	0.2		✓		
StdB63	HVAC-Chiller Min Efficiency	4/1/2015	19.4	-	✓	✓	✓	✓
Total of measure-level savings			**287.7**	**(0.13)**				

* MMtherms = millions of therms

We provide IOU estimates of potential savings from residential standards in Table 5. For the residential standards, the IOUs also used the CEC report as the basis for savings from residential construction. The new construction savings are included as standards B97 and B98 for single-family and multifamily homes, respectively.

Table 5. Evaluation Scope for 2013 Title 24 Residential Standards, IOU Estimated Savings

Standard	Description	C&S Effective Date	2013–2015 Potential Savings GWh*	2013–2015 Potential Savings MMtherms*	Potential	Compliance	NOMAD	Attribution
StdB83	RNC-Lighting	1/1/2015	2.39	(0.05)	✓	✓		
StdB93	RNC-MF DHW Control and Solar	4/1/2015	(0.32)	1.11	✓			
StdB94	RNC-DHW-High Eff. Water Heater Ready	1/1/2015	-	0.07				
StdB95	RNC-DHW-Solar for Electric Heat Homes	1/1/2015	0.08	-				
StdB96	RNC-Solar Ready, Oriented Homes	1/1/2015	0.08	0.01				
StdB97	RNC-SF Whole Building	1/1/2015	15.27	0.53	✓	✓	✓	✓
StdB98	RNC-MF Whole Building	4/1/2015	3.13	0.09	✓			
StdB99	Residential Alterations-SF Whole Building	7/1/2014	6.57	0.23	✓	✓	✓	✓
StdB100	Residential Alterations-MF Whole Building	7/1/2014	1.78	0.05	✓			
Total Residential Potential Savings			**28.97**	**2.04**				

* MMtherms = millions of therms

In the same memo that detailed the NRNC estimate, the IOUs indicated that the residential whole building estimates include savings from standards B84–B92. We present the individual savings estimates for these standards in Table 6. These individual estimates are redundant with the whole building estimate. We note that the whole building estimate of about 29 GWh is less than the 46.8 GWh sum of the individual measures due to interaction between these measures when they are installed simultaneously in new construction.

Table 6. Measure Level Savings for RNC Standards Superseded by Whole Building Analysis, IOU Estimated Savings

Standard	Description	C&S Effective Date	2013–2015 Potential Savings GWh*	2013–2015 Potential Savings MMtherms*	Potential	Compliance	NOMAD	Attribution
StdB84	RNC-Envelope-Wall Insulation	1/1/2015	2.69	0.67	✓	✓	✓	
StdB85	RNC-Envelope-Fenestration	1/1/2015	14.57	(0.34)	✓	✓	✓	✓
StdB86	RNC-Envelope-Roof Envelope	1/1/2015	0.48	0.00	✓			
StdB87	RNC-Envelope-Advanced Envelope	1/1/2015	-	-				
StdB88	RNC-HVAC-Whole House Fans	1/1/2015	8.82	(0.08)	✓	✓	✓	
StdB89	RNC-HVAC-Zoned AC	1/1/2015	10.05	0.23	✓	✓	✓	✓
StdB90	RNC-HVAC-Duct	1/1/2015	10.19	1.06	✓	✓	✓	✓
StdB91	RNC-HVAC-Refrigerant Charge	1/1/2015	-	-				
StdB92	RNC-SFDHW	1/1/2015	-	0.25	✓			
Total of measure-level savings			**46.80**	**1.80**				

* MMTherms = millions of therms

2. Methodology

This chapter provides brief descriptions of methods used to evaluate parameters that determined energy savings under the evaluation protocol.

2.1. Potential Savings

For Title 24 codes, the IOUs and Cadmus define unit savings as the difference in energy consumption between a building or a measure that just meets the 2013 Title 24 codes and a building or measure that just meets the 2008 Title 24 codes. Potential savings are the product of unit savings and quantity of affected units.

2.1.1. Methodology

Cadmus reviewed the IOU estimates of potential energy savings for the 2013 Title 24 building codes, applicable to both alterations and new construction. The statewide IOU potential energy and demand savings estimates were derived from unit energy savings (UES, defined as energy or demand per unit) and estimates of the number of applicable units. For most nonresidential standards, the units were defined as the number of applicable building square feet (based on characteristics such as occupancy type and climate zone). For residential buildings, the unit metric is typically the number of living units.

To develop evaluated statewide potential savings estimates, Cadmus reviewed the primary sources used in the IOU analyses, conducted a gap analysis of the IOU estimates and Cadmus' primary source findings, and evaluated the UES and applicable unit analysis and assumptions.

Review of Primary Sources

Cadmus reviewed the documentation provided by the IOUs to support their statewide savings estimates. The documentation provided to Cadmus in response to the first data request was not comprehensive, leading to several follow-up data requests during 2015 and 2016. Documentation was provided in the form of:

- Codes and Standards Enhancement (CASE) reports for the specific standards evaluated or related to the standards evaluated
- Excel workbooks that correspond to specific CASE reports
- Excel workbooks that support post-CASE report IOU analysis
- 2013 Title 24 CEC Impact Analysis report
- Memos to Cadmus with explanations of methods and assumptions

In addition to the documentation received, Cadmus held several conference calls with the IOUs, during which the IOUs provided further verbal details on their methods and assumptions. For example, in several cases, the IOUs leveraged professional judgment to make assumptions in their analysis, but did not explicitly state this in written documents; thus, this was clarified via conference call in response to Cadmus' inquiry.

Gap Analysis

For many of the standards evaluated, Cadmus found significant gaps in the information provided by the IOUs to explain the IOU-estimated savings. This was one of the reasons for the follow-up data requests described in the previous section. For over 80% of the standards reviewed, Cadmus did not receive sufficient documentation to fully evaluate the analysis from which the IOU savings estimates were derived after two data requests. Cadmus still did not receive sufficient documentation to fully evaluate the analysis from which the IOU savings estimates were derived for over 30% of the standards reviewed after a third data request. If insufficient documentation was received, Cadmus determined whether a rough estimate of savings was appropriate to pursue a more detailed analysis of savings given the available information, research findings, and limitations of the evaluation study scope.

Unit Energy Savings Evaluation

Cadmus reviewed the unit energy savings methodology detailed in the supporting documentation provided by the IOUs. Where models could not be reproduced, Cadmus reviewed the model inputs and assumptions to the extent allowable by the scope of this study. Cadmus pursued secondary research to verify IOU assumptions and estimates where possible, such as market research reports sponsored by the IOUs and/or the CPUC, technical analyses conducted by the federal government, and technical analyses conducted by the IOUs in support of other energy efficiency initiatives outside of codes and standards. In many cases, insufficient secondary research was available to verify the IOU assumptions because of the broad scope and highly specific requirements of these standards. Additionally, the evaluation study scope did not permit detailed investigation of many assumptions asserted for these standards.

Unit Quantity Evaluation

Nonresidential: Existing Floor Stock and New Construction Volumes

Cadmus decided to use the CEC-forecasted existing floor stock and new construction data after reviewing existing floor stock and new construction data purchased from Dodge Data and Analytics[8]. Cadmus observed that the Dodge square footage estimates were considerably higher than the CEC-forecasted estimates for nearly all building types. Cadmus questioned the CEC regarding this discrepancy, and was informed that CEC leverages aspects of the Dodge data in their forecasted estimates, but does not use the square footage values directly because the estimates produce unreliable load forecasting results. Because the CEC uses Dodge to a limited extent in their forecast, but does not use the Dodge square footage estimates directly, Cadmus decided to use the CEC existing floor stock and new construction estimates for the evaluation to ensure more accurate statewide savings estimates than would presumably be calculated using Dodge data.

Cadmus used CEC-forecasted existing floor stock and new construction square footage data provided by the CEC to Cadmus in September 2015 to calculate evaluated statewide energy and demand savings.

[8] Dodge Data & Analytics is a construction project data provider. Cadmus frequently uses Dodge data for nonresidential data. The company website can be found at: https://www.construction.com/

These data were provided by building type and climate zone. To estimate annual square footage for alterations and new construction, Cadmus used 2015 data (alterations) and an average of 2014 and 2015 data (new construction) to enable one square footage data set to be applied each year starting in 2014, which was the year the 2013 Title 24 standards went into effect.

NRAs: Measure Life and Turnover Assumptions

In the current IOU savings estimates and in the 2006–2008 and 2010–2012 evaluations, potential savings from alteration projects were based on assumptions about the measure life (or expected useful life) of measures and systems. For example, the potential for a standard regulating envelope insulation (referred to as "B17") assumed an average roof life of 15 years. Savings from alteration projects then assumed that one-fifteenth (6.7%) of the roof area of existing building stock would be replaced each year. Similarly, savings from lighting alteration projects was based on an assumed measure life of 20 years.

Residential: Number of Newly Constructed Homes

Because over 85% of the estimated savings from residential codes are associated with single-family homes, Cadmus used the reported number of permits for new single-family homes from the Construction Industry Research Board (CIRB) Report[9]. The CIRB report is also used to estimate residential construction volume by the IOUs and CEC.

2.1.2. Prioritization

Cadmus did not conduct evaluation activities for all standards for which the IOUs estimated savings. To optimize use of evaluation resources, Cadmus prioritized the standards in each category that together represented the majority of the total IOU-estimated potential (GWh) for that category. Specifically, we focused our evaluation effort on the following standards:

- NRA: Standards B34, B35, B36, B39, and B41 represent 95% of estimated potential
- NRNC: Standards B43, B45, B46, B49, B50, B51, B54, B56, B57, B58, B61, B63, B65, B66, B75, B78, and B82 represent 92% of estimated potential
- Residential: Standards B83, B84, B85, B88, B89, and B90 represent 83% of estimated potential

2.1.3. Construction Lag Assumptions

The 2013 Title 24 codes became effective on July 1, 2014. This means that projects permitted on or after that date have to comply with the 2013 code. Because a permit has to be obtained before the start of construction and a project has to be completed before it can begin to produce any savings, there is a time lag between permitting and savings.

9 The CIRB report is produced by the California Homebuilding Foundation. Website: http://www.mychf.org/

Based on our past experience, Cadmus makes the following assumptions regarding the lag between the code effective date and the realization of a stream of savings from projects that are permitted under a new code:

- NRA projects: No time lag is assumed because many alteration projects are completed in relatively short time periods (less than three months). We assume these projects begin to produce savings on the effective date of July 1, 2014.
- NRNC projects: We assume a time lag of nine months to allow for a new building to be constructed and occupied. We assume that NRNC projects begin to produce savings on April 1, 2015.
- Residential
    - A time lag of six months is assumed for construction of single-family homes, so we assume that savings begin six months after the effective date or January 1, 2015.
    - A time lag of nine months is assumed for construction of multifamily buildings, so we assume that savings begin nine months after the effective date or April 1, 2015.
    - No time lag is assumed for RA projects, so we assume that such projects begin to produce savings on July 1, 2014.

These time lag assumptions are consistent with assumptions made by the California IOUs in their savings estimates and with other studies of savings that result from construction of more efficient buildings. Cadmus has found many instances of NRNC construction where the time between the permit application date and building completion has been greater than the assumed nine-month average. Further study of this assumption appears to be warranted, but is outside of the scope of this project. We note that underestimating can have two counteracting effects. If buildings are included in the study that were built under a prior code (and no information is available to determine what code they were built under), their level of compliance with the new code is likely to be less so their estimated savings would be less. On the other hand, assuming too short a time lag would mean that the estimated volume of buildings covered by the new code would be overstated.

2.1.4. Relationship Between Whole Building Estimates and Individual Standards

As noted in Section 1.4, the initial IOU estimate of savings included many individual standards (each of which corresponds to specific sections of the 2013 Title 24 code) as well as whole building standards for the NRNC (B82) and RNC (B97 single-family and B98 multifamily) categories. Shading in Table 3 and Table 5 above indicate the specific individual standards that correspond to the whole building standards.

Savings for the three whole building standards were taken from a whole building analysis conducted by CEC in support of their impact analysis of the 2013 Title 24 standards.[10] The IOUs did this to support

[10] CEC. (Consultant Report) *Impact Analysis: California's 2013 Building Efficiency Standards.* CEC-400-2013-008. July 2013. Available online: http://www.energy.ca.gov/2013publications/CEC-400-2013-008/CEC-400-2013-008.pdf

their estimated savings. Cadmus also referenced this analysis for our evaluation. Because the whole building analyses simultaneously captured savings from multiple Title 24 new construction standards, the results of the analyses accounted for the impact on energy savings caused by interactions between multiple standards.

As noted above, Cadmus found that the IOU savings estimates for individual standards included in the whole building analyses did not account for the implementation of multiple standards at once, and thus do not account for interactions and the resulting impact on savings. We noted that the sum of the IOU-estimated savings for the individual standards was generally much greater than the corresponding whole building standard. As indicated above, we requested clarification of the relationship between these inconsistent claims and, as a result, the IOUs provided the memo on whole building and individual measure savings dated September 26, 2016. Our understanding of the relationship between individual standards and whole building savings is based on this memo and our subsequent discussions with representatives of the statewide program.

We reviewed the whole building and individual measure estimates with the evaluation project management team (CPUC staff, advisors, DNV GL, and Cadmus) and also with representatives of the statewide program. We agreed with CPUC staff and the management team to evaluate savings for both the whole building category and for the individual measures.

Because using the potential for individual measures would overstate energy savings, we considered adjustments that would take interactive effects into account and would also make the whole building and individual measure results more consistent. We identified two sources that could reasonably be used to adjust measure potential: the CEC impact analysis and a draft whitepaper[11] that included analysis of interactions between Title 24 measures. We decided to rely on the CEC analysis for a few reasons. First, the IOUs used the CEC analysis as the basis for their whole building savings, and this analysis was completed using a small set of prototype building simulation models weighted according to construction activity across all of the California climate zones. We also noted that the CEC analysis has been publicly available since 2013, whereas the draft whitepaper has not been published.

To reconcile findings for the whole buildings and individual standards, Cadmus did the following:

- Evaluated savings for the whole building standards and
- Evaluated savings for the individual standards with the potential savings for all of these standards scaled to ensure the total potential savings are equal for both cases.

Cadmus acknowledges that the simplified scaling approach used assumes an equal proportional adjustment for each individual standard, which is not likely to be accurate. However, this method meets

[11] Assessment of Energy Savings Overlap Among Building Standard Measures, TRC Energy Services, February 2016. Unpublished.

our objective to align the total potential savings for the individual standards with the whole building standards and more in-depth analysis was beyond the scope of this study.

Cadmus used the following equation to calculate a scaling factor that was applied to the evaluated savings for each standard included in a whole building analysis:

Equation 1

$$Scaling\ Factor = \frac{Whole\ Building\ Evaluated\ Savings}{\sum Evaluated\ Savings\ for\ Standards\ included\ in\ Whole\ Building\ Savings}$$

Cadmus scaled the evaluated savings for the individual standards that overlapped with the whole building standard such that the sum of the scaled, evaluated savings for the individual standards equaled the evaluated savings for the whole building standard.

2.2. Nonresidential Gross Savings/Compliance

2.2.1. Nonresidential Sampling Plan

This section describes the data sources, population characterizations and stratification, standard prioritizations, and sample design that Cadmus used to develop the nonresidential sampling plan and then presents the final sample design.

Data Sources

Cadmus compiled information for the 2015 nonresidential alteration (NRA) and nonresidential new construction (NRNC) populations in California based on data from the California Energy Commission (CEC data) and Dodge Data & Analytics (Dodge data). Between these data sources, we developed our understanding of the population as well as the sampling plan. Table 7 outlines these data sources.

Table 7. Nonresidential Data Sources

Description	Data Source
Nonresidential new construction and existing building stock estimates (square footage by climate zone and building type)	California Energy Commission. Personal communication with Energy Specialist. April 2016.
Jurisdiction square footage within climate regions. Dodge square feet estimates were used to approximate jurisdiction square feet in the CEC data.	Dodge Data & Analytics. Construction Starts Information for the state of California by zip code for 2013-2015. June, 2016.

We acknowledge that the data had limitations; namely, none of these data contained the number of lighting alterations or new construction sites in the state of California. Instead, we used information on square footage within building type and climate region provided in the CEC data and Dodge data. The Dodge data included total square footage in each ZIP code, which we mapped to IOU service areas before calculating the proportion of square footage in each jurisdiction (out of the total square footage in its respective climate region). Cadmus applied these proportions to the total square feet by climate region and building type provided in the CEC data, using existing building stock square footage to represent the NRA population. Cadmus grouped some building types (e.g., we combined large and small offices into a single office category) and climate zones using the same approach used in the previous evaluation.[12]

Even though the Dodge data provided the square footage of new construction and alteration sites in each jurisdiction directly, the CEC and Dodge data did not always align with respect to the amount of square footage estimated within climate regions or building types. Specifically, the CEC data estimated approximately three times the amount of square footage as the Dodge data. We decided to use the square feet provided in the CEC data because utilities represented in this evaluation have used CEC data for many of their estimates and the CEC provides statewide estimation of whole building expected savings based on improvements in building codes and standards.

Although there is uncertainty associated with both the CEC data and Dodge data, utilizing both sources allowed us to calculate sample weights as accurately as possible. However, it is possible that the sample design and sampling weights led to biased results in statewide estimates. For example, if the proportion of all lighting alterations that occurs in a building type is significantly different than the proportion of existing buildings reflected in the CEC data, then the sampling weight does not accurately reflect the proportion of the population represented in the sample.

Nonresidential Population and Stratification

This section discusses the populations of interest for nonresidential lighting alterations and new construction buildings. We discuss in detail the prioritization of standards and stratification of the populations and sample frames.

Standards Prioritization

As noted in the C&S Program Impact Evaluation Plan: Phase One, four nonresidential lighting alteration standards—B34, B35, B36, and B39—represent about 84% of the IOU estimated potential energy savings from the 2013 Title 24 NRA category: 1,025 of 1,226 GWh starting from when the code took effect on 7/1/2014 through the end of 2015. Cadmus focused the current evaluation's sampling plan on these standards because they represent the bulk of the energy savings for this category. The remaining NRA standards—B37 (lighting), B38 (lighting), B40 (envelope-cool roofs), B41 (HVAC), and B42 (air compressors)—are not addressed by this sampling plan. Cadmus incorporated into the evaluation applicable results from other studies where we are currently examining the compliance and savings associated with any of these codes.

Cadmus included all applicable codes in the NRNC category in the sample design.

[12] See Appendix E for climate regions and associated CEC climate zone definitions.

Nonresidential Populations and Sample Frames

In the absence of reliable data on the number of sites in the NRA or NRNC populations, we assumed that square footage, as reported by the CEC, provided a proxy for the number of alterations and new construction buildings in the population, as in the last evaluation.[13] Cadmus used the CEC data to build the sample frames. We stratified the sample frame by building type, expecting consumption within building types to be more similar than consumption between building types. The population of building types included offices, retail buildings, warehouses, schools, hospitals, refrigerated warehouses, and miscellaneous buildings. Within each building type strata, we mapped climate zones to five climate regions, defined as A, B, C, D, and E (details can be found in Appendix E).

Cadmus removed hospitals and refrigerated warehouses from both the NRA and NRNC sample frames because portions of the codes for these building types were outside the Title 24 codes included in this evaluation. We also removed square footage located in climate regions D and E from the sample frames because combined, they accounted for less than 10% of the 2015 building stock and less than 10% of the new construction square feet in California, and after distributing the total sample size to climate regions, samples in these regions would involve too few sites to be representative of the region. The resulting sample frames includes over 90% of the square feet in California.

We present the proportion of existing building stock square footage in each building type category in the population and sample frame in Table 8, as well as the proportion of new construction square footage in each building type category in the population and sample frame in Table 9.

Table 8. 2015 Existing Building Stock by Building Type

Building Type	Thousands of Square Feet in Population	Proportion of Population	Thousands of Lighting Alteration Square Feet in Sample Frame*	Proportion of Sample Frame
Miscellaneous	2,206,809	30%	147,121	32%
Office	1,668,477	23%	111,232	24%
Retail	1,171,062	16%	78,071	17%
Warehouse	1,056,610	14%	70,441	15%
School	861,488	12%	57,433	12%
Hospital	368,093	5%	0	0%
Refrigerated warehouse	56,726	1%	0	0%
Total	**7,389,266**	**100%**	**464,298**	**100%**

* Total lighting alteration square feet in sample frame is calculated as (total square feet in population) x (1/15) for each building type.

13 This assumption was used by the CEC, the IOUs, and the 2010-2012 study evaluators to estimate potential energy savings.

Table 9. 2015 New Construction by Building Type

Building Type	Thousands of Square Feet in Population	Proportion of Population	Thousands of New Construction Square Feet in Sample Frame	Proportion of Sample Frame
Miscellaneous	51,821	32%	48,186	34%
Offices	37,065	23%	34,975	24%
Retail	27,116	17%	25,283	18%
Warehouses	24,986	15%	23,200	16%
Schools	12,909	8%	12,139	8%
Hospital	8,188	5%	0	0%
Refrigerated warehouse	1,501	1%	0	0%
Total	**163,586**	**100%**	**143,783**	**100%**

Sample Design

This section presents the sample design Cadmus developed to satisfy the goals of the nonresidential evaluation. We discuss in detail the sampling challenges, target sample sizes, expected confidence and precision, and sample selection.

Target Sample Sizes and Expected Confidence and Precision

Cadmus determined that a sample size of 50 sites from the lighting alteration sample frame would allow us to complete site visits on time and within budget. Similarly, we anticipated we could feasibly achieve a sample size of 30 sites from the new construction population. We allocated total sample sizes to building types based on the proportion of square footage in each stratum to ensure that each sample was representative of the distribution of buildings in the population.

We estimated error ratios[14] and expected precision[15] for the NRA and NRNC populations based on the previous evaluation's estimated ESAFs (previously referred to as compliance adjustment factors (CAFs)) and reported precision.[16] The previous evaluation estimated an NRA CAF estimate of 580%, with precision of ±26% at 90% confidence, and sample size of 68. Cadmus calculated an error ratio of 1.3 for

14 To calculate the error ratio, we used the following formula with inputs for sample size (n), precision, and the z-statistic for two-tailed 90% confidence (z):

$$ER = \frac{precision * \sqrt{n}}{z}$$

15 To calculate the expected precision for this evaluation, we used the error ratio estimates, target sample sizes, and 90% confidence in the footnoted equation above, solving for precision.

16 Ratio estimators were used to calculate ESAFs (previously known as compliance adjustment factors (CAFs)) in the previous evaluation; thus, an error ratio provides the appropriate measure of variation, rather than the coefficient of variation.

the lighting alteration population from this information, which we then used to estimate an expected precision in this evaluation of ±30% (at 90% confidence) around the population statewide NRA ESAF. For NRNC sites, Cadmus estimated an error ratio of 0.35 based on the previous evaluation's estimated NRNC CAF of 397%, with ±6% precision at 90% confidence, and sample size of 90. We calculated an expected precision of this evaluation's NRNC ESAF at ±11% with 90% confidence.

The sample sizes within each building type are presented in Table 10 for lighting alteration and new construction populations, along with expected precision of energy savings adjustment factors based on the targeted total sample size within each population.

Table 10. Nonresidential Target Sample Sizes

Site Type	Building Type					Total	Expected Precision at 90% Confidence
	Misc.	Office	Retail	Warehouse	Schools		
Lighting Alterations	14	11	8	8	9	50	± 30%
New Construction	10	7	6	5	2	30	± 11%

Cadmus initially focused on stratifying the nonresidential lighting alteration and new construction populations by building type and climate region because we expected the effects of Title 24 and compliance with Title 24 codes to vary by both factors. However, Cadmus faced considerable challenges in recruiting for site visits and these challenges made it impossible to complete the evaluation of the recommended number of buildings within the evaluation timeline. Therefore, we revisited the sampling plan to decrease the sample size and remain on schedule. Cadmus also incorporated the results of our recent analysis that studied 2008 Title 24 code compliance margins to update our sample design. The analysis showed that, among factors including climate region, building type, jurisdiction, and utility territory, building type was the only one with a significant impact on compliance margins. Based on this result, Cadmus recommended decreasing the number of strata and setting sample size targets within only building type categories for this evaluation.[17]

Although we set sample size targets within building type categories only, we incorporated the square footage corresponding to both building type and climate region, as well as jurisdiction, into the sampling weights to account for sampling jurisdictions within climate regions. Details of the weighting scheme are provided in Section 2.2.4.

Sample Selection

Similar to the previous evaluation and the residential sample design, Cadmus implemented a stratified two-stage cluster sample design where we first sampled jurisdictions from each climate region, and then

[17] Note that the results of the 2008 study were not available at the time Cadmus developed the original sample design for this evaluation.

selected nonresidential sites from each of these jurisdictions for site visits. As part of the goals of the evaluation, Cadmus developed the following criteria for nonresidential sites to include in the analysis:

- Nonresidential site
- Site located in an IOU service area
- Site permitted after July 1, 2014 and constructed before December 30, 2016

Cadmus selected jurisdictions within climate regions using probability-proportional-to-size (PPS) sampling. Cadmus did not have a list of nonresidential new construction sites from which to estimate the sizes of each jurisdiction. Instead, we defined size as the square footage of newly constructed nonresidential sites in each jurisdiction.[18] We estimated the square footage of nonresidential sites in each jurisdiction, climate region, and building type by first using the Dodge data to estimate the proportion of square feet in each jurisdiction and climate zone, and then applying this proportion to the square feet in each building type provided in the CEC data.

We excluded jurisdictions from the sample frame if nonresidential sites in non-IOU areas made up the majority of new construction in that jurisdiction, since we were only interested in estimating impacts in IOU territories. Cadmus selected jurisdictions from the remaining jurisdictions in each climate region. The PPS sampling approach gave a higher chance of being selected to jurisdictions with more square feet of nonresidential sites.

To develop sample frames of nonresidential lighting alteration and new construction sites, we requested all permits from the Dodge data meeting the previously mentioned criteria in the sampled jurisdictions. We then selected a simple random sample of the remaining nonresidential sites within each jurisdiction.

Sampling Challenges

Cadmus sampled 24 jurisdictions (8 jurisdictions from climate regions A, B and C each) across the IOU service areas. However, some of the sampled jurisdictions did not contain enough sites that met the criteria of the evaluation to reach the target number of site visits. We sampled 19 additional jurisdictions to reach the total number of sites. When the number of sites in a jurisdiction was small and we faced substantial nonresponse from owners or facility managers for site visits, Cadmus selected all sites within a jurisdiction.

2.2.2. Nonresidential Recruiting, Field Data Collection

Recruiting and Scheduling

The scope of work for this project required recruiting sites within the sample plan to allow our data collection team to visit sites and building departments to view the approved building plans and Title 24

[18] Source of this data: Dodge Data & Analytics. *Construction Starts Information for the state of California by zip code for 2013-2015.* June, 2016. Cadmus used this data to estimate the proportion of square footage in each jurisdiction, since the CEC estimates construction activity by climate zone.

documentation and collect required data for the analysis. Sites were recruited among the permit records provided by the building departments within the sampled jurisdictions.

Building Permit Data Collection

Cadmus obtained permit records from each selected jurisdiction's building department. This data was used to determine the version of the Title 24 code under which the building was potentially permitted prior to visiting specific project sites. Our team determined that all the building departments within our sample have publicly available permit records on their websites. However, publicly available data typically has a very limited content to identify eligible buildings for this evaluation cycle and format varies substantially in each building department's website. Therefore, Cadmus sent a data request to each building department within the sampled jurisdictions. Data requests included building permit records in a spreadsheet format to have the following information:

- Nonresidential building permit records from July 1, 2014, to date of the data request submitted to the building department (August to September, 2016)
- Permit number
- Permit type (new construction or alteration)
- Building address
- Description of the project
- Square footage of the project
- Valuation of the project
- Contact information for the building owner and permit applicant
- Permit application and issue dates

Cadmus sent a data request to a total of 39 building departments and, ultimately, received usable data from 28 jurisdictions. The initial data request was sent to the building departments in 24 sampled jurisdictions across the IOU service areas. Communication with a few building departments continued up to 10 weeks due to their workload and we eventually received data from 18 of these departments. Six of 24 building departments couldn't generate permit reports, were unresponsive despite multiple requests for information, or unwilling to provide the requested information. These building departments declined the data request due to limitations in staff capacity and internal challenges. To attempt to satisfy our sample size, Cadmus sampled 19 additional jurisdictions to have replacements available if needed. Cadmus sent a data request to 15 building departments within these 19 additional jurisdictions and received data from 10 out of 15 building departments, while 5 building departments couldn't generate the requested data due to abovementioned issues.

Overall, Cadmus removed 11 jurisdictions from the sample as they did not provide requested data or provided data that was not usable. Cadmus dropped an additional jurisdiction, City of Davis, from the sample as it had adopted Reach Code requirements. Although City of San Francisco also adopted a Reach Code, Cadmus kept this jurisdiction in the sample. In the City of San Francisco, Reach Code requirements impact new large commercial buildings, major alterations to commercial buildings and first time commercial interior alterations for assembly, business, institutional, mercantile types that are equal or larger than 25,000 square feet[19]. However, data provided by the City of San Francisco revealed that most of the potentially eligible sites in this jurisdiction were smaller than 25,000 square feet. Therefore, Cadmus kept this jurisdiction in the sample considering the number of eligible sites. Table 11 shows the jurisdictions that were removed from the sample.

Table 11. Removed Jurisdictions

Reason for Removal from Sample	Jurisdiction		
Data not available, accessible, or usable	City of Berkeley City of Chico City of Chino City of Downey	City of Ione City of Loma Linda City of Los Altos City of Rialto	City of San Bernardino City of Visalia Orange County
Reach Code Overlap	City of Davis		

Overall, Cadmus secured nearly 153,000 permit records from 28 jurisdictions in California's three climate regions. Table 12 shows the participating jurisdictions from which we received data for this study by climate region.

Table 12. Participating Jurisdictions by Climate Region

Climate Region A	Climate Region B	Climate Region C
City of Oakland	City of Long Beach	City of San Luis Obispo
City of Mountain View	City of San Diego	City of Davis
City of San Francisco	City of Westminster	City of Tracy
City of Santa Rosa	City of Oxnard	City of Bakersfield
City of Santa Maria	City of Fontana	City of Shafter
City of Sunnyvale	City of Santa Ana	City of Hanford
City of Redwood City	City of Montclair	City of San Jose
City of Napa	City of Berkeley	City of Lodi
County of Santa Clara	County of Los Angeles	
County of Santa Barbara	County of San Bernardino	

Because California does not have a uniform or centralized method for managing building permit data, each jurisdiction provided information to Cadmus in different formats and to different levels of completeness. The building departments that were able and willing to provide the requested permit data did so in formats ranging from spreadsheets that contained most of the requested information to weekly PDF files. The usability of jurisdiction building permit data depended mainly on the format in which the data were provided, completeness, and the amount of irrelevant permit types that required

[19] City and County of San Francisco Department of Building Inspection. *Implementation of Green Building Regulations.* January 1, 2014. Available online: http://sfdbi.org/sites/default/files/AB-093.pdf

additional filtering to remove them from the sample. Most jurisdictions did not have the capacity to provide customized reports or filter out the unrelated permit types for this study. In some cases, jurisdictions provided very limited data in the reports, but had online tools to allow for additional research on permit types for some sites.

Building Permit Data Eligibility Screening

Cadmus conducted a detailed eligibility screening process to review, clean and identify potentially eligible permit records for recruitment prior to phone screening and scheduling. After Cadmus received the requested data, our team undertook several steps to convert the raw permit data into recruiting tools that would allow us to schedule engineers to visit the project sites. These steps included formatting the received data, determining the project's eligibility for the study, and researching additional project contact information. Since most jurisdictions did not provide site contact information with the permit records, our team had to conduct a comprehensive search to find viable contact information from public sources.

To be considered potentially eligible for the study, permit records were required to meet the data and phone screening criteria illustrated in Table 13.

Table 13. Project Eligibility and Screening Criteria

Permit Type	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6
New Construction	Permitted per 2013 T24 code	Project Valuation >$90,000	If Multifamily, have more than 3 stories	Include Conditioned Space	Construction completed and site accessible	Non-Participant in Utility Rebate Program
Lighting Alteration	Permitted per 2013 T24 code	Project Valuation >$10,000	If Multifamily, have more than 3 stories	Electrical permit acquired for lighting upgrade	Alteration completed and site accessible	Non-Participant in Utility Rebate Program

Recruitment Screening and Scheduling

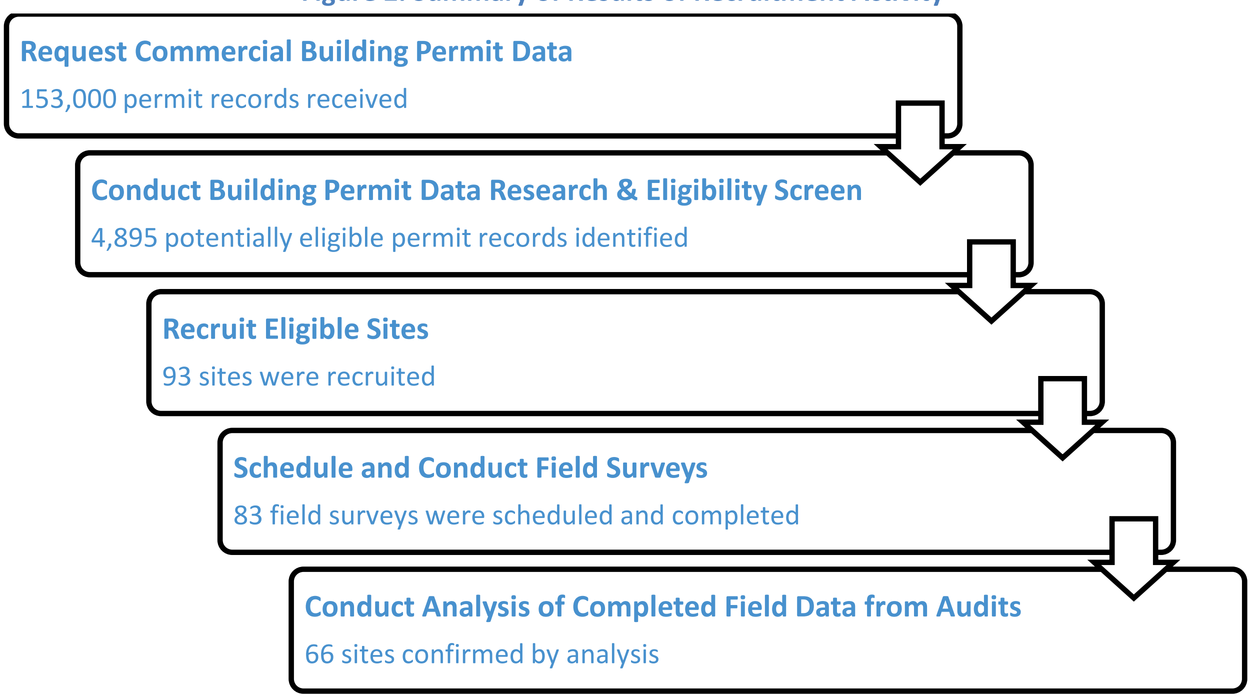
The evaluation team developed a unique recruiting process tailored specifically to the study criteria and constraints on the availability of the building department permit data. Cadmus utilized both its own recruiting team and a call center, Martec Group, for recruiting.

Cadmus expected that it would be challenging to find building owners or managers willing to host site audits. Unlike most incentive programs where participants are required (or at least requested) to assist evaluators, the C&S Program has no participants. In this case, buildings qualified because they were built during a particular time period and their owners have no obligation to participate. To overcome this challenge, Cadmus used the methods described here on a large scale to reach the target number of audits.

Cadmus developed a detailed recruitment process and phone scripts specific to nonresidential new construction and lighting alteration projects and provided all day long training to all recruiters to enhance quality control. All recruiters navigated each commercial site's contacts to determine the appropriate point of contact, through which they could determine whether a site was eligible for the study (beyond what can be found in the permit records), and if the property owner or manager would consent to participate. Recruiters called through the list until the list was exhausted. Each site was contacted three times for recruitment, or until our request for a site-visit was denied. We offered $100 prepaid Visa Gift Cards to building owners or property managers willing to escort our engineers through their facilities.

Cadmus' recruiting team and the call center confirmed 93 survey appointments. In some cases, the respondent canceled the appointment completely or left open the option to reschedule. In other instances, some of the scheduled surveys resulted only in partial audits, or were disqualified due to the site's participation in utility energy-efficiency rebate programs (e.g., Savings by Design), or found to be not eligible during the site visit because the site was not built or renovated under 2013 Title 24. Consequently, the number of sites analyzed was less than the number of confirmed survey appointments. The evaluation team completed total of 66 surveys (49 new construction and 17 lighting alteration sites). Figure 2 summarizes the process and overall results of the recruitment activity.

Figure 2. Summary of Results of Recruitment Activity



Scheduling Data Collection Team

Communication between the recruiter, scheduler, and data collection team relied heavily on collaboration on a SharePoint site. The SharePoint site was utilized as a repository for the results of the data collection visits. Each nonresidential building visited was given a folder named with a specific identification number. The data collection team uploaded the data collection forms, photos taken on sites and other supporting documents such as plans and Title-24 documentation to the appropriate folder. Also, a private Outlook Calendar was created to allow schedulers to create building site visit appointments and forward them on to the data collection team. The team could access all the information for any appointment by going to the calendar.

Data Collection Tool Development

Cadmus developed a data collection tool with two versions that allowed the data collection team to collect the information necessary to populate the EnergyPro software model for a nonresidential new construction or lighting alteration project. The data collection tool, developed in Excel, could be used either on a tablet or laptop on-site or as a paper printout. The goal of the form was to be able to collect required data for the analysis through onsite observations, interviews with facility personnel and review of Title 24 documentation and building plans.

The data collection form was designed to match the minimum input required to model a nonresidential building in EnergyPro. The goal was to provide required information about the building to the modeler that directly corresponded to the required input screens.

Data Collection Team

Cadmus used its own site engineers and DNV GL engineers for the field data collection. DNV GL was responsible for about 25% of the site visits and Cadmus collected field data for the rest of the sites. All of the field team members were located in California, which reduced travel time and the costs associated with travel. All of the team members were experienced in collecting data for nonresidential construction. Cadmus provided the overall management of the data collection teams, which included coordination of site visits and a quality assurance review of data collected on site. To further reduce travel, sites closely located to each other were grouped and scheduled one after another. This reduced the number of overnight trips to the sites.

Data Collection Training

Cadmus designed and conducted a two-day training in October, 2016 to instruct the data collection team. The first day of the training was provided in classroom in the DNV GL office in Oakland and covered the following topics:

- Goals of the data collection effort
- Data collection process and overview of the sampling process
- Overview of the data collection form
- Collecting data from the plans and Title 24 compliance documentation
- Collecting data on-site
- Interaction with the building departments

The second day of the training was provided on-site. First two scheduled site visits for two newly constructed buildings were visited by a group of Cadmus and DNV GL field surveyors together and a senior engineer from Cadmus provided a hands-on training on site to cover the topics discussed during in class training.

Field Data Collection

The main objectives of our field data collection included: (1) perform rigorous data collection based on the specifications of the critical measures covered by Title 24, (2) inform the analysis by incorporating all building parameters and characteristics that impact the savings associated with those measures in a measurable way, and (3) provide insights to improve savings estimates.

Cadmus deployed a range of methods and tools to achieve these objectives through a consistent, integrated, and transparent approach. In choosing our data-gathering techniques, we sought to balance the certainty gained with project resources spent. We measured where experience has shown that energy use can vary widely, thus resulting in large uncertainty of estimates. Through this approach, we verified whether the applicable measures: (1) are in compliance with 2013 Title 24 code, (2) exceed the code requirements, or (3) do not meet the code requirements. We performed the following three steps to assess compliance of each site:

1. Research of Building Department Records

During our recruiting process, data collection team asked point of contacts whether or not they would be able to provide our engineer with building plans and permit documentation when they arrived on-site. Often, building owners either had these documents on file, or they requested them from their property manager. However, it was not uncommon that our point of contact would be unable to produce the necessary documentation for our evaluation effort. Under such circumstances, Cadmus and DNV GL engineers visited building departments to obtain all available documents related to the plan review and permitting process for each surveyed site. The documentation included but was not limited to:

- Architectural, electrical, and mechanical drawings
- Construction details and specification books
- Title-24 documentation (envelope, lighting and mechanical)

2. Site Data Collection

Cadmus conducted site visits to physically verify the building's parameters and characteristics for new construction and lighting alteration commercial project types. The data collected in the field informed the input values that were specified in the whole-building energy modeling on a per-site basis.

While on-site, field engineers documented accessible details regarding the facility's construction. This information included:

- 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
- Lighting densities and control types.

3. Interviews with Facility Personnel

As part of the data collection process, data collection team often talked with staff familiar with the facility and verify the accuracy of the assumptions that related to energy savings calculations. To maintain consistency across sites and assess compliance in accordance with the code-modeling requirements, we did not collect and use self-report data on operating hours. Alternately, we used EnergyPro's default schedules per each commercial building as certified by California Energy Commission (CEC).

To inform the analysis, the evaluation team also referred to manufacturers' cut sheets of installed equipment, when manufacturers' names and/or product numbers were provided, and satellite images of each site, where relevant. Where we found discrepancies between the as-built drawings and project documentations and the data collected on-site, the physically verified data supplanted the as-designed documentation.

2.2.3. Nonresidential Site Analysis and Modeling

Field data collected by Cadmus and DNV GL field data collection teams helped evaluation team to estimate annual energy consumption of each site. Evaluation team determined annual energy consumption using a simulation model approach based on site measurements and observations. DNV GL was responsible for developing the simulation models for the sites visited by DNV GL engineers which account for about 25% of the sites visited. Similarly, Cadmus developed simulation models for the sites visited by its in-house field data collection team. Both teams met regularly on weekly basis to make sure both teams follow the same methodologies for developing the simulation models and discuss any potential discrepancies.

To create these simulation models, both teams used EnergyPro, a DOE-2 engine modeling software developed by EnergySoft, LLC. EnergyPro was selected because it met the needs of the impact evaluation that included level of accuracy required; the methods, codes, and baseline definition and its underlying assumptions; level of detail of the output data; and the capability to customize and automate parametric runs to estimate measure-level savings. Cadmus worked closely with EnergySoft, LLC to develop a custom version of the software that produced the following:

- Baseline model based on the data collected on-site that minimally complies with the 2008 Title 24

- Baseline model based on the data collected on-site that minimally complies with the 2013 Title 24
- Model based on the data collected on-site (as-built)
- The ability to generate measure-level savings for each measure identified in the potential studies

Site visits and as-built project documentation, including architectural drawings and Title 24 energy code compliance documentation from building code jurisdictions, provided the building parameters and characteristics for modeling. The parameters and characteristics used as input values for the baseline building were to reflect the building as if it were built to minimum requirements of the prior code. The evaluated 2008 and 2013 energy savings are the difference in annual energy use between the as-built and 2013 Title 24 code and the as-built and 2008 Title 24 code building, respectively.

Modeling Quality Control

Throughout the simulation modeling process, Cadmus coordinated with DNV GL regarding any discrepancies with the data or questionable results from the EnergyPro export. Prior to the simulation modeling process, Cadmus provided a comprehensive training to DNV GL on different features of the custom EnergyPro version developed for the study and the quality control process.

Cadmus developed a multi-level quality control process for the simulation models. Simulation modeling leads at Cadmus and DNV GL reviewed the simulation models by their teams. Once all 67 simulation models were created, simulation modeling leads at Cadmus reviewed all the simulation models and reviewed them for any anomalies or discrepancies. Cadmus specifically reviewed all Power Adjustment Factors (PAFs) applied to the models to ensure that PAFs were only applied as allowed by the 2013 Title 24 energy code. They also reviewed the accuracy of the model inputs, verifying that the models fully captured the data collected in the field.

2.2.4. Nonresidential Statewide Gross Savings/Compliance Estimation

Cadmus calculated nonresidential whole building energy savings adjustment factors (ESAF) for electric annual savings, CPUC-defined peak demand savings, and gas annual savings. We expected kWh and kW evaluated savings to have similar relationships with their respective expected savings, producing similar ESAF values. We also expected kWh and therms to have a negative relationship (i.e. as kWh savings increases, therms savings decreases), however this is not indicative of a relationship between their ESAF values. We provide results by building type, and the state as a whole in Section 3.2.2. This section details the method Cadmus used to apply sample weights and estimate ESAFs and evaluated savings[20]. The same method applies to both the new construction and lighting alterations analyses, as well as both the analyses for whole-building compliance and individual standard compliance.

[20] Särndal, C., Swensson, B., & Wretman, J. (2003). Model assisted survey sampling. New York: Springer.

Cadmus evaluated a subset of standards, prioritizing selection based on the IOU estimate of potential savings for each standard and practical considerations for the analysis of each standard. Evaluated standards include fenestration, lighting controls, and HVAC controls. Table 5 in Appendix F summarizes our approach to analyzing individual standards.

Sample Weights

The process of calculating applies to both lighting alterations and new construction projects. Cadmus applied sample weights that followed the sample design described in Section 2.2.1. Because we simple random sampled nonresidential sites, we did not apply site-level sample weights.[21]

Equation 2 provides the jurisdiction-level sample weights. Since we sampled jurisdictions with PPS sampling, we calculated jurisdiction-level sample weights as the inverse of the proportion of nonresidential square footage relative to the climate region overall, by building type. Cadmus applied the ratio of total climate regions to the observed climate regions to estimate the population consumption within each building type, denoted by w_k and provided in Equation 3, to account for cases where we did not observe every climate region within a building type.

Equation 2

$$w_{hki} = \frac{1}{Probability\ of\ selecting\ jurisdiction\ 'i'} = \frac{M'_{hk}}{M'_{hki}}$$

Equation 3

$$w_k = \frac{Total\ climate\ regions\ in\ building\ type\ 'k'}{Observed\ climate\ regions\ in\ building\ type\ 'k'} = \frac{N_k}{n_k}$$

Where:

h	=	Indicates climate region ‘h’
k	=	Indicates building type ‘k’
i	=	Indicates jurisdiction ‘i’
w_{hki}	=	Sample weight of jurisdiction ‘i’ in climate region ‘h’ and building type ‘k’
w_k	=	Ratio of total climate regions to observed climate regions in building type ‘k’ (not required for all building types)
M'_{hk}	=	Total nonresidential square footage in climate region ‘h’ and building type ‘k’

[21] Due to the site visit recruitment challenges, sites recruited via contacting building contractors were not randomly selected within jurisdictions, which may introduce bias into the estimates.

M'_{hki} = Total nonresidential square footage in jurisdiction 'i', climate region 'h', and building type 'k'

N_k = Total number of climate regions in building type 'k'

n_k = Number of climate regions observed in building type 'k'

Energy Savings Adjustment Factor Analysis

Cadmus calculated whole building ESAFs for annual electric savings, CPUC-defined peak demand savings, and gas annual savings. The following sections outline the methodology used to estimate site-level and population evaluated savings and ESAFs by building type and statewide for both nonresidential lighting alterations and new construction projects.

Nonresidential Site Estimates

Cadmus calculated expected savings for each nonresidential site as the difference between the energy consumption for the site if it just met the 2008 Title 24 and just met the 2013 Title 24. This is the expected savings for each site based on 100% compliance with each of the codes. We estimated the evaluated savings as the difference between the 2008 Title 24 consumption and the estimated consumption of the site as-built, based on the data collected on site.

The CPUC aims to assess the impact of the C&S program under conditions where the savings from the 2013 Title 24 were limited to the change in consumption between the amount allowed under the 2008 Title 24 and the 2013 Title 24. To do so, Cadmus estimated building-type and statewide ESAFs by restricting the evaluated savings to be no greater than the expected savings of the building. We refer to these estimates as the bounded ESAFs, and they are provided in Section 3.2.2 along with the unbounded results. We also discuss the implications of bounding these results in Section 3.2.2.

Population Statewide Evaluated Savings

To estimate population evaluated savings for each building type, Cadmus applied the sample weights described above. Equation 4 presents the estimation approach, which first calculates the total evaluated savings in jurisdiction 'i', and then the total evaluated savings across all jurisdictions in climate region 'h', by building type. Summing across climate regions within building type 'k' (and applying the climate region ratio w_k when necessary) provides the total population evaluated savings for building type 'k'. To estimate population statewide evaluated savings, Cadmus summed across building type population evaluated savings. We calculate population building type and statewide expected savings ($\hat{x}_{.k..}$) similarly.

Equation 4

$$\hat{y}_{.k..} = w_k * \underbrace{\sum_{h=1}^{N_h} \frac{1}{n_{hk}} * \sum_{i=1}^{n_{hk}} w_{hki} * \frac{M'_{hki}}{m'_{hki}} \underbrace{\sum_{j=1}^{m_{hki}} y_{hkij}}_{\text{Total savings in jurisdiction 'i'}}}_{\text{Total savings across all jurisdictions in climate region 'h', building type 'k'}}$$

Where:

$\hat{y}_{.k..}$	=	Evaluated savings for building type ‘k’
y_{hkij}	=	Observed savings for nonresidential site ‘j’ in jurisdiction ‘i’, climate region ‘h’, and building type ‘k’
m_{hki}	=	Number of nonresidential sites sampled in jurisdiction ‘i’, climate region ‘h’, and building type ‘k’
m'_{hki}	=	Total square feet of nonresidential sites sampled in jurisdiction ‘i’, climate region ‘h’, and building type ‘k’

We provide the ESAF by building type as the ratio of estimated total evaluated savings and estimated total expected savings within building type. Equation 5 provides this calculation. We calculated population statewide ESAF as the ratio of estimated population statewide evaluated savings and estimated population statewide expected savings. Results are provided for unbounded and bounded results in Section 3.2.2.

Equation 5

$$ESAF_k = \frac{\hat{y}_{.k..}}{\hat{x}_{.k..}}$$

Where:

$ESAF_k$	=	Weighted energy savings adjustment factor in building type ‘k’

2.2.5. Nonresidential Mandatory Measures - Daylighting

As requested by the CPUC, we performed an additional analysis to determine the potential energy savings due to Title 24 mandatory daylighting control requirements to assess how much noncompliance with the code might affect energy use. This study focused on the primary sidelit area, since most facilities in the sample included perimeter zones with fenestrations.

Definition of Mandatory Requirements and Changes

Daylighting standards saw significant changes between the 2008 and 2013 Title 24 code for both the daylit zone definition and daylit area controls requirements. Specifically, the primary sidelit zone was defined as the "unobstructed area next to perimeter windows that extends two feet on either side of the window in a direction parallel to the window and one window head height perpendicular to the window" and "limited by any permanent vertical obstructions that are higher than 5 feet tall" in the 2008 code.[22] The 2013 code defined the primary sidelit area as "the area on a building plan directly adjacent to each vertical glazing, one window head height deep into the area, and window width plus 0.5 times window head height wide on each side of the rough opening of the window, minus any area on a plan beyond a permanent obstruction that is 6 feet or taller as measured from the floor."[23] Where the window head height is defined as the distance from the floor to the top of the highest window in both versions. Both 2008 and 2013 primary sidelit definitions are summarized in the figures below.

[22] 2008 Nonresidential Compliance Manual. Chapter 5. http://www.energy.ca.gov/2008publications/CEC-400-2008-017/rev1_chapters/NRCM_Chapter_5_Indoor_Lighting.pdf

[23] 2013 Nonresidential Compliance Manual. Chapter 5. http://www.energy.ca.gov/2013publications/CEC-400-2013-002/chapters/05_indoor_lighting.pdf

Figure 3 : 2008 Title 24 Sidelit Area Plan View

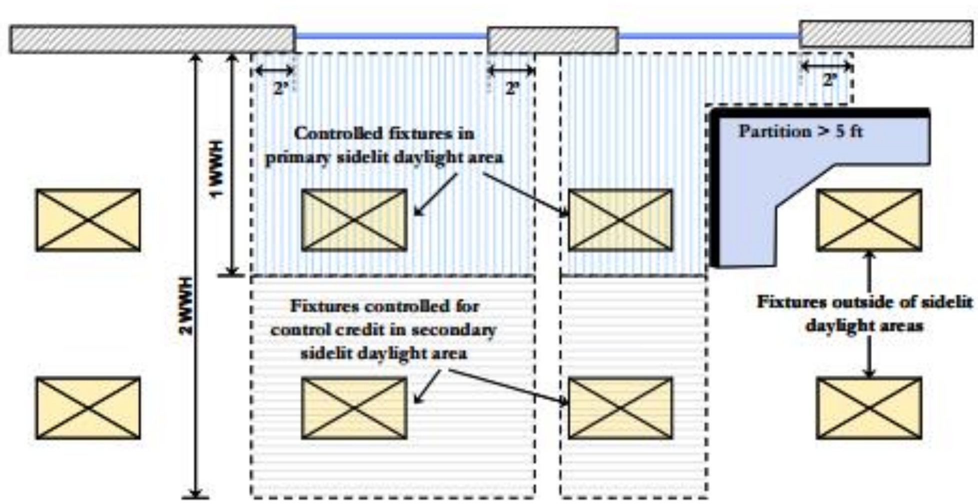
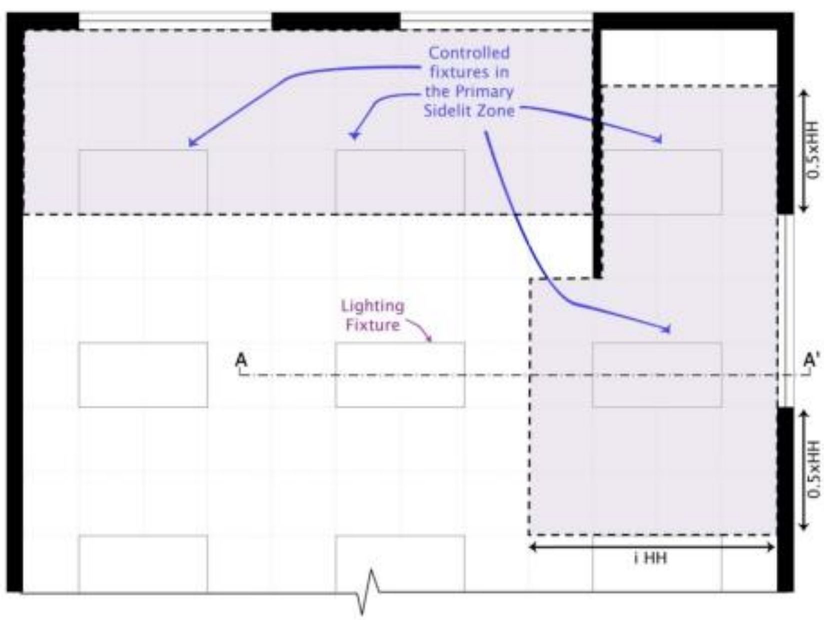


Figure 4: 2013 Title 24 Sidelit Area Plan View



Some changes were made to the controls requirements between the 2008 and 2013 versions of Title 24. Where the mandatory lighting control requirements differ relevant to the primary sidelit area (not including parking garages) is summarized below.

- 2008 Title 24 requirements:
    - The daylight area shall have at least one lighting control that controls at least 50% of the general lighting power in the daylight area except where the daylight area is < 250ft^2 in an enclosed area.

- Automatic multi-level daylighting controls when primary sidelit zone > 2,500 ft^2.
- 2013 Title 24 requirements:
  - For all luminaires in primary daylit zones, automatic daylighting controls shall be installed, except where:
    - Spaces have <120 W of general lighting installed in the daylit zones.
    - Spaces with < 24 ft^2 of glazing.
- 2008 and 2013 requirements:
  - Automatic daylighting controls shall provide multi-level lighting except when the controlled lighting has a power density < 0.3 W/ft^2.
  - For each space, the combined illuminance from controlled lighting and daylighting shall not be less than the illuminance from controlled lighting when do daylight is available.
  - In areas served by lighting that is daylight controlled, when the illuminance received from the daylight is greater than 150 percent of the design illuminance received from the general lighting system at full power, the general lighting power in that daylight zone shall be reduced by a minimum of 65 percent.

For alteration sites, Table 141.0-E in the 2013 Building Energy Efficiency Standards gives an alternate option for compliance. It states if the installed lighting power is less than 85% of the allowed lighting power than the area may not require daylight controls. These stipulations and exceptions were built into the daylight analysis workbook and are discussed further in the following sections. Data regarding which compliance option was chosen was not available for the sites in the study, so any site without daylight controls that met the lighting power and area controls requirement were assumed to have used the alternate compliance option.

Methodology

Using available lighting, daylighting, zoning, and envelope field data collected for the nonresidential site analyses, we input 200 zones from 53 sites into the daylighting analysis workbook[24]. An estimate for savings due to daylighting controls was determined by comparing annual energy use estimates for the 2008 Title 24 base case, the 2013 Title 24 base case, and the as-built values. These estimates were determined from the data collected onsite at each facility, as well as the assumptions detailed below.

Field Data Collection

The data obtained during the field data collection that was used in the daylighting analysis is summarized below.

- Data available for all sites:

[24] We had data for a mixture of new construction and alterations. For some sites, data were not available or there were no applications of daylighting.

- Site zip code to determine appropriate climate zone designation
- Facility primary economic use
- Lighting
  - Zone floor area (ft^2)
  - Zone total as-built watts (W)
  - Control type
- Available for some sites:
  - Building layout sketches with zone dimensions
  - Daylighting sidelit area (ft^2)
  - Wall area (ft^2) and window-wall-ratio (%) – for new construction sites only

Lastly, we collected some data onsite that was indirectly used for determining or confirming the analysis workbook inputs. These references include:

- Facility Address
- Construction drawing sets
- Photos showing glazing areas
- Ceiling height

Limitations

Not all sites were appropriate for inclusion in the daylighting analysis. Out of 65 sites we included in this analysis, nine did not qualify for the daylighting analysis due to lack of vertical fenestrations. These nine were either interior spaces, or had skylights as their only glazing so they were excluded from the analysis. Another limitation we encountered was lack of glazing data. Two sites did not have enough data for the analysis. Window head height was not collected for any of the sites and the glazing area was not collected at the alteration sites. We often estimated these values from the onsite photos or Google satellite or street view images, if needed. Other limitations were lack of data for values such as glazing visible transmittance, facility hours of operation, and design illuminance, so we made appropriate assumptions for these inputs.

Assumptions and References

Details of assumed values are summarized in this section.

Visible Light Transmittance (VLT): After contacting six major glass manufacturers (Pilkington, PPG, AFG, Cardinal, Guardian, and Visteon) in an attempt to gather sales data for visible transmittance values without success, we received a helpful response from Guardian. The sales associate could not share detailed information, but he could confirm that their most popular glazing by far for commercial applications was a 68% VLT option. He also mentioned for typical glazing dimensions, the overall window VLT value may drop 5-9% once the frame is included. For these reasons, we selected a conservative value of 60% VLT for our calculations.

<u>Annual Hours of Use</u>: For simplicity and consistency, we used the annual hours of use from the 2013 Nonresidential ACM schedule for each building category.[25] For this analysis, we considered a site to be occupied when the occupancy schedule fraction was greater than 0.1. See Table 14 for the occupancy schedules.

Table 14: ACM Fractional Occupancy Schedules by Building Type

		Hour of Day																								Total	
Building Type	Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	hrs	hr/wk
Assembly	WD	.00	.00	.00	.00	.00	.00	.00	.00	.20	.20	.20	.80	.80	.80	.80	.80	.80	.80	.20	.20	.20	.20	.10	.00	14	
	Sat	.00	.00	.00	.00	.00	.00	.00	.00	.20	.20	.20	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.80	.10	.00	14	
	Sun	.00	.00	.00	.00	.00	.00	.00	.00	.10	.10	.10	.10	.10	.70	.70	.70	.70	.70	.70	.70	.70	.70	.20	.00	10	94
Data	WD	.00	.00	.00	.00	.05	.10	.25	.65	.65	.65	.65	.60	.60	.65	.65	.65	.65	.40	.25	.10	.05	.05	.05	.00	13	
	Sat	.00	.00	.00	.00	.00	.00	.05	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.05	.05	.05	.00	.00	.00	.00	10	
	Sun	.00	.00	.00	.00	.00	.00	.00	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.00	.00	.00	.00	0	75
Health	WD	.00	.00	.00	.00	.00	.00	.00	.10	.50	.80	.80	.80	.80	.80	.80	.80	.80	.50	.30	.30	.20	.20	.00	.00	14	
	Sat	.00	.00	.00	.00	.00	.00	.00	.10	.30	.40	.40	.40	.40	.40	.40	.40	.40	.10	.10	.00	.00	.00	.00	.00	9	
	Sun	.00	.00	.00	.00	.00	.00	.00	.00	.05	.05	.05	.05	.05	.05	.05	.05	.00	.00	.00	.00	.00	.00	.00	.00	0	79
Lab	WD	.05	.05	.05	.05	.05	.05	.05	.10	.20	.90	.90	.45	.45	.90	.90	.90	.90	.90	.30	.10	.10	.10	.05	.05	11	
	Sat	.05	.05	.05	.05	.05	.05	.05	.10	.10	.30	.30	.30	.30	.10	.10	.10	.10	.10	.05	.05	.05	.05	.05	.05	4	
	Sun	.05	.05	.05	.05	.05	.05	.05	.10	.10	.30	.30	.30	.30	.10	.10	.10	.10	.10	.05	.05	.05	.05	.05	.05	4	63
Manufacturing	WD	.00	.00	.00	.00	.00	.00	.10	.20	.95	.95	.95	.95	.50	.95	.95	.95	.95	.30	.10	.10	.10	.10	.05	.05	11	
	Sat	.00	.00	.00	.00	.00	.00	.10	.10	.30	.30	.30	.30	.10	.10	.10	.10	.10	.05	.05	.00	.00	.00	.00	.00	4	
	Sun	.00	.00	.00	.00	.00	.00	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.00	.00	.00	.00	.00	.00	0	59
Office	WD	.00	.00	.00	.00	.00	.00	.10	.20	.95	.95	.95	.95	.50	.95	.95	.95	.95	.30	.10	.10	.10	.10	.05	.05	11	
	Sat	.00	.00	.00	.00	.00	.00	.10	.10	.30	.30	.30	.30	.10	.10	.10	.10	.10	.05	.05	.00	.00	.00	.00	.00	4	
	Sun	.00	.00	.00	.00	.00	.00	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.00	.00	.00	.00	.00	.00	0	59
Residential	WD	.90	.90	.90	.90	.90	.90	.70	.40	.40	.20	.20	.20	.20	.20	.20	.30	.50	.50	.50	.70	.70	.80	.90	.90	24	
	Sat	.90	.90	.90	.90	.90	.90	.70	.40	.40	.20	.20	.20	.20	.20	.20	.30	.50	.50	.50	.70	.70	.80	.90	.90	24	
	Sun	.90	.90	.90	.90	.90	.90	.70	.40	.40	.20	.20	.20	.20	.20	.20	.30	.50	.50	.50	.70	.70	.80	.90	.90	24	168
Restaurant	WD	.15	.15	.05	.00	.00	.00	.00	.05	.05	.05	.20	.50	.80	.70	.40	.20	.25	.50	.80	.80	.80	.50	.35	.20	16	
	Sat	.30	.25	.05	.00	.00	.00	.00	.00	.00	.05	.20	.45	.50	.50	.35	.30	.30	.30	.70	.90	.70	.65	.55	.35	16	
	Sun	.20	.20	.05	.00	.00	.00	.00	.00	.00	.00	.10	.20	.25	.25	.15	.20	.25	.35	.55	.65	.70	.35	.20	.20	15	111
Retail	WD	.00	.00	.00	.00	.00	.00	.00	.10	.20	.50	.50	.70	.70	.70	.70	.80	.70	.50	.50	.30	.30	.00	.00	.00	13	
	Sat	.00	.00	.00	.00	.00	.00	.00	.10	.20	.50	.60	.80	.80	.80	.80	.80	.80	.60	.20	.20	.20	.10	.00	.00	13	
	Sun	.00	.00	.00	.00	.00	.00	.00	.00	.00	.10	.20	.20	.40	.40	.40	.40	.40	.20	.10	.00	.00	.00	.00	.00	8	86
School	WD	.00	.00	.00	.00	.00	.00	.00	.05	.75	.90	.90	.80	.80	.80	.80	.45	.15	.05	.15	.20	.20	.10	.00	.00	12	
	Sat	.00	.00	.00	.00	.00	.00	.00	.00	.10	.10	.10	.10	.10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	0	
	Sun	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	0	60
Warehouse	WD	.00	.00	.00	.00	.00	.00	.00	.15	.70	.90	.90	.90	.50	.85	.85	.85	.20	.00	.00	.00	.00	.00	.00	.00	10	
	Sat	.00	.00	.00	.00	.00	.00	.00	.00	.20	.20	.20	.20	.10	.10	.10	.10	.00	.00	.00	.00	.00	.00	.00	.00	4	
	Sun	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	0	54

25 2013 Title 24 Nonresidential AMC Reference Manual. Appendix 5.4B. Available online: http://energy.ca.gov/title24/2013standards/ACM_Supporting_Content/

Design Illuminance: We selected 300 lux based on the Daylight Autonomy calculation threshold in the 2013 Daylighting Controls CASE Report.[26]

Annual Hourly Global Horizontal Illuminance: We extracted hourly illuminance values from Typical Meteorological Year (TMY) files obtained from the National Solar Radiation Data Base.[27]

Table 15: Weather File by Climate Zone

Climate Zone	Weather File
CZ01	725945TYA.csv - ARCATA AIRPORT
CZ02	724957TYA.csv - SANTA ROSA (AWOS)
CZ03	724930TYA.csv - OAKLAND METROPOLITAN ARPT
CZ04	745090TYA.csv - MOUNTAIN VIEW MOFFETT FLD NAS
CZ05	723940TYA.csv - SANTA MARIA PUBLIC ARPT
CZ06	722950TYA.csv - LOS ANGELES INTL ARPT
CZ07	722900TYA.csv - SAN DIEGO LINDBERGH FIELD
CZ08	722977TYA.csv - SANTA ANA JOHN WAYNE AP
CZ09	722880TYA.csv - BURBANK-GLENDALE-PASSADENA AP
CZ10	722869TYA.csv - RIVERSIDE MUNI
CZ11	725910TYA.csv - RED BLUFF MUNICIPAL ARPT
CZ12	724830TYA.csv - SACRAMENTO EXECUTIVE ARPT
CZ13	723890TYA.csv - FRESNO YOSEMITE INTL AP
CZ14	746120TYA.csv - CHINA LAKE NAF
CZ15	747185TYA.csv - IMPERIAL
CZ16	725955TYA.csv - MONTAGUE SISKIYOU COUNTY AP

We assumed linear, continuous dimming as the control type for all cases, with the total illuminance equal to the design illuminance of 300 lux whenever daylighting was providing 0-99% of illumination. Also, we excluded occupancy sensor savings or reductions in the analysis based on the assumption that that no occupancy sensors were installed in the daylit spaces.

Results

Overall, new construction projects saw higher rates of compliance with daylight controls installation than the alterations. Of the 15 new construction sites for which results were available, all sites had at least one space that required daylighting per the 2013 code. We confirmed daylighting controls were installed at 53% of these sites (8 of 15). For alteration sites, we determined that 61% (23 of 38) had at

26 Codes and Standards Enhancement Initiative (CASE) Final Report Daylighting Controls. 2013 California Building Energy Efficiency Standards. June 2013. Page 37.

27 National Solar Radiation Data Base. Online: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#C

least one space with daylighting requirements, of which 22% (5 of 23) were confirmed to have controls installed. However, 13% of alteration sites (5 of 38) had daylighting controls installed even though they met the alternate compliance lighting power requirements or were not required to have controls at all.

Space-by-space analysis showed similar results with higher installation rates in new construction projects. For new construction spaces, 59% (46 of 78) of spaces were required to have daylighting controls, based on the 2013 code, and 74% (34 of 46) of those met the requirement. However, 63% (49 of 78) of all the spaces had controls installed, because an additional 15 of the 32 spaces that were not required to have daylighting controls installed did have them. For the alteration sites, controls were required in 25% (30 of 122) of the spaces and they were installed in 13% (4 of 30) of the spaces where they were required. They were also installed in an additional 26 spaces where they were not required or where the lighting power met the alternate compliance option requirements. Overall, controls were installed in 25% (30 of 122) of the alterations spaces. Table 16 summarizes our findings.

Table 16: Alteration and New Construction Rate of Daylighting Controls Installation Results

		Sites			Spaces		
		Installed	Not Installed	Total	Installed	Not Installed	Total
Alterations	Required	5	18	23	4	26	30
	Not Required	5	10	15	26	66	92
	Total	10	28	38	30	92	122
New Construction	Required	8	7	15	34	12	46
	Not Required	0	0	0	15	17	32
	Total	8	7	15	49	29	78
All	Required	13	25	38	38	38	76
	Not Required	5	10	15	41	83	124
	Total	18	35	53	79	121	200

The results showed significant differences in compliance with the daylighting control requirements across building types. This is detailed in Table 17, which accounts for both alteration and new construction sites.

Table 17. Installation Rates of Required Daylighting Controls by Building Type for Alteration and New Construction Sites

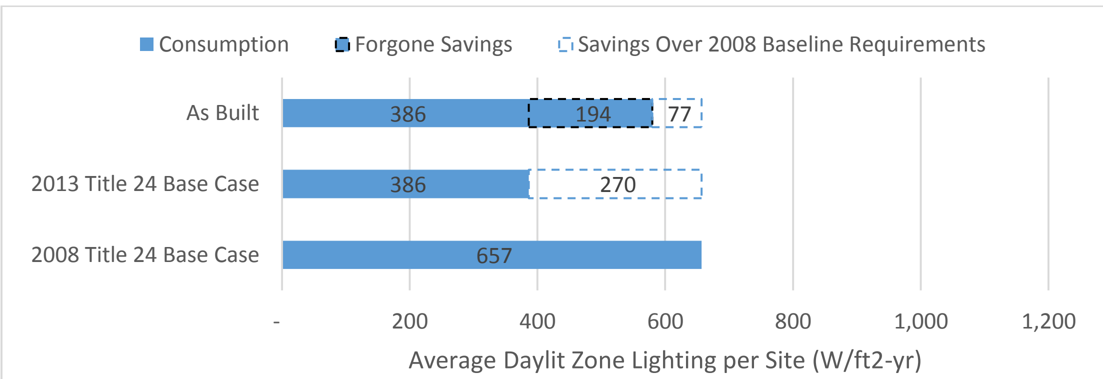
Building Type	Number of Sites with Daylight Controls Installed	Number of Sites Requiring Daylight Controls	Install Rate
Education	4	3	133%
Office	7	13	54%
Restaurant	1	4	25%
Retail	4	12	33%

Although the sample sizes are relatively small, our analysis suggested that adherence to the daylighting controls requirements varies by building type and is likely to be good for new construction, but relatively poor for alterations. We also found during our data collection that the lighting plan calculations were done incorrectly in some cases so the number of controlled fixtures was wrong.

Due to the low installation rates observed for controls, only 44% of expected savings from daylighting requirements were captured across all 53 sites we studied after normalizing results to total site floor area. It should be noted, cases where daylight controls are installed in spaces not requiring them are not included in the results below and do not affect the savings assessment.

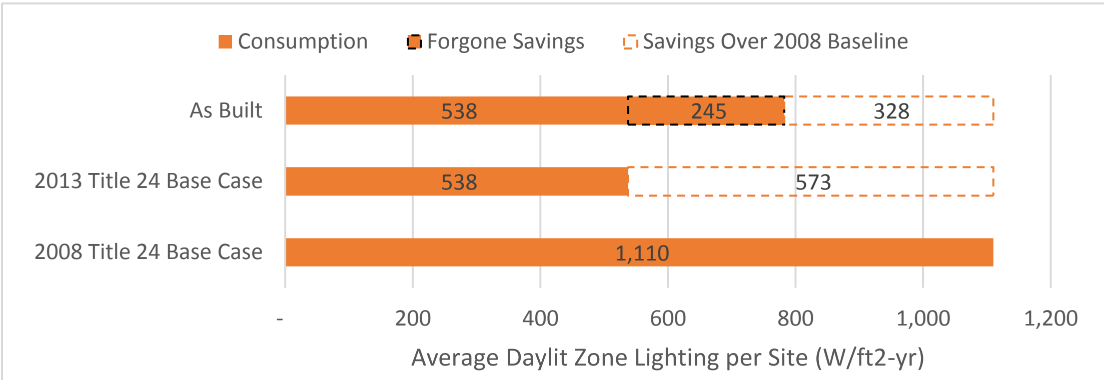
The 23 alteration sites where daylight controls were required captured only 14% of expected daylighting savings. The 86% of forgone savings translate to an average of 194 W/(ft^2-yr) per site, which accounts for approximately 1.57% of total building consumption (see Figure 5).

Figure 5: Alteration Sites Average Annual Lighting Consumption and Savings per Site



The 15 new construction sites had a higher compliance rate and captured 57% of expected savings from daylighting. The 43% of forgone savings translate to an average of 245 W/(ft^2-yr) per site, which accounts for approximately 1.84% of total building consumption (see Figure 6**)**.

Figure 6: New Construction Sites Annual Average Lighting Consumption and Savings per Site



The large difference between the 2008 Title 24 base case consumption for alterations and new construction sites exists primarily because the new construction sites had significantly more sidelit space compared to the total floor area. In this study, sidelit space accounted for 8% of total floor area in alteration sites and 23% of total floor area in new construction sites.

Recommendations

Based on the results above, it is recommended to target future trainings at certain sectors. Of the four building types we had enough data for, education projects are the only type meeting the daylighting requirements and the restaurant design community particularly could benefit from further training. Also, due to the lower rate of compliance for alteration sites, these may provide a good training opportunity as well. On a site-by-site basis, some architectural and lighting plan drawings that included the daylight zones appeared to have calculated them incorrectly. For instance, one site showed the width of the daylight zone as equal to the window width, rather than adding the 0.5 x head height distance to each side. This reduced the number of controlled fixtures by one out of the four total in the space.

2.2.6. PAF Analysis

This section describes an additional analysis that the CPUC requested Cadmus to perform to investigate the energy impact of PAF (Power Adjustment Factors) on lighting energy and whole building energy use. We used EnergyPro to analyze a pair of simulation models for five new construction sites. One model of each pair includes no PAF credits, while the other model is the as-built scenario with PAF credits included for each applicable light fixture. Only the light fixtures with controls that are eligible for PAF credits actually receive the PAF credits in the simulation models. Thus, some of the as-built models may have a mix of lighting fixtures that do receive PAF credit, while other lighting fixtures do not receive PAF credit.

Site NR031 is a 2,600 sf community assembly and conference building. The main meeting area is modeled as a conference area. All the lighting in the main conference area is LED and is controlled by a combined manual dimming system with partial-on occupancy sensors. This is eligible for a PAF of 0.25 for the entire 2400 sf conference area. All the lighting in the 200 sf of restrooms is LED and is controlled by partial-on occupancy sensors. This is eligible for a PAF of 0.20 for the entire 200 sf restroom area. Based on the EnergyPro simulations, the lighting energy savings is 24% and the whole building energy savings is 4% due to the PAF.

Site NR047 is a 2,529 sf retail photography studio. All the lighting in the building is LED and has demand response control. This is eligible for a PAF of 0.05 for the entire building. The lighting energy savings is 5% and the whole building energy savings is 0.7% due to the PAF.

NR057 is a 1,071 sf office. The lighting is a mix of T8 and LED. None of the lighting has any controls eligible for PAF. For the purpose of this PAF exercise, we investigated the scenario if all the lighting had demand response control. This would be eligible for a PAF of 0.05 for the entire building. The lighting energy savings for this scenario would be 5% and the whole building energy savings would be 0.6% due to the PAF.

NR082 is a 3,870 sf office. All the lighting in the building is LED. None of the lighting has any controls eligible for PAF. For the purpose of this PAF exercise, we investigated the scenario if all the lighting had demand response control. This would be eligible for a PAF of 0.05 for the entire building. The lighting energy savings for this scenario would be 5% and the whole building energy savings would be 1% due to the PAF.

Site NR083 is a 5,593 sf fire station. The lighting is a mix of T8 and LED. Some but not all of the lighting has partial-on occupancy sensor control. This is eligible for a PAF of 0.20 for the applicable areas. The lighting energy savings is 7% and the whole building energy savings is 2% due to the PAF.

Based on this sample of buildings, the PAF requirements have a relatively small effect on code energy savings, typically less than one percent of expected energy savings.

2.3. Residential Gross Savings/Compliance

2.3.1. Residential Sampling

This section describes the data sources, standard prioritizations, population characterizations, and stratification approach that Cadmus used to develop the residential sample design. Residential single family homes were selected at or near the final stages of construction and before occupancy to allow efficient collection of the most essential data.

Data Sources

As shown in Table 18, Cadmus compiled information on single-family new construction starts in California in 2015 from CEC and CIRB data. Between these data sources, we developed our understanding of the population.

Table 18. Residential Primary Data Sources

Description	Data Source
California residential (single-family) new construction building starts by climate zone	CEC*
California residential (single-family) new construction building starts by jurisdiction within climate zone	Construction Industry Research Board (CIRB);California Homebuilding Foundation

* Received through personal communication with energy specialist at CEC. April 2016.

Before designing the sample for this compliance analysis, Cadmus examined the distribution of the residential housing data. We grouped CEC Title 24 climate zones into climate regions using the same approach as the previous evaluation and the current nonresidential evaluation.[28]

Residential New Construction Standards and Population

This section discusses what specific 2013 Title 24 standards we selected for detailed data collection and analysis and the study population.

Standards Prioritization

As shown in the C&S Program Impact Evaluation Plan: Phase Two Addendum[29], seven standards that apply to single-family new construction represent 84% of the total IOU-estimated potential savings (64 of 76 GWh): B83 lighting, B84 wall insulation, B85 fenestration, B88 whole house fans, B89 zoned air conditioning and B90 HVAC ducts Standard B97, whole building, includes all of the standards. Because evaluation resources were limited, Cadmus focused the sampling plan on these codes as they represented the majority of the energy savings.

Residential New Construction Population

Using the CEC housing start data, Cadmus summarized single-family new construction starts for each California Title 24 climate zone, aggregated into climate regions, as shown in Table 19. We removed climate regions D and E from the sample frame because they accounted for less than 5% of the 2015 new housing starts in California and because, after distributing the total sample size to regions, samples in these regions would involve too few sites to be representative of the region. The resulting sample

28 See Appendix E for climate regions and associated CEC climate zone definitions.

29 The Evaluation Plan: Phase Two Addendum is available through the CPUC Evaluation Project Public Review Site at the following URL: https://pda.energydataweb.com/#/

frame accounts for over 95% of the new housing starts. In Table 19, we present the number of new housing starts in each climate region in the population and the sample frame.

Table 19. 2015 New Housing Starts by Climate Region

Climate Region	Description	Single-Family Starts in Population	Proportion of Population	Single-Family Starts in Sample Frame	Proportion of Sample Frame
A	North and Central Coastal Region	23,980	37%	23,980	38%
B	South Coastal Region	22,817	36%	22,817	37%
C	Central Valley	15,784	25%	15,784	25%
D	Desert	1,515	2%*	0	0%
E	Mountains	46	0%*	0	0%
Total		**64,142**	**100%**	**62,581**	**100%**

* Note that the majority of new construction is located in regions A (North and Central Coastal), B (South Coastal), and C (Central Valley), with just over 2% in regions D (Desert) and E (Mountain) combined.

Sample Design

This section presents the sample design Cadmus developed to satisfy the goals of the residential evaluation. We discuss in detail sampling challenges, target sample sizes, expected confidence and precision, and sample selection.

Target Sample Sizes and Expected Confidence and Precision

Cadmus designed the sample sizes for residential housing starts based on the recruitment schedule, evaluation timeline, and budget for this evaluation. We also incorporated expected compliance and variation in the population based on the previous evaluation, which estimated an ESAF (previously called a CAF) of 120% with precision of ±15% at 90% confidence from a sample of 194 new housing starts. From this information, Cadmus estimated an error ratio[30] of 1.13 for the residential new construction population.[31] We used this error ratio to calculate a sample size of 87 single-family homes for this evaluation, which we allocated across climate regions A, B, and C. We set 90% confidence and ±20%

30 To calculate the error ratio, we used the following formula with inputs for sample size (n), precision, and the z-statistic for two-tailed 90% confidence (z):

$$ER = \frac{precision * \sqrt{n}}{z}$$

31 The ESAF was referred to as the compliance adjustment factor, CAF, in the last evaluation and we have renamed it to better capture its meaning. Cadmus used ratio estimators to calculate CAF in the previous evaluation. Thus, an error ratio, rather than the coefficient of variation, provided the appropriate measure of variation.

precision targets[32] based on three factors: (1) our goal to collect compliance data for a representative sample, (2) the expected variation in compliance, and (3) our desire to keep the schedule and costs reasonable. Table 20 summarizes these results.

Table 20. Residential New Construction Sample Sizes

Climate Region	Description	Proportion of Single-Family Starts in Sample Frame	Sample Size	Expected Precision at 90% Confidence
A	North and Central Coastal Region	38%	33	N/A
B	South Coastal Region	37%	32	N/A
C	Central Valley	25%	22	N/A
Total		**100%**	**87**	**± 20%**

Sample Selection

Similar to the previous evaluation, Cadmus implemented a stratified two-stage cluster sample design in which we first sampled jurisdictions from each climate region and then selected sites from each of these jurisdictions for site visits. Sites that met the following criteria were eligible to be sampled:

- Residential single-family site
- Site located in an IOU service area
- Site permitted after July 1, 2014

To sample jurisdictions, Cadmus first developed a list of jurisdictions to include in the sample frame from CIRB data provided by the California Homebuilding Foundation. These data included counts of new housing starts constructed within each jurisdiction. We excluded jurisdictions from the sample frame if the majority of new housing starts in that jurisdiction were not served by an IOU because the evaluation is focused on the IOU service territories. Cadmus used probability-proportional-to-size sampling to draw a sample from the remaining jurisdictions in each climate region. This approach gave a higher chance of being selected to jurisdictions with larger populations of housing starts.

To develop a sample frame of housing starts, we requested additional CIRB data from the California Homebuilding Foundation for all housing starts located in the sampled jurisdictions. We then selected a simple random sample of housing starts within each jurisdiction. However, Cadmus experienced difficulties reaching the target number of site visits for this evaluation, explained in detail in the following section. To help recruit for site visits, we additionally contacted building contractors of housing starts in the sampled jurisdictions, who provided a list of all homes they built that met the evaluation criteria and were in an IOU territory. Some of these housing starts were outside of sampled jurisdiction; however, we included these housing starts in the sample regardless to reach the target sample sizes.

32 To calculate the expected precision for this evaluation, we used the error ratio estimates, target sample sizes, and 90% confidence in the footnoted equation above, solving for precision.

Sampling Challenges

Cadmus initially identified a sample of 42 jurisdictions across the three climate regions. However, the sampled jurisdictions did not contain enough sites that met the criteria of the evaluation to reach the target number of site visits. To supplement the original sample, Cadmus added 24 additional jurisdictions, but once again fell short of the target number of buildings. As described earlier in this section, we additionally contacted building contractors for sites located in the sampled jurisdictions to obtain a list of sites outside of the sampled jurisdictions they had built that met the criteria required to be included in this evaluation.

Although this recruitment technique helped us achieve the recommended sample size, we acknowledge that new housing starts recruited by contractors were not sampled randomly. Cadmus notes that this can introduce bias into the results. However, we believed it was critical to the evaluation that we achieve the target sample size and we included only about 10% of new housing starts that were not randomly sampled in our analysis.

2.3.2. Residential Recruiting, Field Data Collection

Recruiting and Scheduling

The scope of work for this project required recruiting builders within the sample plan to allow our data collection team to visit building departments to view the approved building plans and Title 24 documentation. The data collection team was then able to visit the building site to do testing and a physical inspection of the home to document the characteristics of the home and assess whether what was submitted in the building plans and Title 24 documents was actually applied to the built home.

Building Permit Data/CIRB

To obtain the building permit data, all building departments required a public records request be submitted with detailed descriptions of what we wanted to view. The building department then had up to 10 days to respond to the request. The majority of building departments were cooperative and would reserve a space for our team to view the files. However, the 10-day waiting period made it difficult to confirm the house visits with the builders. We were informed that builders were required to have both their building plans and the Title 24 documents on-site. So, when recruiting builders, we confirmed this fact and, for the majority of the data collection, we were able to skip the building department visit.

The initial recruitment of builders utilized the CIRB data. Unfortunately, this data was not sufficient for identifying homes to include in this evaluation. Few homes were identified through this method because the data regularly led to homes that had been built under a previous building code, were remodels, were duplexes, had long since been occupied, or had been delayed.

Given the issues identified with the initial recruitment approach, we determined it would be more effective and efficient to directly research builders within each jurisdiction. This approach, which largely consisted of online research, proved to be considerably more successful. It provided the ability to more directly target homes that met the requirements of the study. We contacted builders to identify homes that were available for testing, while, at the same time, screening was completed to ensure that each home qualified for inclusion in our study.

Recruitment Screening

We developed phone scripts for use by those recruiting buildings for participation in the study and to solicit building department participation. We also drafted and sent a letter to prospective building departments explaining the study and requesting their cooperation in assisting the data collection team during the data collection process. All potential homes were screened during the initial contact with the builder to confirm that they met the following criteria:

- Permitted under the 2013 Title 24 codes. Several of the builders were still building with permits pulled under the 2008 code.
- At the final stage of construction so that duct and envelope air leakage testing could occur
- Not built under the Advanced Home Program

Alternative Recruiting Strategies

To increase recruitment, we also decided to reach out to homeowners directly who might agree to participate in this study. Facebook has been used in the past to recruit participants for various studies with some success. We established parameters for recruiting responders who had been in their home six months or less, lived in the sample areas, and agreed to allow our data teams in for testing. We offered an original incentive of $150 to recruit respondent, but raised it to $200 after two weeks of lackluster responses. All in all, this method was not successful for this study, as we received only seven responses. Of those seven, only one was willing to allow the testing; unfortunately, she was leaving the country and would not be available in the time frame we needed.

The greatest challenge in securing participation through the approach of directly researching builders was with custom home builders. The builder was, in many cases, interested in the study. However, there were often variables that did not allow for participation. Those variables most often included the builder's client being unwilling to participate or homes that were much larger than average in which completion would not be reached during the testing period. Consequently, we included very few custom homes in the sample, but we did not have data to determine whether custom homes were underrepresented in our sample. We note that one weakness of past studies has been overrepresentation by custom builders because of their willingness to participate so this type of bias was not a factor in our study.

Although custom homes proved to be a challenge overall, recruitment of homes built by larger-scale builders proved to be the biggest key to the overall success of the recruiting effort. The recruitment of many of the homes by larger-scale builders was achieved by first receiving the approval from the person in charge of an entire region. With this regional approval, it made it possible to work directly with the individuals at the ground level. This ability allowed for the opportunity to identify and arrange testing of multiple homes in numerous jurisdictions. These homes represented a large number of homes tested overall.

Recruitment Statistics

The information provided in Table 21 demonstrates the level of effort necessary to successfully recruit and schedule 87 homes for site visits for this study. Only 10% of the builders contacted agreed to participate in the study, requiring 362 total contacts (either by phone or e-mail) to recruit and schedule the homes.

Table 21. Recruiting Statistics

Measure	Total
Total number of builders contacted	157
Total number of builders who participated	16
Average number of contacts (either phone calls or e-mail) to gain permission and schedule per builder	5
Total number of builders opted out/out of business	141
Average number of contacts (either phone calls or email) to receive a refusal*	2
Reasons for opting out:	
Homes built under 2008 code	4
Builder couldn't get homeowners' permission	8
No response to request	32
Builders participated in Advanced Home Program	4
No inventory/homes not at stage needed	55
Refused to participate**	27
Builder out of business/contact info not current	11

* Approximately half of the builders contacted that refused required a minimum of four phone calls or e-mails because of finding the correct person to give permission or denial.

** Reasons for refusals included political concerns, denial from legal department, or builders were too busy.

Scheduling Data Collection Team

Communication between the recruiter, scheduler, and data collection team relied heavily on collaboration on a SharePoint site. This SharePoint site had a calendar app that allowed the scheduler to create building department and building site visit appointments and forward them on to the data collection team. The team could access all the information for any appointment by going to the calendar. This SharePoint site was also the repository for the results of the data collection visits. Each house visited was given a folder named with the house identification number. The data collection team uploaded photos and the data collection form to the appropriate folder.

Data Collection Tool Development

We developed a data collection tool that allowed the data collection team to collect the information necessary to populate the EnergyPro software model for a particular house. The data collection tool, developed in Excel, could be used either on a tablet or laptop on-site or as a paper printout. The goal of the form was to be able to collect data directly from the Title 24 compliance documentation and building plans and verify the data at the building site.

The data collection form was designed to directly match the input required to model a house in EnergyPro. The goal was to provide information about the house to the modeler in a format that directly corresponded to the required input screens. This would reduce the overall time necessary to develop the model. For example, the building envelope portion of the form collected information on building assembly areas, orientations, and installed insulation R-values. Specific building envelope information was collected for each heating and cooling system zone in the house. Heating, cooling, and water heating manufacturers' make and model numbers were collected in addition to duct location.

Title 24 Credits

Several credits that can be used as trade-offs are available in the residential provisions of Title 24. For the development of the form, each credit was reviewed to determine what would need to be verified to comply with the code. Spaces to collect data on 26 credits were included on the form. The data collection form included a section for each specific credit that was assumed as part of the process of demonstrating compliance with Title 24. For example, one credit is allowed for ducts located entirely within conditioned space and having a maximum duct leakage rate. This required the data collection team to visually inspect that all of the ducts were installed in conditioned space on-site and to also perform a duct air leakage test. The form also required that the data collection team take a picture of the appropriate CF-2R form, which is the form that is used to document the credit, to use for future reference.

Standards

The data collection form was designed to collect information necessary to determine compliance and energy savings for each of the standards. The standards included measures that were either considered credits (e.g., zoned air conditioning) or mandatory measures (e.g., envelope wall insulation).

Mandatory Measures

Cadmus included a place on the data collection form to collect data on mandatory measures that are part of the residential standard. We included only measures that resulted in energy savings and for which energy savings could be calculated. For example, we collected data to determine compliance with the high-efficacy lighting and automatic lighting control requirements because complying with this provision resulted in energy savings and the savings can be calculated. On the other hand, we did not collect data on vapor retarders required for unvented framing cavities primarily because this requirement protects the cavity from moisture migration, but does not save energy.

Data Collection Training

We designed and conducted a one-day training to instruct the data collection team on the following topics:

- Goals of the data collection effort

- Data collection process
- Interaction with the building department and the builders
- Overview of the data collection form
- Collecting data from the plans and Title 24 compliance documentation
- Collecting data on-site
- Overview of the sampling process and where data collection will occur

Development of Training Materials

The course covered the proposed data collection process and included a short overview of building recruitment, scheduling, and then the building department and on-site visits. Cadmus reached out to the data collection team prior to the training to determine how much experience the team had working directly with building department staff and builders. Based on the feedback received, we included information in the training that walked the data collector through interacting with the building department and the builder.

The data collection form was used as the basis for the development of the training materials. It was important for the data collection team to understand what data were needed to complete each portion of the form, where the information could be obtained from the building plans and Title 24 compliance forms (e.g., CF-1R and CF-2R), and what to check on the building site to verify that the feature that was installed complied with Title 24. The discussion of each energy efficiency feature contained in the form was accompanied by an example (diagram or picture of the feature) and also a slide containing the compliance documentation form that needed to be referenced to determine if the feature was used to gain compliance for the building.

Training Deployment

Cadmus deployed the training session in August 2016 in the DNV GL office in Oakland. The training was designed to be taught in the classroom in one day. The original training concept was for two days, with one day in the classroom and the other spent in the field at a construction site. Based on the experience of the data collection team, the class was shortened to one day of classroom training. Cadmus designed the class to solicit classroom interaction throughout the presentation to ensure that everyone understood what and how data should be collected. Also, because the data collection team was experienced, it was important to solicit input from them on data collection techniques and processes that were or were not reasonable as far as testing for building envelope and duct leakage, in addition to other areas of interest pertaining to this study. Both DNV GL and Redhorse had several ideas for improving the process that were ultimately integrated into the data collection process and form.

Data Collection Team

Cadmus used DNV GL and Redhorse staff for the data collection team. All of the field team members were located in California, which reduced travel time and the costs associated with travel. All of the team members were experienced in collecting data for residential construction and had experience in conducting building envelope air leakage tests and duct leakage testing. DNV GL provided management of the data collection teams, which included a quality assurance review of all data collection forms. To further reduce travel, the Redhorse team focused their data collection efforts on the southern part of the state (specifically, Bakersfield and San Luis Obispo and south) and DNV GL focused on Northern California and the Central Valley (Fresno region). This reduced the number of overnight trips to the jurisdictions and construction sites and allowed the teams to drive to the locations, thus eliminating the need to ship testing equipment.

Field Data Collection

The field data collection process was designed to collect Title 24 compliance data at the building department prior to the site visit and then at the site of the home under construction. But the complete approved plan submittal package, including Title 24 forms, were found on the initial job site visits allowing the data collection team to review the plans at the job site without needing to visit the building departments. Builders were required to have these documents onsite and available to the building department staff. Based on these findings. The building department visits were eliminated from the study. The field team visited each house at or near the final stage of construction when all systems were installed (heating, cooling, and water heating) in addition to weatherstripping around the doors and windows. It was necessary for the house to be completed so that the building envelope leakage and duct leakage tests could be conducted.

Data Collection from Plans and Documentation

The study was designed to collect the following data from the building plans and Title 24 compliance documentation:

- Building geometry used to determine areas and orientation for each building assembly type (e.g., exterior walls and fenestration). This information came from the building plans and was required by EnergyPro to develop a model of the building.
- Information on the efficiency features and level of efficiency that were assumed to demonstrate compliance with Title 24. This included credits that were used to gain compliance with the standard that required third-party verification.

The information collected from the plans and Title 24 documentation was then used to guide the building site visit. The building site visit was designed to complete the following:

- Verify that the planned efficiency measures and levels of efficiency were installed in the project
- Conduct an envelope air leakage test using the testing protocols described in Title 24
- Conduct a duct leakage test using the testing protocols described in Title 24

Two-person data collection teams were sent to the house site visits to reduce the time needed for both processes. It was important to limit the amount of time necessary for data collection in an effort to reduce the time required by builders participating in this study.

The data collection team was instructed to take pictures of selected plan pages and of the Title 24 documentation that could be used as backup and as a source of information about the house should questions arise during the quality assurance and modeling portion of the study. Builders were generally receptive to this form of data collection so allowed the data collection team take pictures.

Site Visit

As stated above the field team visited each house at or near the final stage of construction when all systems were installed. This stage of construction also ensured that any of the credits taken to demonstrate compliance were installed and could be visually verified. The data collection team verified that all of the features that were called for in the building plans and Title 24 documentation were installed on-site. When possible, the data collection team visited adjacent houses in the same subdivision to review features that were “covered up” in the house that was selected for the study. These were features that were typically located in walls that were behind sheetrock. It was not possible to visually inspect the wall insulation R-value and insulation installation in the sampled house, but, often, the insulation was exposed in a similar, if not identical house in the development, allowing the data collection team to visually inspect the insulation and apply that finding to the sampled house.

Where backup documentation was necessary, pictures were taken of the exterior of the house and also of the different efficiency features (e.g., insulation installation and efficiency features installed to comply with the credits).

2.3.3. Residential Analysis, Site Modeling

Cadmus received the site-visit data that were used to estimate annual energy consumption. We modeled the whole building consumption and compliance separately from the lighting consumption and compliance. The software selected for the analysis, EnergyPro, did not model energy use from lighting systems so a separate calculation was required.

The data collection forms that were used for the modeling process corresponded with the inputs from the energy modeling software. The data collection forms also included a space to record lighting specifications for each house, including fixture type, bulb type, switch type, and quantity. This information was captured for each room.

Whole Building Analysis

Selecting the Most Appropriate Energy Simulation Tool

For the modeling software, Cadmus selected EnergyPro, produced by EnergySoft. EnergyPro was selected because it met the needs of the impact evaluation that included level of accuracy required; the methods, codes, and baseline definition and its underlying assumptions; level of detail of the output data; and the capability to customize and automate parametric runs to estimate measure-level savings. Cadmus worked closely with EnergySoft to develop a custom version of the software that produced the following:

- Baseline model based on the data collected on-site that minimally complies with the 2008 Title 24
- Baseline model based on the data collected on-site that minimally complies with the 2013 Title 24
- Model based on the data collected on-site (as-built)
- The ability to generate measure-level savings for each measure identified in the potential studies

Modeling Quality Control

Throughout the whole-building modeling process, Cadmus coordinated with DNV GL regarding any discrepancies with the data or questionable results from the EnergyPro export. DNV GL also received all of the energy models and reviewed them for any anomalies. They also reviewed the accuracy of the model inputs, verifying that the models fully captured the data collected in the field.

Lighting Analysis

Cadmus used Excel to conduct the lighting analysis. Cadmus received enough data from each house to determine total annual energy consumption.

Lighting Consumption

Cadmus calculated lighting consumption for each room for each house. The goal was to have a consumption total for the house as-built, a consumption total for the house built to the 2008 standards, and a consumption total for a house built to the 2013 standards. Equation 6 was used to calculate total annual energy use in kWh. Equation 7 was used to calculate demand energy in kW.

Equation 6

$$\frac{Wtg \times Bq \times Fq \times Hr \times SF}{1000}$$

Where:

Wtg	=	The wattage of the bulb installed
Bq	=	The quantity of bulbs installed in the given fixture
Fq	=	The quantity of fixtures controlled by the given switch

Hr = The total annual hours of operation for that room[33]

SF = The switch factor accounting for the reduction of energy consumption based on which switch was installed.

Equation 7

$$\frac{Wtg \times Bq \times Fq}{1000}$$

Where:

Wtg = The wattage of the bulb installed

Bq = The quantity of bulbs installed in the given fixture

Fq = The quantity of fixtures controlled by the given switch

We calculated the 2008 and 2013 Title 24 baseline energy use and demand by incorporating the efficacy and control requirements in these two equations to model the house to be minimally compliant.

For each room, the following standards informed each model to determine 2008 compliance and 2013 Title 24 compliance:

- At least 50% of the total installed load in kitchens must be high-efficacy lighting.[34]
- Lighting in internally illuminated cabinets must not exceed 20 watts per linear foot.
- Bathrooms require at least one high-efficacy luminaire. All other lighting must be high efficacy or controlled by a vacancy sensor.
- Lighting in garages, laundry rooms, and utility rooms must be high efficacy and controlled by vacancy sensors.
- Lighting in space types other than those listed above must be either high efficacy or controlled by a dimmer or vacancy sensor.

33 Hours of operation were based on the approved hours of operation presented in the 2013 CASE initiative on residential lighting. http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/2011-04-04_workshop/review/Residential_Lighting.pdf

34 Because the 2013 Title 24 requirement for kitchens is based on the distribution of load between high and low efficacy lighting, and not an efficacy requirement, we had to develop an approach to estimate what the load and energy use would be for high and low efficacy lighting to meet the code. We made the assumption that the lighting output of the combination of lighting that would meet the 2013 Title 24 (in lumens) would equal the as-built lighting output and the load (watts) would be split equally between high and low efficacy lighting. This produced an equation for calculating the compliant lighting types.

2.3.4. Residential Statewide Gross Savings/Compliance Estimation

Cadmus calculated whole building ESAFs for electricity annual savings, CPUC-defined peak demand savings, and gas annual savings. We provide ESAFs and savings by climate region and the state as a whole in Section 3.2.3. For single-family homes, the IOU-estimated savings reflect the approach used by the CEC to separate energy analysis into lighting and non-lighting categories. Because non-lighting represents all other aspects of the building, the IOUs refer to these as "whole building" savings in their documentation. We provide results separately for lighting and non-lighting as well as combined results.

The following sections detail the method Cadmus used to apply sample weights and estimate ESAFs and evaluated savings.[35] Note that the same method applies to both the whole building (non-lighting) analysis as well as the analysis for individual standards. Cadmus evaluated a subset of standards, prioritizing selection based on the IOU estimate of potential savings for each standard and practical considerations for the analysis of each standard. Evaluated standards include wall insulation, fenestration, whole house fans, zoned air conditioning, and HVAC ducts.

Sample Weights

Cadmus applied sample weights that followed the sample design described in Section 2.3.1. Because we simple random-sampled housing starts, we did not apply site-level sample weights. We acknowledge that because of site visit recruitment challenges, housing starts recruited via contacting building contractors were not randomly selected within jurisdictions, which may introduce bias to the estimates.

Equation 8 provides the jurisdiction-level sample weights. Since we sampled jurisdictions with PPS sampling, we calculated jurisdiction-level sample weights equal to the inverse of the probability of selecting a jurisdiction, which is the proportion of new housing starts in a jurisdiction relative to the climate region overall. Due to sampling challenges, we included housing starts not initially selected in the sample. Applying sample weights will help correct for any bias introduced from the non-random selection by accounting for any differences between the distribution of sampled jurisdictions within climate regions and the distribution of the population of jurisdictions that occur within climate regions[36].

Equation 8

$$w_{hi} = \frac{1}{Probability\ of\ selecting\ jurisdiction\ i} = \frac{M_h}{M_{hi}}$$

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[35] Särndal, C., Swensson, B., & Wretman, J. (2003). Model Assisted Survey Sampling. New York: Springer.

[36] The distribution of building types in the population of jurisdictions is estimated using the proportion of square feet each jurisdiction accounts for in each climate region in the Dodge data and applying this proportion to the CEC data. This is the best estimate of how the building types are distributed among each jurisdiction at this time.

Where:

h = Indicates climate region ‘h’

i = Indicates jurisdiction ‘i’

w_{hi} = Sampling weight of jurisdiction ‘i’ in climate region ‘h’

N_h = Total number of jurisdictions in climate region ‘h’

M_{hi} = Number of housing starts in jurisdiction ‘i’ and climate region ‘h’

M_h = Number of housing starts in climate region ‘h’

Energy Savings Adjustment Factor Analysis

Cadmus calculated whole building ESAFs for annual electric savings, CPUC-defined peak demand savings, and gas annual savings. The following sections outline the methodology used to estimate site-level and population evaluated savings and ESAFs by building type and statewide.

Residential Site Estimates

Cadmus calculated expected savings for each residential site as the difference between the energy consumption for the site between the 2008 Title 24 codes and the 2013 Title 24 codes. This is the expected savings for each site based on 100% compliance with each of the codes. We estimated the evaluated savings as the difference between the 2008 Title 24 consumption and the estimated consumption of the site as-built, based on the data collected on site.

The CPUC aims to assess the impact of the C&S program under conditions where the savings from the 2013 Title 24 were limited to the change in consumption between the amount allowed under the 2008 Title 24 and the 2013 Title 24. To do so, Cadmus estimated climate region and statewide ESAFs by restricting the evaluated savings to be no greater than the expected savings of the building. We refer to these estimates as the bounded ESAFs, and they are provided in Section 3.2.3 in addition to the unbounded results. We discuss the implications of bounding these results in Section 3.2.3.

Population Statewide Evaluated Savings

To estimate population evaluated savings for each climate region, Cadmus applied the sample weights described above. Equation 9 presents the estimation approach, which first calculates the total evaluated savings in jurisdiction ‘i', and then the total evaluated savings across all jurisdictions in climate region ‘h’. Summing across climate regions provides the total population statewide evaluated savings. We calculate population building type and statewide expected savings ($\hat{x}_{.k..}$) similarly.

Equation 9

$$\hat{y}_{h..} = \frac{1}{n_h}\sum_{i=1}^{n_h} w_{hi} * \underbrace{\frac{M_{hi}}{m_{hi}} * \sum_{j=1}^{m_{hi}} y_{hij}}_{\text{Total savings in jurisdiction 'i'}}$$

Where:

$\hat{y}_{h..}$ = Estimated total evaluated savings in climate region ‘h’

y_{hij} = Evaluated savings for new housing start ‘j’ in jurisdiction ‘I’ and climate region ‘h’

M_{hi} = Number of new home starts in jurisdiction ‘i’ and climate region ‘h’

m_{hi} = Number of new home starts sampled in jurisdiction ‘i’ and climate region ‘h’

n_h = Number of sampled jurisdictions in climate region ‘h’

2.3.5. Residential Mandatory Measures

Mandatory measures that had an energy impact were included in the data collection and energy calculations. We did not include mandatory measures that protect assemblies from the elements, for example vapor retarders. In addition measures where the impact of their absence would be included in results of air or duct leakage testing were not included on the form, for example backdraft dampers for exhaust systems. The data collection process included collection of sufficient information on each mandatory measure to assess compliance and the impact on energy use for the house. Features that impacted the durability of the building (e.g., vapor retarders) were not included. EnergyPro was modified to account for the impact of all high-energy-use measures with one exception: energy savings from lighting requirements were calculated separately.

2.4. Net Savings/NOMAD

This section presents a brief summary of the methodology that the evaluation team used to estimate the NOMAD trend for each product or technology regulated by the Title 24 standards. For a more detailed description, please refer to the CPUC C&S Volume One Report. As noted in the evaluation protocol discussion in Section 1.2, the NOMAD value was used to adjust gross standard savings, with the result being considered net standard savings. A separate attribution analysis (described in the following section) is conducted to determine the program influence on standard development and adoption.

It is important to understand NOMAD’s meaning: NOMAD projects what the annual sales or installations or construction of items meeting the standards would have been had standards not been adopted. It estimates the market share of products meeting the requirements of a specific standard over time. Once a standard takes effect, the natural market no longer exists. The evaluation, however, required estimating the naturally occurring market trend—the counterfactual—to derive net savings for each standard.

2.4.1. NOMAD Methodology

To determine the ISSM model coefficients necessary to calculate net energy savings for each Title 24 standard, the evaluation team used an online market adoption tool in a Delphi panel framework, developed and applied in the two preceding C&S program evaluations.

The Delphi panel approach is a structured, interactive technique for obtaining expert group inputs, typically to develop forecasts. Each expert answers a questionnaire that provides a forecast and the expert's rationale in two or more rounds. After each round, a facilitator provides the group with an anonymous summary of the experts' forecasts and their supporting arguments for the forecasts. The experts can then revise their forecasts, again providing their supporting arguments. The process ends after a number of rounds and is intended to reach consensus or stability.

2.5. Net Program Savings/Attribution

"Attribution" refers to the portion of net code or standard energy savings that can be credited to the utilities' C&S program efforts for enabling or assisting the adoption of each appliance or building standard. The attribution analysis results in an attribution score (a percentage between 0% and 100%) that represents the relative contribution of the program to adoption of the 2013 Title 24 building codes. The evaluation team calculated attribution for 2013 Title 24 building codes in the 2013–2015 program cycle. We used the same evaluation approach as the 2006–2008 and 2010–2012 program cycles for federal and California appliance standards and California building codes.[37]

The process of determining attribution entailed the following steps:

1. We collected data on stakeholder activities from a range of sources, including rulemaking dockets, Code Change Theory Reports (CCTRs) (written by the IOUs), and stakeholder interviews.
2. A panel of independent codes and standards experts assessed the program's contributions to the adoption of each standard based on a careful and systematic review of the evidence and determined an attribution score.

The evaluation team estimated the relative effort required to adopt a new code in three factor areas, described in more detail in the next section. We applied each estimate of relative effort as a weight to the factor score to calculate an overall attribution score.

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[37] The Cadmus Group. March 9, 2009. **"**The Proposed Cadmus Attribution Methodology (Revised)." This document can be found online at: http://www.energydataweb.com/cpuc/search.aspx . Search for the text "attribution methodology (revised)" to access this document.

The following sections provide a description of our attribution model, data collection, and attribution analysis for the residential and commercial 2013 Title 24 building codes.

2.5.1. Methodology: The Attribution Model

The model sets forth specific criteria for evaluating the contributions of the C&S program to standards development and adoption. Our team conducted attribution analysis for twenty eight (28) 2013 Title 24 building codes, including the following:

- 2013 T24 Residential New Construction (three codes)
- 2013 T24 Nonresidential Alterations (nine codes)
- 2013 T24 Nonresidential New Construction (16 codes)

The model focuses on three areas of activity representing the fundamental requirements that must be met for the CEC (for state codes) to adopt a code; these are referred to as “factors” in the model and are described below:

The Development of Compliance Determination Methods and Other Special Analytic Techniques

Code officials (in the case of building codes) and regulators must have the tools and methods that allow them to verify compliance with the code. In some cases, determining compliance entails having a reliable test method or acceptance test. In other cases, it involves having an analytical tool that produces results indicating whether compliance is achieved. In addition, some standards require the development of new analytic methods to estimate energy and demand savings.

The Development of Code Language and Technical, Scientific, and Economic Information in Support of the Standard

The code must be defined in careful technical language that spells out covered products, effective dates, and required efficiency levels. Also, significant scientific, engineering, and economic research must be completed before a code can be adopted. This research typically concerns estimates of energy and peak demand savings and the cost-effectiveness of measures. Since implementation of the C&S program began, much of this research and development at the state level has been summarized in CASE reports funded by the utilities for codes and standards in which they played a significant role.

Demonstrating the Feasibility or Market Acceptance of Code Adoption

An implicit requirement for adopting a new code is that compliance with the standard be practical and feasible. Supporters of the code must address stakeholder concerns and demonstrate, through market research, that stakeholders can comply with the code. Three conditions must be met to satisfy this requirement. First, the market must be capable of supplying the products and services necessary to comply with the code. If a product is not readily available in the marketplace, the technology must be well developed and manufacturers capable of increasing supply before the code goes into effect. Second, the code must not impose unreasonable and avoidable costs on end users, manufacturers, and other stakeholders. Third, the code must not create significant negative externalities related to human health or the environment.

2.5.2. Data Collection Activities

The evaluators based the determination of C&S program credit on a systematic and thorough review of available evidence about program activities. The evaluation team collected information from a variety of sources, including documents provided by the C&S program (CCTR, CASE reports, etc.), public documents (transcripts, public comments, etc.), and stakeholder interviews. The following section describes the sources.

Review of Public and C&S Program Documents

The evaluation team collected information about C&S program and other stakeholder contributions to the development and adoption of each 2013 Title 24 building code from a large number of primary and secondary public sources, including CASE reports, notes and presentation materials from CEC hearings and workshops, stakeholder letters, and comments to the CEC. We also reviewed documents provided by the C&S program including CCTRs. We carefully read these sources, and extracted information about C&S program and other stakeholder activities and entered it into a spreadsheet for future reference in determining C&S program credit.

Stakeholder Interviews

The evaluation team conducted interviews with key stakeholders to fill remaining gaps in its understanding of the development of codes. Although the focus of each interview varied, we generally asked about the stakeholder’s involvement in the rulemaking process, their impression of the C&S program’s involvement, key issues that arose during the rulemaking, and the stakeholder’s assessment of the C&S program’s contributions.

2.5.3. Estimation of Factor Scores

The following three principles guided the determination of credit:

1. Attribution would be determined by disinterested third-party technical experts who did not have a stake in the amount of credit that was awarded.
2. Credit would be awarded on the basis of evidence about C&S program activities obtained from written sources and interviews.
3. The scoring process would be transparent, documented, and repeatable.

To adhere to these three principles, we convened a panel of independent codes and standards experts to determine the C&S program credit. The panel consisted of four experts: one represented the Midwest Energy Efficiency Alliance, one represented the Pacific Northwest National Laboratory, one represented the Washington Department of Commerce, and one represented the City of Seattle. One of the four panel members was a participant in the 2010–2012 program cycle attribution panel.

The panel convened in Cadmus' Portland, Oregon, offices for a two-day session in January 2017. Portland was impacted by severe winter weather during this meeting, and one of the panelists and the panel facilitator joined remotely. At this meeting, we explained the attribution model and the scoring protocol and instructed the panelists about the kinds of evidence they should consider and the determination of the factor scores. We told the panelists that the contribution of the program to each factor was to be judged relative to the contributions of other stakeholders such as industry associations and manufacturers, efficiency advocates, and the CEC. In addition, we told the panelists that the amount of effort required for a factor should not influence the determination of the factor score.

The deliberations of the panel began with a presentation by Cadmus. We explained the development of the code, including the prescriptive or performance requirements, the key stakeholders, and the history of the development of the standard. We then presented evidence about the C&S program contributions within each factor area. The panel members discussed their thoughts on the three factors for each code or standard and considered the inputs of all stakeholders, including the C&S program. The discussion often included the members expressing an opinion on each factor score, asking our team questions about the rulemaking activities, and discussing any issues or thoughts among themselves, including technical discussions on the difficulty of each development that we were able to use to inform our weighting after the panel. After this discussion, the panel could come to an agreement on the factor scores, vote on the scores as individuals, or ask our team for more information and reach agreement at a later time in light of new information. If the panel could not agree on factor scores, the final score would be an average of the preferred factor scores of the members.

To ensure that the panel had the time necessary to fully evaluate the codes and standards presented, Cadmus only presented 16 of the 28 standards to the panel. These standards were prioritized based on total savings. Cadmus selected a subset of 16 of the highest energy-saving standards within our initial sample to be scored by the panel. In sessions that followed the outline of the panel sessions, a Cadmus evaluator responsible for the standard presented the standard development, stakeholders, history, and evidence to the other members of the attribution evaluation team. We discussed the factors internally, expressed opinions on each factor score, and developed an attribution score.

2.5.4. Estimation of Factor Weights

Cadmus developed factor weights, internally, for each code for this program cycle. We based the factor weights on our understanding of how resources were allocated across the factor areas for each code. This assessment was based on the data collected through our review of rulemaking documents and stakeholder interviews.

As a check against our factor weights, we asked the IOUs to provide their estimates of the factor weights for each standard. We distributed a survey similar to that used in the previous evaluations to the IOUs. For each code, we asked, "What was the percentage allocation of total stakeholder resources across the factor areas in the development of the code, where resources are defined in terms of budgets?" We also asked the IOUs to provide a brief explanation of the reasoning behind their weights.

We compared our weights to those provided by the IOUs. If the weights were relatively close, we used the weights developed internally. If large discrepancies existed between our weights and the IOUs' weights (generally 10% or more), we reviewed the justification provided by the IOUs, conducted additional research, and then made adjustments to the weights as necessary. For example, if we gave a low weight to factor two based on the assumption that a data collection activity described in the CCTR required minimal resources, but the IOUs weighted factor two very highly, we reviewed the IOUs' explanation as well as the supporting documentation and, if the additional detail was convincing, adjusted the weight upward.

2.5.5. Estimation of the Attribution Scores

As a final step in the process, we calculated the attribution score for each state or federal code or standard. The attribution score measures the contribution of the C&S program to adoption of a standard and multiplies net energy savings to determine the amount attributable to the C&S program. We calculated the attribution score by multiplying the factor weight and factor score for each factor within a code, then summing those weighted scores.

3. Findings for Protocol Parameters

This chapter presents parameter value findings for each standard and stage of the protocol.

3.1. Potential Savings

3.1.1. Nonresidential Potential

Unit Savings

Cadmus focused its evaluation on the nonresidential standards responsible for over 95% of estimated alterations potential savings and 92% of estimated new construction potential savings, as discussed in Section 2.1.2. Table 22 summarizes our findings for unit energy and demand savings for the nonresidential standards focused on in this evaluation. The unit savings for all of these standard are per square foot of construction or project with two exceptions. For Standard B65, unit savings are per laboratory hood and for Standard B66, savings are per ECM motor.

Table 22. Findings for Unit Savings

Title 24 Code	Unit Savings	IOU Estimate	Evaluated	Interactive Effects or Scaling Factor
Std B34: NRA-Lighting-Alterations-New Measures	Energy (kWh)	0.54714	0.57791	1.00000
	Demand (kW)	0.00011	0.00011	1.00000
	Gas (therms)	-0.00098	-0.00103	0.00000
Std B35: NRA-Lighting-Alterations-Existing Measures	Energy (kWh)	1.84145	0.41307	1.10000
	Demand (kW)	0.00071	0.00006	1.32000
	Gas (therms)	-0.00519	0.00000	-0.00410
Std B36: NRA-Lighting-Egress Lighting Control	Energy (kWh)	0.18771	0.44093	1.00000
	Demand (kW)	0.00000	0.00000	1.00000
	Gas (therms)	0.00000	0.00000	0.00000
Std B39: NRA-Lighting-Warehouses and Libraries	Energy (kWh)	0.80891	0.80891	1.10000
	Demand (kW)	0.00008	0.00008	1.32000
	Gas (therms)	0.00000	0.00000	-0.00410
Std B41: NRA-HVAC-Equipment Efficiency	Energy (kWh)	0.31310	0.29652	1.00000
	Demand (kW)	0.00011	0.00010	1.00000
	Gas (therms)	0.01204	0.00880	0.00000
Std B43: NRNC-Lighting-Daylighting	Energy (kWh)	1.27300	0.56951	0.73375
	Demand (kW)	0.00056	0.00028	0.83330
	Gas (therms)	-0.00121	-0.00198	2.64017
Std B45: NRNC-Lighting-Retail	Energy (kWh)	1.57316	1.15413	0.73375
	Demand (kW)	0.00039	0.00032	0.83330

Title 24 Code	Unit Savings	IOU Estimate	Evaluated	Interactive Effects or Scaling Factor
	Gas (therms)	0.00000	0.00000	2.64017
Std B46: NRNC-Lighting-Egress Lighting Control	Energy (kWh)	0.16770	0.39692	1.00000
	Demand (kW)	0.00000	0.00000	1.00000
	Gas (therms)	0.00000	0.00000	0.00000
Std B49: NRNC-Lighting-Warehouses and Libraries	Energy (kWh)	0.80891	0.80891	0.73150
	Demand (kW)	0.00008	0.00008	0.83330
	Gas (therms)	0.00000	0.00000	-0.00410
Std B50: NRNC-Lighting-Parking Garage	Energy (kWh)	1.11060	0.89891	1.00000
	Demand (kW)	0.00022	0.00008	1.00000
	Gas (therms)	0.00000	0.00000	0.00000
Std B51: NRNC-Lighting-Controllable Lighting	Energy (kWh)	0.57459	0.57459	0.73150
	Demand (kW)	0.00000	0.00000	0.83330
	Gas (therms)	0.00000	0.00000	-0.00410
Std B54: NRNC-Lighting-Office Plug Load Control	Energy (kWh)	0.08515	0.37258	0.73150
	Demand (kW)	0.00001	0.00010	0.83330
	Gas (therms)	0.00000	0.00000	-0.00410
Std B56: NRNC-Envelope-Fenestration	Energy (kWh)	0.46235	0.20415	0.73375
	Demand (kW)	0.00013	0.00007	0.83330
	Gas (therms)	-0.00070	0.00000	2.64017
Std B57: NRNC-HVAC-HVAC Controls and Economizers	Energy (kWh)	0.37201	0.14034	0.73375
	Demand (kW)	0.00000	0.00000	0.83330
	Gas (therms)	0.00000	0.00000	2.64017
Std B58: NRNC-HVAC-Fan Control & Economizers	Energy (kWh)	2.61000	1.91507	0.73375
	Demand (kW)	0.00000	0.00000	0.83330
	Gas (therms)	-0.00150	-0.00396	2.64017
Std B61: NRNC-HVAC-Kitchen Ventilation	Energy (kWh)	43.340	31.801	0.73375
	Demand (kW)	0.00751	0.00626	0.83330
	Gas (therms)	0.40000	1.05607	2.64017
Std B63: NRNC-HVAC-Chiller Min Efficiency	Energy (kWh)	2.27730	0.06606	0.73375
	Demand (kW)	0.00000	0.00000	0.83330
	Gas (therms)	0.00000	0.00000	2.64017
Std B65: NRNC-HVAC-Laboratory Exhaust	Energy (kWh)	41.920	11148.75	1.00000
	Demand (kW)	0.01040	2.40350	1.00000
	Gas (therms)	1.66000	690.250	0.00000
	Energy (kWh)	200.833	1689.92	0.73150

Title 24 Code	Unit Savings	IOU Estimate	Evaluated	Interactive Effects or Scaling Factor
Std B66: NRNC-HVAC-Small ECM Motor	Demand (kW)	0.00000	0.00000	0.83330
	Gas (therms)	0.00000	0.00000	0.00000
Std B75: NRNC-Refrigeration-Supermarket	Energy (kWh)	2.11795	2.11772	1.00000
	Demand (kW)	0.00018	0.00018	1.00000
	Gas (therms)	0.22165	0.22211	0.00000
Std B78: NRNC-Process-Data Centers	Energy (kWh)	275.00	280.00	1.00000
	Demand (kW)	0.00800	0.00800	1.00000
	Gas (therms)	0.00000	0.00000	0.00000
Std B82: NRNC-Whole Building	Energy (kWh)	0.97749	1.46569	1.00000
	Demand (kW)	0.00026	0.00038	1.00000
	Gas (therms)	0.00551	0.00803	0.00000

Construction Volume and Measure Quantities

The IOUs and CEC based their estimate of annual construction volume on the models maintained by the CEC. Cadmus used CEC-forecasted existing floor stock and new constructions square footage data provided by the CEC to Cadmus in September 2015 to calculate evaluated statewide energy and demand savings. These data were provided by building type and climate zone. To estimate annual square footage for alterations and new construction, Cadmus used 2015 data (alterations) and an average of 2014 and 2015 data (new construction) to enable one square footage data set to be applied each year starting in 2014, which was the year the 2013 Title 24 standards went into effect.

For each of the measures shown in Table 22, the unscaled unit savings represent the impact of the measure on a square foot of either altered or new construction building space, with the exception of unit savings for standards B65 and B66, which represent the measure impact per lab hood or small HVAC motor affected by the standards, respectively.

Nonresidential Potential Scaling Factors

Cadmus applied Equation 1 (in Section 2.1.4) to determine appropriate scaling factors for the potential savings from the individual nonresidential standards that overlapped with the whole building standard B82. We present the calculated scaling factors in Table 23. We find that, *as a group,* when these measures are incorporated into new nonresidential construction, they are expected to produce between 83% of demand and 73% of the electricity savings and 264% of net gas savings that they were expected to produce in an isolated analysis.

Table 23. Scaling Factors for Nonresidential Potential Whole Building Standards

Description	Sum of Savings From Individual Standards	Whole Building Savings	Scaling Factor
Electric Energy (GWh)	301.1	220.9	73.4%
Demand (MW)	69.3	57.8	83.3%
Gas Energy (MTherms)	0.46	1.2	264.0%

3.1.2. Residential Potential

Unit Savings

As noted in Section 2.1.2, we focused our evaluation on the six standards that are responsible for over 80% of the residential savings according to the IOU estimate. All savings associated with these standards are expected to be produced by single-family homes. Table 24 summarizes our findings for unit energy and demand savings. In all cases, we found that the IOU estimate of unit savings on a per-standard basis was reasonable for measures that were installed independently.

As noted earlier in this report, the IOUs identified the CEC whole building analysis as the basis for their savings claim in the September 26, 2016, memo cited above. Per their documentation, all savings from nine standards (B84–B92) were included in the whole building estimate. However, the IOUs' estimate of savings from these standards is much greater than the CEC's whole building estimate (submitted by the IOUs as standards B97 and B99). In order to have just one value for potential savings from single-family construction, the unit savings from these individual measures were scaled such that the total potential for the individual standards is equal to the potential for whole building construction. This adjustment recognizes that there are substantial interactive effects when multiple measures are implemented in a single building.

Unit savings for standard B83 were not adjusted because lighting savings were not included in the CEC whole building analysis. Because the adjustments to the other standards reflect interaction between standards, no other interactive factors were applied to standards B84–B92. Cadmus did apply interactive factors (the same values used for residential appliance standards) to standard B83 to account for the expected interactions.

Table 24. Findings for Unit Savings

Title 24 Code	Unit Savings	IOU Estimate	Evaluated	Scaling Factor
B83: RNC-Lighting	Energy (kWh)	105.0	105.0	N/A
	Demand (kW)	N/A	N/A	N/A
	Gas (therms)	N/A	N/A	N/A
B84: RNC-Envelope Wall Insulation	Energy (kWh)	99.0	99.0	0.482
	Demand (kW)	0.080	0.080	0.490

Title 24 Code	Unit Savings	IOU Estimate	Evaluated	Scaling Factor
	Gas (therms)	34.0	34.0	0.371
B85: RNC Envelope Fenestration	Energy (kWh)	639.0	639.0	0.482
	Demand (kW)	1.53	1.53	0.490
	Gas (therms)	-15.00	-15.00	0.371
B88: RNC HVAC Whole House Fans	Energy (kWh)	387.0	387.0	0.482
	Demand (kW)	N/A	N/A	N/A
	Gas (therms)	-3.54	-3.54	0.371
B89: RNC-HVAC Zoned AC	Energy (kWh)	441.0	441.0	0.482
	Demand (kW)	0.61	0.61	0.490
	Gas (therms)	9.90	9.90	0.371
B90: RNC-HVAC Duct	Energy (kWh)	623.0	623.0	0.482
	Demand (kW)	0.75	0.75	0.490
	Gas (therms)	21.40	21.40	0.371

Construction Volume and Measure Quantities

The IOUs and CEC based their estimate of annual construction volume—22,796 new homes per year—on the CIRB report. Cadmus obtained updated CIRB data for 2013 and 2014 and used the average construction volume of 37,040 new single-family homes per year in the evaluation.

For each of the measures shown in Table 24, the unscaled unit savings represent the impact of the measure on an average single-family home. Cadmus observed the incidence of whole house fans (B88) and Zoned AC controls (B89) to be less than 10% in the 87 homes in our new construction sample. Because we determined that these standards are not mandatory statewide, we assumed incidence of 20% for each of these measures in our evaluated savings.

Residential Potential Scaling Factors

Cadmus applied Equation 1 (in Section 2.1.4) to determine appropriate scaling factors for the potential savings from the individual residential standards, B84–B92. We present the calculated scaling factors in Table 25. We find that, *as a group,* when these measures are incorporated into new residential construction, they are expected to produce between 37% and 49% of the savings that they were expected to produce in an isolated analysis.

Table 25. Scaling Factors for Residential Potential

Description	Sum of Savings From Individual Standards	Whole Building Savings	Scaling Factor
Electric Energy (GWh)	51.5	24.8	48.2%
Demand (MW)	67.3	33.0	49.0%
Gas Energy (MTherms)	2.3	0.9	37.1%

3.2. Gross Savings/Compliance

Cadmus presents the ESAFs and estimates from the compliance analysis in this section. We include residential, nonresidential new construction, and nonresidential lighting alterations results by climate region, building type (nonresidential only), and for the state overall. Savings are provided for lighting and non-lighting combined and separately. Furthermore, Cadmus provides results from the whole building analyses as well as from the analyses of individual standards.

3.2.1. Site-Level Findings

Cadmus calculated site-level evaluated savings and expected savings to compute ESAFs according to the methodologies described in Section 2.2. We found three types of results:

Negative evaluated savings:	Annual consumption > 2008 standard consumption
Positive evaluated savings < Expected savings:	Energy performance does not meet 2013 Title 24
Positive evaluated savings > Expected savings:	Energy performance is better than 2013 Title 24

When evaluated savings exceed expected savings at the site level, site energy performance is better than the 2013 code requirements. As discussed earlier, the CPUC staff believe that outside factors, and not the 2013 code, cause buildings to be more efficient than required by the code at the site level. In an attempt to be comprehensive, Cadmus estimated the ESAFs and population evaluated savings by analyzing both the raw data and by bounding the evaluated savings at the site level, restricting evaluated savings to be equal to or below expected savings. Bounding the evaluated savings this way limits the strata level ESAFs to be at most 100%.

Note that this method of bounding at the site level may not achieve a statewide ESAF bounded at 100% when there exists a mix of positive and negative evaluated and expected savings among sites within a strata. For example, suppose that half the sites in a building type achieved positive evaluated savings, but had negative expected savings. When these sites are bounded at 100% of expected savings, they achieve negative bounded evaluated savings in aggregate. However, suppose the other half of sites achieved positive bounded savings. There exists the possibility that the sum of bounded evaluated savings is greater than the sum of bounded expected savings, even though both may be negative. This situation will produce an ESAF value that is less than 100% for the building type, even though evaluated savings are greater than expected savings. Aggregating to the statewide level, this can produce an ESAF that is greater than 100%. This situation occurs for nonresidential new construction therms savings, when bounded. We provide details in Appendix G.

3.2.2. Nonresidential Findings

This section outlines the results of the nonresidential studies for new construction and lighting alterations, including an overview of site visit challenges, sites included and removed from the final analysis, post-stratification of building types, and the ESAF and precision estimates within building types and at the statewide level.

Site Visit Challenges and Final Sample Sizes

Cadmus sampled according to the sample design outlined in Section 2.2.1 where we stratified by building type (warehouses, schools, retail buildings, offices, and miscellaneous buildings). After we obtained the Dodge permit data for all sampled jurisdictions, we contacted every lighting alteration and new construction site that met the criteria for this evaluation. Cadmus targeted 50 site visits for nonresidential lighting alterations and 30 site visits for nonresidential new construction projects, with specified sample size targets within building type categories outlined in Table 10.

Because of the recruiting challenges previously mentioned, we had difficulty achieving the target sample sizes within each building type, and for new construction we were unable to complete the target total site visits. In total, we conducted 52 lighting alteration site visits and 19 new construction site visits. Of those, three lighting alteration sites and 2 new construction sites had invalid data and were unusable in the analysis. We incorporated 49 lighting alteration sites and 17 new construction sites in the analysis. Table 26 provides the distribution of the sampled lighting alteration sites across building type categories.

Table 26. Nonresidential Sample Sizes

Site Type	Building Type					Total
	Misc.	Office	Retail	Warehouse	Schools	
Lighting Alterations	18	19	7	4	1	49
New Construction	7	3	7	0	0	17

Post-Stratification

Due to site recruitment challenges, the school and warehouse building types contained too few sites to generate meaningful results. Cadmus decided to post-stratify the final sample and identified building types within the miscellaneous strata that occurred frequently. The post-stratification for lighting alterations placed schools under the miscellaneous stratum and created restaurants as a new stratum. The final new construction post-strata placed both schools and warehouses under the miscellaneous stratum. The sample sizes after post-stratification are presented below in Table 27.

Table 27. Nonresidential Final Post-Stratified Sample Sizes

Site Type	Building Type					Total
	Misc.	Office	Retail	Warehouse	Restaurant	
Lighting Alterations	9	19	7	4	10	49
New Construction	5	3	7	NA	2	17

ESAF and Precision Estimates

Cadmus computed ESAF and precision estimates within building types and at the statewide level. Building type level estimates are provided in Appendix G. We present unbounded and bounded statewide ESAF and precision estimates for electric annual savings, CPUC-defined peak (demand) savings, and gas annual savings in Table 28. Cadmus achieved the desired ±30% statewide relative precision for unbounded kWh and kW savings in lighting alteration projects, however a combination of negative and positive savings resulted in invalid precision estimates for Therms. Additionally, we expected new construction precision estimates of ±11%, however due to the small sample sizes we were unable to calculate the variability of sites within jurisdictions. Relative precision provides a range around the point estimate that contains the true population value, where the margin of error is defined relative to the point estimate.

Table 28. Nonresidential Statewide ESAFs and Precision Estimates

Site Type	Sample Size	Estimates	kWh	kW	Therms
Lighting Alterations	49	ESAF Unbounded	148%	165%	148%*
		Relative Precision (at 90% Confidence)	19%	18%	N/A**
		ESAF Bounded	91%	89%	91%*
New Construction	17	ESAF Unbounded	149%	156%	149%*
		Relative Precision (at 90% Confidence)	N/A***	N/A***	N/A***
		ESAF Bounded	93%	82%	93%*

* Cadmus found that Therms ESAF statewide estimates were invalid due to a combination of negative and positive savings estimates, therefore we assumed that the ratio of the population of Therms evaluated savings to expected savings will be similar to the ratio for kWh savings.
** Precision is unreliable around Therms lighting alteration ESAF because some building types over-complied with the 2013 codes and some building types under-complied, even with the 2008 code, producing a combination of negative and positive savings estimates.
*** Precision for new construction sites was unable to be calculated due to the small number of sites sampled within each jurisdiction.

Cadmus computed statewide ESAFs and precision estimates for individual standards within sampled homes for the nonresidential lighting alteration population. Table 29 presents unbounded standard ESAF estimates for electric annual savings, CPUC-defined peak demand savings, and gas annual savings. Similar to the whole building unbounded results, the statewide precision estimates are higher than expected for each standard.

Table 29. Nonresidential Lighting Alteration Unbounded Statewide ESAFs for Individual Standards

Standard	Sample Size	kWh		kW		Therms	
		ESAF	Relative Precision at 90% Confidence*	ESAF	Relative Precision at 90% Confidence*	ESAF	Relative Precision at 90% Confidence*
B56 Fenestration	49	154%	19%	174%	18%	-4%	N/A
B51 Lighting Controls	49	151%	19%	170%	18%	-19%	N/A
B57 HVAC Controls	49	155%	19%	174%	18%	30%	N/A

* Precision is unreliable around Therms ESAF because some building types over-complied with the 2013 codes and some building types under-complied, even with the 2008 code, producing a combination of negative and positive savings estimates.

3.2.3. Residential Findings

Cadmus computed ESAF and precision estimates within climate regions and at the statewide level. We present results for electric annual savings, CPUC-defined peak (demand) savings, and gas annual savings for non-lighting and lighting separately, and combined, in the tables below. We summarize the unbounded and bounded ESAF values in Table 30. We include the relative precision values for unbounded ESAFs because these are most accurate when no constraints are applied. The statewide results are provided below in Table 30. Detailed climate region level and statewide savings and ESAF results can be found in Appendix G.

We found that ESAFs tend to be less than 100%, especially for electric energy and demand. These values mean that the housing starts in our sample were not achieving the full potential energy savings expected from the 2013 Title 24 code. Lighting results in Table 30 show negative ESAF estimates for kWh, but positive ESAF estimates for kW. These findings are due a combination of factors. Several sites had incandescent lighting installed and failed to meet the 2008, as well as 2013, Title 24. Several sites also did not have compliant lighting controls. Combined, these occurrences led to overall negative savings of the as-built homes compared to the 2008 Title 24. However, the lack of code-required controls did not affect the demand savings, so the overall ESAF for demand was positive. Relative precision estimates exceeded the expected precision of ±20%. This was because we calculated the expected precision from the previous evaluation using only nonresidential sites and there was a larger amount of variability found from in the residential sites with respect to savings.

The high unbounded gas ESAF estimates are a result of high efficiency gas furnace and water heating equipment found in Climate Regions B and C. Increased ceiling insulation R-values and installed glazing U-factors more efficient than required by code also contributed to the high ESAF by reducing the overall heating load for the house, thus requiring less run time by the furnace. The high gas ESAF estimates were negatively affected by high gas usage from domestic water heaters that included circulating hot water plumbing systems. For the homes we sampled, the pumps on the circulation systems were controlled by time clocks, not an "on-demand" control as required by the 2013 Title 24 code. The CEC Approved Calculation Manual requires that circulation systems with time clock controls be modeled as running 24 hours-a-day resulting in an estimated high gas usage for the water heaters.

Table 30. Residential Statewide ESAFs and Precision Estimates

Sample Size	Estimates	kWh			kW			Therms
		Non-Lighting	Lighting	Combined	Non-Lighting	Lighting	Combined	Non-Lighting
87	ESAF Unbounded	67.8%	-8.9%	53.9%	79.3%	59.2%	79.2%	196.1%
	Relative Precision	31%	493%*	41%	31%	55%	31%	24%
87	ESAF Bounded	67.2%	-9.4%	53.3%	75.9%	59.2%	75.7%	87.4%

* Precision is very high for the statewide kWh lighting ESAF because of the large amount of variability within each climate region and the largely under-complying nature of as-built lighting measures.

Cadmus computed statewide ESAFs and precision estimates for individual standards within sampled homes. Table 31 presents unbounded standard ESAF estimates for electric annual savings, CPUC-defined peak demand savings, and gas annual savings. Similar to the whole building unbounded results, the statewide precision estimates are higher than expected for each standard. The high therms ESAF value for standard B88 for gas reflects the very small sample size. These values are provided for information only—evaluated savings are based on the whole building analysis.

Table 31. Residential Unbounded Statewide ESAFs for Individual Standards

Standard	Sample Size	kWh		kW		Therms	
		ESAF	Relative Precision at 90% Confidence*	ESAF	Relative Precision at 90% Confidence*	ESAF	Relative Precision at 90% Confidence*
B84 Wall Insulation	87	76.1%	28.7%	89.7%	29.2%	217.5%	22.5%
B85 Fenestration	87	46.5%	32.6%	53.0%	33.3%	140.7%	29.3%
B88 Whole House Fan	6	59.0%	N/A	75.7%	N/A	867.9%	N/A
B89 Zoned Air Conditioning	7	41.5%	N/A	64.6%	N/A	55.6%	N/A
B90 HVAC Ducts	87	68.3%	33.3%	81.8%	29.9%	195.0%	25.2%

* "N/As" in the precision are the result of too few jurisdictions within a climate region.

3.3. *Net Savings/NOMAD*

Table 32 presents the evaluated NOMAD values and the values estimated by IOUs for 2014 and 2015. The evaluated values represent the results of the two rounds of the NOMAD estimation process, as described in the methodology section. Because of practical limits on the time available to recruit experts and other real-world constraints, the team dedicated more evaluation resources to the standards with the greatest estimated energy savings, designating these as priority standards. For the standards not appearing in the table, the team used the NOMAD estimate provided by the IOUs.

Table 32. Net NOMAD Adjustment Evaluated and IOU Estimate

2013 Title 24 Building Codes		IOU Estimated Net NOMAD Adjustment		Evaluated Net NOMAD Adjustment	
		2014	2015	2014	2015
B34	Lighting-Alts.-New Measures	-25%	-29%	-23%	-25%
B35	Lighting-Alts.-Existing Measures	-25%	-29%	-13%	-16%
B36	Lighting-Egress Lighting Control	-25%	-29%	-14%	-16%
B37	Lighting-MF Building Corridors	-25%	-29%	-9%	-10%
B38	Lighting-Hotel Corridors	-25%	-29%	-15%	-16%
B39	Lighting-Warehouses, Libraries	-25%	-29%	-25%	-28%
B40	Envelope-Cool Roofs	-20%	-23%	-44%	-48%
B41	HVAC-Equipment Efficiency	-25%	-29%	-25%	-29%
B42	Process-Air Compressors	-14%	-17%	-37%	-41%
B43	Lighting-Daylighting	-4%	-5%	-10%	-11%
B45	Lighting-Retail	-25%	-29%	-22%	-26%
B46	Lighting-Egress Lighting Control	-25%	-29%	-7%	-9%
B47	Lighting-MF Building Corridors	-25%	-29%	-4%	-5%
B48	Lighting-Hotel Corridors	-25%	-29%	-7%	-8%
B49	Lighting-Warehouses, Libraries	-25%	-29%	-11%	-14%
B50	Lighting-Parking Garage	-25%	-29%	-25%	-31%
B51	Lighting-Controllable Lighting	-1%	-2%	-14%	-16%
B54	Lighting-Office Plug Load Control	-1%	-2%	-6%	-7%
B57	HVAC Controls, Economizers	-14%	-17%	-8%	-10%
B58	HVAC-Fan Control & Economizers	-14%	-17%	-13%	-16%
B61	HVAC-Kitchen Ventilation	-1%	-2%	-17%	-18%
B78	Process-Data Centers	-14%	-17%	-27%	-27%
B82	Whole Building	-25%	-29%	-8%	-9%
B85	RNC-Envelope-Fenestration	-44%	-49%	-44%	-49%
B88	RNC-HVAC-Whole House Fans	-17%	-20%	-1%	-1%
B89	RNC-HVAC-Zoned AC	-17%	-20%	-8%	-10%
B90	RNC-HVAC-Duct	-17%	-20%	-18%	-19%
B97	RNC-SF Whole Building	-17%	-20%	-39%	-40%
B99	Residential Alterations-SF Whole Building	-17%	-20%	-27%	-28%

3.4. Net Savings/Attribution

Table 33 reports the factor scores, factor weights, and final attribution score for the 2013 Title 24 building code. The factor scores indicate the percentage contributions of the C&S program to the development of the codes in each factor area. The final attribution score is the weighted average of the factor scores. Codes B34 to B42 are for NRA, code B43 to B81 are for NRNC, and codes B85, B89, and B90 are for RNC. Factor scores determined by the panel are shaded in gray.

Table 33. 2013 Title 24 Codes Attribution Scores and Weighting

2013 Title 24 Building Codes		Factor Score			Weight			Final Attribution Score
		Compliance	Technical	Feasibility	Compliance	Technical	Feasibility	
B34	Lighting-Alts.-New Measures	5%	60%	80%	15%	55%	30%	58%
B35	Lighting-Alts.-Existing Measures	5%	60%	80%	15%	55%	30%	58%
B36	Lighting-Egress Lighting Control	5%	85%	85%	5%	60%	35%	81%
B37	Lighting-MF Building Corridors	70%	65%	70%	25%	45%	30%	68%
B38	Lighting-Hotel Corridors	70%	65%	70%	25%	45%	30%	68%
B39	Lighting-Warehouses, Libraries	70%	75%	80%	25%	50%	25%	75%
B40	Envelope-Cool Roofs	5%	55%	60%	0%	60%	40%	57%
B41	HVAC-Equipment Efficiency	15%	10%	30%	25%	5%	70%	0%
B42	Process-Air Compressors	75%	55%	10%	40%	40%	20%	54%
B43	Lighting-Daylighting	35%	65%	75%	35%	50%	15%	56%
B50	Lighting-Parking Garage	40%	70%	65%	10%	60%	30%	66%
B51	Lighting-Controllable Lighting	85%	70%	60%	40%	20%	40%	72%
B53	Lighting-Outdoor Lighting, Controls	10%	70%	75%	10%	65%	25%	65%
B54	Lighting-Office Plug Load Control	90%	70%	85%	20%	55%	25%	78%
B56	Envelope-Fenestration	35%	70%	75%	60%	20%	20%	50%
B57	HVAC-HVAC Controls, Economizers	75%	68%	75%	30%	40%	30%	72%
B58	HVAC-Fan Control & Economizers	78%	75%	70%	20%	70%	10%	75%
B61	HVAC-Kitchen Ventilation	85%	75%	60%	25%	30%	45%	71%
B63	HVAC-Chiller Min Efficiency	30%	50%	60%	5%	70%	25%	52%
B65	HVAC-Laboratory Exhaust	10%	55%	70%	10%	60%	30%	55%
B66	HVAC-Small ECM Motor	73%	55%	75%	30%	40%	30%	66%
B75	Refrigeration-Supermarket	10%	55%	70%	0%	60%	40%	61%
B77	Process-Air Compressors	70%	65%	50%	30%	50%	20%	64%
B78	Process-Data Centers	50%	73%	73%	15%	30%	55%	69%
B81	Solar-Solar Ready	90%	70%	25%	20%	60%	20%	65%
B85	Envelope-Fenestration	25%	65%	65%	10%	50%	40%	61%
B89	HVAC-Zoned AC	85%	70%	40%	20%	55%	25%	66%
B90	HVAC-Duct	10%	80%	50%	0%	70%	30%	71%

The attribution panel determined each high-priority attribution score, coming to consensus based on discussions of the data collected by the attribution team. Although the panel did not create the weights, they discussed what they thought potential weights would be while deciding on their scores. We originally intended to have the panel score lighting code B51, controllable lighting, but we did not receive sufficient data (despite repeated requests to the IOUs) to feel comfortable that we were presenting a complete and unbiased picture of the rulemaking events that led to the standard.

Standard B41 HVAC Equipment Efficiency

This standard is different from most Title 24 standards since the main provisions were included in ASHRAE 90.1-2010 and also because the Department of Energy (DOE) proceeded with a rulemaking requiring states to adopt ASHRAE 90.1-2010 or an equivalent standard. The IOUs also recognized that adoption of this standard differed from most others: for most Title 24 standards, the IOUs estimate attribution between 80% and 85% but for standard B41, they estimated attribution of 39%.

Since Cadmus' initial determination was that the CEC had to adopt this standard, attribution scores were not determined by the independent panel. After the IOUs provided additional information about the role of the program in development of the ASHRAE standards and the CEC adoption process, Cadmus evaluated attribution using the internal process ordinarily used for standards with relatively low potential savings.

The Cadmus team determined that the program should receive an attribution score of 25%. This standard received a lower attribution score than other Title 24 standards, due to work done by both DOE and the ASHRAE committee. This allowed for a less-involved adoption process than other standards. The standard was derived from ASHRAE 90.1-2010 and heavily leveraged the ASHRAE adoption process for technical and standard language information. Overall, their most significant contribution was the outreach and feasibility work performed to ensure that work done by both ASHRAE and DOE could be translated to the California regulatory environment. Additionally, the IOUs held a number of stakeholder meetings working to communicate the proposed standard with stakeholders determine how to best meet the standard requirements. This is why the IOUs received a higher factor score for factor 3 relative to the other factors.

4. Results for the Statewide Program

We present overall evaluation findings in this section. We determined the overall impact of the 2013 Title 24 code by integrating the parameter findings documented in the preceding chapters according to the protocol. These calculations are documented in the ISSM model, which will be published along with this report and appendices.

4.1. Findings for 2013 Title 24 and Major Groups

In this section, we report overall findings for the major categories and groups of standards. As noted previously, the major categories include the NRA, NRNC, and residential groups of standards.

In the following sections, we report on the findings of individual standards within each of the major categories. We focus on those standards within each group that produce the greatest savings.

As discussed, results can be reported on a statewide basis or in terms of savings allocated to the IOUs. For electric energy and demand, the IOUs represent about 72% of the statewide total, hence the savings total allocated to the IOUs also is about 72% of the statewide total. For gas savings, the IOUs represent 99% of the gas supplied; so statewide and IOU totals are practically the same. All values shown are statewide savings unless specifically identified as IOU-specific findings.

Table 34. Evaluated vs. IOU Estimate: 2013–2015 PY Statewide Total Savings for 2013 Title 24 (GWh)*

GWh	IOU Estimated Savings				Evaluated Savings			
	Potential	Gross	Net	Net Program	Potential	Gross	Net	Net Program
NRA	1,226.1	1,017.6	738.9	582.9	1,029.9	922.9	718.5	425.6
NRNC	382.3	317.3	262.0	213.4	403.7	351.7	313.2	213.0
Residential	29.0	24.0	19.2	14.0	50.4	32.1	21.3	14.6
2013-2015 Total	**1,637.3**	**1,359.0**	**1,020.1**	**810.3**	**1,484.0**	**1,306.8**	**1,053.0**	**653.1**
Evaluated/IOU Estimated					**91%**	**96%**	**103%**	**81%**

*Values may not sum exactly due to rounding.

Table 35. Evaluated vs. IOU Estimate: IOU Share of 2013–2015 PY 2013 Title 24 Electricity Savings (GWh)*

GWh	Percentage of Statewide Sales	IOU Estimated Savings				Evaluated Savings			
IOU		Potential	Gross	Net	Net Program	Potential	Gross	Net	Net Program
PG&E	31.60%	517.4	429.4	322.4	256.0	469.0	413.0	332.7	206.4
SCE	32.60%	533.8	443.0	332.6	264.2	483.8	426.0	343.3	212.9
SDG&E	7.40%	121.2	100.6	75.5	60.0	109.8	96.7	77.9	48.3
All IOUs	**71.60%**	**1172.3**	**973.0**	**730.4**	**580.2**	**1062.6**	**935.7**	**753.9**	**467.6**
Evaluated/IOU Estimated						**91%**	**96%**	**103%**	**81%**

*Values may not sum exactly due to rounding.

Table 36. Evaluated vs. IOU Estimate: 2013–2015 PY Statewide Total Savings for 2013 Title 24 (MW)*

MW	IOU Estimated Savings				Evaluated Savings			
	Potential	Gross	Net	Net Program	Potential	Gross	Net	Net Program
NRA	320.7	266.2	192.9	149.3	178.8	156.0	118.7	61.6
NRNC	56.1	46.5	36.7	29.9	65.1	53.6	48.9	32.5
Residential	34.0	28.3	22.6	16.3	60.2	46.1	30.4	20.8
2013-2015 Total	**410.8**	**340.9**	**252.2**	**195.6**	**304.1**	**255.7**	**198.0**	**114.9**
Evaluated/IOU Estimated					**74%**	**75%**	**79%**	**59%**

*Values may not sum exactly due to rounding.

Table 37. Evaluated vs. IOU Estimate: IOU Share of 2013–2015 PY 2013 Title 24 Demand Savings (MW)*

MW	Percentage of Statewide Sales	IOU Estimated Savings				Evaluated Savings			
IOU		Potential	Gross	Net	Net Program	Potential	Gross	Net	Net Program
PG&E	31.60%	129.8	107.8	79.7	61.8	96.1	80.8	62.6	36.3
SCE	32.60%	133.9	111.2	82.2	63.7	99.1	83.4	64.6	37.5
SDG&E	7.40%	30.4	25.2	18.7	14.5	22.5	18.9	14.7	8.5
All IOUs	**71.60%**	**294.1**	**244.2**	**180.6**	**140.0**	**217.7**	**183.1**	**141.8**	**82.3**
Evaluated/IOU Estimated						**74%**	**75%**	**79%**	**59%**

*Values may not sum exactly due to rounding.

Table 38. Evaluated vs. IOU Estimate: 2013–2015 PY Statewide Total Savings for 2013 Title 24 Including Interactive Effects (MMTherms)*

MMTherms	IOU Estimated Savings				Evaluated Savings			
	Potential	Gross	Net	Net Program	Potential	Gross	Net	Net Program
NRA	1.73	1.44	1.03	-0.64	1.83	1.36	0.87	-0.31
NRNC	4.27	3.54	3.34	2.66	5.25	4.45	4.33	2.74
Residential	2.04	1.70	1.53	1.19	2.70	2.36	1.86	1.40
2013-2015 Total	**8.05**	**6.68**	**5.90**	**3.22**	**9.77**	**8.17**	**7.07**	**3.83**
Evaluated/IOU Estimated					**121%**	**122%**	**120%**	**119%**

*Values may not sum exactly due to rounding.

Table 39. Evaluated vs. IOU Estimate: 2013–2015 PY Statewide Total Savings for 2013 Title 24 Excluding Interactive Effects (MMTherms)*

MMTherms	IOU Estimated Savings				Evaluated Savings			
	Potential	Gross	Net	Net Program	Potential	Gross	Net	Net Program
NRA	3.46	2.87	2.07	0.24	3.18	2.59	1.87	0.31
NRNC	4.59	3.81	3.59	2.87	5.56	4.71	4.55	2.91
Residential	2.09	1.73	1.56	1.22	2.78	2.36	1.86	1.40
2013-2015 Total	**10.14**	**8.42**	**7.21**	**4.32**	**11.52**	**9.66**	**8.29**	**4.62**
Evaluated/IOU Estimated					**114%**	**115%**	**115%**	**107%**

*Values may not sum exactly due to rounding.

Table 40. Evaluated vs. IOU Estimate: IOU Share of 2013-2015 PY 2013 Title 24 Gas Savings Including Interactive Effects (MMTherms) *

MMTherms	Percentage of Statewide Sales	IOU Estimated Savings				Evaluated Savings			
IOU		Potential	Gross	Net	Net Program	Potential	Gross	Net	Net Program
PG&E	36.50%	2.94	2.44	2.16	1.18	3.57	2.98	2.58	1.40
SCG	58.40%	4.70	3.90	3.45	1.88	5.71	4.77	4.13	2.23
SDG&E	4.10%	0.33	0.27	0.24	0.13	0.40	0.33	0.29	0.16
All IOUs	**99.00%**	**7.97**	**6.61**	**5.85**	**3.19**	**9.68**	**8.09**	**6.99**	**3.79**
Evaluated/IOU Estimated						**121%**	**122%**	**120%**	**119%**

*Values may not sum exactly due to rounding.

Table 41. Evaluated vs. IOU Estimate: IOU Share of 2013-2015 PY 2013 Title 24 Gas Savings Excluding Interactive Effects (MMTherms) *

MMTherms	Percentage of Statewide Sales	IOU Estimated Savings				Evaluated Savings			
IOU		Potential	Gross	Net	Net Program	Potential	Gross	Net	Net Program
PG&E	36.50%	3.70	3.07	2.63	1.58	4.20	3.52	3.03	1.69
SCG	58.40%	5.92	4.92	4.21	2.52	6.73	5.64	4.84	2.70
SDG&E	4.10%	0.42	0.35	0.30	0.18	0.47	0.40	0.34	0.19
All IOUs	**99.00%**	**10.04**	**8.33**	**7.14**	**4.28**	**11.40**	**9.56**	**8.21**	**4.58**
Evaluated/IOU Estimated						**114%**	**115%**	**115%**	**107%**

*Values may not sum exactly due to rounding.

4.2. *Findings for NRA*

In this section, we present evaluation findings for five of the nine NRA standards. These five standards—B34, B35, B36, B39, and B41—represent 95% of the potential energy savings and also 95% of the net program savings. We provide summaries for the other four NRA standards listed below in Appendix K.

- Standard B37 NRA-Lighting-MF Building Corridors
- Standard B38 NRA-Lighting-Hotel Corridors
- Standard B40 NRA-Envelope-Cool Roofs
- Standard B42 NRA-Process-Air Compressors

4.2.1. Standard B34 NRA-Lighting-Alterations-New Measures

As shown in Table 42, Cadmus found a slightly higher unit energy savings (UES) in terms of kWh than the IOU estimate. This was the result of a more detailed analysis of the building types that were not analyzed in the CEC analysis on which the overall analysis is based. Our analysis is described in detail in Appendix H. As shown in Table 43, Cadmus found somewhat higher potential, gross, and net energy savings than the IOU estimate. The gross savings reflect the ESAF value based on Cadmus' study of 49 actual sites. However, net program savings are slightly lower due to the finding of a lower attribution score that the IOUs estimated.

Table 42. Evaluated vs. IOU Estimated Unit Energy Savings for Standard B34

NRA-Lighting-Alterations-New Measures	Unit Savings			Interactive Energy Savings Factor (kWh/kWh)	Interactive Demand Savings Factor (kW/kW)	Interactive Gas Savings Adjustment Factor (Therms/GWh)
	Electricity (kWh)	Demand (kW)	Gas (Therms)			
IOU Estimate	0.547	0.00011	-0.00098	1.00	1.00	-0.00403
Evaluated	0.578	0.00011	-0.00103	1.00	1.00	0.00000

Table 43. Evaluated vs. IOU Estimated Market Size and Savings for Standard B34

NRA-Lighting-Alterations-New Measures	Year	Units	GWh							MW	MMtherms
			Potential Energy Savings	ESAF	Gross Energy Savings	NOMAD Adjustment	Net Energy Savings	Attrib.	Program Net Energy Savings	Program Net Demand Savings	Program Net Gas Savings
IOU Estimate	2014	204,066,263	111.7	83%	92.7	-25%	69.2	84%	58.4	11.27	(0.34)
	2015	404,805,359	221.5	83%	183.8	-29%	130.7	84%	110.1	21.27	(0.64)
	Total		**333.1**		**276.5**		**199.9**		**168.5**	**32.55**	**(0.98)**
Evaluated	2014	202,628,572	117.1	91%	106.6	-23%	82.4	58%	47.6	9.04	(0.08)
	2015	401,953,417	232.3	91%	211.4	-25%	158.6	58%	91.6	17.39	(0.16)
	Total		**349.4**		**317.9**		**241.0**		**139.2**	**26.43**	**(0.25)**

4.2.2. Standard B35 NRA-Lighting-Alterations-Existing Measures

We present our UES findings in Table 44. These savings are produced from several sources including LPD reduction, lighting control upgrades (tuning), and auto-shutoff controls. Our analysis found much lower savings per square foot but as shown in Table 45, much more building area to which these savings apply. The details of our analysis are included in Appendix H. Once a higher ESAF value, lower NOMAD estimates and lower attribution are factored in, we found net energy savings (GWh) of slightly less than half of the IOU estimate. In terms of demand savings, the IOU estimate includes annual potential of 122.8 MW. Our review of the IOU analysis found that this calculation was based on an incorrect value for applicable square footage. As a result the submitted IOU estimate is much larger than it would have been if the correct square footage value had been used.

Table 44. Evaluated vs. IOU Estimated Unit Energy Savings for Standard B35

NRA-Lighting-Alterations-Existing Measures	Unit Savings			Interactive Energy Savings Factor (kWh/kWh)	Interactive Demand Savings Factor (kW/kW)	Interactive Gas Savings Adjustment Factor (Therms/GWh)
	Electricity (kWh)	Demand (kW)	Gas (Therms)			
IOU Estimate	1.841	0.00071	-0.00519	1.00	1.00	0.00000
Evaluated	0.413	0.00006	0.00000	1.10	1.32	-0.00410

Table 45. Evaluated vs. IOU Estimated Market Size and Savings for Standard B35

NRA-Lighting-Alterations-Existing Measures	Year	Units	GWh							MW	MMtherms
			Potential Energy Savings	ESAF	Gross Energy Savings	NOMAD Adjustment	Net Energy Savings	Attrib.	Program Net Energy Savings	Program Net Demand Savings	Program Net Gas Savings
IOU Estimate	2014	86,657,571	159.6	83%	132.4	-25%	99.0	85%	84.4	32.72	(0.24)
	2015	171,902,247	316.5	83%	262.7	-29%	186.7	85%	159.2	61.74	(0.45)
	Total		**476.1**		**395.2**		**285.7**		**243.6**	**94.46**	**(0.69)**
Evaluated	2014	186,249,982	84.6	91%	77.0	-13%	66.7	58%	38.5	6.74	(0.14)
	2015	369,463,280	167.9	91%	152.8	-16%	128.2	58%	74.0	12.95	(0.28)
	Total		**252.5**		**229.8**		**194.8**		**112.5**	**19.69**	**(0.42)**

4.2.3. Standard B36 NRA-Lighting-Egress Lighting Control

We present our findings for UES values for standard B36 in Table 46. Cadmus found that the IOU savings estimate for this standard did not reflect the latest analysis from a supporting workbook that was provided by the IOUs in response to our data request. Although Cadmus identified less building area to which this standard applied, potential savings are still 12 greater than estimated by the IOUs. We show the overall results of our evaluation in Table 47. Based on our finding of a higher ESAF, lower NOMAD, and similar attribution, net program savings are found to be 42% greater than the estimate.

Table 46. Evaluated vs. IOU Estimated Unit Energy Savings for Standard B36

NRA-Lighting-Egress Lighting Control	Unit Savings			Interactive Energy Savings Factor (kWh/kWh)	Interactive Demand Savings Factor (kW/kW)	Interactive Gas Savings Adjustment Factor (Therms/GWh)
	Electricity (kWh)	Demand (kW)	Gas (Therms)			
IOU Estimate	0.188	0.00000	0.00000	1.10	1.32	0.00000
Evaluated	0.441	0.00000	0.00000	1.00	1.00	0.00000

Table 47. Evaluated vs. IOU Estimated Market Size and Savings for Standard B36

NRA-Lighting-Egress Lighting Control	Year	Units	GWh							MW	MMtherms
			Potential Energy Savings	ESAF	Gross Energy Savings	NOMAD Adjustment	Net Energy Savings	Attrib.	Program Net Energy Savings	Program Net Demand Savings	Program Net Gas Savings
IOU Estimate	2014	202,178,192	41.7	83%	34.6	-25%	25.9	82%	21.2	-	-
	2015	401,060,000	82.8	83%	68.7	-29%	48.9	82%	39.9	-	-
	Total		**124.6**		**103.4**		**74.7**		**61.1**	**-**	**-**
Evaluated	2014	105,813,151	46.7	91%	42.5	-14%	36.3	81%	29.4	-	-
	2015	209,901,087	92.6	91%	84.2	-16%	70.7	81%	57.3	-	-
	Total		**139.2**		**126.7**		**107.0**		**86.7**	**-**	**-**

4.2.4. Standard B39 NRA-Lighting-Warehouses and Libraries

Cadmus submitted several data requests, but did not receive the data necessary to properly confirm the UES estimates or assumptions that support the estimate. Cadmus was unable to find any secondary research to benchmark these kinds of lighting controls savings in warehouses or libraries. We agree there are energy savings potential for these standards and we accept the per-unit savings estimates from the CASE report as reasonable for electric energy (kWh) and demand (kW) as shown in Table 48.

We provide our integrated results in Table 49. With slightly higher square footage and ESAF values, gross savings are substantially higher than estimated by the IOUs. Since we found lower attribution, the net program savings are only slightly above the IOU estimate.

Table 48. Evaluated vs. IOU Estimated Unit Energy Savings for Standard B39

NRA-Lighting-Warehouses and Libraries	Unit Savings			Interactive Energy Savings Factor (kWh/kWh)	Interactive Demand Savings Factor (kW/kW)	Interactive Gas Savings Adjustment Factor (Therms/GWh)
	Electricity (kWh)	Demand (kW)	Gas (Therms)			
IOU Estimate	0.809	0.00008	0.00000	1.10	1.32	-0.00410
Evaluated	0.809	0.00008	0.00000	1.10	1.32	-0.00410

Table 49. Evaluated vs. IOU Estimated Market Size and Savings for Standard B39

NRA-Lighting-Warehouses and Libraries	Year	Units	GWh							MW	MMtherms
			Potential Energy Savings	ESAF	Gross Energy Savings	NOMAD Adjustment	Net Energy Savings	Attrib.	Program Net Energy Savings	Program Net Demand Savings	Program Net Gas Savings
IOU Estimate	2014	34,160,645	30.4	83%	25.2	-25%	18.9	84%	15.8	1.81	(0.06)
	2015	67,764,323	60.3	83%	50.0	-29%	35.6	84%	29.9	3.41	(0.11)
	Total		**90.7**		**75.3**		**54.4**		**45.7**	**5.22**	**(0.17)**
Evaluated	2014	37,120,782	33.0	91%	30.1	-25%	22.4	75%	16.8	2.04	(0.06)
	2015	73,636,335	65.5	91%	59.6	-28%	42.7	75%	32.0	3.89	(0.12)
	Total		**98.6**		**89.7**		**65.1**		**48.8**	**5.93**	**(0.18)**

4.2.5. Standard B41 NRA-HVAC-Equipment Efficiency

Table 50 and Table 51 present our findings for the HVAC efficiency standard. We found slightly lower potential due to lower UES values (especially for gas UES) and lower square footage to which the standard applies. Net program savings are also less than the IOU estimate due to a finding of 25% attribution versus the 39% included in the IOU estimate.

Table 50. Evaluated vs. IOU Estimated Unit Energy Savings for Standard B41

NRA-HVAC-Equipment Efficiency	Unit Savings			Interactive Energy Savings Factor (kWh/kWh)	Interactive Demand Savings Factor (kW/kW)	Interactive Gas Savings Adjustment Factor (Therms/GWh)
	Electricity (kWh)	Demand (kW)	Gas (Therms)			
IOU Estimate	0.313	0.00011	0.01204	1.00	1.00	0.00000
Evaluated	0.297	0.00010	0.00880	1.00	1.00	0.00000

Table 51. Evaluated vs. IOU Estimated Market Size and Savings for Standard B41

NRA-HVAC-Equipment Efficiency	Year	Units	GWh							MW	MMtherms
			Potential Energy Savings	ESAF	Gross Energy Savings	NOMAD Adjustment	Net Energy Savings	Attrib.	Program Net Energy Savings	Program Net Demand Savings	Program Net Gas Savings
IOU Estimate	2014	154,519,167	48.4	83%	40.2	-25%	30.0	39%	11.7	4.11	0.45
	2015	306,519,000	96.0	83%	79.7	-29%	56.6	39%	22.1	7.75	0.85
	Total		**144.4**		**119.8**		**86.6**		**33.8**	**11.85**	**1.30**
Evaluated	2014	150,385,944	44.6	83%	37.0	-25%	27.7	25%	7.0	2.25	0.21
	2015	298,319,943	88.5	83%	73.4	-29%	52.2	25%	13.2	4.24	0.39
	Total		**133.0**		**110.4**		**79.8**		**20.2**	**6.49**	**0.60**

4.3. Findings for NRNC

In this section, we present findings for the 40 standards included in the NRNC category. A complete list is provided in Table 3 and Table 4 above. Due to the quantity of individual standards, we have chosen to present results for four non-overlapping categories: whole building (12 standards), Lighting (9 standards), HVAC (10 standards), and Process/Other (9 standards).

4.3.1. Standard B82 Whole Building

This "standard" was created by the IOUs to represent the twelve standards that were included in the CEC analysis (cited above) of energy savings from the 2013 Title 24 code. The specific standards include lighting, envelope, fenestration, HVAC, boilers, and chillers. Cadmus' review of this standard (and many of the individual standards) is detailed in Appendix H. Where the CEC only included a subset of building types, Cadmus extended the analysis to include all building types. This was the main reason we found higher potential savings as shown in Table 53 below.

We found an ESAF of 93% based on field research and building simulation analyses. This ESAF is 10% higher than the value used by the IOUs. We determined NOMAD and attribution values by using weighted averages of the findings for the individual component standards. Even with the lower attribution finding, the evaluated GWh savings are 57% larger than the IOU estimate.

Table 52. Evaluated vs. IOU Estimated Unit Energy Savings for Standard B82

NRNC-Whole Building	Unit Savings			Interactive Energy Savings Factor (kWh/kWh)	Interactive Demand Savings Factor (kW/kW)	Interactive Gas Savings Adjustment Factor (Therms/GWh)
	Electricity (kWh)	Demand (kW)	Gas (Therms)			
IOU Estimate	0.977	0.00026	0.00551	1.00	1.00	0.00000
Evaluated	1.466	0.00038	0.00803	1.00	1.00	0.00000

Table 53. Evaluated vs. IOU Estimated Market Size and Savings for Standard B82

NRNC-Whole Building	Year	Units	GWh						Program Net Energy Savings	MW	MMtherms
			Potential Energy Savings	ESAF	Gross Energy Savings	NOMAD Adjustment	Net Energy Savings	Attrib.	Program Net Energy Savings	Program Net Demand Savings	Program Net Gas Savings
IOU Estimate	2015	123,054,483	120.3	83%	99.8	-29%	71.0	83%	58.8	15.35	0.33
	Total		**120.3**		**99.8**		**71.0**		**58.8**	**15.35**	**0.33**
Evaluated	2015	113,570,029	166.5	93%	154.8	-9%	140.8	66%	92.9	21.42	0.51
	Total		**166.5**		**154.8**		**140.8**		**92.9**	**21.42**	**0.51**

4.3.2. NRNC Lighting Standards

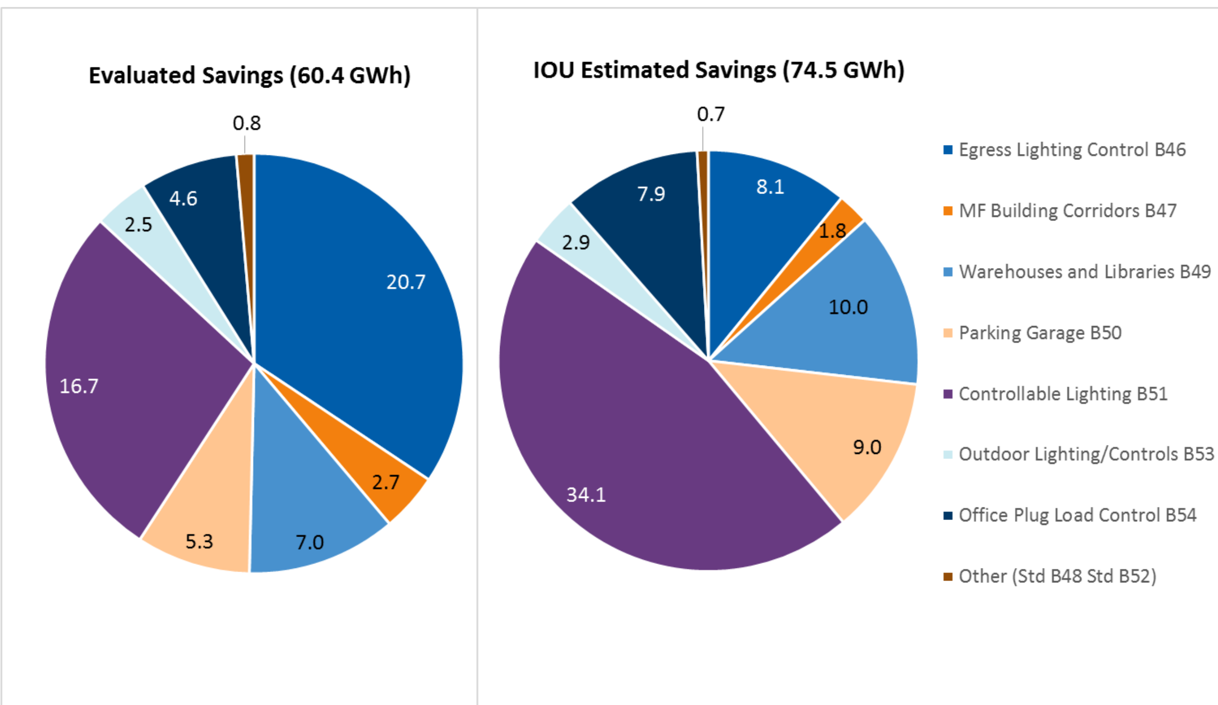
Cadmus included standards B46 through B54 in this group of lighting standards. As shown in Table 54 we found less savings for this group than the IOUs estimated.

Table 54. Evaluated vs. IOU Estimated Savings for NRNC Lighting Standards

NRNC Lighting	Year	GWh							MW	MMtherms
		Potential Energy Savings	ESAF	Gross Energy Savings	NOMAD Adjustment	Net Energy Savings	Attrib.	Program Net Energy Savings	Program Net Demand Savings	Program Net Gas Savings
IOU Estimate	2015	128.0	83%	106.3	-16%	89.6	83%	74.5	5.15	(0.20)
	Total	**128.0**		**106.3**		**89.6**		**74.5**	**5.15**	**(0.20)**
Evaluated	2015	112.0	83%	93.0	-15%	78.9	76%	60.4	4.33	(0.17)
	Total	**112.0**		**93.0**		**78.9**		**60.4**	**4.33**	**(0.17)**

We provided a breakdown of net program savings in Figure 7. We found higher savings for standard B46 but lower savings for the other standards in this group.

Figure 7. Net Program Savings for NRNC Lighting Standards (GWh)



4.3.3. NRNC HVAC Standards

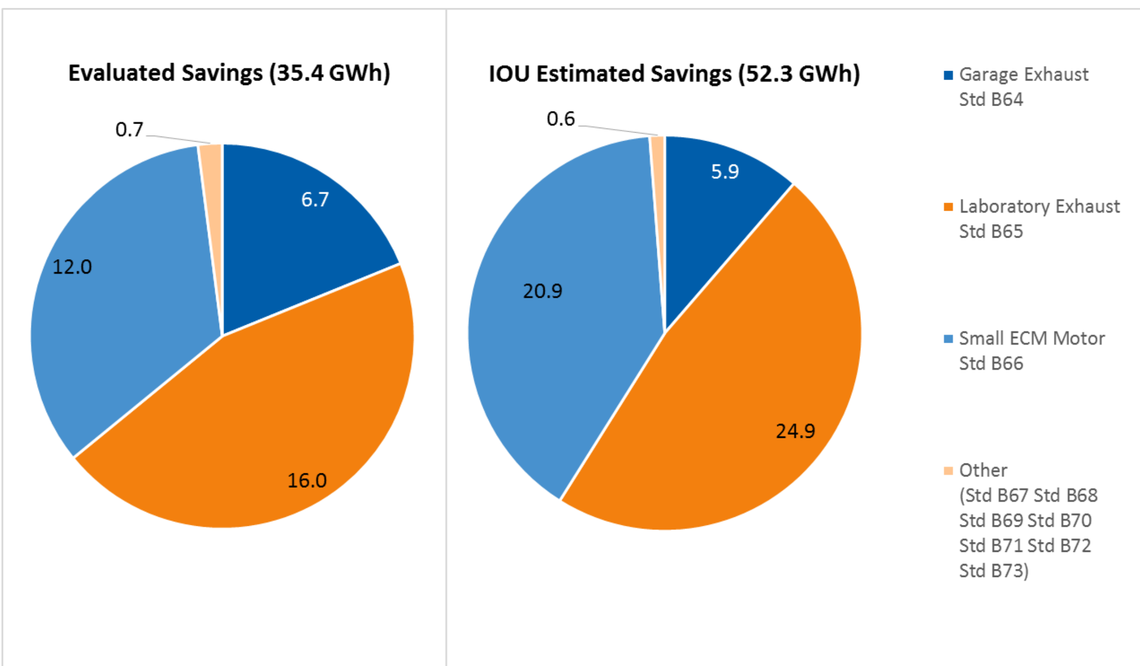
Cadmus included standards B64 through B73 in this group of HVAC standards. As shown in Table 55, we found less savings for this group overall than the IOU estimates.

Table 55. Evaluated vs. IOU Estimated Savings for NRNC HVAC Standards

NRNC HVAC	Year	GWh							MW	MMtherms
		Potential Energy Savings	ESAF	Gross Energy Savings	NOMAD Adjustment	Net Energy Savings	Attrib.	Program Net Energy Savings	Program Net Demand Savings	Program Net Gas Savings
IOU Estimate	2015	85.8	83%	71.2	-8%	65.2	80%	52.3	8.32	1.08
	Total	**85.8**		**71.2**		**65.2**		**52.3**	**8.32**	**1.08**
Evaluated	2015	73.7	83%	61.1	-7%	56.6	62%	35.4	5.86	1.10
	Total	**73.7**		**61.1**		**56.6**		**35.4**	**5.86**	**1.10**

We present a breakdown of the net program savings for the HVAC group in Figure 8. In both the IOU estimate and the evaluated results, the laboratory exhaust standard, the small ECM motor standard, and the garage exhaust standard produce the bulk of the savings.

Figure 8. Net Program Savings for NRNC HVAC Standards (GWh)



4.3.4. NRNC Process and Other Standards

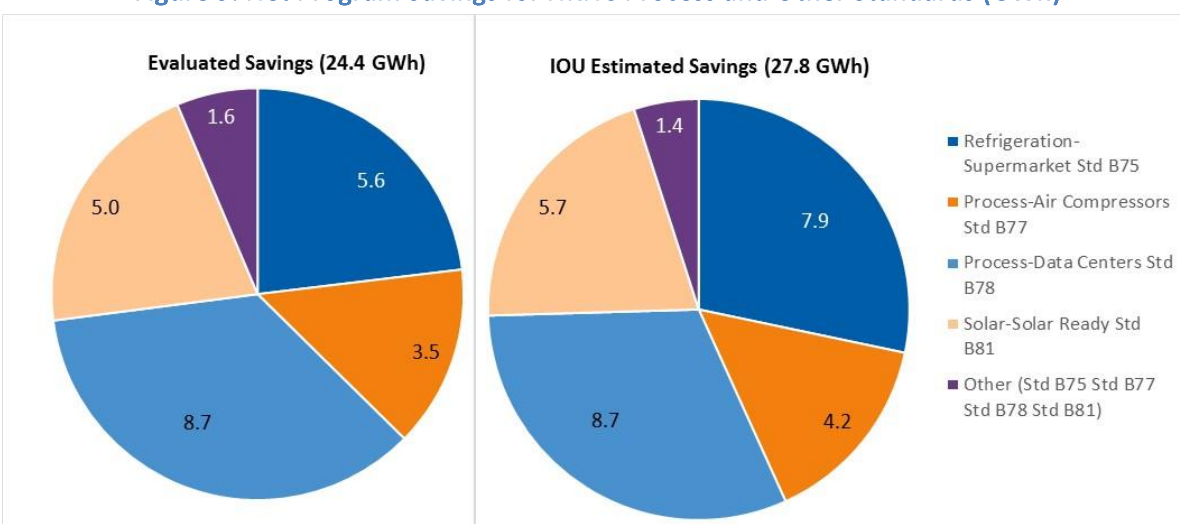
Cadmus included standards B74 through B81 in this group that includes refrigeration, process (boilers, air compressors, and data centers), and hot water standards. As shown in Table 56, we found slightly how potential savings and slightly lower net program savings for this category.

Table 56. Evaluated vs. IOU Estimated Savings for NRNC Process / Other Standards

NRNC Process and Other	Year	GWh							MW	MMtherms
		Potential Energy Savings	ESAF	Gross Energy Savings	NOMAD Adjustment	Net Energy Savings	Attrib.	Program Net Energy Savings	Program Net Demand Savings	Program Net Gas Savings
IOU Estimate	2015	48.1	83%	39.9	-9%	36.2	77%	27.8	1.08	1.46
	Total	**48.1**		**39.9**		**36.2**		**27.8**	**1.08**	**1.46**
Evaluated	2015	51.6	83%	42.8	-14%	36.9	66%	24.4	0.90	1.30
	Total	**51.6**		**42.8**		**36.9**		**24.4**	**0.90**	**1.30**

We present a breakdown of the net program savings for the HVAC group in Figure 9. Evaluation findings confirm that the IOU estimates.

Figure 9. Net Program Savings for NRNC Process and Other Standards (GWh)



4.4. Findings for Residential Construction

We present evaluation findings for all residential standards in Table 57. Overall, Cadmus found slightly higher program net savings than were included in the IOU estimates, although several key protocol parameters were slightly lower than the IOU estimates.

The increase in overall potential savings is largely driven by the increase in annual construction of single family homes. Since the code became effective in July 2014 and we assume that alteration savings begin to occur immediately following the code effective date, we also identified savings from alterations in 2014 that the IOUs did not include in their estimate.

Table 57. Evaluated Vs. IOU Estimate:
2013–2015 PY Total Savings for all 2013 Title 24 Residential Standards

		GWh							MW	MMtherms
	Year	Potential Energy Savings	ESAF	Gross Energy Savings	NOMAD Adjustment	Net Energy Savings	Attrib.	Program Net Energy Savings	Program Net Demand Savings	Program Net Gas Savings
IOU	2014	-		-		-		-	-	-
	2015	29.0	83%	24.0	-20%	19.2	73%	14.0	16.3	1.2
	Total	**29.0**	**83%**	**24.0**	**-20%**	**19.2**	**73%**	**14.0**	**16.3**	**1.2**
EVAL	2014	6.3	69%	4.4	-25%	3.3	69%	2.2	3.1	0.1
	2015	44.1	63%	27.8	-28%	18.1	68%	12.3	17.7	1.3
	Total	**50.4**	**64%**	**32.1**	**-27%**	**21.3**	**68%**	**14.6**	**20.8**	**1.4**

We provide the detail on three single family standards, B97, B83, and B99 in this section. These standards represent 90% of the 2013 Title 24 residential savings. In addition, results for individual standards that were superseded by the single family whole building approach are included in section 4.4.2. We provide detail on two multifamily standards and three solar standards in Appendix M.

4.4.1. B97 RNC Whole Building Single Family

As noted previously, this standard is included in the IOU estimate to summarize all savings from construction of new single-family homes under the 2013 Title 24 codes, with the exception of the RNC lighting standard, B83. The IOUs relied on the CEC impact analysis for their estimate of total savings. Specific standards included in this category are shown in Table 5 above, and include standards B84–B92.

Cadmus evaluated the ESAF for new single-family homes through the field research and analysis described above. For the NOMAD and attribution parameters, Cadmus relied on weighted averages of the values found for individual measures and the values estimated by the IOUs.

For single-family homes, Cadmus' evaluation found an ESAF of 67% for electric energy savings, which was lower than the IOU estimate. When we combined the NOMAD and attribution values for the individual standards included in the single-family group, we found a larger NOMAD adjustment and slightly lower attribution than the IOU estimate.

Table 58. Evaluated Vs. IOU-Estimated Savings for Standard B97 Single-Family Whole Building

RNC-SF Whole Building	Year	Units	Electric Savings (GWh)							MW	Gas Savings
			Potential Energy Savings	ESAF	Gross Energy Savings	NOMAD Adjustment	Net Energy Savings	Attrib.	Program Net Energy Savings	Program Net Demand Savings	Program Net Gas Savings
IOU	2015	22,796	15.3	83%	12.7	-20%	10.1	72%	7.3	9.70	0.25
	Total		**15.3**		**12.7**		**10.1**		**7.3**	**9.70**	**0.25**
EVAL	2015	37,040	24.8	67%	16.7	-40%	10.0	68%	6.8	10.14	0.30
	Total		**24.8**		**16.7**		**10.0**		**6.8**	**10.14**	**0.30**

4.4.2. B84 through B92: Measures that Contribute to New Single-Family Homes Savings

As noted, the IOUs identified standards B84–B92 as the measures that are included in in the estimated whole building savings for new single-family homes. Because the IOU estimates do not reflect the impact of expected interactions between measures, the sum of the expected savings of these individual standards are much greater than for the IOUs' estimate for whole building savings.

To incorporate expected interactions, Cadmus adjusted the sum of potential savings from these standards to be equal to the evaluated potential for new single-family construction to provide consistency between these two views of savings and to improve comparability of findings.

Cadmus evaluated the protocol parameters shown in Table 59 for each of these measures based on the IOUs' estimated potential savings, as detailed in Chapter 2 and Chapter 3. Our field research and building analysis found lower ESAF values than the 83% assumed by the IOUs.

Cadmus found that the duct standard B90 contributes the greatest portion of the program net savings. Although we found substantial potential savings for the fenestration standard B85, our analysis found an ESAF of only 47%, whereas the NOMAD panel found that nearly half of the market would already have adopted this level of efficiency.

Table 59. Evaluated Vs. IOU-Estimated Savings for Components of New Single-Family Home Savings

All values for 2015			Units	GWh							MW	Mtherms
				Potential Savings	ESAF	Gross Savings	NOMAD Adjustment	Net Savings	Attrib.	Program Net Savings	Program Net Demand Savings	Program Net Gas Savings
IOU	B84	Env-Wall Insul	22,796	2.69	83%	2.24	-20%	1.79	83%	1.49	1.64	0.37
	B85	Env-Fenest	22,796	14.57	83%	12.09	-49%	6.16	80%	4.93	11.77	(0.11)
	B86	Env-Roof Env	22,796	0.48	83%	0.40	-20%	0.32	68%	0.22	0.39	0.00
	B88	HVAC-WH Fans	22,796	8.82	83%	7.32	-20%	5.86	84%	4.92	-	(0.05)
	B89	HVAC-Zoned AC	22,796	10.05	83%	8.34	-20%	6.68	81%	5.41	7.49	0.12
	B90	HVAC-Duct	22,796	10.19	83%	8.45	-20%	6.77	73%	4.91	-	0.51
		Total		**46.80**	**83%**	**38.84**	**-29%**	**27.58**	**79%**	**21.87**	**21.30**	**0.85**
Eval	B84	Env-Wall Insul	37,040	2.11	76%	1.60	-20%	1.28	83%	1.07	1.29	0.59
	B85	Env-Fenest	37,040	11.40	47%	5.30	-49%	2.70	61%	1.65	4.56	(0.09)
	B86	Env-Roof Env	37,040	0.38	83%	0.31	-20%	0.25	68%	0.17	0.31	0.00
	B88	HVAC-WH Fans	7,408	1.38	59%	0.81	-1%	0.80	84%	0.68	-	(0.01)
	B89	HVAC-Zoned AC	7,408	1.57	42%	0.65	-10%	0.59	66%	0.39	0.85	0.01
	B90	HVAC-Duct	37,040	7.97	68%	5.44	-19%	4.41	71%	3.13	-	0.72
		Total		**24.81**	**57%**	**14.11**	**-29%**	**10.03**	**71%**	**7.09**	**7.01**	**1.22**

4.4.3. B83 RNC Lighting

We present our findings for the RNC lighting standard B83 in Table 60. Although we found that the potential savings were larger because of the higher volume of home construction, our analysis of the 87 sites visited found a slightly negative ESAF. This indicates that new homes are not meeting the requirements of the previous (2008) Title 24 codes.[38] For this reason, we used an ESAF value of 0% and found no savings from this code.

Table 60. Evaluated Vs. IOU-Estimated Savings for Standard B83 RNC Lighting

RNC-Lighting	Year	Units	GWh							MW	Mtherms
			Potential Energy Savings	ESAF	Gross Energy Savings	NOMAD Adjustment	Net Energy Savings	Attrib.	Program Net Energy Savings	Program Net Demand Savings	Program Net Gas Savings
IOU	2015	22,796	2.4	83%	2.0	-20%	1.6	80%	1.3	-	(0.03)
	Total		**2.4**		**2.0**		**1.6**		**1.3**	**-**	**(0.03)**
EVAL	2015	37,040	3.9	0%	0.0	-20%	0.0	80%	-	-	
	Total		**3.9**		**0.0**		**0.0**		**-**	**-**	**-**

38 This was the result of some new homes having incandescent bulbs installed and several with improper controls with high efficacy fixtures. These noncomplying cases had a significant effect on lighting energy use. They had a lesser effect on demand savings because the controls did not affect demand.

4.4.4. B99 Residential Alterations Single Family

Cadmus presents the evaluation results for standard B99 in Table 61. Cadmus changed the start date for this standard to be the effective date of the 2013 Title 24 codes, July 2014, consistent with our general assumption for alteration projects. Potential savings were also adjusted to reflect a higher expected volume of construction. Cadmus applied the ESAF and attribution values used for standard B97, new single-family construction, to this standard.

Table 61. Evaluated Vs. IOU-Estimated Savings for Standard B99

RA-SF Whole Building	Year	Units	GWh							MW	Mtherms
			Potential Energy Savings	ESAF	Gross Energy Savings	NOMAD Adjustment	Net Energy Savings	Attrib.	Program Net Energy Savings	Program Net Demand Savings	Program Net Gas Savings
IOU	2014	0	-	N/A	0.00	N/A	0	N/A	-	-	-
	2015	9,802	6.57	83%	5.45	-20%	4.36	72%	3.14	4.17	0.11
	Total		**6.57**		**5.45**		**4.36**		**3.14**	**4.17**	**0.11**
EVAL	2014	8,029	5.38	67%	3.61	-27%	2.64	68%	1.8	2.68	0.08
	2015	15,927	10.67	67%	7.17	-28%	5.17	68%	3.5	5.25	0.16
	Total		**16.05**		**10.78**		**7.81**		**5.29**	**7.93**	**0.24**

4.5. Findings for All Title 24 Codes

Table 62, Table 63, Table 64, and Table 65 present the three-year total savings from all previously evaluated Title 24 standards and the 2013 Title 24 standards. This enables the team to calculate overall totals for electricity, demand, and gas.

Table 62. 2013–2015 Electricity Savings for Evaluated Title 24 Standards (GWh)*

Standards Group	Potential Energy Savings	Gross Energy Savings	Net Energy Savings	Program Net Energy Savings
2005 T-24	939	797	377	239
2008 T-24	1,166	4,735	2,924	694
2013 T-24 NRA	1,030	923	718	426
2013 T-24 NRNC	404	352	313	213
2013 T-24 Residential	50	32	21	15
Total	**3,589**	**6,839**	**4,354**	**1,586**
PG&E	1,134	2,161	1,376	501
SCE	1,170	2,229	1,420	517
SDG&E	266	506	322	117
All Other	1,019	1,942	1,237	450

*Values may not sum exactly due to rounding.

Table 63. 2013–2015 Demand Savings for Evaluated Title 24 Standards (MW)*

Standards Group	Potential Energy Savings	Gross Energy Savings	Net Energy Savings	Program Net Energy Savings
2005 T-24	270.2	220.5	104.7	61.8
2008 T-24	279.0	1,093.3	679.4	171.2
2013 T-24 NRA	178.8	156.0	118.7	61.6
2013 T-24 NRNC	65.1	53.6	48.9	32.5
2013 T-24 Residential	60.2	46.1	30.4	20.8
Total	**853.2**	**1,569.5**	**982.1**	**347.9**
PG&E	269.6	496.0	310.3	109.9
SCE	278.2	511.7	320.2	113.4
SDG&E	63.1	116.1	72.7	25.7
All Other	242.3	445.7	278.9	98.8

*Values may not sum exactly due to rounding.

Table 64. 2013–2015 Gas Savings for Evaluated Title 24 Standards Including Interactive Effects (MMTherms)*

Standards Group	Potential Energy Savings	Gross Energy Savings	Net Energy Savings	Program Net Energy Savings
2005 T-24	13.13	13.12	10.53	7.88
2008 T-24	29.23	21.00	14.54	15.84
2013 T-24 NRA	1.83	1.36	0.87	-0.31
2013 T-24 NRNC	5.25	4.45	4.33	2.74
2013 T-24 Residential	2.70	2.36	1.86	1.40
Total	**52.13**	**42.29**	**32.13**	**27.55**
PG&E	19.03	15.44	11.73	10.06
SCG	30.44	24.70	18.76	16.09
SDG&E	2.14	1.73	1.32	1.13
All Other	0.52	0.42	0.32	0.28

*Values may not sum exactly due to rounding.

Table 65. 2013–2015 Gas Savings for Evaluated Title 24 Standards Excluding Interactive Effects (MMTherms)*

Standards Group	Potential Energy Savings	Gross Energy Savings	Net Energy Savings	Program Net Energy Savings
2005 T-24	13.22	13.14	10.55	7.90
2008 T-24	34.23	35.31	23.10	17.35
2013 T-24 NRA	3.18	2.59	1.87	0.31
2013 T-24 NRNC	5.56	4.71	4.55	2.91
2013 T-24 Residential	2.78	2.36	1.86	1.40
Total	**58.97**	**58.11**	**41.94**	**29.87**
PG&E	21.52	21.21	15.31	10.90
SCG	34.44	33.94	24.49	17.44
SDG&E	2.42	2.38	1.72	1.22
All Other	0.59	0.58	0.42	0.30

*Values may not sum exactly due to rounding.

4.6. Uncertainty Analysis

As described in Section 1.2 above, the evaluation protocol is used to determine energy and demand savings attributable to the C&S Program. The protocol defines the major factors used to calculate savings. The process begins with an estimate of potential savings, a product of unit savings and market-size estimates, and continues with a series of adjustments to the potential to arrive at savings for each utility. The methods used to determine the various parameters for Title 24 building codes are described in Chapter 2 of this report. The methods used to evaluate parameters for appliance standards are described in Chapter 3 of Volume One of this report[39].

Due to the variety of methods used, each evaluation component is subject to different sources of uncertainty and the uncertainty is associated with sampling, measurement error, and various estimation methodologies. Thus, a simple approach to developing precision estimates based on sampling statistics is not appropriate for quantifying the uncertainty in total energy savings estimates. Instead, Cadmus used a Monte Carlo simulation approach to examine the uncertainty around estimates of cumulative savings in 2013-2015.

4.6.1. Inputs

The Monte Carlo method uses random selection from probability distributions that specify a range of values that each evaluation input can take. In general, we assumed that each input is an estimated mean that could vary according to the properties of a normal distribution centered on the evaluated value (i.e., is symmetric and 95% of the values are within two standard deviations of the mean). Note that in this evaluation, we updated the default distribution to be normal rather than the triangle distribution used in the prior evaluations. We selected the normal distribution based on the fact that most of the evaluation inputs are estimated means and the central limit theorem states that the distribution of estimated means will be approximately normally distributed. We acknowledge that rarely will any random variable conform exactly to the normal distribution assumptions, but do expect the approximation to provide good information on uncertainty for the purposes of this analysis. We used a truncated normal distribution for any evaluation input with finite upper and lower bounds. As an example, NOMAD market adoption rates are strictly bound between zero and one.

Cadmus reviewed all of the inputs to the ISSM and identified the subset that would be allowed to vary in the Monte Carlo analysis. The results of this review are summarized in Table 66.

Cadmus identified a subset of thirteen standards (out of the total 75 standards within the scope of the evaluation) that produce 82% of the net program savings. For this group of standards, we considered each of the major inputs to the ISSM to determine the appropriate distribution type and distribution ranges. The results of this review are summarized in Table 67

39 Cadmus Energy Services. *California Statewide Codes and Standards Program Impact Evaluation Report Phase Two, Volume One: Appliance Standards*, Prepared for the California Public Utilities Commission. 2017.

For all of the remaining evaluated inputs, Cadmus calculated the standard deviation of the mean (i.e., the standard error) based on either 20% relative precision at 90% confidence or precision and confidence reported in the previous or current evaluation.

Table 66. Inputs to Uncertainty Analysis

Protocol Stage	Inputs	Range for Uncertainty Analysis
Potential energy savings	Unit energy savings	Normal distribution centered around evaluation result and standard deviation proportional to the defined range for each standard. • For the thirteen standards with the greatest impact, ranges were set based on standard-specific data as shown in **Error! Reference source not found.**. • For all other standards, a range of +/-20% was used.
	Annual installations (market volume)	
	Interactive effects	Not varied for analysis
	Effective Date	Not varied for analysis
Gross energy savings (Adjustment for noncompliance)	Potential energy savings	See previous protocol stage
	ESAF	Normal distribution centered around evaluation result and standard deviation proportional to +/-20%
Net energy savings (Adjustment for net NOMAD)	Gross energy savings	See previous protocol stage
	Market Adoption Curve	Normal distribution centered around evaluation result and standard deviation proportional to the defined range for each standard • For the thirteen standards with the greatest impact, ranges were set based on standard-specific data as shown in **Error! Reference source not found.**. • For all other standards, a range of +/-20% was used.
	Utility program effects	Not varied for analysis
Net program energy savings (Adjustment for attribution)	Net energy savings	See previous protocol stage
	Weighted attribution score	Normal distribution centered around evaluation result and standard deviation proportional to +/-20%

As noted above, Cadmus reviewed the probability distributions and parameters for a small number of standards responsible for a large part of the net program savings. Specifically, we reviewed the parameters for the thirteen standards that are responsible for 82% of the net program savings (of the standards being evaluated). This review resulted in updating the default distribution assumptions described above, to the values and ranges summarized in Table 67.

Table 67. Inputs for Standards Responsible for Most (82%) GWh Savings

REF [1]	Standard	Unit Energy Savings	Market Volume	ESAF [2]	Comments
Fed 7	General Service Fluorescent Lamps	±20%	±33%	±20%	Unit energy savings and compliance bounds set to default. Market volume bounds based on range of 16.1-32.1 million in the market as a percent of the evaluated input.
Std 9	Residential Pool Pumps, 2-speed Motors, Tier 2	±10%	-19% and +31%	±10%	Unit energy savings and compliance bounds based on previous evaluation. Market volume varies depending on useful life of motors. Evaluation assumes 4 year life and the limits are based on 5 year life and 3 year life. The distribution is skewed and bounded between large positive values, therefore, we used a gamma distribution.[3]
Std 28b	Televisions - Tier 2	±5%	±5%	73% and 99%	Unit energy savings and market volume bounds based on the large amount of high quality data in the NPD database that captures 74% of unit sales data. Compliance evaluated input value is also the upper bound, the lower bound represents the extreme case where none of the units not included in the NPD database are compliant and is highly unlikely. The distribution is therefore skewed and bounded by zero and one, therefore, we used a beta distribution.[4]
Std 29	Small Battery Chargers – Tier 1 (consumer with no USB charger or USB charger <20 watt-hours)	±10%	±20%	±7.5%	Unit energy savings are a weighted average of many product types which we assume varies by less than ±10%. Market volume bounds set to default. Compliance bounds based on a sample of 121 products with evaluated input estimated with 7.5% relative precision at 90% confidence.
Fed 11	Residential Refrigerators & Freezers	±10%	±5%	±3%	Unit energy savings based on extensive product-specific data--we assume the average value varies by less than ±10%. Market size bounds based on AHAM database where we expect ±5% variation from year to year. Compliance bounds based on a sample of 185 products where the evaluated input was estimated with 3% precision at 90% confidence.
Std B34	NRA-Lighting-Alterations-New Measures	±10%	±25%	±19%	Unit energy savings are a weighted average of analysis of many different types of building space. We assume these values vary by less than ±10%. Market volume is based on assumed replacement rates for lighting systems. Since data on actual rates is limited we assume this could vary by ±25%. Compliance bounds based on reported precision
Std B35	NRA-Lighting-Alterations-Existing Measures				
Std B36	NRA-Lighting-Egress Lighting Control				

REF [1]	Standard	Unit Energy Savings	Market Volume	ESAF [2]	Comments
Std B39	NRA-Lighting-Warehouses and Libraries				±19% at 90% confidence for evaluated ESAF estimates (kWh).
Std B46	NRNC-Egress Lighting Control	±10%	±10%	±20%	Unit energy savings are a weighted average of analysis of many different types of building space. We assume these values vary by less than ±10%. Market volume bounds based on the construction activity model maintained by CEC database—we assume that these values vary by ±10%. Compliance bounds set to default.
Std B51	NRNC-Controllable Lighting				
Std B65	NRNC-HVAC-Laboratory Exhaust				
Std B82	NRNC-Whole Building				

[1] These standards account for 2,690, or 82%, of the total 3,277 net program energy savings.

[2] Energy Savings Adjustment Factor or ESAF is the ratio of expected energy savings to potential energy savings.

[3] The gamma distribution is specified with shape parameter set to the evaluated value and is truncated with minimum -19% and maximum +31%. It is asymmetric with mean equal to the evaluated value and values ranging between -19% and +31%. Note that a distribution between zero and ten is used for the Monte Carlo draws and then draws are scaled up to the magnitude of market volume by multiplying by 100,000.

[4] The beta distribution is specified with shape parameters set to 10.0 and 0.01 and truncated with minimum 73% and maximum 99.99%. It is asymmetric with mean 98% and values ranging between ±6%.

4.6.2. Results

We ran the model 1000 times to generate a distribution of savings and adjustment estimates, shown below in Table 68. Because we observed that the combination of positive and negative values for gas savings, resulting from the inclusion of interactive effects, resulted in a great deal of uncertainty in the estimates, we ran the uncertainty analysis with interactive effects turned off for gas.

The 90% confidence intervals for program net energy savings are based on differences between the means and the 5th and 95th percentiles. They are within ±25% of the evaluated values for program net energy savings.

Table 68. Uncertainty Analysis Results

Three-Year Uncertainty Statistics	Evaluated Value	Expected Value and Variation		Percentiles			90% Confidence Interval	
		Mean	StDev	5%	50%	95%	LB	UB
Energy (GWh)								
Potential energy savings	9,983	10,049	1,094	8,407	9,997	11,847	16%	18%
Adjustment for noncompliance [1]	(916)	(1,366)	272	(1,865)	(1,330)	(971)	37%	29%
Gross energy savings	9,067	8,684	980	7,239	8,653	10,274	17%	18%
Adjustment for net NOMAD	(2,916)	(2,779)	419	(3,486)	(2,738)	(2,173)	25%	22%
Net energy savings	6,151	5,905	696	4,819	5,892	7,115	18%	20%
Adjustment for attribution	(2,829)	(2,756)	497	(3,628)	(2,723)	(2,018)	32%	27%
Program Net Energy Savings	**3,322**	**3,149**	**478**	**2,445**	**3,122**	**3,932**	**22%**	**25%**
Demand (MW)								
Potential energy savings	1,663	1,664	238	1,319	1,648	2,067	21%	24%
Adjustment for noncompliance [1]	(151)	(249)	59	(358)	(241)	(168)	44%	32%
Gross energy savings	1,512	1,415	213	1,109	1,400	1,758	22%	24%
Adjustment for net NOMAD	(515)	(478)	100	(655)	(468)	(338)	37%	29%
Net energy savings	997	937	133	747	928	1,164	20%	24%
Adjustment for attribution	(576)	(541)	104	(723)	(532)	(388)	33%	28%
Program Net Energy Savings	**421**	**396**	**51**	**321**	**394**	**482**	**19%**	**22%**
Gas (Mtherms)								
Potential energy savings	39	39	4	33	39	46	16%	18%
Adjustment for noncompliance [1]	(3)	(6)	1	(8)	(5)	(4)	43%	34%
Gross energy savings	36	33	4	28	33	40	17%	19%
Adjustment for net NOMAD	(10)	(9)	2	(12)	(9)	(7)	27%	25%
Net energy savings	26	24	3	19	24	29	19%	22%
Adjustment for attribution	(16)	(15)	2	(19)	(15)	(12)	26%	22%
Program Net Energy Savings	**10**	**9**	**1**	**7**	**9**	**11**	**22%**	**26%**

1 Confidence intervals for the adjustment for noncompliance have large lower bounds because the evaluated value is not in the center of the distribution (a function of the skewed distribution of compliance described above).

5. Conclusions and Recommendations

5.1. Code Savings Estimation

Conclusion: This evaluation highlighted the benefits and challenges of using whole-building savings analyses to establish potential energy savings from Title 24 and evaluate savings. We considered savings attributable to individual code requirements, as well, and identified significant differences between the estimates provided by the two approaches. A weakness in the individual code/measure approach is the lack of a method for taking into account interactions among requirements. The whole building approach using simulations implicitly accounts for interactions.

Conclusion: The IOUs have relied on the analyses conducted for the CEC to estimate whole building code savings. However, the analyses conducted for the CEC have been documented insufficiently for program evaluation purposes and, because they serve a different purpose, they have not taken a comprehensive approach (for example, by including all building types) that would be needed to estimate Title 24 statewide impacts.

Recommendation: Future C&S Program evaluations should rely primarily on whole building analyses to evaluate Title 24 savings. To support this, we recommend that the IOUs, CPUC, and CEC collaborate to develop an approach designed to quantify statewide Title 24 savings using a consistent building simulation approach. We recommend that the program evaluation focus on verifying the inputs, assumptions, and outputs of these simulations and updating them as needed. We recommend that the IOUs develop a CASE report documenting the whole building analyses.

Conclusion: Although the impact estimation would be most efficient and accurate using a whole building analysis, studies of individual code requirements and measures are useful. These analyses provide insights into what measures are expected to have the largest impacts and they inform efforts to improve code compliance.

Recommendation: We recommend that the IOUs continue to document estimated savings and their activities supporting each of the code changes incorporated in each Title 24 update. We also recommend that the IOUs research ways to assess and account for interactions among the individual code changes to increase the consistency with the whole building estimates.

Conclusion: The data collected and estimated on unit savings and construction/alterations during the evaluation can provide a solid basis for estimating the potential savings accurately. With sufficiently large samples and accurate market data, the evaluators could develop an independent estimate of potential savings that could replace an IOU estimate of the potential.

Recommendation: We recommend that the CPUC examine the feasibility and resource requirements needed to rely on the evaluation to estimate the potential Title 24 savings as an alternative to using an estimate provided by the IOUs based on CEC analyses.

Conclusion: For this evaluation, we estimated code energy savings in two ways: (1) comparing the as-built building to the 2008 Title 24 requirements and (2) limiting the as-built building to being no more efficient than required by the 2013 code and comparing the limited values to the 2008 Title 24 requirements. The first approach treats the baseline as the 2008 Title 24 and allows all efficiency improvements over the 2013 Title 24 to contribute to the savings. The second approach also uses the 2008 Title 24 baseline, but assumes that any efficiency improvements over the 2013 Title 24 occur for reasons other than the new code so they do not contribute to program savings. The ESAF factor takes into account the savings of buildings, whether they meet the 2013 Title 24 or not. For the current evaluation, we used a slightly different approach for the appliance standards. Unit savings for appliances are based on the difference between the baseline and new standard efficiencies, but the compliance adjustment just accounts for the proportion of products that meet the new standard.

Recommendation: We recommend that the CPUC continue research on the most appropriate and consistent way to define the baseline, unit savings, and compliance, and examine opportunities to align the evaluation methods used to determine the impacts of both codes and standards.

Conclusion: Acquisition of accurate data on building construction and alterations has been a challenge for each of the C&S Program evaluations. This has been especially problematic for commercial buildings, while the CIRB data provide a fairly reliable estimate of residential new construction. Residential alterations also continue to be difficult to estimate accurately. These data are important for evaluating the Title 24 impacts, but they are critical for all projections of building energy use, such as demand forecasts.

Recommendation: We recommend that the CPUC consider researching diverse sources of building construction and alterations data and collaborating with the CEC in its efforts to improve data for the building sector in response to recent legislation requiring significant increases in building energy savings.

Conclusion: Our efforts to recruit homes to include in this evaluation were most successful when we worked with the building industry, particularly large builders.

Recommendation: We recommend that future evaluations focus on recruiting builders to provide access to homes for purposes of assessing construction practices. We also recommend that the CPUC consider conducting research on the housing market to determine the distribution of construction among large, medium, and small builders to use that information to fill any gaps. We also recommend that future evaluations investigate similar industry sources to provide improved access to commercial buildings for analyses of their construction characteristics.

Conclusion: One challenge faced by the evaluation was identifying buildings that were constructed under the 2013 Title 24. This was especially true for nonresidential buildings, which typically take longer to construct than residential buildings. The lag between when a new code is effective and buildings are constructed under it is important for two reasons. First, it affects the number of buildings available for estimating compliance. In the case of nonresidential buildings, this is particularly problematic as the relatively long time required for construction limits the pool of buildings available to study and tends to increase the proportion of smaller commercial buildings. Second, the savings estimation depends on adjustments to the construction volume based on the length of time required to construct buildings. Based on some limited empirical data, we made assumptions in this analysis about the typical time lag between the code effective date and construction completion.

Recommendation: The CPUC and IOUs should consider conducting both secondary and primary research to establish improved estimates of the lag between code-effective date and construction completion for both residential and commercial buildings. Any such study should address the variation in the lag by building type and market factors, such as construction downturns.

Recommendation: The CPUC should examine ways to develop sufficiently accurate code compliance estimates in the near-term, but plan to true-up the estimates by allowing sufficient time to pass to collect accurate date on code compliance. This is especially true for commercial buildings, which may take longer than a year to complete. The CPUC should consider supplementing the current evaluation of non-residential new construction Title 24 impacts with additional data collection and analysis now that additional buildings have been constructed under the 2013 Title 24.

5.2. Compliance Issues

Conclusion: Compliance of residential buildings with the 2013 Title 24, as measured with the ESAF, is considerably lower than it was when residential compliance was last evaluated for the 2005 Title 24. In that evaluation, the average ESAF exceeded 100%, indicating that, on average, new homes were more efficient than required by the code.

Recommendation: We recommend that the CPUC consider conducting a study with builders and other industry members to understand why compliance has declined with the new code and what types of steps could be taken to improve compliance.

Conclusion: Compliance with some specific code requirements was relatively poor. Examples include the installation of demand-control valves in homes with residential hot water recirculation pumps. Another example was common failure to meet the mandatory daylighting control requirements in commercial buildings, particularly in alterations, and incorrect calculations.

Recommendation: We recommend that the IOUs and CEC target compliance improvement efforts on those code requirements for which the evaluation found relatively poor compliance. The IOUs could conduct additional research to identify specific code requirements that are not being commonly met and use the findings to inform their compliance improvement activities.

5.3. Special Investigations

Conclusion: We conducted two special studies as part of this evaluation to address the potential impacts of noncompliance with specific code mandatory requirements in the 2013 Title 24. One requirement was for daylighting controls in commercial building spaces and the other was application of the proper

PAF in association with controls. We assessed the level of compliance with the daylighting control requirements and the impacts, and we calculated the theoretical effect of improper application of the PAF requirements. Our analyses showed that the energy impacts of both types of measures were very small, on the order of 1% of building consumption.

Recommendation: We recommend that the CPUC minimize the efforts dedicated to analyzing similar requirements, but include them in future evaluations to the extent that evaluation scopes permit.