CONSULTANT REPORT

California Statewide Codes and Standards Program Phase Two, Volume Two: Appendices E – P Impact Evaluation Report

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E. Data Categories Used for Sampling

In order to sample and analyze climate-dependent measures, Cadmus developed five climate regions based on the sixteen climate zones defined by the California Energy Commission. We summarize the mapping of zones to regions and provide a description of each in Table 1. These five climate regions were used in the development of sample strategies for both the nonresidential and the residential categories.

Table 1. Climate Zone to Region Mapping

Climate Region	Climate Zones	Description
A	1, 2, 3, 5	North and Central Coastal Region
B	6, 7, 8, 9, 10	South Coastal Region
C	4, 11, 12, 13	Central Valley
D	14, 15	Desert
E	16	Mountains

Table 2. Building Type Selection

Building Type Category	Building Type Selection
Offices	Small offices and large offices
Retail	Retail
Restaurant	Restaurant
Food Service	Food
Warehouses	Non-refrigerated warehouses
Schools	School and colleges
Miscellaneous	Hotels and miscellaneous
Hospitals	Excluded
Refrigerated warehouses	Excluded

Table 3. Proportion of 2015 Existing Building Stock Population Square Footage by Climate Region and Building Type

Climate Region	Building Type					
	Miscellaneous	Office	Retail	Warehouse	Schools	Total
A	5%	4%	3%	2%	2%	**15%**
B	18%	13%	9%	8%	7%	**55%**
C	8%	6%	4%	4%	3%	**24%**
D	1%	1%	1%	0.6%	0.5%	**4%**
E	1%	0.7%	0.5%	0.4%	0.4%	**3%**
Total	**32%**	**24%**	**17%**	**15%**	**12%**	**100%**

Discrepancies between the sum of cell percentages and the total percentages occur due to rounding errors.

Table 4. Proportion of 2015 Existing Building Stock Sample Frame Square Footage by Climate Region and Building Type

Climate Region	Building Type					
	Miscellaneous	Office	Retail	Warehouse	Schools	Total
A	5%	4%	3%	2%	2%	**16%**
B	19%	14%	10%	9%	7%	**59%**
C	8%	6%	4%	4%	4%	**25%**
Total	**32%**	**24%**	**17%**	**15%**	**12%**	**100%**

Discrepancies between the sum of cell percentages and the total percentages occur due to rounding errors.

Table 5. Proportion of 2015 New Construction Population Square Footage by Climate Region and Building Type

Climate Region	Building Type					
	Miscellaneous	Office	Retail	Warehouse	Schools	Total
A	6%	4%	3%	3%	1%	**17%**
B	17%	12%	9%	8%	4%	**50%**
C	9%	6%	5%	4%	2%	**26%**
D	1%	1%	1%	0.6%	0.3%	**4%**
E	1%	0.7%	0.5%	0.5%	0.2%	**3%**
Total	**34%**	**24%**	**18%**	**16%**	**8%**	**100%**

Discrepancies between the sum of cell percentages and the total percentages occur due to rounding errors.

Table 6. Proportion of 2015 New Construction Sample Frame Square Footage by Climate Region and Building Type

Climate Region	Building Type					
	Miscellaneous	Office	Retail	Warehouse	Schools	Total
A	6%	5%	3%	3%	1%	**18%**
B	18%	13%	10%	9%	4%	**54%**
C	9%	6%	5%	4%	3%	**27%**
Total	**34%**	**24%**	**18%**	**16%**	**8%**	**100%**

Discrepancies between the sum of cell percentages and the total percentages occur due to rounding errors.

F. Approach To Measure Level Analysis

Table 7 was developed to document the standards for which Cadmus worked with EnergySoft (the maker of EnergyPro simulation software) to provide measure-specific parametric analyses for nonresidential standards.

Table 7. Summary of Nonresidential Analysis Approach

REF	End Use	Description	Metrics and Features to Field Verify	GWh Savings (ISSM)	EnergyPro to Report Measure-Level Savings?	Analysis Approach	Collect Data?	Baseline
B82	Whole Building	NRNC Whole Building	Data collection form	179	Yes	EnergyPro	Yes	2008 T24 standard (baseline) model
B43	Lighting	NRNC Lighting Daylighting	Daylighting area and controls	105	Can't model	Manual calculation	Yes	2008 T24 lighting requirements
B56	Envelope	NRNC Envelope Fenestration	U-factor	86	Yes	EnergyPro	Yes	2008 T24 fenestration requirements
			SHGC		Yes	EnergyPro	Yes	2008 T24 fenestration requirements
B51	Lighting	NRNC Controllable Lighting	Lighting power and controls	75	Yes	EnergyPro	Yes	2008 T24 lighting requirements
B57	HVAC	NRNC HVAC Controls, Economizers.	Economizers on smaller units	68	Yes	EnergyPro	Yes	2008 T24 HVAC requirements
			DCV controls		Yes	EnergyPro	Yes	2008 T24 HVAC requirements

Table 8 was developed to document the standards for which Cadmus worked with EnergySoft (the maker of EnergyPro simulation software) to provide measure-specific parametric analyses for residential standards.

Table 8. Summary of Residential Analysis Approach

CASE topic	Metrics and features to field verify	Should EPro report measure level savings?	GWh savings (ISSM)	how to analyze	collecting data?	baseline?
B83 lighting	all bathrooms have at least one high efficacy luminaire, and all other lighting in each bathroom is high efficacy or controlled by vacancy sensors	can't model	2.4	manual calc	yes	2008 T24 mandatory lighting requirements
	garages, laundry rooms, and utility rooms: all lighting is high efficacy & controlled with vacancy sensors	can't model		manual calc	yes	
	kitchens: up to 50 watts for dwelling units ≤ 2,500 sf & 100 watts for larger dwelling units may be exempt from the 50% high efficacy requirement when all lighting in the kitchen is controlled in accordance with section 150.0(k)2, and is controlled by vacancy sensors or dimmers	can't model		manual calc	yes	
B84 wall insulation	insulation R-value in cavity	No because these features are not separate requirements. Need to meet U-0.065 for wall assembly	2.7	EnergyPro simulation	yes	2008 T24 Table 151-C Component Package D: Wall U-factors by CTZ
	insulation R-value of continuous insulation				yes	
	framing material, size, spacing				yes	
	other assembly details to calc total U-factor				yes	
B85 fenestration	area-weighted average U-factor	yes	14.6	EnergyPro simulation	yes	2008 T24 Table 151-C Component Package D: Fenestration U-factors & SHGC
	SHGC	yes			yes	
B88 whole house fans	fan airflow	no standard	8.8	note if this compliance option is present or not	yes	no whole house fan installed
	fan efficiency (W/cfm)	no standard			yes	
	fixed or variable speed motor	can't model			yes	
	HVAC cooling capacity?? Needed or no??	can't model			yes	
B89 zoned air conditioning	is compressor single or variable speed	no standard	10.0	EnergyPro simulation	yes	include recirculation bypass duct
	air handler efficiency (cfm/ton) for multi-zoned systems	yes			yes	
	fan efficiency (W/cfm)	yes			yes	
	eliminate bypass ducts that recirculate cooled air back to the return system	yes			yes	
B90 HVAC ducts	air handler efficiency (cfm/ton)	yes unless taking exception for return duct sizing	10.2	EnergyPro simulation	yes	300 cfm/ton and 0.80 W/CFM per CASE report baseline
	fan efficiency (W/cfm)	yes unless taking exception for return duct sizing			yes	
	HVAC cooling capacity	no standard			yes	
	return duct diameter	can't model			yes	
	total return grille gross area	can't model			yes	
	duct leakage rate (% of nominal airflow)	yes			yes	
B97 whole building	need 2008 standard, 2013 standard, and 2013 proposed whole bldg (total)	yes	15.3	EnergyPro simulation	yes	2008 standard (baseline) model

G. Energy Savings Adjustment Factor Detail

Cadmus 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. We 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 calculated building type and statewide energy savings adjustment factors (ESAFs) as the ratio of estimated population evaluated savings to population expected savings, and provided relative precisions around these ratios. Relative precision is the margin of error relative to the point estimate, and provides a range around the point estimate that contains the true population value. For example, we estimated an NRA population total electric energy savings of 600 million kWh with 19% relative precision at 90% confidence: we can state that the true NRA population total savings falls within the range of ±19% of 600 million kWh. Large relative precision estimates occur when there is a large amount of variability in the data, thus introducing less certainty in our population estimate. Cadmus provides evaluated savings, expected savings, ESAFs, and relative precisions by building type and at the statewide level for nonresidential lighting alterations and new construction sites, and by climate regions for residential new construction sites.

ESAF values can be interpreted as the proportion of actual savings a building achieved out of its expected savings based on improvements in the Title 24 codes. We observed the following scenarios:

- **Evaluated savings and expected savings were both positive.** This results in a positive ESAF value. We expected the building to consume less under the 2013 code than under the 2008 code, and it did.
- **Evaluated savings and expected savings were both negative.** This results in a positive ESAF value. We expected the building to consume more in the 2013 code than in the 2008 code, and it did.
- **Either the expected or evaluated savings estimates is negative while the other is positive.** This results in a negative ESAF value:
    - *Negative evaluated savings combined with positive expected savings* implies that the building consumed more than expected under the 2008 codes, but we expected consumption to decrease from the 2008 to 2013 codes.
    - *Positive evaluated savings combined with negative expected savings* implies that the building consumed less than expected under the 2008 codes, but we expected consumption to increase from the 2008 to 2013 codes.

Table 9. Nonresidential Lighting Alteration Unbounded ESAFs and Precision Estimates

Climate Region	Sample Size	Compliance Measurement	Evaluated Savings	Expected Savings	ESAF	Relative Precision (at 90% Confidence)
Miscellaneous	9	kWh	128,226,411	89,699,437	143%	24%
		kW	29,006	18,037	161%	22%
		Therms	1,088,257	54,586	1994%	149%
Office	19	kWh	237,405,606	154,669,852	153%	27%
		kW	57,804	32,148	180%	22%
		Therms	(158,862)	198,202	-80%	265%
Retail	7	kWh	175,774,011	150,537,899	117%	54%
		kW	40,020	34,035	118%	53%
		Therms	(524,423)	(446,099)	118%	60%
Restaurant	10	kWh	22,832,240	-	NA	NA
		kW	5,288	-	NA	NA
		Therms	(179,797)	-	NA	NA
Warehouse	4	kWh	27,107,143	4,680,394	579%	181%
		kW	9,456	1,563	605%	179%
		Therms	(72,553)	(18,397)	394%	188%
Statewide	49	kWh	591,345,411	399,587,582	148%	19%
		kW	141,574	85,783	165%	18%
		Therms	152,622	(211,708)	-72%	N/A*

*Cadmus determined it is inappropriate to report precision estimates at the statewide level due to a combination of positive and negative savings from the different building type strata.

Table 10. Nonresidential Lighting Alteration Bounded ESAFs

Climate Region	Sample Size	Compliance Measurement	Evaluated Savings	Expected Savings	ESAF	Relative Precision (at 90% Confidence)
Miscellaneous	9	kWh	84,761,542	89,699,437	94%	29%
		kW	17,399	18,037	96%	26%
		Therms	54,151	54,586	99%	177%
Office	19	kWh	153,358,407	154,669,852	99%	30%
		kW	31,915	32,148	99%	17%
		Therms	165,429	198,202	83%	110%
Retail	7	kWh	121,619,051	150,537,899	81%	48%
		kW	25,569	34,035	75%	42%
		Therms	(293,146)	(446,099)	66%	88%
Restaurant	10	kWh	-	-	N/A	N/A
		kW	-	-	N/A	N/A
		Therms	-	-	N/A	N/A
Warehouse	4	kWh	4,680,394	4,680,394	100%	163%
		kW	1,563	1,563	100%	140%
		Therms	(511)	(18,397)	3%	2473%
Statewide	49	kWh	364,419,394	399,587,582	91%	20%
		kW	76,445	85,783	89%	15%
		Therms	(74,076)	(211,708)	35%	N/A*

*Cadmus determined it is inappropriate to report precision estimates at the statewide level due to a combination of positive and negative savings from the different building type strata.

Table 11. Nonresidential New Construction Unbounded ESAFs and Precision Estimates

Climate Region	Sample Size	Compliance Measurement	Evaluated Savings	Expected Savings	ESAF	Relative Precision (at 90% Confidence)*
Miscellaneous	5	kWh	224,609,976	58,274,418	385%	10%
		kW	47,250	11,805	400%	14%
		Therms	2,096,082	(105,469)	-1987%	139%
Office	3	kWh	94,629,975	61,844,817	153%	N/A
		kW	42,814	26,817	160%	N/A
		Therms	3,249,762	178,737	1818%	N/A
Retail	7	kWh	68,434,137	132,309,817	52%	N/A
		kW	34,810	40,184	87%	N/A
		Therms	2,465,552	(838,186)	-294%	N/A
Restaurant	2	kWh	19,443,591	21,031,724	92%	N/A
		kW	10,852	8,006	136%	N/A
		Therms	4,593,524	1,288,008	357%	N/A
Statewide	17	kWh	407,117,678	273,460,777	149%	N/A
		kW	135,726	86,811	156%	N/A
		Therms	12,404,920	523,089	2371%	N/A

*Statewide precision estimates were unable to be determined due to the fact that site were sampled within jurisdictions, and since the sample sizes were small, we did not have sufficient sites within jurisdictions to obtain building type or statewide precision estimates.

Table 12. Nonresidential New Construction Bounded ESAFs

Climate Region	Sample Size	Compliance Measurement	Evaluated Savings	Expected Savings	ESAF	Relative Precision (at 90% Confidence)*
Miscellaneous	5	kWh	58,274,418	58,274,418	100%	0.13%
		kW	11,805	11,805	100%	59%
		Therms	(105,469)	(105,469)	100%	3%
Office	3	kWh	50,774,071	61,844,817	82%	N/A
		kW	26,817	26,817	100%	N/A
		Therms	178,737	178,737	100%	N/A
Retail	7	kWh	125,412,464	132,309,817	95%	N/A
		kW	24,339	40,184	61%	N/A
		Therms**	(192,115)	(838,186)	23%	N/A
Restaurant	2	kWh	19,443,591	21,031,724	92%	N/A
		kW	8,006	8,006	100%	N/A
		Therms	1,288,008	1,288,008	100%	N/A
Statewide	17	kWh	253,904,544	273,460,777	93%	N/A
		kW	70,966	86,811	82%	N/A
		Therms	1,169,160	523,089	224%**	N/A

*Statewide precision estimates were unable to be determined due to the fact that site were sampled within jurisdictions, and since the sample sizes were small, we did not have sufficient sites within jurisdictions to obtain building type or statewide precision estimates.
** At the site level, some Retail sites achieved positive evaluated savings when they had negative expected savings. When these sites were bounded at 100% of expected savings, Retail sites overall achieved negative evaluated savings. However, because of the sites that achieved positive bounded evaluated savings, the overall bounded evaluated savings are still greater than the overall expected savings (though both negative), leading therms to achieve greater than 100% at the statewide level.

Table 13. Residential Unbounded ESAFs and Precision Estimates

Climate Region	Sample Size	Estimates	kWh			kW			Therms		
			Non-Lighting	Lighting	Combined	Non-Lighting	Lighting	Combined	Non-Lighting	Lighting	Combined
A	33	Evaluated Savings	319,415	-101,988	217,427	1,861	10	1,871	267,156	N/A	267,156
		Expected Savings	711,067	312,380	1,023,447	1,637	20	1,656	295,794	N/A	295,794
		ESAF	44.9%	-32.6%	21.2%	113.7%	51.8%	113.0%	90.3%	N/A	90.3%
		Relative Precision (at 90% confidence)	97.8%	143.7%	132.2%	43.7%	61.6%	43.5%	28.1%	N/A	28.1%
B	32	Evaluated Savings	5,328,264	786,359	6,114,623	13,109	97	13,206	843,350	N/A	843,350
		Expected Savings	8,390,110	2,423,713	10,813,823	16,980	195	17,175	358,888	N/A	358,888
		ESAF	63.5%	32.4%	56.5%	77.2%	49.5%	76.9%	235.0%	N/A	235.0%
		Relative Precision (at 90% confidence)	39.4%	112.2%	45.7%	45.2%	97.3%	45.6%	15.2%	N/A	15.2%
C	22	Evaluated Savings	6,333,511	-1,034,743	5,298,768	10,334	69	10,402	2,917,434	N/A	2,917,434
		Expected Savings	8,558,617	1,185,594	9,744,211	13,272	81	13,353	1,399,702	N/A	1,399,702
		ESAF	74.0%	-87.3%	54.4%	77.9%	84.6%	77.9%	208.4%	N/A	208.4%
		Relative Precision (at 90% confidence)	49.1%	142.7%	72.9%	47.6%	31.5%	47.2%	33.1%	N/A	33.1%
Statewide	87	Evaluated Savings	11,981,190	-350,373	11,630,817	25,304	175	25,479	4,027,940	N/A	4,027,940
		Expected Savings	17,659,794	3,921,687	21,581,481	31,889	296	32,185	2,054,384	N/A	2,054,384
		ESAF	67.8%	-8.9%	53.9%	79.3%	59.2%	79.2%	196.1%	N/A	196.1%
		Relative Precision (at 90% confidence)	31.4%	492.7%*	41.1%	30.6%	55.2%	30.7%	24.2%	N/A	24.2%

* 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..

Table 14. Residential Bounded ESAFs

Climate Region	Sample Size	Estimate	kWh			kW			Therms		
			Non-Lighting	Lighting	Combined	Non-Lighting	Lighting	Combined	Non-Lighting	Lighting	Combined
A	33	Evaluated Savings	300,482	-102,335	198,146	1,447	10	1,457	143,967	N/A	143,967
		Expected Savings	711,067	312,380	1,023,447	1,637	20	1,656	295,794	N/A	295,794
		ESAF	42.3%	-32.8%	19.4%	88.4%	51.8%	88.0%	48.7%	N/A	48.7%
B	32	Evaluated Savings	5,253,175	769,108	6,022,282	12,789	97	12,885	311,794	N/A	311,794
		Expected Savings	8,390,110	2,423,713	10,813,823	16,980	195	17,175	358,888	N/A	358,888
		ESAF	62.6%	31.7%	55.7%	75.3%	49.5%	75.0%	86.9%	N/A	86.9%
C	22	Evaluated Savings	6,318,921	-1,035,245	5,283,677	9,956	69	10,025	1,340,730	N/A	1,340,730
		Expected Savings	8,558,617	1,185,594	9,744,211	13,272	81	13,353	1,399,702	N/A	1,399,702
		ESAF	73.8%	-87.3%	54.2%	75.0%	84.6%	75.1%	95.8%	N/A	95.8%
Statewide	87	Evaluated Savings	11,872,578	-368,472	11,504,106	24,192	175	24,367	1,796,491	N/A	1,796,491
		Expected Savings	17,659,794	3,921,687	21,952,538	31,889	296	32,185	2,054,284	N/A	2,054,284
		ESAF	67.2%	-9.4%	53.3%	75.9%	59.2%	75.7%	87.4%	N/A	87.4%

H. Potential Energy Savings - Nonresidential

Introduction

This appendix summarizes Cadmus' evaluation of potential energy and demand savings for the following nonresidential standards:

1. B34: NRA Lighting Alterations, New Measures
2. B35: NRA Lighting Alterations, Existing Measures
3. B41: NRA Equipment Efficiency—recently added
4. B36, B46: NRA and NRNC Egress Lighting Control
5. B39, B49: NRA and NRNC Lighting-Warehouses and Libraries
6. B82: NRNC Whole Building
7. B45: NRNC Lighting-Retail
8. B43: NRNC Daylighting
9. B51: NRNC Controllable Lighting
10. B58: NRNC Fan Control & Economizers
11. B61: NRNC Kitchen Ventilation
12. B63: NRNC Chiller Minimum Efficiency
13. B65: NRNC Laboratory Exhaust
14. B57: NRNC HVAC Controls and Economizers
15. B75: NRNC Supermarket Refrigeration
16. B78: NRNC Data Centers
17. B54: NRNC Office Plug Load Control
18. B56: NRNC Fenestration
19. B50: NRNC Lighting-Parking Garage
20. B66: NRNC Small HVAC motors

Interactive Effects

Final evaluated savings include interactive effects where appropriate. For nonresidential alterations measures, building alterations may occur that require compliance only with the Title 24 standards applicable to the system type altered. For example, a lighting retrofit project will trigger compliance with Title 24 lighting alterations standards, but will not trigger compliance with the Title 24 HVAC alterations standards if the HVAC system is not altered. Therefore, for nonresidential alterations measures, Cadmus did not calculate savings impacts from the overlap among multiple alterations standards. Cadmus only considered impacts to energy consumption of other building systems based on compliance with nonresidential alterations standards, most notably for the impact on building HVAC system operation resulting from lighting system efficiency improvements.

For nonresidential new construction standards, Cadmus accounted for the implementation of multiple standards concurrently in a newly constructed building. The investor-owned utility (IOU) estimates for most new construction standards did not account for the interaction between multiple new construction standards; thus, the evaluated savings for many new construction standards were lower than the original IOU estimates. Standard B82: Whole Building captured savings from multiple Title 24 new construction standards simultaneously through a whole building energy simulation approach. Standard B82 overlapped with seven individual new construction standards also submitted for evaluation. To account for the interactions between the individual standards, Cadmus scaled the evaluated savings for each individual measure so that the sum of individual standard savings equaled the total savings evaluated for standard B82. Cadmus excluded negative gas interactive effects for lighting standards for the gas scaling factor calculation to minimize an inflated gas scaling factor. Therefore, no negative interactive effects were evaluated for the individual lighting standards that overlap with the whole building standard. Cadmus also excluded electric interactive effects where possible for lighting standards from the electric scaling factors. The scaling factor approach is described in the Potential Energy section of the main report, and is shown in Table 15 below.

For nonresidential new construction standards likely to be implemented in a commercial building simultaneously with other new construction standards, Cadmus applied the whole building scaling factors described in the previous paragraph to account for the interactions between standards and the resulting reduced potential energy savings. Because the gas scaling factor was skewed by negative savings for some individual standards that overlapped with standard B82, Cadmus did not apply the gas scaling factor to these additional nonresidential new construction standards to avoid inflated results. Instead of applying the gas whole building scaling factor, Cadmus only applied a negative gas interactive effects factor for lighting standards and no interaction factor for non-lighting standards.

In Table 15, each of the electric factors listed was multiplied by the GWh per year or MW evaluated savings estimate, as appropriate, to calculate final evaluated electric impacts with interactive effects included. The gas energy interactive effects factor was multiplied by the GWh per year evaluated savings estimates to calculate final evaluated gas impacts (for standards affecting electric end uses in conditioned spaces).

Table 15.Nonresidential Potential Final Evaluated Energy Savings: Interactive Effects Factors Applied

Standard Evaluated	Electric Energy Interactive Effects Factor (kWh/kWh)	Electric Demand Interactive Effects Factor (kW/kW)	Gas Energy Interactive Effects Factor (therms/kWh)	Notes
Alterations				
B35: Lighting Alterations, Existing Measures	1.10	1.32	-0.0041	Interactive effects caused by lighting impacts on HVAC systems
B34: Lighting Alterations, New Measures	N/A	N/A	N/A	Whole building energy savings analysis did not require additional interactive effects multipliers.

Standard Evaluated	Electric Energy Interactive Effects Factor (kWh/kWh)	Electric Demand Interactive Effects Factor (kW/kW)	Gas Energy Interactive Effects Factor (therms/kWh)	Notes
B41: HVAC Equipment Efficiency	N/A	N/A	N/A	Whole building energy savings analysis did not require additional interactive effects multipliers.
B36: Egress Lighting Controls	N/A	N/A	N/A	Interactive effects not included because of savings occurring during unoccupied and unconditioned building times
B39: Warehouse and Library Lighting	1.10	1.32	-0.0041	Interactive effects caused by lighting impacts on HVAC systems
New Construction				
B82: Whole Building	N/A	N/A	N/A	Whole building energy savings analysis did not require additional interactive effects multipliers.
B43: Daylighting	0.733	0.833	264.017	Scaling factor applied because of overlap with standard B82: Whole Building. Gas scaling factor is large because only two whole building standards had evaluated gas savings, which were then scaled to the whole building gas impacts.
B56: Fenestration	0.733	0.833	264.017	Scaling factor applied because of overlap with standard B82: Whole Building. Gas scaling factor is large because only two whole building standards had evaluated gas savings, which were then scaled to the whole building gas impacts.
B45: Retail Lighting	0.733	0.833	264.017	Scaling factor applied because of overlap with standard B82: Whole Building. Gas scaling factor is large because only two whole building standards had evaluated gas savings, which were then scaled to the whole building gas impacts.
B58: Fan Control & Economizers	0.733	0.833	264.017	Scaling factor applied because of overlap with standard B82: Whole Building. Gas scaling factor is large because only two whole building standards had evaluated gas savings, which were then scaled to the whole building gas impacts.
B61: Kitchen Ventilation	0.733	0.833	264.017	Scaling factor applied because of overlap with standard B82: Whole Building. Gas scaling factor is large because only two whole building standards had evaluated gas savings, which were then scaled to the whole building gas impacts.
B63: Chiller Minimum Efficiency	0.733	0.833	264.017	Scaling factor applied because of overlap with standard B82: Whole Building. Gas scaling factor is large because only two whole building standards had evaluated gas savings, which were then scaled to the whole building gas impacts.
B57: Economizer Controls	0.733	0.833	264.017	Scaling factor applied because of overlap with standard B82: Whole Building. Gas scaling factor is large because only two whole building standards had evaluated gas savings, which were then scaled to the whole building gas impacts.
B51: Controllable Lighting	0.733	0.833	-0.0041	Whole building interactive effects factor included to account for interaction of new construction standards implemented simultaneously within whole building setting.
B65: HVAC-Laboratory Exhaust	N/A	N/A	N/A	
B66: Small ECM Motor	0.733	0.833	N/A	Whole building electric interactive effects factor included to account for interaction of new construction standards implemented simultaneously within whole building setting.

Standard Evaluated	Electric Energy Interactive Effects Factor (kWh/kWh)	Electric Demand Interactive Effects Factor (kW/kW)	Gas Energy Interactive Effects Factor (therms/kWh)	Notes
B49: Warehouse and Library Lighting	0.733	0.833	-0.0041	Whole building electric interactive effects factor included to account for interaction of new construction standards implemented simultaneously within whole building setting.
B78: Process-Data Centers	N/A	N/A	N/A	
B50: Parking Garage Lighting	N/A	N/A	N/A	Interactive effects not included because savings occur in unconditioned space
B46: Egress Lighting Control	N/A	N/A	N/A	Interactive effects not included because savings occur during unoccupied and unconditioned building times
B75: Supermarket Refrigeration	N/A	N/A	N/A	Interactive effects not included because savings overlap between this standard and other new construction standards is assumed to be negligible.
B54: Office Plug Load Control	0.733	0.833	-0.0041	Whole building electric interactive effects factor included to account for interaction of new construction standards implemented simultaneously within whole building setting.
Standards Not Formally Evaluated, but Adjusted for Standard Interactions				
B47: Multifamily Building Corridor Lighting	0.733	0.833	-0.0041	Whole building electric interactive effects factor included to account for interaction of new construction standards implemented simultaneously within whole building setting.
B73: HVAC Acceptance Requirements	0.733	0.833	N/A	
B74: Warehouse Refrigeration	0.733	0.833	N/A	
B48: Hotel Corridor Lighting	0.733	0.833	-0.0041	
B52: Demand Response Lighting	0.733	0.833	-0.0041	

Standard Evaluated	Electric Energy Interactive Effects Factor (kWh/kWh)	Electric Demand Interactive Effects Factor (kW/kW)	Gas Energy Interactive Effects Factor (therms/kWh)	Notes
B69: Occupant-Controlled Smart Thermostats	0.733	0.833	N/A	
B59: HVAC Reduced Reheat	0.733	0.833	N/A	
B70: Low Temperature Radiant Cooling	0.733	0.833	N/A	
B72: HVAC Outside Air	0.733	0.833	N/A	

H.1. B34: Nonresidential Lighting Alterations, New Measures

Table 16 lists the findings Cadmus used to estimate potential energy savings for B34: Nonresidential Lighting Alterations, New Measures.

Table 16. Nonresidential Annual Potential Energy Savings Estimates: Standard B34

Description	IOU Estimate	Evaluated*
Total electric energy savings (GWh/yr)	221.5	232.293
Total demand reduction (MW)	42.8	45.1
Total gas energy savings (MMtherms/yr)	-1.29	-0.41
Total applicable units (Million sq. ft.)	404.8	402.0

* Evaluated savings in this table include interactive effects because of the whole building savings analysis approach.

H.1.a. Standard Description

Standard B34: Nonresidential Lighting Alterations, New Measures requirements are listed in Sections 130.1 and 140.6 of the 2013 Title 24 California Building Energy Efficiency Standards. To calculate savings for this standard, Cadmus used the energy savings results from the California Energy Commission's (CEC's) 2013 Building Efficiency Standards Impact Analysis between the following baseline and standard cases:[1]

[1] 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

- **Baseline**: The baseline scenario covers lighting alterations compliant with the CEC's 2008 nonresidential building efficiency standards for lighting system alterations, sections 131 and 146.[2] Sections 131 and 146 describe mandatory requirements for lighting system controls and lighting power density (LPD) levels.
- **Standard:** The standard covers lighting alterations compliant with the CEC's 2013 nonresidential building efficiency standards for lighting system alterations, sections 130.1 and 140.6.[3] Sections 130.1 and 140.6 describe mandatory requirements for lighting system controls and LPD levels.

H.1.b. IOU-Estimated Potential Energy Savings Estimates

Unit Energy Savings Estimates

The IOUs developed statewide potential savings estimates using unit energy savings (UES) estimates for standard B34 that were based on results from CEC's 2013 Building Efficiency Standards Impact Analysis. The analysis relied on EnergyPlus Version 6 building simulation software to model energy consumption for multiple building types in California's 16 climate zones. The CEC impact analysis leveraged Department of Energy (DOE) building prototype models, which were modified to be compliant with the CEC's building efficiency standards for two scenarios: 2008 standards and 2013 standards. Because the DOE building prototypes did not fully align with the building types used for CEC's building construction forecast in California,[4] the CEC impact analysis weighted some of the DOE building prototype results together to estimate savings for a single CEC construction building type.

The CEC impact analysis report presented results for six building types that align with CEC's construction forecast: large office, restaurant, retail, non-refrigerated warehouse, school, and hotel. The CEC's impact analysis did not include results for the following forecast building types because of uncertainty in building characteristics, lack of DOE prototypes, and/or lack of sufficient baseline information: small office, food, refrigerated warehouse, college, and miscellaneous. The impact analysis did not model hospitals because building efficiency standards did not apply to the hospital sector.

The IOUs estimated savings for the six building types not included in CEC's impact analysis by calculating an average UES for the six modeled building types, weighted by the square footage of

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2 CEC. *2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings.* CEC-400-2008-001-CMF. December 2008. Available online: http://www.energy.ca.gov/2008publications/CEC-400-2008-001/CEC-400-2008-001-CMF.PDF

3 CEC. *2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings*. CEC-400-2012-004-CMF-REV2, May 2012. Available online: http://www.energy.ca.gov/2012publications/CEC-400-2012-004/CEC-400-2012-004-CMF-REV2.pdf

4 The building types used for CEC's new construction forecast are the same as CEC's existing building stock building types.

existing building stock associated with each modeled building type. The IOUs applied this weighted average to each of the building types not included in the CEC impact analysis (except hospitals). The IOUs documented their analysis in a workbook titled *Lighting Alteration savings estimate—For Cadmus.xls* and provided it to Cadmus in response to a data request. Table 17 shows the IOU-estimated results.

Table 17. IOU-Estimated UES by Forecast Building Type

Forecast Building Type	UES (kWh/ sq. ft./yr)	UES (W/ sq. ft.)	UES (therms/ sq. ft./yr)	Building Type Proxy for UES
Office: small	0.547	0.106	-0.001	Weighted average
Office: large	0.557	0.085	0.000	N/A
Restaurant	0.000	0.000	0.000	N/A
Retail	1.454	0.310	-0.004	N/A
Food	0.547	0.106	-0.001	Weighted average
Non-refrigerated warehouse	0.015	0.002	-0.000	N/A
Refrigerated warehouse	0.547	0.106	-0.001	Weighted average
School	0.022	0.003	0.000	N/A
College	0.547	0.106	-0.001	Weighted average
Hospital	0.547	0.106	-0.001	Weighted average
Hotel	0.181	0.025	-0.000	N/A
Miscellaneous	0.547	0.106	-0.001	Weighted average

* Although IOUs estimated unit energy savings for hospitals, they reported the applicable square footage as zero.

Statewide Potential Energy Savings Estimate

The IOUs calculated the applicable square footage of standard B34 for each forecast building type using CEC's forecasted existing floor stock for the year 2014, as reported in the CEC impact analysis report completed in 2013.[5] The CEC impact analysis assumed that lighting systems were replaced every 15 years, and, thus, the lighting alterations savings applied to one-fifteenth of the total existing floor area per building type per year. The IOUs used this same assumption in their estimates of applicable square footage; they reduced the applicable square footage estimate further by removing the estimated portion of square footage for which lighting alteration projects would not be required to comply with the 2013 building efficiency standard requirements.

The IOUs determined the reduced square footage by estimating the portion of lighting alteration projects in which 10% or more of luminaires in a space are modified, which is the trigger that requires lighting alteration projects to comply with the 2013 building efficiency standards. To support the

5 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

development of the lighting alterations Codes and Standards Enhancement Initiative (CASE) report,[6] the CASE report authors conducted an online survey of lighting retrofit stakeholders (designers, contractors, and program implementers) in 2011, receiving 26 responses. According to the CASE report, responses from the stakeholder survey indicated that 69% of lighting alterations spaces replace 50% or more of luminaires in a space, and 21% of spaces replace between 10% and 50% of luminaires in a space. Although the CASE report stated that 21% of spaces replace between 10% and 50% of luminaires in a space, the supporting analysis[7] assumed that 22% of spaces replaced between 10% and 50% of luminaires in a space, for a total of 91% of spaces replacing between 10% and 100% of luminaires in a space.[8]

Table 18 lists the IOUs’ assumptions for applicable square footage by building type for standard B34.

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6 Chappell, Rasin. Codes and Standards Enhancement Initiative (CASE) Final Report – Lighting Alterations and Modifications in Place. June 2013.

7 IOUs. *Lighting Alteration savings estimate—For Cadmus.xls.* IOUS submitted this workbook to Cadmus in December 2015.

8 *Ibid.* According to this workbook, 91% was calculated as the sum of 22% and 69%, the percentage of spaces replacing between 10% and 50% and over 50% of luminaires, respectively. The 22% figure used in the analysis differed from the corresponding quantity of 21% reported in the CASE report.

Table 18. IOU Assumptions for Applicable Square Footage by Forecast Building Type

Forecast Building Type	Total Existing Floor Area: 2013 CEC Forecast (Million sq. ft.)	Total Lighting Alteration Floor Area* (Million sq. ft./yr)	Total Lighting Alteration Floor Area Applicable to B34 Standard** (Million sq. ft./yr)
Office: small	397	26	24
Office: large	1,286	86	78
Restaurant	191	13	12
Retail	1,176	78	71
Food	311	21	19
Non-refrigerated warehouse	1,057	70	64
Refrigerated warehouse	59	4	4
School	554	37	34
College	349	23	21
Hospital	353	24	0
Hotel	331	22	1***
Miscellaneous	1,272	85	77
Total	**7,336**	**489**	**405**

* IOUs calculated the total lighting alteration area per year as (total existing floor area) x (1/15) for each building type.

** IOUs calculated the total lighting alteration floor area applicable to standard B34 as (total lighting alteration area) x (22% + 69%) for each building type.

*** IOUs applied a 6.2% factor to calculate applicable hotel square footage. No explanation was provided.

Table 19 shows the total annual electric and gas savings reported by the IOUs for this standard. The IOUs calculated statewide savings by multiplying UES estimates by applicable square footage for each building type. Cadmus could not reproduce the reported annual gas impact estimate. Additionally, the reported annual gas estimate differed from the supporting analysis submitted by the IOUs, which detailed calculations for an annual gas impact estimate of -0.4 million therms per year.

Table 19. IOU-Estimated Annual Energy Savings Estimate: Standard B34

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
221.5	42.8	-1.29

H.1.c. Evaluation Findings

Unit Energy Savings

Cadmus accepts the CEC impact analysis as the best source for determining UES estimates for standard B34.[9] We also agree that estimating impacts for the building types excluded from the CEC impact analysis is reasonable, but instead of using a weighted average of all building types as a proxy for the excluded building types, we used similar building types as proxies in most cases for the evaluation analysis. Table 20 lists the evaluated UES estimates, including assumptions for the excluded building types.

The UES estimates for the CEC impact analysis were reported by building type and climate zone.[10] Thus, to develop UES estimates for a building type excluded from the CEC impact analysis, Cadmus used a proxy building type included in the CEC analysis. We then calculated a weighted average UES, weighted by the square footage per climate zone of the excluded building type. For example, Cadmus used the large office UES as a proxy for the small office UES (the CEC analysis excluded small offices). To calculate an average UES for small offices, we averaged the large office UES values for each climate zone together based on the proportion of small office square footage in each climate zone.

Cadmus evaluated the potential overlap between this standard and standard B39: Warehouse Lighting Alterations and B38: Hotel Corridor Lighting Alterations. Based on a review of the CEC impact analysis report, Cadmus determined that the warehouse and hotel corridor occupancy sensors required by the 2013 Title 24 lighting alterations requirements were likely not modeled in the CEC analysis, and therefore the savings for standard B34 do not overlap with standards B39 and B38.

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9 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

10 The IOUs provided a summary of the building model outputs for the CEC impact analysis by CEC forecast building type and climate zone in December 2015 (originally sourced from the CEC). The analysis is not publicly available and must be requested from the CEC.

Table 20. Evaluated Unit Energy Savings (UES) by Building Type

Forecast Building Type	UES (kWh/ sq. ft./yr)	UES (W/ sq. ft)	UES (therms/ sq. ft./yr)	Building Type Proxy for UES
Office: small	0.563	0.086	0.000*	Used large office UES, weighted by small office square footage by climate zone
Office: large	0.561	0.086	0.000*	N/A
Restaurant	0.000	0.000	0.000	N/A
Retail	1.463	0.312	-0.004	N/A
Food	1.468	0.314	-0.004	Used retail UES, weighted by food square footage by climate zone**
Non-refrigerated warehouse	0.015	0.002	0.000*	N/A
Refrigerated warehouse	0.015	0.002	0.000*	Used non-refrigerated warehouse UES, weighted by refrigerated warehouse square footage by climate zone**
School	0.022	0.003	0.000*	N/A
College	0.022	0.003	0.000*	Used school UES, weighted by college square footage by climate zone
Hospital	N/A	N/A	N/A	Not included because of inapplicability of 2013 building efficiency standards
Hotel	0.182	0.025	0.000*	N/A
Miscellaneous	0.532	0.103	-0.001	Weighted average of all 11 building types UES estimates

* Impact of less than 0.0005 therms/sq.ft./yr rounds to zero.

** Cadmus considered lighting operating characteristics and occupancy patterns for retail buildings to be reasonably close to grocery stores. We also considered lighting characteristics and occupancy patterns to be reasonably similar between refrigerated and non-refrigerated warehouses.

Applicable Square Footage

Cadmus based the evaluated square footage estimates by building type and climate zone on updated CEC forecast data for 2015 existing building stock provided by the CEC in September 2015.

Cadmus accepts the IOU assumption that lighting systems are replaced every 15 years on average, which is based on assumptions in the CEC impact analysis. We are not aware of better data.

Cadmus reviewed the online survey results reported in the lighting alterations CASE report as the basis of assumptions for the percentage of applicable square footage. We used this data source because of a lack of secondary research on the portion of building space in which 10% or more of luminaires are replaced. However, Cadmus noted the survey results in the CASE report indicated 21% of building spaces replace 10% to 50% of luminaires, [11] which differed from the IOU workbook analysis that reported 22% for the same number.[12] Because the CASE report provided more detailed survey results supporting the assumption of 21% and not 22%, we applied 21% to the evaluated square footage estimates.

Table 21 shows the evaluated square footage by building type for standard B34.

Table 21. Evaluated Applicable Square Footage by Forecast Building Type

Forecast Building Type	Total Existing Floor Area 2015 CEC Forecast (Million Sq. ft.)	Total Lighting Alteration Floor Area* (Million Sq. ft./yr)	Total Lighting Alteration Floor Area Applicable to B34 Standard** (Million Sq. ft./yr)
Office: small	379	25	23
Office: large	1,289	86	77
Restaurant	186	12	11
Retail	1,171	78	70
Food	311	21	19
Non-refrigerated warehouse	1,057	70	63
Refrigerated warehouse	57	4	3
School	563	38	34
College	298	20	18
Hospital	368	25	0
Hotel	343	23	1***
Miscellaneous	1,366	91	82
Total	**7,389**	**493**	**402**

* Total lighting alteration area is calculated as (total existing floor area) x (1/15) for each building type.
** Total lighting alteration floor area applicable to standard B34 is calculated as (total lighting alteration area) x (21% + 69%) for each building type.
*** Cadmus accepted the 6.2% factor applied to hotel square footage because the amount of hotel square footage affected by the Title 24 commercial lightings standards (excludes hotel rooms) will be significantly less than the total.

[11] Chappell, Rasin. Codes and Standards Enhancement Initiative (CASE) Final Report – Lighting Alterations and Modifications in Place. June 2013.

[12] IOUs. *Lighting Alteration savings estimate—For Cadmus.xls.* IOUs submitted this workbook to Cadmus in December 2015.

Table 22 shows the final evaluated savings estimate for standard B34: Nonresidential Lighting Alterations, New Measures outlined in Table 21.

Table 22. Nonresidential Evaluated Annual Potential Energy Savings Estimate: Standard B34

Interactive Effects	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings without interactive effects	N/A	N/A	N/A
Final evaluated savings with interactive effects	232.3	45.1	-0.41

* The whole building analysis used to estimate savings only produced whole building impacts. Final evaluated savings include interactive effects.

H.2. B35: Nonresidential Lighting Alterations, Existing Measures

Table 23 provides a summary of the findings Cadmus used to estimate potential energy savings for standard B35: Nonresidential Lighting Alterations, Existing Measures.

Table 23. Nonresidential Annual Potential Energy Savings Estimates: Standard B35

Description	IOU Estimate	Evaluated*
Total electric energy savings (GWh/yr)	316.5	152.6
Total demand reduction (MW)	122.8	22.8
Total gas energy savings (MMtherms/yr)	-0.89	0.00
Total applicable units (Million sq. ft.)	Varies	Varies

* Evaluated savings in this table exclude interactive effects. Final evaluated savings include interactive effects.

H.2.a. Standard Description

Standard B35: Nonresidential Lighting Alterations, Existing Measures captures savings from the change in the threshold between 2008 and 2013 for the number of altered luminaires that trigger the Title 24 requirements for lighting alterations. Before adoption of the 2013 Title 24 standards, lighting retrofit projects that altered less than 50% of luminaires in a space were not required to comply with Title 24 LPD standards. Additionally, before the 2013 Title 24 standards, lighting retrofit projects that did not include specific wiring changes stipulated in the 2008 Title 24 standards were not required to comply with Title 24 lighting controls requirements. With the adoption of 2013 Title 24, lighting retrofit projects that alter 10% or more of luminaires are required to comply with 2013 Title 24 lighting controls and LPD standards.

Because standard B34 captures the energy savings caused by changes in lighting controls and LPD requirements between the 2008 and 2013 Title 24 standards, standard B35 is intended to capture savings achieved up to the 2008 Title 24 efficiency level for lighting alterations, but only for the projects that would not have been required to comply with Title 24 before 2013 that are now required to comply.[13] This includes projects in which 10% to 50% of luminaires are altered. It also includes projects that do not alter wiring in such a way as to trigger 2008 Title 24 requirements, but where 10% to 100% of luminaires are altered and, thus, lighting controls would be required under 2013 Title 24.

For standard B35, the relevant requirements of the 2008 Title 24 California Building Energy Efficiency Standards are listed in Sections 131 (indoor lighting controls), 146 (LPD), and 149(b)1I (lighting alterations compliance triggers).[14] Also for standard B35, the relevant requirements of the 2013 Title 24 California Building Energy Efficiency Standards are summarized in Table 141.0-E (lighting alterations compliance triggers).[15] As described above, the savings for this standard are derived from the energy savings resulting from lighting alterations projects complying with 2008 Title 24 lighting efficiency levels that were not previously required to comply with Title 24 and would have thus followed typical lighting retrofit practices with no efficiency requirements. Additional savings because of the differences in specific lighting control and LPD requirements between 2008 and 2013 Title 24 standards are captured in standard B35, described here:

- **Baseline:** The baseline scenario encompasses projects that would not have had to comply with 2008 Title 24 lighting alterations requirements, but are now required to comply with Title 24 because of the change in the Title 24 compliance triggers between 2008 and 2013.
- **Standard:** The standard covers lighting alterations compliant with CEC's 2008 nonresidential building efficiency standards for lighting system alterations, Sections 131 and 146.[16] Sections 131 and 146 describe mandatory requirements for lighting system controls and LPD levels. The 2008 lighting controls and LPD requirements are applied to the portion of projects that would trigger 2013 Title 24 lighting alterations requirements, but would not previously have triggered 2008 lighting controls requirements. These include projects in which 10% to 50% of luminaires in a space are altered and must now comply with LPD requirements and projects in which 10%

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13 The lighting alterations CASE report analysis, dated June 2013, supports a blended B34 and B35 analysis with efficiency levels at the 2013 Title 24 level. The B34 reported savings have since been based on the CEC impact analysis and not the CASE report. Additionally, the supporting workbook *Lighting Alteration savings estimate—For Cadmus.xls* submitted by the IOUs in December 2015 indicates that the B35 savings for "existing measures" are intended to capture 2008 efficiency levels and not 2013 efficiency levels.

14 CEC. *2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings*. CEC-400-2008-001-CMF. December 2008. Available online: http://www.energy.ca.gov/2008publications/CEC-400-2008-001/CEC-400-2008-001-CMF.PDF

15 CEC. *2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings.* CEC-400-2012-004-CMF-REV2. May 2012. Available online: http://www.energy.ca.gov/2012publications/CEC-400-2012-004/CEC-400-2012-004-CMF-REV2.pdf

16 CEC. *2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings*. CEC-400-2008-001-CMF. December 2008. Available online: http://www.energy.ca.gov/2008publications/CEC-400-2008-001/CEC-400-2008-001-CMF.PDF

to 100% of luminaires in a space are altered and wiring would not have been altered in such a way as to previously trigger 2008 Title 24 control requirements, but that now must comply with lighting controls requirements.

Section 131 of the 2008 Title 24 standards lists requirements for area controls, multilevel lighting controls, daylighting, and shut-off controls. Table 24 summarizes the key requirements[17] from Section 131 that are relevant to the B35 analysis.

Table 24. 2008 Title 24 Section 131 Lighting Controls Key Requirements

2008 Title 24 Section	Key Requirements
131(a)—Area Controls	Not addressed in B35 analysis
131(b)— Multi-level lighting controls*	Multilevel controls required for enclosed spaces 100 feet or larger with connected load that exceed 0.8 watts per square foot Multilevel controls "shall have at least one control step that is between 30 percent and 70 percent of design lighting power and allow the power of all lights to be manually turned off. A reasonably uniform level of illuminance shall be achieved by any of the following: Continuous or stepped dimming of all lamps or luminaires; or Switching alternate lamps in luminaires, alternate luminaires, and alternate rows of luminaires."
131(c)—Daylight Areas	Not addressed in B35 analysis
131(d)—Shut-off Controls	All indoor lighting systems shall be equipped with separate automatic controls to shut off the lighting. Automatic controls may be an occupant sensor, automatic time switch, or other device capable of automatically shutting off the lighting.

* Multilevel lighting controls represented by institutional tuning in IOU saving analysis

Section 145 of the 2008 Title 24 standards lists LPD requirements, through either the complete building method or the area category method. Table 25 and Table 26 show the LPD requirements for the complete building method and the area category method, respectively.

17 CEC. *2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings*. CEC-400-2008-001-CMF. December 2008. Available online: http://www.energy.ca.gov/2008publications/CEC-400-2008-001/CEC-400-2008-001-CMF.PDF

Table 25. 2008 Title 24 Complete Building Method LPD Values

2008 Title 24 Table 146-E Type of Use*	2008 Title 24 Table 146-E Allowed Lighting Power (W/sq. ft.)*
Auditoriums	1.5
Classroom building	1.1
Commercial and industrial storage buildings	0.6
Convention centers	1.2
Financial institutions	1.1
General commercial and industrial work buildings	
• High bay	1.0
• Low bay	1.0
Grocery stores	1.5
Library	1.3
Medical buildings and clinics	1.1
Office buildings	0.85
Parking garages	0.3
Religious facilities	1.6
Restaurants	1.2
Schools	1.0
Theaters	1.3
All others	0.6

* Fields taken from Table 146-E of the 2008 Title 24 Building Efficiency Standards

Table 26. 2008 Title 24 Area Category Method Select LPD Values

2008 Title 24 Table 146-F Type of Use*	2008 Title 24 Table 146-F Allowed Lighting Power (W/sq. ft.)*
Offices > 250 sq. ft.	0.9
Offices ≤ 250 sq. ft.	1.1
Retail merchandise sales, wholesale showrooms	1.6

* Select fields taken from Table 146-E of the 2008 Title 24 Building Efficiency Standards. Not all area categories are shown in this table.

H.2.b. IOU-Estimated Potential Energy Savings Estimates

Unit Energy Savings Estimates

The IOUs documented the UES estimates for standard B35 in multiple workbooks provided to Cadmus in response to a series of data requests.[18] The workbooks split the UES reported estimates into three components for each building type: LPD reduction, multilevel controls (represented by tuning controls),

[18] IOUs. Lighting Alteration savings estimate—For Cadmus.xls. Statewide savings for retrofits.xls. Analysis of Threshold Change.xls. Summary.xls. IOUs submitted these workbooks to Cadmus in December 2015.

and auto-shutoff controls. The IOUs did not assess savings for daylighting controls or area controls. Table 27 lists the reported UES estimates for these three components; the analysis approach for each component is described in the subsequent sections.

Instead of using 2008 Title 24 LPD levels as the efficient case for UES calculations to avoid double-counting with standard B34, the IOUs used the 2013 LPD levels as described in the supporting analysis workbooks.[19] The B34 and B35 standard analyses appear to be merged in the lighting alterations CASE report from June 2013, which does not differentiate between lighting alterations "new measures" (B34) and "existing measures" (B35).[20] The IOUs used the CASE report analysis to support the savings calculations for B35, which is likely why the IOUS initially used the 2013 LPD levels for the B35 LPD reduction analysis component. However, instead of revising the analysis to reflect the 2008 LPD levels, the IOUs carried the 2013 LPD level through in the supporting workbook analysis*,* provided by the IOUs in December 2015. This supporting workbook indicates that the B35 savings for "existing measures" were intended to capture 2008 efficiency levels and not 2013 efficiency levels.

Table 27. IOU-Estimated Electric Energy UES by Forecast Building Type

Forecast Building Type	UES (kWh/sq. ft./yr)		
	Tuning Controls	Auto-shutoff Controls	LPD Reduction
Office: small	0.330	0.610	1.390
Office: large	0.540	0.610	2.280
Restaurant	0.820	0.520	2.310
Retail	0.810	0.520	2.280
Food	1.440	0.520	3.230
Non-refrigerated warehouse	0.310	1.620	1.720
Refrigerated warehouse	0.360	1.800	2.040
School	0.610	0.520	2.060
College	0.550	0.610	1.870
Hospital*	N/A	N/A	N/A
Hotel	0.550	0.000	2.060
Miscellaneous	0.400	0.000	1.360

* IOUs did not report UES for hospitals; they reported applicable square footage as zero.

IOU-Estimated LPD Reduction UES

The IOUs based the savings for the LPD reduction component on the difference in energy consumption between projects not previously required to comply with Title 24 Section 146 and have non-compliant LPD levels, as well as projects that must now comply with Title 24 Section 146 LPD requirements. They

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19 IOUs. *Statewide savings for retrofits.xls.* IOUs submitted these workbooks to Cadmus in December 2015.

20 Chappell, Rasin. Codes and Standards Enhancement Initiative (CASE) Final Report—Lighting Alterations and Modifications in Place. June 2013.

used results from California's Commercial End Use Survey (CEUS) to estimate baseline lighting power densities for projects that would not previously have complied with Title 24 standards.[21]

The CEUS report includes results for LPD (watts per square foot) by building type. However, the IOU savings estimate employed a weighted average LPD reduction of 0.51 watts per square foot that was derived from CEUS building data for all spaces that did not already meet the 2013 Title 24 LPD requirements. For these buildings that did not already meet 2013 Title 24 LPD requirements, the IOUs weighted the building LPDs by the corresponding building square footage, which the IOUs then applied in the assumed LPD baseline. The baseline (CEUS) and the efficient case (2013 Title 24) LPD levels are shown in Table 27.

The CEUS report also provides results for commercial building energy intensity (kWh per square foot per year) by CEC forecast building type. As illustrated in the following equation, the IOUs used these data to establish the weighted average hours of lighting use per year based on the average energy intensity and average LPD per building type:

$$CEUS\ Hours\ of\ Lighting\ Use\ \left(\frac{hrs}{yr}\right) = \frac{CEUS\ Energy\ Intensity\ \left(\frac{kWh}{sqft-yr}\right) \times 1000\ \left(\frac{W}{kW}\right)}{CEUS\ LPD\ \left(\frac{W}{sqft}\right)}$$

Table 28 lists the CEUS energy intensities and calculated CEUS average lighting hours. The IOUs used the CEUS lighting hours of use per year for each building type to calculate savings from the weighted average reduction in LPD for all building types because of the 2013 Title 24 requirements.

$$LPD\ Reduction\ Savings\ \left(\frac{kWh}{sqft-yr}\right) = \frac{0.51\ \left(\frac{W}{sqft}\right)}{1000\ \left(\frac{W}{kW}\right)} \times\ CEUS\ Hours\ of\ Lighting\ Use\ \left(\frac{hrs}{yr}\right)$$

Table 28 also shows the resulting LPD reduction savings by building type.

Table 28. IOU-Estimated LPD Reduction Energy Savings Estimates and Calculation Variables

CEC Forecast Building Type	Energy Intensities from CEUS (kWh/sq. ft./yr)	Baseline LPD Levels from CEUS (W/sq. ft.)	CEUS Average Hours of Lighting Energy Use (hrs/yr)	CEUS Weighted Average LPD Reduction* (W/sq. ft.)	Reported LPD Reduction Energy Savings (kWh/sq. ft./yr)
Office: small	3.83	1.39	2,755	0.51	1.390
Office: large	4.46	0.99	4,505		2.280
Restaurant	6.45	1.41	4,574		2.310
Retail	6.05	1.34	4,515		2.280
Food	8.55	1.34	6,381		3.230

21 Itron, Inc. *California Commercial End-Use Survey.* CEC-400-2006-005. Prepared for the CEC. March 2006. Available online: http://www.energy.ca.gov/2006publications/CEC-400-2006-005/CEC-400-2006-005.PDF

CEC Forecast Building Type	Energy Intensities from CEUS (kWh/sq. ft./yr)	Baseline LPD Levels from CEUS (W/sq. ft.)	CEUS Average Hours of Lighting Energy Use (hrs/yr)	CEUS Weighted Average LPD Reduction* (W/sq. ft.)	Reported LPD Reduction Energy Savings (kWh/sq. ft./yr)
Non-refrigerated warehouse	2.21	0.65	3,400		1.720
Refrigerated warehouse	2.74	0.68	4,029		2.040
School	3.5	0.86	4,070		2.060
College	3.84	1.04	3,692		1.870
Hospital	N/A	N/A	N/A		N/A
Hotel	3.5	0.86	4,070		2.060
Miscellaneous	2.63	0.98	2,684		1.360

* Weighted average LPD reduction calculated as difference in CEUS LPD and 2013 Title 24 LPD requirements for each building surveyed in CEUS study that did not already meet 2013 Title 24 LPD requirements. Average weighted according to the square footage associated with each building LPD.

IOU-Estimated Tuning UES

Savings for the tuning reduction component are based on the difference in energy consumption between projects that were not previously required to comply with Title 24 wiring alterations that would trigger Section 131(b) controls requirements and projects that must now comply with 2013 Title 24 Section 131(b) lighting controls requirements.

The IOUs used institutional tuning as the representative multilevel control strategy compliant with Section 131(b) of the 2008 Title 24 for all building types. The analysis assumed energy savings of 15% because of tuning. In response to a data request, the IOUs provided a copy of a CASE report[22] titled “Requirements for Controllable Lighting” to support the 15% savings assumption; however, this CASE report did not provide an analysis or derivation of the 15% savings assumption. The IOUs assumed the tuning savings would apply to 2013 Title 24-compliant LPD levels for each building type; the IOUs also used the CEUS hours of lighting use discussed in the LPD Reduction section in the calculation, shown in the following energy savings equation:

$$Tuning\ Savings\ \left(\frac{kWh}{sqft - yr}\right) = \frac{2013\ Title\ 24\ LPD\ \left(\frac{W}{sqft}\right)}{1000\ \left(\frac{W}{kW}\right)} \times\ CEUS\ Hours\ of\ Lighting\ Use\ \left(\frac{hrs}{yr}\right) \times 15\%$$

22 Avery, Doug, Benya, James, Neils, Danielle. 2011 California Building Efficiency Standards—Requirements for Controllable Lighting. March 21, 2011.

Table 29 shows the 2013 Title 24 LPD levels used in the tuning savings analysis and the final tuning energy savings estimates.

Table 29. 2013 Title 24 LPD Levels and IOU-Estimated Tuning Savings Estimates

CEC Forecast Building Type	Efficient LPD Levels from 2013 Title 24 Table 140.6-B for Complete Building Method	Reported Tuning Energy Savings (kWh/sq. ft./yr)
Office: small	0.8	0.331
Office: large	0.8	0.541
Restaurant	1.2	0.823
Retail	1.2*	0.813
Food	1.5	1.436
Non-refrigerated warehouse	0.6	0.306
Refrigerated warehouse	0.6	0.363
School	1.0	0.610
College	1.0	0.554
Hospital	n/a	n/a
Hotel	0.9**	0.549
Miscellaneous	1**	0.403

* Retail LPD based on Area Category LPD for "Retail Merchandise Sales, Wholesale Showroom Areas" per 2008 Title 24 Table 140.6-C based on no retail building type in the LPD table for the complete building method (Table 140.6-B)

** In the supporting workbook, *Statewide savings for retrofits.xls*, the IOUs indicated that, because of challenges estimating an average efficient LPD from the Title 24 whole building and area category LPD parameters, the efficient LPD levels were set to slightly above the baseline LPD levels so no savings were generated.

IOU-Estimated Auto-Shutoff Controls UES

The IOUs based savings for the auto-shutoff controls component on the difference in energy consumption between projects that were not previously required to comply with Title 24 wiring alterations that would trigger Section 131(d) controls requirements and projects that must now comply with 2013 Title 24 Section 131(d) lighting controls requirements.

The IOU analysis calculated auto-shutoff controls for offices and retail building types only, shown in Table 30. The IOUs applied the results from these analyses to other building types as proxy savings and analyzed office building savings in two components: savings from open areas and private offices.

The analysis assumed savings from open-office auto-shutoff controls were 15%, based on results of a nighttime field survey conducted by the CASE authors to support CASE report analysis. The results of the nighttime field survey (which included a survey of 71 commercial buildings in California conducted on weekday evenings) are detailed in the CASE report. Based on hourly evening observations of each floor by a surveyor on the exterior of the buildings, the CASE authors estimated about 15% of the installed LPD was left on overnight as non-egress lighting load (the first 10% of the load was counted as egress lighting). The analysis assumed that all overnight load would be shut off with auto-shutoff controls, thereby resulting in 15% of installed LPD savings during nighttime hours. Based on their professional judgment, the IOUs assumed the unoccupied open-office hours were 10:00 p.m. to 6:00 a.m. Monday through Saturday, and all day Sunday. The IOUs also assumed the installed LPD levels were compliant with 2013 Title 24 area category requirements for office spaces greater than 250 feet (0.8 watts per square foot).

The IOUs assumed savings from private office vacancy sensors were 21% during daytime occupied hours and 15% during nighttime unoccupied hours. Based on professional judgement, the IOUs assumed that nighttime unoccupied hours were the same as open offices, from 10:00 p.m. to 6:00 a.m. Monday through Saturday, and all day Sunday. In response to a data request, the IOUs provided a copy of a report on bi-level lighting from 2002 authored by ADM Associates, Inc., to support the 21% savings assumption.[23] This report stated savings of approximately 21% for private offices because of manual bi-level controls. The IOUs assumed the installed LPD levels were compliant with 2013 Title 24 area category requirements for office spaces less than 250 feet (1.1 watts per square foot).

The IOUs weighted the open office and private office auto-shutoff savings together based on proportion of office space attributed to each space type (74% open office and 20% private office, according to the supporting analysis in the workbook *Statewide savings for retrofits.xls* provided by the IOUs). The IOUs did not provide the sources for this space breakdown.

The IOUs assumed (based on professional judgment) that the retail savings from auto-shutoff controls occurred during unoccupied periods between 10:00 p.m. and 6:00 a.m. every day of the week. The IOUs assumed savings of 26.6% during unoccupied times, but did not provide justification in the lighting alterations CASE report; the IOUs further reduced savings by 50% to account for retailers intentionally leaving display lights on. The IOUs assumed the installed LPD levels aligned with CEUS LPD levels for retail buildings (1.34 watts per square foot).

The IOUs based warehouse savings from auto-shutoff controls on a separate analysis. In response to a data request, the IOUs provided a supporting workbook title *Summary.xls* that contained the warehouse UES estimates, but did not provide further details on how they derived those UES estimates.

23 ADM Associates, Inc. *Final Report on Bi-Level Lighting Study.* Prepared for Heschong Mahone Group and Southern California Edison. May 2002.

Table 30. Building Types Analyzed for IOU-Estimated Auto-Shutoff Savings

<table>
<tr><th>CEC Forecast Building Type</th><th>Assumed LPD Level (W/sq. ft.)</th><th>Unoccupied Hours (hrs/yr)</th><th>Savings from Auto-shutoff or Vacancy Sensors</th><th>Auto-shutoff Savings (kWh/sq. ft./yr)</th></tr>
<tr><td>Office: open area</td><td>0.8
(2013 Title 24 Area Category Method)</td><td>3,744</td><td>15%</td><td>0.45*</td></tr>
<tr><td rowspan="2">Office: private office</td><td rowspan="2">1.1
(2013 Title 24 Area Category Method)</td><td>3,744 (evening)</td><td>15%</td><td rowspan="2">1.07*</td></tr>
<tr><td>5,016 (daytime)</td><td>21%</td></tr>
<tr><td>Retail</td><td>1.34
(CEUS average retail LPD)</td><td>2,902</td><td>13.3%**</td><td>0.52</td></tr>
</table>

* A single UES estimate (0.61 kWh/sq. ft./yr) for offices was calculated as the weighted average between open areas and private offices UES estimates using an assumed distribution of space types.

** 13.3% calculated from 50% x 26.6%

Table 31 lists a summary of IOU-estimated auto-shutoff UES estimates.

Table 31. IOU-Estimated Auto-Shutoff Energy Savings Estimates and Assumptions

CEC Forecast Building Type	Auto-shutoff Savings (kWh/sq. ft./yr)	IOU Assumptions
Office: small	0.610	
Office: large	0.610	
Restaurant	0.520	Same as retail
Retail	0.520	
Food	0.520	Same as retail
Non-refrigerated warehouse	1.620	From separate warehouse analysis
Refrigerated warehouse	1.800	From separate warehouse analysis
School	0.520	Same as retail
College	0.610	Same as offices
Hospital	0.000	
Hotel	0.000	
Miscellaneous	0.000	

IOU-Estimated Demand UES

The IOUs estimated annual demand savings of 122.8 MW. A supporting workbook *Lighting Alteration savings estimate—For Cadmus.xls* with some details on the demand calculations was provided by the IOUs in response to a data request. The exact estimate of 122.8 MW was not reported in the workbook, however a similar estimate of 119.2 MW was reported. This workbook contained a summary of statewide MW demand savings per building type from the CASE report that could not be reproduced based on the CASE report information. The 119.2 MW figure was calculated by the IOUs with the intention of using more recent statewide square footage data than the CASE report in combination with demand UES estimates derived from the CASE report statewide demand savings. However, the IOUs applied the applicable square footage for standard B34 erroneously instead of the applicable square footage for standard B35. This resulted in demand savings of 119.2 MW instead of demand savings of 36.5 MW that would have been calculated by the IOUs had the applicable square footage calculated by the IOUs for B35 been applied.

For the demand calculation, the IOUs back-calculated demand UES estimates by dividing the total MW from the CASE report (based on older statewide square footage data) by the older statewide square footage data to establish an UES estimates (kW per square foot) by building type.[24] The back-calculated demand UES estimates in the supporting workbook *Lighting Alteration savings estimate—For Cadmus.xls* differed from the demand UES estimates in the supporting workbook *Statewide savings for retrofits.xls*, which was based on an analysis of weekday occupancy schedules derived from CEUS data.

The IOUs developed demand savings for the CASE report analysis and included these savings in the *Lighting Alteration savings estimate—For Cadmus.xls* workbook for small offices, retail, refrigerated warehouses, and hotels. The IOUs applied the average results for these building types weighted by building type square footage to other building types. The IOUs assumed no demand savings for auto-shutoff savings because they assumed the savings occurred outside of the peak demand period. Table 32 shows the IOU-estimated demand UES estimates.

24 Note that the IOUs back-calculated older square footage estimates by dividing the CASE report's GWh per year estimate by the kWh per square foot per year estimates for each building type.

Table 32. IOU-Estimated Demand Unit Energy Savings Estimates and Assumptions

CEC Forecast Building Type	Tuning Controls Savings (W/sq. ft.)	Auto-shutoff Controls Savings (W/sq. ft.)	LPD Reduction Savings (W/sq. ft.)	IOU Assumptions
Office: small	0.415	0	0.162	Small office occupancy schedule
Office: large	0.186	0	0.096	Weighted average*
Restaurant	0.186	0	0.096	Weighted average*
Retail	0.088	0	0.037	Retail occupancy schedule
Food	0.186	0	0.096	Weighted average*
Non-refrigerated warehouse	0.186	0	0.096	Weighted average*
Refrigerated warehouse	1.611	0	1.345	Refrigerated warehouse occupancy schedule
School	0.186	0	0.096	Weighted average*
College	0.186	0	0.096	Weighted average*
Hospital	0.000	0	0.000	N/A
Hotel	0.007	0	0.005	All commercial occupancy schedule
Miscellaneous	0.186	0	0.096	Weighted average*

* Weighted average of small office, retail, refrigerated warehouse, and all commercial occupancy schedules according to small office, retail, refrigerated warehouse, and hotel square footage, respectively.

IOU-Estimated Gas UES

The IOUs estimated gas impacts for all savings components (LPD reduction, tuning controls, and auto-shutoff controls) by multiplying electric UES estimates by the interactive effects factor -0.0041 therms per kWh. However, there appeared to be an error in the IOUs' calculation detailed in a supporting workbook because gas impacts were only calculated for the tuning savings and LPD reduction savings components. The IOUs assumed therm impacts were zero for auto-shutoff controls.

Statewide Potential Energy Savings Estimate

The IOUs' calculated the applicable square footage of the B35 standard for each forecast building type using the CEC's forecasted existing floor stock for the year 2014 as reported in the CEC impact analysis report (completed in 2013).[25] The CEC impact analysis assumed that lighting systems are replaced every fifteen years, and, thus, assumed that lighting alterations savings apply to one-fifteenth of the total

[25] 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

existing floor area per building type per year. The IOUs used this same assumption in their estimates of applicable square footage. The IOUs reduced the applicable square footage estimate further as follows:

- Case 1: Removed the estimated portion of square footage for lighting alteration projects that would already have had to comply with the 2008 Title 24 requirements for LPD reduction requirements, and for which compliance would not have been required under the 2013 Title 24 lighting efficiency compliance triggers.
- Case 2: Removed the estimated portion of square footage for lighting alteration projects that would already have had to comply with the 2008 Title 24 requirements for lighting controls requirements, and for which compliance would not have been required under the 2013 Title 24 lighting efficiency compliance triggers.
- Case 3: Reduced applicable square footage for lighting controls by 50% to account for buildings that already install lighting controls, regardless of Title 24 requirements (based on professional judgment).

For Case 1, the 2008 Title 24 LPD requirements would already have applied to all projects for which 50% or more of luminaires in a space are modified. Under the 2013 Title 24 compliance triggers, projects for which 10% to 50% of luminaires in a space are modified would now be required to comply with LPD requirements. Additionally, because the LPD reduction analysis only accounted for buildings that did not already comply with Title 24 LPD requirements, the IOUs applied an additional reduction factor of 62% regardless of the portion of luminaires modified. The IOUs based this reduction factor on the assumption that 38% of projects would already have complied with Title 24 LPD requirements based on CEUS data.

For Case 2, projects with specific wiring alterations (per 2008 Title 24 specifications) would have been required to comply with 2008 Title 24 lighting control requirements. Under the 2013 Title 24 compliance triggers, projects for which 10% to 100% of luminaires in a space are modified would now be required to comply with lighting controls. A portion of projects with 10% to 100% of modified luminaires in a space would have had wiring alterations that would have triggered 2008 Title 24 lighting controls requirements.

In support of the development of the lighting alterations CASE report,[26] the IOUs conducted an online survey of lighting retrofit stakeholders (designers, contractors, and program implementers) in 2011, with 26 responses received. According to the CASE report, responses from the stakeholder survey indicated that 69% of lighting alterations spaces replace 50% or more of luminaires in a space, and 21% of spaces replace between 10% and 50% of luminaires in a space. While the CASE report stated that 21% of spaces replace between 10% and 50% of luminaires in a space, the supporting analysis provided

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[26] Chappell, Rasin. Codes and Standards Enhancement Initiative (CASE) Final Report – Lighting Alterations and Modifications in Place. June 2013.

by the IOUs[27] in response to one of Cadmus' evaluation data requests assumed that 22% of spaces replaced between 10% and 50% of luminaires in a space, for a total of 91% of spaces replacing between 10% and 100% of luminaires in a space.[28]

Additionally, the lighting stakeholder survey in the CASE report indicated that 30% of projects would have had wiring alterations that triggered 2008 Title 24 lighting controls requirements. However, the IOU analysis erroneously applied a reduction factor of 70% instead of 60% to the square footage to account for projects that would not already have complied with Title 24 lighting controls requirements.

The IOUs used the following algorithm to estimate applicable square footage for LPD reduction requirements:

$$Applicable\ square\ footage = (Total\ Existing\ Stock) \times \frac{1}{15} \times (22\% \times 62\%)$$

The IOUs used following algorithm to estimate applicable square footage for lighting controls requirements:

$$Applicable\ square\ footage = (Total\ Existing\ Stock) \times \frac{1}{15} \times (22\% + 69\% \times 70\%) \times 50\%$$

Table 33 summarizes the IOU assumptions for applicable square footage by building type for standard B35.

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27 IOUs. *Lighting Alteration savings estimate—For Cadmus.xls.* IOUs submitted these workbooks to Cadmus in December 2015.

28 *Ibid.* According to this workbook, 91% was calculated as the sum of 22% and 69%, the percentage of spaces replacing between 10% and 50% and over 50% of luminaires, respectively. The 22% figure used in the analysis differed from the corresponding quantity of 21% reported in the CASE report.

Table 33. IOU-Estimated Applicable Square Footage by Forecast Building Type

Forecast Building Type	Total Existing Floor Area – 2013 CEC Forecast (Million Sq. ft.)	Total Lighting Alteration Floor Area* (Million sq. ft./yr)	Total Lighting Alteration Floor Area Applicable to B35 Standard - Tuning** (Million sq. ft./yr)	Total Lighting Alteration Floor Area Applicable to B35 Standard – Auto-shutoff** (Million sq. ft./yr)	Total Lighting Alteration Floor Area Applicable to B35 Standard – LPD Reduction** (Million sq. ft./yr)
Office: small	397	26	9	9	4
Office: large	1,286	86	30	30	12
Restaurant	191	13	4	4	2
Retail	1,176	78	28	28	11
Food	311	21	7	7	3
Non-refrigerated warehouse	1,057	70	25	25	10
Refrigerated warehouse	59	4	1	1	1
School	554	37	13	13	5
College	349	23	8	8	3
Hospital	353	24	8	8	3
Hotel	331	22	8	8	3
Miscellaneous	1,272	85	30	30	12
Total	**7,336**	**489**	**172**	**172**	**67**

* Total lighting alteration area is calculated as (total existing floor area) x (1/15) for each building type.

** Total lighting alteration floor area applicable to B35 standard for tuning and auto-shutoff controls is calculated as (total lighting alteration area) x (22% + 69% x 70%) x 50% for each building type. For the LPD reduction, the calculation is (total lighting alteration area) x (22% x 62).

Table 34 summarizes the total annual electric and gas savings reported by the IOUs for this standard B35: Nonresidential Lighting Alterations, Existing Measures. The IOUs calculated the statewide savings by multiplying UES estimates by applicable square footage for each building type.

Table 34. Nonresidential IOU-Estimated Annual Energy Savings Estimate: Standard B35

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
316.5	122.8	-0.89

H.2.c. Evaluation Findings

Unit Energy Savings

For the UES analysis, Cadmus disagrees with the use of the 2013 Title 24 LPD requirements to represent the efficient cases for the LPD reduction, tuning controls, and auto-shutoff controls savings components. To prevent overlap with the B34 standard, and to be consistent with the most recent description of the B35 standard provided by the IOUs, Cadmus used the 2008 Title 24 LPD levels for the evaluated savings where appropriate.

We accept the use of the CEUS study to represent LPD baseline conditions for the LPD reduction component of the savings, as well as to estimate average lighting hours of use per year. The CEUS represents existing lighting system conditions in the year(s) in which the survey took place and leading up to the publication of the CEUS report in March 2006; thus, it does not necessarily reflect what lighting contractors would be newly retrofitting in spaces in 2014 and later without having to comply with Title 24 standards. However, we consider the CEUS conditions a reasonable baseline proxy because of the likelihood that lighting contractors would replace like-for-like in lighting retrofit projects that do not require redesign for Title 24 standards compliance.

Additionally, the lighting hours of use derived from the CEUS energy intensity and LPD estimates reflect a total weighted average of lighting hours for each building that appropriately corresponds with the LPD assumptions and capture the lighting control strategies (or lack of strategies) employed in those buildings. Cadmus considers the CEUS lighting hours a more consistent source than alterative options, such as the Database for Energy Efficient Resources (DEER), which may derive lighting operating hours from multiple sources that may not align with CEUS or the baseline intended to be captured for this standard.

Cadmus evaluated the potential overlap between this standard and standard B39: Warehouse Lighting Alterations. The savings workbook *Summary.xls* submitted in support of the warehouse UES estimates for standard B35 did not include details of the UES analysis and was the same analysis used for standard B39 (the B39 savings included an arbitrary reduction factor not included in the B35 workbook). However, the original analysis for this standard B35 appeared to conflate standards B34 and B35 for lighting alterations new measures and existing measures, respectively. The CASE report for standard B39 describes a 2008 Title 24 baseline; therefore, Cadmus did not identify overlap between standards B39 and B35 and evaluated savings for the warehouse building type for standard B35.

Cadmus considered the 2008 Title 24 compliance lighting occupancy schedules reported in the 2008 Alternative Calculation Manual that are intended to account for the implementation of Title 24 lighting controls requirements.[29] The Title 24 compliance lighting schedules indicate the percentage of total

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[29] CEC. (Consultant Report) *Nonresidential Alternative Calculation Method (ACM) Approval Manual*. CEC-400-2008-003. December 2008. Available online: http://www.energy.ca.gov/2008publications/CEC-400-2008-003/CEC-400-2008-003-CMF.PDF

building LPD operating for each hour of the day for weekdays and weekends. Using the 2008 Title 24 LPD requirements and occupancy schedules, Cadmus calculated the annual kWh per square foot per year consumption for all building types. These kWh per square foot per year estimates reflect consumption with 2008 Title 24 LPD and lighting controls requirements implemented. Cadmus then calculated the difference in consumption (energy savings) between these calculated kWh per square foot per year estimates based on 2008 Title 24 occupancy schedules and the average energy intensities reported in the CEUS report. This unit energy consumption difference represents the savings because of 2008 Title 24 LPD and lighting controls requirements over the CEUS LPD and lighting operating hours baseline. Finally, Cadmus compared these calculated UES per building type to the total IOU-estimated B35 energy savings (for LPD reduction and control requirements) per building type. For about half the building types, the IOU UES estimates were higher than Cadmus' Title 24 occupancy schedule-based UES estimates, and vice versa for the other half of building types. We applied the UES estimates we calculated using the Title 24 occupancy schedules to our evaluated square footage applicable to lighting controls. Total savings using this method were close to the IOU estimate of 317 GWh per year. Cadmus decided not to use this method for the final evaluated savings for a few reasons. First, it is unclear how the Title 24 occupancy schedules were derived and what lighting controls they may include. Secondly, CEUS likely overstates the energy consumption of the true baseline for this standard because the CEUS results were based on existing commercial building systems surveyed in 2006, and do not necessarily represent the lighting systems that would have been newly retrofitted in 2008 if Title 24 lighting requirements did not apply. Thus, we believe a more conservative savings estimate based on the methodology in the following sections is more realistic.

Lastly, Cadmus applied interactive effects factors to the electric energy and electric demand savings to account for interactions with building HVAC systems. The factors applied were 1.10 kWh/kWh and 1.32 kW/kW for electric energy and demand, respectively. Gas interactive effects were also calculated using a factor of -0.0041 therms/kWh. These factors were established through the 2008 Title 24 Codes and Standards evaluation. The evaluation report identifies the specific DEER workpapers on which these values are based.

Evaluated LPD Reduction UES

Cadmus agrees with CEUS as a viable data source for baseline LPD estimates; however, Cadmus evaluated savings for the LPD reduction component using CEUS LPD estimates for each building type instead of the CEUS weighted average LPD of 0.51 watts per square foot for all buildings that did not already comply with 2013 Title 24 LPD levels. Because CEUS LPD estimates were available by building type, and the IOUs used the building-type specific CEUS hours of use to estimate LPD reduction savings, an analysis with separate LPD estimates by building type was the most consistent approach. Cadmus could not verify the IOUs' LPD reduction assumptions for warehouses (which the IOUs evaluated separately from the remaining building types) because of incomplete documentation of the IOU analysis.

Additionally, the 0.51 watts per square foot estimate represents buildings that did not comply with 2013 Title 24 LPD levels instead of the 2008 Title 24 LPD levels which were intended to be the efficient case for standard B35; for some building types the 2013 LPD requirements are stricter than the 2008 LPD requirements. Because the CEUS LPD estimates that already complied with Title 24 LPD requirements were accounted for in the UES analysis, Cadmus did not apply a reduction to the applicable square footage to account for the portion of CEUS buildings that were already compliant. The IOUs applied this reduction in their analysis because the UES analysis did not account CEUS surveyed buildings with LPDs already compliant with Title 24 requirements. Cadmus did not apply this reduction to avoid an overlap of discounted savings.

To determine the efficient building LPD levels from the 2008 Title 24 section 140.6, Cadmus selected LPD levels from Table 140.6-B for the complete building method, and selected LPD levels from Table 140.6-C for the area category method if no reasonable match could be found in Table 140.6-B. If no match could be found in either table (miscellaneous type), or multiple LPDs made estimating an average difficult (hotel type), we selected the “All others” building type from Table 140.6-B to allow calculating savings. In some cases, the average CEUS LPD level for a given building type was more efficient than the 2008 Title 24 LPD requirement. This was the case for retail, food, and school building types. In these cases, no LPD reduction savings were realized in the evaluation analysis. Cadmus calculated the LPD reduction savings for each building type as follows:

$$LPD\ Reduction\ Savings\ \left(\frac{kWh}{sqft-yr}\right) = \frac{\left(CEUS\ LPD\ \left(\frac{W}{sqft}\right) - 2008\ T24\ LPD\ \left(\frac{W}{sqft}\right)\right)}{1000\ \left(\frac{W}{kW}\right)} \times CEUS\ Hours\ of\ Lighting\ Use\ \left(\frac{hrs}{yr}\right)$$

Table 35 lists a summary of the LPD assumptions and evaluated LPD reduction savings.

Table 35. Evaluated LPD Reduction Energy Savings Estimates and Calculation Variables

CEC Building Type	CEUS Average Hours of Lighting Energy Use (hrs/yr)*	Baseline LPD Levels from CEUS (W/sq. ft.)	Efficient LPD Levels from 2008 Title 24 Section 146 (W/sq. ft.)**	Calculated LPD Reduction (W/sq. ft.)	Evaluated LPD Reduction Energy Savings (kWh/sq. ft./yr)
Office: small	2755	1.39	0.85	0.54	1.488
Office: large	4505	0.99	0.85	0.14	0.631
Restaurant	4574	1.41	1.2	0.21	0.961
Retail	4515	1.34	1.6	0.00	0.000***
Food	6381	1.34	1.5	0.00	0.000***
Non-refrigerated warehouse	3400	0.65	0.6	0.05	0.170
Refrigerated warehouse	4029	0.68	0.6	0.08	0.322
School	4070	0.86	1.0	0.00	0.000***
College	3692	1.04	1.0	0.04	0.148
Hospital	n/a	n/a	n/a	n/a	n/a
Hotel	4070	0.86	0.6	0.26	1.058
Miscellaneous	2684	0.98	0.6	0.38	1.020

* CEUS average hours of lighting use calculations described in the reported LPD reduction UES section.

** "Commercial and industrial storage" complete building category selected for non-refrigerated and refrigerated warehouse. "Retail merchandise sales, wholesale showrooms" area category selected for retail. "All others" complete building category selected for hotel and miscellaneous.[30]

*** CEUS baseline LPD levels were already more efficient than 2008 Title 24 LPD requirements, thus no savings.

Evaluated Tuning Controls UES

Cadmus accepts the assumption of 15% savings from multilevel lighting controls required by the 2008 Title 24 section 130(b). According to section 130(b), the multilevel controls are required to have a control step between 30% and 70% of design lighting power as well as allow the power of all lights to be manually turned off. Additionally, uniform illuminance should be achieved through continuous or stepped dimming of the luminaires.

Although institutional tuning is not a convincing representative control for manual multilevel controls, we agree that 15% savings attributable to manual bi-level controls is a reasonable estimate given the data currently available. In response to a data request for standard B35, the IOUs submitted a copy of a 2002 Bi-Level Lighting study drafted by ADM Associates, Inc. for Southern California Edison for the

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[30] CEC. *2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings*. CEC-400-2008-001-CMF. December 2008. Available online: http://www.energy.ca.gov/2008publications/CEC-400-2008-001/CEC-400-2008-001-CMF.PDF

Nonresidential New Construction (NRNC) program on behalf of the CPUC.[31] This report estimates total savings from bi-level manual switching to be about 16% total over weekdays and weekends combined based on measured lighting data from 79 commercial buildings including offices, retail stores, and schools built after 1992. Cadmus will continue to refer to savings from the multilevel controls component as "tuning" to maintain consistency in this evaluation report and avoid confusion.

Cadmus calculated savings using the following formula. (The 2008 LPD levels used for this analysis are listed in Table 35.)

$$Tuning\ Savings\ \left(\frac{kWh}{sqft-yr}\right) = \frac{2008\ Title\ 24\ LPD\ \left(\frac{W}{sqft}\right)}{1000\ \left(\frac{W}{kW}\right)} \times CEUS\ Hours\ of\ Lighting\ Use\ \left(\frac{hrs}{yr}\right) \times 15\%$$

Table 36 shows the evaluated tuning energy savings.

Table 36. Evaluated Tuning Savings

CEC Forecast Building Type	Evaluated Tuning Energy Savings (kWh/sq. ft./yr)
Office: small	0.351
Office: large	0.574
Restaurant	0.823
Retail	0.908
Food	1.283
Non-refrigerated warehouse	0.000*
Refrigerated warehouse	0.000*
School	0.525
College	0.554
Hospital	0.000
Hotel	0.000*
Miscellaneous	0.000*

* Buildings with connected loads less than 0.8 watts per square foot are exempt from the 2008 Title 24 multilevel control requirements detailed in section 131(b). The 2008 Title 24 LPD requirements for these building types are less than 0.8 watts per square foot; therefore, no savings were calculated for multilevel controls for these building types.

[31] ADM Associates, Inc. *Final Report on Bi-Level Lighting Study.* Prepared for Heschong Mahone Group and Southern California Edison. May 2002.

Evaluated Auto-Shutoff Controls UES

Cadmus accepts the assumption of 15% of installed lighting load can be saved from auto-shutoff controls during unoccupied times, per the auto-shutoff control requirements of 2008 Title 24 section 130(d). While the Lighting Alterations CASE authors based the nighttime survey of commercial office buildings used to establish the percentage of installed lighting load that can be shut off on rough exterior observations and not robust metering and analysis, Cadmus considers the savings assumption of 15% reasonable. A Lawrence Berkeley National Laboratory (LBNL) meta analysis of lighting controls savings looked at 240 savings estimates from 88 papers and case studies for multiple building types and determined that the average savings from occupancy sensors was reported to be about 28%.[32] Occupancy sensors serve a similar purpose as the auto-shutoff sensors used for the IOU analysis, which is to turn lights off during unoccupied periods. Therefore, Cadmus considered the 15% savings assumption for auto-shutoff controls reasonable. The auto-shutoff savings estimates are further reduced by 50% in the applicable square footage analysis, making the final savings estimate for auto-shutoff controls more conservative.

The IOUs presented a more detailed analysis for offices, separated into private office and open office space with different savings estimates in each space. They did not provide a source for the assumptions regarding the proportion of private offices versus open offices. Cadmus chose to base the auto-shutoff control analysis for offices on the complete building LPD levels and not differentiate between the private and open offices to avoid additional assumptions that may not provide additional precision of estimates. Additionally, Cadmus chose to use complete-building LPD levels when a clear match existed between the CEC forecast building type (small and large offices) and the 2008 Title 24 Table 146-B building types, instead of using area-category LPD levels.

Additionally, instead of applying savings from offices and retail to other building types not analyzed for auto-shutoff controls, Cadmus applied the 15% savings factor assumed for all building types, using building-type specific LPD levels and schedules. Because no supporting explanation was given for the 13.3% savings estimate for retail, Cadmus applied the same 15% savings factor which is within the bounds of occupancy sensor savings from the LBNL meta analysis.

Although the nighttime field survey used in the CASE report analysis had the limitations discussed above, Cadmus chose to accept this source in support of the unoccupied hours period during which 15% of the installed on-egress lighting load is presumed to be left on, and, therefore, could be saved through auto-shutoff controls. The CASE report presented occupancy schedules derived from CEUS that Cadmus could not easily verify, but they appeared reasonably consistent with the proposed schedules. We could not reproduce the CEUS comparative occupancy schedules given the limitations of this evaluation. We also could not verify the IOUs' auto-shutoff control savings assumptions for warehouses

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[32] Williams, Alison, et al. *A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings*. Lawrence Berkeley National Laboratory. LBNL-5095E. September 2011. Available online: https://ees.lbl.gov/sites/all/files/a_meta-analysis_of_energy_savings_from_lighting_controls_in_commercial_buildings_lbnl-5095e.pdf

(which the IOUs evaluated separately from the remaining building types) because of incomplete documentation of the IOU analysis. Therefore, Cadmus calculated savings for this building type consistent with other building types, assuming occupancy seven days a week with auto-shutoff control savings opportunities between 10:00 p.m. and 6:00 a.m.

Lastly, Cadmus considered the 2008 Title 24 compliance lighting occupancy schedules from the 2008 Title 24 Nonresidential Alternative Calculation Manual. These lighting occupancy schedules indicate the percentage of building LPD active for each hour of the day for weekdays and weekends. Because these schedules are intended to reflect lighting schedules after the implementation of Title 24 lighting controls requirements, they do not provide estimates for the LPD reduced because of controls. However, they do support the IOU-estimated assumptions regarding building occupancy and reduced LPD levels during weeknights and weekends.

Table 37 summarizes the evaluated analysis and savings for the auto-shutoff controls, as well as the 2008 LPD levels used for this analysis.

Table 37. Building Types Analyzed for Evaluated Auto-Shutoff Savings

CEC Forecast Building Type	Unoccupied Hours that Auto-Shutoff Controls are Active	Hours Controlled	Evaluated Auto-shutoff Savings (kWh/sq. ft./yr)
Office: small	10:00 p.m. to 6:00 a.m. Mon–Sat, all day Sunday	3744	0.741
Office: large	10:00 p.m. to 6:00 a.m. Mon–Sat, all day Sunday	3744	0.741
Restaurant	10:00 p.m. to 6:00 a.m. every day	2920	0.466
Retail	10:00 p.m. to 6:00 a.m. every day	2920	0.520
Food	10:00 p.m. to 6:00 a.m. every day	2920	0.520
Non-refrigerated warehouse	10:00 p.m. to 6:00 a.m. every day	N/A	0.233
Refrigerated warehouse	10:00 p.m. to 6:00 a.m. every day	N/A	0.233
School	10:00 p.m. to 6:00 a.m. Mon–-Fri, all weekend	4576	0.523
College	10:00 p.m. to 6:00 a.m. every day	2920	0.388
Hospital	N/A	N/A	0.000
Hotel	N/A	N/A	0.000
Miscellaneous	N/A	N/A	0.000

Evaluated Demand UES

The reported statewide demand savings analysis was very convoluted and involved multiple back-calculations from unreproducible CASE report estimates to incorporate more recent square footage estimates. The IOUs mistakenly used the applicable square footage estimates for standard B34 instead of the applicable square footage estimates for standard B35 to calculate statewide demand savings, resulting in a more than three-fold increase in demand savings. Cadmus applied applicable square footage for standard B35 to the evaluated statewide savings.

The IOUs did not provide calculations detailing the UES analysis from the raw data and assumptions that they then applied to the more recent square footage estimates (mistakenly for standard B34) to establish estimated demand savings of 119.2 MW reported in their supporting analysis workbook *Lighting Alteration savings estimate—For Cadmus.xls*, which was close to the final submitted claim of 122.8 MW. Consequently, Cadmus used the UES analysis provided in the workbook *Statewide savings for retrofits.xls* to develop evaluated savings; although the UES assumptions in this workbook did not match the UES estimates on which the submitted claim was based, they could be tied back to the CASE report methodology and reviewed.

According to the lighting alterations CASE report, the IOUs calculated demand savings from the LPD reduction by multiplying the weighted average LPD reduction of 0.51 watts per square foot from CEUS (for buildings that did not already comply with 2013 Title 24 LPD requirements) by the percentage of lights on during the CPUC's peak period (determined using occupancy schedules derived from the CEUS metered data). Cadmus accepted this general methodology, including using CEUS as an appropriate data source for occupancy schedules. However, Cadmus used the LPD reductions described in the Evaluated Tuning Controls UES section of this evaluation in place of the weighted average LPD reduction of 0.51 watts per square foot. Thus, for building types where the CEUS LPD levels were already better than 2008 Title 24 LPD requirements, no demand savings were realized.

According to the lighting alterations CASE report, the IOUs calculated demand savings from tuning by multiplying the 15% tuning savings assumption by the percentage of lights on during the CPUC's peak period (determined using occupancy schedules derived from the CEUS metered data). As mentioned in the Evaluated Tuning Controls UES section, Cadmus accepted the 15% savings assumption based on a comparison with results from an LBNL meta-analysis on institutional tuning savings.

Cadmus considered using DEER coincidence factors for evaluated demand savings, but decided not to use these factors because they were derived from metering studies that would reflect the implementation of lighting controls. These coincidence factors would not account for the change in lighting operation achieved by the implementation of lighting controls.

Table 38 summarizes evaluated demand savings.

Table 38. Evaluated Demand Unit Energy Savings Estimates and Assumptions

CEC Building Type	Tuning Controls Savings (W/sq. ft.)	Auto-shutoff Controls Savings (W/sq. ft.)	LPD Reduction Savings (W/sq. ft.)	Cadmus Assumptions
Office: small	0.105	0	0.276	Office occupancy schedule
Office: large	0.105	0	0.072	Office occupancy schedule
Restaurant	0.122	0	0.142	All commercial occupancy schedule
Retail	0.150	0	0.000*	Retail occupancy schedule
Food	0.136	0	0.000*	All commercial occupancy schedule
Non-refrigerated warehouse	0.063	0	0.035	N/A
Refrigerated warehouse	0.063	0	0.056	N/A
School	0.087	0	0.000*	All commercial occupancy schedule
College	0.102	0	0.027	All commercial occupancy schedule
Hospital	0.000	0	0.000	N/A
Hotel	0.087	0	0.176	All commercial occupancy schedule
Miscellaneous	0.100	0	0.258	All commercial occupancy schedule

* No LPD reduction demand savings because of no LPD reduction energy savings. For these building types, the CEUS LPD levels were more efficient than the 2008 Title 24 LPD levels.

Evaluated Gas UES

Cadmus accepts the approach to estimate gas impacts by multiplying statewide savings estimates by the interactive effects factor -0.0041 therms per kWh. This interactive effects factor was used in the 2008 Building Efficiency Standards evaluation.

Applicable Square Footage

Cadmus based evaluated square footage estimates by building type and climate zone on updated CEC forecast data for 2015 existing building stock provided by the CEC in September 2015.

Cadmus accepts the IOU assumption that lighting systems are replaced every 15 years on average, which is based on assumptions in the CEC impact analysis. Cadmus is not aware of better data to support a more robust assumption.

Cadmus reviewed the online survey results reported in the lighting alterations CASE report as the basis of assumptions for the percentage of applicable square footage and accepted this data source because of a lack of secondary research on the portion of building space in which 10% or more of luminaires are replaced. However, Cadmus noted the survey results in the CASE report indicated 21% of building spaces replace 10% to 50% of luminaires,[33] which differed from the IOU supporting workbook analysis that reported 22% for the same number.[34] The CASE report provided more detailed survey results that supported the assumption of 21% and not 22%, so Cadmus applied 21% to the evaluated square footage estimates.

Because the evaluated LPD reduction analysis accounted for buildings that did not already comply with 2008 Title 24 LPD requirements, Cadmus removed the IOUs' additional reduction factor of 62% from the evaluated applicable square footage analysis. The IOUs based this reduction factor on the assumption that 38% of projects would already have complied with Title 24 LPD requirements based on CEUS data.

Additionally, the CASE report in the lighting stakeholder survey indicated that 30% of projects would have had wiring alterations that triggered 2008 Title 24 lighting controls requirements. However, the IOU analysis erroneously applied a reduction factor of 70% instead of 60% to the square footage to account for projects that would not already have complied with Title 24 lighting controls requirements. Cadmus used 60% in the square footage analysis.

Lastly, Cadmus identified a calculation error in the IOUs' lighting controls square footage analysis. The IOUs only applied a 60% reduction because of projects undergoing wiring changes that would trigger 2008 Title 24 lighting controls requirements to projects in which 50% or more of luminaires were replaced. Because the 2008 lighting control requirements trigger is decoupled from the LPD requirements trigger, the IOUs should have applied the reduction to projects that would have to comply with control requirements to both the portion of projects with 50% or more of luminaires replaced (69%) as well as the portion of projects with 10% to 50% of luminaires replaced (21%). Cadmus used the following algorithm to evaluate applicable square footage for LPD reduction requirements:

$$Applicable\ square\ footage = (Total\ Existing\ Stock) \times \frac{1}{15} \times (21\%)$$

Cadmus used the following algorithm to evaluate applicable square footage for lighting controls requirements:

$$Applicable\ square\ footage = (Total\ Existing\ Stock) \times \frac{1}{15} \times (21\% + 69\%) \times 60\% \times 50\%$$

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33 Chappell, Rasin. Codes and Standards Enhancement Initiative (CASE) Final Report – Lighting Alterations and Modifications in Place. June 2013.

34 IOUs. *Lighting Alteration savings estimate—For Cadmus.xls.* IOUs submitted these workbooks to Cadmus in December 2015.

Table 39 shows the evaluated square footage by building type for standard B35.

Table 39. Evaluated Applicable Square Footage by Forecast Building Type

Building Type	Total Existing Floor Area —2015 CEC Forecast (Million Sq. ft.)	Total Lighting Alteration Floor Area* (Million sq. ft./yr)	Total Lighting Alteration Floor Area Applicable to Tuning Savings (Million sq. ft./yr)	Total Lighting Alteration Floor Area Applicable to Auto-Shutoff Savings (Million Sq. ft./yr)	Total Lighting Alteration Floor Area Applicable to LPD Reduction Savings (Million sq. ft./yr)
Office: small	379	25	7	7	5
Office: large	1,289	86	23	23	18
Restaurant	186	12	3	3	3
Retail	1,171	78	21	21	16
Food	311	21	6	6	4
Non-refrigerated warehouse	1,057	70	19	19	15
Refrigerated warehouse	57	4	1	1	1
School	563	38	10	10	8
College	298	20	5	5	4
Hospital	368	25	7	7	5
Hotel	343	23	6	6	5
Miscellaneous	1,366	91	25	25	19
Total	**7,389**	**493**	**133**	**133**	**103**

* Total lighting alteration area is calculated as (total existing floor area) x (1/15) for each building type.

Table 40 shows the final evaluated savings estimate for standard B35: Nonresidential Lighting Alterations, Existing Measures.

Table 40. Nonresidential Evaluated Annual Potential Energy Savings Estimate: Standard B35

Interactive Effects*	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings without interactive effects	152.6	22.8	0.00
Final evaluated savings with interactive effects	167.9	30.0	-0.63

* The interactive effects factors are discussed in the Interactive Effects section at the beginning of this appendix. Final evaluated savings include interactive effects.

H.3. B41: Nonresidential Alterations HVAC Equipment Efficiency

Table 41 lists the IOU-estimated and Cadmus-evaluated potential energy and demand savings for the B41: Nonresidential Alterations HVAC Equipment Efficiency Standard.

Table 41. Nonresidential Annual Potential Energy Savings Estimates: Standard B41

Description	IOU Estimate	Evaluated*
Total electric energy savings (GWh/yr)	96.0	88.5
Total demand reduction (MW)	33.7	28.5
Total gas energy savings (MMtherms/yr)	3.69	2.62
Total applicable units (Million sq. ft.)	306.5	298.3

* Evaluated savings in this table include interactive effects because of the whole building analysis savings estimation approach.

H.3.a. Standard Description

B41: Nonresidential Alterations, HVAC Equipment Efficiency standard requirements are listed in Sections 130.1 and 140.6 of the 2013 Title 24 California Building Energy Efficiency Standards. Cadmus derived the savings for this standard from the energy savings results from the CEC's 2013 Building Efficiency Standards Impact Analysis between the following baseline and standard cases described here:[35]

- **Baseline**: The baseline scenario covers HVAC equipment efficiency requirements for building alterations compliant with the 2008 Title 24, Section 112.[36]
- **Standard:** The standard covers HVAC equipment efficiency requirements for building alterations compliant with the 2013 Title 24, Section 110.2.[37]

H.3.b. IOU-Estimated Potential Energy Savings Estimates

Per-Unit Savings Estimates

The IOUs developed statewide potential savings estimates using UES estimates for standard B41 that were based on results from the CEC's 2013 Building Efficiency Standards Impact Analysis. The analysis

[35] 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

[36] CEC. *2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings.* CEC-400-2008-001-CMF. December 2008. Available online: http://www.energy.ca.gov/2008publications/CEC-400-2008-001/CEC-400-2008-001-CMF.PDF

[37] CEC. *2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings*. CEC-400-2012-004-CMF-REV2, May 2012. Available online: http://www.energy.ca.gov/2012publications/CEC-400-2012-004/CEC-400-2012-004-CMF-REV2.pdf

relied on EnergyPlus Version 6 building simulation software to model energy consumption for multiple building types in California's sixteen climate zones. The CEC impact analysis also leveraged DOE building prototype models, which were modified to be compliant with the CEC's Title 24 requirements for two scenarios: 2008 and 2013. Because the DOE building prototypes did not fully align with the building types used for the CEC's building construction forecast in California,[38] the CEC impact analysis weighted some of the DOE building prototype results together to estimate savings for a single CEC construction forecast building type.

The CEC report presented results for six building types that align with the CEC's construction forecast: large office, restaurant, retail, non-refrigerated warehouse, school, and hotel. The CEC's impact analysis did not include results for the following forecast building types because of uncertainty in building characteristics, lack of DOE prototypes, and/or lack of sufficient baseline information: small office, food, refrigerated warehouse, college, and miscellaneous. The impact analysis did not model hospitals because building efficiency standards did not apply to the hospital sector.

The IOUs estimated a single average UES they deemed applicable to all 12 CEC forecast building types, including the six building types excluded from the CEC's impact analysis. They calculated an average UES for electric energy, electric demand, and gas energy by dividing the reported total statewide savings for GWh, MW, and MMtherms by total reported square footage (for all modeled building types), as reported in the CEC impact analysis. The IOUs then applied the average UES to all 12 CEC forecast building types, including the building types modeled by the CEC (where building-specific UES estimates were available). As summarized in Table 42, the IOUs documented this analysis in a memo titled *EnergyEfficiency2013-2015-Portfolio_DR_EMV_114_EEStats_25240* and provided it to Cadmus in response to a data request.[39]

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38 The building types used for the CEC's new construction forecast are the same as the CEC's existing building stock building types.

39 Memo titled *EnergyEfficiency2013-2015-Portfolio_DR_EMV_114_EEStats_25240* and submitted by the IOUs to the CPUC and Cadmus in November 2016.

Table 42. IOU-Estimated UES by Forecast Building Type

Forecast Building Type	UES (kWh/ sq. ft./yr)	UES (W/ sq. ft.)	UES (therms/ sq. ft./yr)	Building Type Proxy for UES*
Office: small	0.313	0.110	0.012	Average
Office: large	0.313	0.110	0.012	Average
Restaurant	0.313	0.110	0.012	Average
Retail	0.313	0.110	0.012	Average
Food	0.313	0.110	0.012	Average
Non-refrigerated warehouse	0.313	0.110	0.012	Average
Refrigerated warehouse	0.313	0.110	0.012	Average
School	0.313	0.110	0.012	Average
College	0.313	0.110	0.012	Average
Hospital	0.313	0.110	0.012	Average
Hotel	0.313	0.110	0.012	Average
Miscellaneous	0.313	0.110	0.012	Average

* The IOUs calculated the average using total statewide savings divided by total statewide square footage for all building types, as reported in the CEC impact analysis.

Statewide Potential Energy Savings Estimate

The IOUs calculated the applicable square footage of the B41 standard for each forecast building type using the CEC's forecasted existing floor stock for the year 2014 (as stated in the 2013 CEC impact analysis report).[40] The CEC impact analysis assumed that HVAC equipment is replaced every 20 years, and thus, it assumed that HVAC equipment alterations savings apply to one-twentieth of the total existing floor area per building type per year. The IOUs used this same assumption in their estimates of applicable square footage; they reduced the applicable square footage estimate further using professional judgement for some building types, per a supporting memo and subsequent phone call between the IOUs, their consultants, and Cadmus.[41]

The IOUs reduced the applicable square footage for refrigerated warehouses by 90% and reduced applicable square footage for colleges, hospitals, hotels, and miscellaneous building types by 50%. Table 43 lists the IOUs' assumptions for applicable square footage by building type for standard B41.

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40 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

41 Memo titled *EnergyEfficiency2013-2015-Portfolio_DR_EMV_114_EEStats_25240* and submitted by the IOUs to the CPUC and Cadmus in November 2016. Conference call between the IOUs, the IOU consultants, and Cadmus took place on November 30, 2016.

Table 43. IOU Assumptions for Applicable Square Footage by Forecast Building Type

Forecast Building Type	Total Existing Floor Area: 2013 CEC Forecast (Million sq. ft.)	Total HVAC Alteration Area:* (Million sq. ft./yr)	% Floor Area Affected by the Standard	Total Lighting Alteration Floor Area Applicable to B41 Standard (Million sq. ft./yr)
Office: small	397	20	100%	20
Office: large	1,286	64	100%	64
Restaurant	191	10	100%	10
Retail	1,176	59	100%	59
Food	311	16	100%	16
Non-refrigerated warehouse	1,057	53	100%	53
Refrigerated warehouse	59	3	10%	0
School	554	28	100%	28
College	349	17	50%	9
Hospital	353	18	50%	9
Hotel	331	17	50%	8
Miscellaneous	1,272	64	50%	32
Total	**7,336**	**367**		**307**

* IOUs calculated the total HVAC alteration area as (total existing floor area) x (1/20) for each building type.

Table 44 shows the total annual potential electric and gas savings estimated by the IOUs for this standard. The IOUs calculated statewide savings by multiplying UES estimates by applicable square footage for each building type.

Table 44. IOU-Estimated Annual Energy Savings Estimate: Standard B41

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
96.0	33.7	3.69

H.3.c. Evaluation Findings

Unit Energy Savings

Cadmus accepts the CEC impact analysis as the best source for determining unit energy savings estimates for standard B41.[42] We also agree that estimating impacts for the building types excluded from the CEC impact analysis is reasonable, but instead of using the same average UES for all building types, we used UES results for individual building types from the CEC impact analysis, as well as results

[42] 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

for individual building types as proxies for most of the building types excluded from the CEC impact analysis. Cadmus confirmed with CEC that the square footage from the excluded building types was not accounted for in its impact analysis. Table 45 lists the evaluated UES estimates, including assumptions for the excluded building types.

The CEC impact analysis reported the UES estimates by building type and climate zone.[43] Thus, to develop UES estimates for a building type excluded from the analysis, Cadmus used a proxy building type included in the CEC analysis. We then calculated a weighted average UES for the proxy building type, weighted by the square footage per climate zone of the excluded building type. For example, we used the large office UES as a proxy for the excluded small office UES. To calculate an average UES for small offices, Cadmus averaged the large office UES values for each climate zone together based on the proportion of small office square footage in each climate zone.

43 A summary of the building model outputs for the CEC impact analysis by CEC forecast building type and climate zone was provided by the IOUs in December 2015 (originally sourced from the CEC). The analysis is not currently publicly available and must be requested from the CEC.

Table 45. Evaluated UES by Forecast Building Type

Forecast Building Type	UES (kWh/sq. ft./yr)	UES (W/sq. ft.)	UES (therms/sq. ft./yr)	Building Type Proxy for UES
Office: small	0.051	0.026	0.000*	Used large office UES, weighted by small office square footage by climate zone
Office: large	0.049	0.025	0.000*	N/A
Restaurant	2.907	1.215	0.291	N/A
Retail	0.686	0.189	-0.002	N/A
Food	0.281	0.000*	0.000*	Weighted average of all 11 building types UES estimates
Non-refrigerated warehouse	0.001	0.000*	0.000*	N/A
Refrigerated warehouse	0.001	0.000*	0.000*	Used non-refrigerated warehouse UES, weighted by refrigerated warehouse square footage by climate zone****
School	0.085	0.030	0.000**	N/A
College	0.084	0.030	0.000**	Used school UES, weighted by college square footage by climate zone
Hospital	0.000***	0.000***	0.000***	Not included because of inapplicability of 2013 building efficiency standards
Hotel	N/A*	N/A *	N/A *	N/A
Miscellaneous	0.281	0.000*	0.000*	Weighted average of all 11 building types UES estimates

* CEC impact analysis reported zero savings for this building type.

** Non-zero savings round to zero.

*** The CEC impact analysis excluded hospitals because of the inapplicability of Title 24 requirements.

**** The proxy reduced the applicable square footage for refrigerated warehouses because of the low incidence of HVAC equipment in refrigerated warehouses and, therefore, there was a low portion of conditioned space relative to total square footage.

Applicable Square Footage

Cadmus based the evaluated square footage estimates by building type and climate zone on updated CEC forecast data for 2015 existing building stock provided by the CEC in September 2015.

Cadmus accepts the IOU assumption that HVAC systems are replaced every 20 years on average, which is based on assumptions in the CEC impact analysis. Cadmus also accepted the IOU square footage reductions based on professional judgment. Cadmus considers a 90% reduction in applicable square footage for refrigerated warehouses acceptable given that the portion of space conditioned by HVAC equipment is much smaller than the overall footprint (and total square footage) of refrigerated warehouses. The refrigerated warehouse storage space would not fall under the HVAC equipment efficiency requirements of this standard. We determined the applicable portion of hospital square footage to be zero based on the inapplicability of the Title 24 requirements to this sector. We accept the additional assumptions regarding reduced applicable square footage.

Table 46 shows the evaluated square footage by building type for standard B34.

Table 46. Evaluated Applicable Square Footage by Forecast Building Type

Forecast Building Type	Total Existing Floor Area: 2015 CEC Forecast (Million sq. ft.)	Total HVAC Alteration Area:* (Million sq. ft./yr)	Percentage of Floor Area Affected by the Standard	Total HVAC Alteration Floor Area Applicable to B41 Standard (Million sq. ft./yr)
Office: small	379	19	100%	19
Office: large	1,289	64	100%	64
Restaurant	186	9	100%	9
Retail	1,171	59	100%	59
Food	311	16	100%	16
Non-refrigerated warehouse	1,057	53	100%	53
Refrigerated warehouse	57	3	10%	0
School	563	28	100%	28
College	298	15	50%	7
Hospital	368	18	0%	0
Hotel	343	17	50%	9
Miscellaneous	1,366	68	50%	34
Total	**7,389**	**369**		**298**

* Total HVAC alteration area evaluated as (total existing floor area) x (1/20) for each building type.

Table 47 shows the final evaluated savings estimate for this standard.

Table 47. Nonresidential Evaluated Annual Potential Energy Savings Estimate: Standard B41

Interactive Effects	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings without interactive effects*	N/A	N/A	N/A
Final evaluated savings with interactive effects	88.5	28.5	2.62

* The whole building analysis used to estimate savings only produced whole building impacts. Final evaluated savings include interactive effects.

H.4. B36, B46: Egress Lighting Control

Table 48 summarizes the findings Cadmus used to estimate potential energy savings for standards B36 and B46: Egress Lighting Control.

Table 48. Nonresidential Annual Potential Energy Savings Estimate: Standards B36 and B46

Description	IOU Estimate (NRA B36)	Evaluated (NRA B36)*	IOU Estimate (NRNC B46)	Evaluated (NRNC B46)*
Total electric energy savings (GWh/yr)	82.8	92.6	25.1	44.4
Total demand reduction (MW)	0.0	0.0	0.0	0.0
Total gas energy savings (MMtherms)	0.00	0.00	0.00	0.00
Total applicable units (Million sq. ft.)	401.1	209.9	149.8	111.8

* Evaluated savings in this table exclude interactive effects. Final evaluated savings do not account interactive effects for this standard because savings occur during unoccupied times.

H.4.a. Standard Description

The standards B36 and B46: Egress Lighting Control requirements are listed in Section 130.1(a) and 130.1(c) of the 2013 Title 24 California Building Energy Efficiency Standards. The CASE report supporting this standard details energy savings between the following baseline and standard cases:[44]

- **Baseline:** Section 130.1(a) Area Controls of the 2008 Title 24 California Building Energy Efficiency Standards states that all luminaries shall be functionally controlled with manually switched on and off lighting controls. The code makes an exception to this rule for egress lighting: up to 0.3 watts per square foot of lighting in any area within a building may be continuously illuminated during occupied times to allow for emergency egress.

  Section 103.1(c) Shut-Off Controls of the 2008 Title 24 California Building Energy Efficiency Standards states that all indoor lighting must be controlled by a control capable of automatically shutting off all lighting when the space is typically unoccupied. The code makes an exception to this rule for egress lighting: up to 0.3 watts per square foot of lighting in any area within a building may be continuously illuminated, provided that the area is designated an emergency egress area. This lighting power density exception for egress lighting appears to be quite generous, since the CASE report does not use 0.3 watts per square foot as a baseline for calculating savings. Instead, they attempt to establish an actual use LPD for egress lighting by building type.

- **Standard:** The standard contains many of the components of the baseline standard, with the following key changes:

  - Section 130.1(a) Area Controls of the 2013 Title 24 California Building Energy Efficiency Standards states that all luminaries shall be functionally controlled with manually switched on and off lighting controls. The code makes an exception to this rule for egress lighting: up to 0.2 watts per square foot of lighting in any area within a building may be continuously illuminated during occupied times to allow for emergency egress.

44 California Utilities Statewide Codes and Standards team. 2013 California Building Energy Efficiency Standards: Final Report Control of Egress Lighting. June 2013.

- Section 103.1(c) Shut-Off Controls of the 2013 Title 24 California Building Energy Efficiency Standards states that all indoor lighting must be controlled by a control capable of automatically shutting off all lighting when the space is typically unoccupied. The CASE report makes an exception to this rule for egress lighting: up to 0.05 watts per square foot of lighting in any area within an office building may be continuously illuminated, provided that the area is designated an emergency egress area. There is no exception to Shut-Off Controls for non-office building types.

The requirements for B36, B46 – Egress Lighting Control are covered in Section 130.1(a) and 130.1(c) of the 2013 Title 24 California Building Energy Efficiency Standards.[45]

H.4.b. IOU-Estimated Potential Energy Savings Estimates

Unit Energy Savings Estimates

The IOUs provided a CASE report for egress lighting as back-up documentation for their estimated savings,[46] however the CASE report statewide numbers did not align with the total statewide savings estimates for standards B36 and B46 submitted to Cadmus. Cadmus requested additional information and explanation through a data request and received a supporting Excel workbook that also did not completely align with the IOU estimates. Consequently, Cadmus reviewed the CASE report methodology and the supporting workbook as the best sources of energy savings estimate analysis.

The CASE report estimated annual per-unit electric energy savings for each building type using the product of the change in LPD, the change in hours the LPD change took effect over, and the percentage of space in which egress lighting was left on overnight. The UES calculation used in the provided supporting workbook titled *NRNC-Lighting-Egress Lighting Control – Statewide Savings for Egress* is below:

$$UES = \%BuildingSpaceEgressLighting * (BaselineLPD - StandardLPD) \\ * (BaselineHoursPerYear - ProposedHoursPerYear)/1000$$

Where $BaselineLPD$ is a product of the whole building LPD from the complete building method values and the percentage of connected load that is egress lighting. The CASE report authors conducted an online survey and found that office buildings have approximately 0.16 watts per square foot of egress lighting, which is 19% of the total building allowance of 0.80 watts per square foot. The CEC used this 19% factor for all building types. The standard LPD for egress lighting is from the final code language. It is 0.05 watts per square foot for office buildings and 0.00 for all other building types.

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[45] CEC. 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings. CEC-400-2012-004-CMF-REV2. May 2012.

[46] Chappell, Cathy, and Douglass, David. Codes and Standards Enhancement Initiative (CASE) Final Report – Control of Egress Lighting. June 2013.

The LPD change effects hours that a building is typically unoccupied. The CASE report estimated how often buildings (except schools) were typically unoccupied by assuming they were unoccupied on Sunday and for nine hours a day every other day of the week, for a total of approximately 78 hours per week. The CASE report assumed that schools already switched off as much of their lighting as they were able to because of tight budgets. The assumption about schools was conservative, as it reduced savings for schools for this standard to zero.

The CASE report based the percentage of space in which egress lighting was left on overnight on the results of two surveys for office buildings conducted by the CASE authors. This percentage was then applied to all building types. The first survey was a nighttime lighting survey that estimated that 7% of connected load was egress lighting left on overnight. The second survey was an online survey that found the office buildings had approximately 0.16 watts per square foot of egress lighting, which was 19% of the total building allowance of 0.80 watts per square foot. (The quotient of 7% and 19% results in 37% factor for the percentage of space in which egress lighting was left on overnight.)

The IOUs did not calculate demand savings because of energy savings occurring during off-peak hours.

Statewide Potential Energy Savings Estimate

The CASE report based total existing and new construction nonresidential floor areas on the CEC's 2013 forecast. For existing square footage, the report divided the total area by the assumed effective useful life (EUL) of the lighting installation. This quotient provides an estimate for the amount of existing square footage that will require alterations in a single year.

The CASE report applied a factor (the percentage of floor space affected, which varied from 25% to 100%) to the total square footage to identify the applicable affected area for this standard. The report assumed that 75% of warehouses were continually occupied, which corresponds with an affected floor space of 25%. The report also assumed that retail spaces left on 25% of their lighting for advertising purposes, which corresponds with an affected floor space of 75%. Finally, the report claims that large office and college buildings had continuously occupied security stations that accounted for 5% of the square footage for those building types. The percentage of floor space factor was 100% for all other building types. While Cadmus was unable to verify these assumptions using secondary sources, we find these assumptions generally conservative.

The IOU square footage estimate for this standard does not match the square footage in the CASE report. Cadmus was unable to verify the ISSM 2015 square footage claims.

Table 49 summarizes the savings reported by the IOUs for this standard.

Table 49. Nonresidential IOU-Estimated Annual Potential Energy Savings: B36, B46

Standard	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
NRA B36	82.8	0.0	0.00
NRNC B46	25.1	0.0	0.00

H.4.c. Evaluation Findings

Cadmus found that the IOU savings estimate for this standard does not reflect the latest analysis from a supporting workbook that was provided for the evaluation in response to data request. Cadmus' estimates are based on the methodology from the supporting workbook provided by the IOUs. The evaluated square footages are much closer to the square footage in the supporting workbook than to the IOU estimate for B36, but are closer to the IOU estimate than the supporting workbook for B46. The square footages in the supporting workbook are 401 million square feet for B36 and 150 million square feet for B46.

Cadmus verified the series of assumptions regarding typical hours of occupancy by reviewing the 2013 Title 24 compliance lighting occupancy schedules from the 2013 Title 24 Nonresidential Alternative Calculation Manual. These lighting occupancy schedules indicate the percentage of building LPD active for each hour of the day for weekdays and weekends. While these schedules are intended to reflect lighting schedules after the implementation of Title 24 lighting controls requirements, they do not provide estimates for savings attributable to lighting controls. However, they do support the IOU-estimated assumptions regarding building occupancy.

Cadmus was unable to verify two inputs for the unit energy savings (UES) for this standard. The first is office building survey results for the percentage of connected load that is egress lighting being applied to all building types. Means-of-egress vary significantly between building types, meaning that the percentage of connected load that is egress lighting should vary between building types as well. The second, which is related to the first, is the office building survey results for the percentage of building space in which egress lighting is left on overnight being applied to all building types. While these are notable uncertainties in the unit energy savings estimation, Cadmus finds them reasonable and was unable to find any secondary sources to either confirm or disprove the assumptions listed above. As a result, Cadmus accepts the per-unit savings estimates from the CASE report for electric energy (kWh).

The reported per-unit electric savings calculation is incorrect. The error lies in the order of operations, which results in calculating the product of a difference instead of the difference of products. Below is the corrected form of the equation used for the evaluated savings:

$$UES = \%BuildingSpaceEgressLighting * (BaselineLPD * BaselineHoursPerYear - ProposedLPD * ProposedHoursPerYear)/1000$$

Correcting this error accounts for the difference in reported and evaluated per-unit savings. Because of energy savings occurring during off-peak hours, Cadmus did not calculate demand savings.

Cadmus used CEC forecast estimates to determine applicable square footage. The square footage assumptions received from the CEC in September 2015 do not align with the CASE report square footage estimates by building type. The final evaluated savings estimate for this standard are shown in Table 50. The correction of the unit energy savings calculation is the main driver behind the difference in IOU-estimated and evaluated savings.

Table 50. Nonresidential Evaluated Annual Potential Energy Savings Estimate: B36, B46

Interactive Effects*	Standard	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings without interactive effects	NRA B36	91.9	0.0	0.00
	NRNC B46	44.4	0.0	0.00
Final evaluated savings with interactive effects	NRA B36	92.6	0.0	0.00
	NRNC B46	44.4	0.0	0.00

*No interactive effects factors were applied to the final evaluated savings for these standards because egress lighting savings were assumed to occur during unoccupied times when buildings are not conditioned.

H.5. B39, B49: Lighting-Warehouses and Libraries

Table 51 provides a summary of the findings Cadmus used to estimate potential energy savings for standards B39, B49: Lighting-Warehouses and Libraries.

Table 51. Nonresidential Annual Potential Energy Savings Estimate: Standards B39, B49

Description	IOU Estimate (NRA B39)	Evaluated* (NRA B39)	IOU Estimate (NRNC B49)	Evaluated* (NRNC B49)
Total electric energy savings (GWh/yr)	60.3	59.6	30.1	21.0
Total demand reduction (MW)	6.9	6.2	3.4	2.2
Total gas energy savings (MMtherms)	-0.23	0.00	-0.11	0.00
Total applicable units (Million sq. ft.)	67.8	73.6	33.9	25.9

* Evaluated savings in this table exclude interactive effects. Final evaluated savings include interactive effects.

H.5.a. Standard Description

The standards B39, B49: Lighting-Warehouses and Libraries requirements are listed in Section 103.1(c) of the 2013 Title 24 California Building Energy Efficiency Standards. The CASE report supporting this standard details energy savings between the following baseline and standard cases:[47]

- **Baseline:** The baseline for these standards is the 2008 Title 24 code. [48] The 2008 code includes lighting controls and lighting power density requirements for all applicable building types including warehouses. These requirements are detailed in sections 131 and 146.
- **Standard:** The final code language designates areas that must install occupancy sensors in addition to the lighting controls requirements in Section 130.1(c)1. The code language requires occupant sensor lighting controls in warehouse aisle ways and open spaces, and library book stack aisles. The occupancy sensors will independently control lighting in each individual aisle. They will automatically reduce lighting power in the designated aisle by at least 50% during unoccupied periods. Language is included to ensure a uniform level of illuminance for paths of egress, as are exceptions for lighting power densities that are 20% lower than the lighting power allowance for that space.[49]

The current requirements for B39, B49: Lighting-Warehouses and Libraries are detailed in Section 130.1(c)6 of the 2013 Title 24 California Building Energy Efficiency Standards.[50]

H.5.b. IOU-Estimated Potential Energy Savings

Unit Energy Savings Estimates

The IOUs provided a CASE report for this standard, as well as a supporting workbook.[51] The CASE report's supporting workbook calculated UES for this standard by weighting an average of UES for different warehouse area types by the appropriate percentage of each area type. The UES calculations for each area type were in a separate supporting workbook not provided to Cadmus. The CASE report

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47 California Utilities Statewide Codes and Standards team. 2012 California Building Energy Efficiency Standards: Final Report Automated Lighting Controls and Switching Requirements in Warehouses and Libraries. December 2012.

48 CEC. 2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings. December 2008.

49 2012 California Building Energy Efficiency Standards: Final Report Automated Lighting Controls and Switching Requirements in Warehouses and Libraries. California Utilities Statewide Codes and Standards team. December 2012.

50 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012.

51 Chappell, Cathy, and Howlett, Owen. Codes and Standards Enhancement Initiative (CASE) Final Report – Automated Lighting Controls and Switching Requirements in Warehouses and Libraries. December 2012.

developed assumptions with a stakeholder group about the distributions of area types: 75% aisle space and 25% open space, as well as 85% non-refrigerated, 10% refrigerated, and 5% freezer area.

Statewide Potential Energy Savings Estimate

The CASE report based total existing and new construction nonresidential floor areas on the CEC's 2014 forecast. The report used an assumed EUL of 15 years to determine the amount of applicable yearly nonresidential alterations area. The IOU-estimated square footage does not match the square footage estimates developed in the CASE report or the CASE report's supporting documentation. Table 52 shows the savings reported by the IOUs for standards B39, B49: Lighting-Warehouses and Libraries.

Table 52. Nonresidential IOU-Estimated Annual Potential Energy Savings: Standards B39, B49

Standard	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
NRA B39	60. 3	6.9	-0.23
NRNC B49	30.1	3.4	-0.11

H.5.c. Evaluation Findings

Cadmus submitted several data requests, but did not receive the data necessary to properly confirm the UES estimates or assumptions. 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, but the scope of this evaluation did not include calculating UES values from scratch.

As such, we accept the per-unit savings estimates from the CASE report as reasonable for electric energy (kWh) and demand (kW) for B39 and B49 based on professional judgement. Cadmus evaluated the potential overlap between this standard and standard B34: Lighting Alterations, New Measures. Based on a review of the CEC impact analysis report, Cadmus determined that the warehouse occupancy sensors required by the 2013 Title 24 lighting alterations requirements were likely not modeled in the CEC analysis used to establish savings for standard B34, and therefore the savings for standard B39 do not overlap with standard B34.

Cadmus used CEC forecast estimates it received in September 2015 to determine applicable square footage. We used the same assumptions the CASE report used to determine the distribution of warehouse area types. The square footage assumptions received from the CEC in September 2015 were more recent than the square footage estimates from the CEC by building type used in the CASE report. Table 53 shows the final evaluated savings estimate for standards B39 and B49: Lighting-Warehouses and Libraries. Adjusting the square footage accounts for the differences in savings between the IOU-estimated and evaluated results.

Table 53. Nonresidential Evaluated Annual Potential Energy Savings Estimate: Standards B39, B49

Interactive Effects*	Standard	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings without interactive effects	NRA B39	59.6	6.2	0.00
	NRNC B49	21.0	2.2	0.00
Final evaluated savings with interactive effects	NRA B39	65.5	8.1	-0.24
	NRNC B49	15.4	1.8	-0.09

* The interactive effects factors are discussed in the Interactive Effects section at the beginning of this appendix. Final evaluated savings include interactive effects.

H.6. B82: Nonresidential New Construction, Whole Building

Table 54 lists the IOU-estimated and Cadmus-evaluated potential energy savings for standard B82: Nonresidential New Construction, Whole Building.

Table 54. Nonresidential Annual Potential Energy Savings Estimates: Standard B82

Description	IOU Estimate	Evaluated*
Total electric energy savings (GWh/yr)	179.2	220.9
Total demand reduction (MW)	46.8	57.8
Total gas energy savings (MMtherms/yr)	1.01	1.21
Total applicable units (Million sq. ft.)	116.4	158.7

* Evaluated savings in this table include interactive effects based on the whole building savings analysis approach.

H.6.a. Standard Description

Standard B82: Nonresidential New Construction—Whole Building captures many of the 2013 Title 24 requirements for new construction. The IOUs based their estimated potential on the whole building new construction results from CEC's 2013 Building Efficiency Standards Impact Analysis between the following baseline and standard cases:[52]

- **Baseline**: The baseline scenario covers new construction buildings compliant with the 2008 Title 24 requirements for new construction. [53]
- **Standard:** The standard covers new construction buildings compliant with the 2013 Title 24 requirements for new construction.[54]

  The CEC's 2013 whole building impact analysis only covered adopted measures that could be modeled using CEC's preferred energy modeling software, EnergyPlus Version 6. The nonresidential new construction standards covered by the CEC impact analysis include the following, per a memo submitted to Cadmus and the CPUC by the IOU team:[55]

- B43: Daylighting
- B44: Indoor Lighting Controls
- B45: Retail Lighting
- B55: Cool Roofs
- B56: Fenestration
- B57: HVAC Controls and Economizers (partially)[56]
- B58: HVAC Fan Control and Economizers
- B59: HVAC Reduced Reheat
- B60: Guest Room OC Controls
- B61: Kitchen Ventilation
- B62: Commercial Boilers
- B63: Chiller Min Efficiency

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52 California Energy Commission Consultant Report, Impact Analysis: California's 2013 Building Efficiency Standards, CEC-400-2013-008, July 2013. Accessible at http://www.energy.ca.gov/2013publications/CEC-400-2013-008/CEC-400-2013-008.pdf

53 2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2008-001-CMF, December 2008. Accessible at http://www.energy.ca.gov/2008publications/CEC-400-2008-001/CEC-400-2008-001-CMF.PDF

54 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012. Accessible at http://www.energy.ca.gov/2012publications/CEC-400-2012-004/CEC-400-2012-004-CMF-REV2.pdf

55 Memo submitted by the IOU to the CPUC and Cadmus teams on Thursday, December 22nd, titled *Memo 2013 Title 24 WB and IM Savings 12222016*.

56 The IOUs clarified in a data request response to Cadmus that assuming 50% is a reasonable estimate of the portion of the IOU-estimated savings from the CASE report that apply to the whole building analysis.

H.6.b. IOU-Estimated Potential Energy Savings Estimates

Unit Energy Savings Estimates

The IOUs used the UES estimates from CEC's 2013 building efficiency standards impact analysis to develop their reported statewide savings. The CEC's analysis relied on EnergyPlus Version 6 building simulation software to model multiple DOE building prototypes in California's 16 climate zones. The CEC also modified DOE's building prototype models to be compliant with the Title 24 two scenarios: 2008 standards and 2013 standards. Because the DOE building prototypes did not fully align with the building types used for CEC's building construction forecast in California,[57] the CEC weighted some of the DOE building prototype results together to estimate savings for a single CEC construction forecast building type.

The CEC report presented results for six building types that align with CEC's construction forecast: large office, restaurant, retail, non-refrigerated warehouse, school, and hotel. The analysis did not include results for the following forecast building types because of uncertainty in building characteristics, lack of DOE prototypes, and/or lack of sufficient baseline information: small office, food, refrigerated warehouse, college, and miscellaneous. The CEC did not model hospitals because building efficiency standards did not apply to the hospital sector. Table 55 shows the IOUs' UES estimates by building type based on the CEC analysis.

Table 55. IOU-Estimated UES by Building Type

Forecast Building Type	UES (kWh/ sq. ft./year)	UES (kW/ sq. ft.)	UES (therms/ sq. ft./year)	Modeled in CEC Impact Analysis?
Office: small*	0.000	0.000	0.000	No
Office: large	1.111	0.274	0.003	Yes
Restaurant	3.698	1.394	0.279	Yes
Retail	3.400	0.899	-0.009	Yes
Food*	0.000	0.000	0.000	No
Non-refrigerated warehouse	0.149	-0.027	-0.008	Yes
Refrigerated warehouse*	0.000	0.000	0.000	No
School	0.896	0.267	0.001	Yes
College*	0.000	0.000	0.000	No
Hospital*	0.000	0.000	0.000	No
Hotel	0.618	0.124	0.006	Yes
Miscellaneous*	0.000	0.000	0.000	No

* The IOUs assumed zero savings for the building types based on their exclusion from the CEC analysis.

57 The building types used for the CEC's new construction forecast are the same as the CEC's existing building stock building types.

Statewide Potential Energy Savings Estimate

For new construction square footage applicable to standard B82, the IOUs used the whole building new construction square footage from the CEC impact analysis for each forecast building type.[58]

Table 56 lists the IOUs' assumptions for applicable square footage by building type for standard B82.

Table 56. IOU Assumptions for Applicable Square Footage by Forecast Building Type

Forecast Building Type	Total Existing Floor Area: 2013 CEC Forecast (Million sq. ft.)
Office: small	N/A
Office: large	28
Restaurant	5
Retail	32
Food	N/A
Non-refrigerated warehouse	32
Refrigerated warehouse	N/A
School	10
College	N/A
Hospital	N/A
Hotel	9
Miscellaneous	N/A
Total	**116**

Table 57 shows the total annual electric and gas savings reported by the IOUs for this standard. The IOUs calculated statewide savings by multiplying UES estimates by applicable square footage for each building type.

Table 57. IOU-Estimated Annual Potential Energy Savings Estimate: Standard B82

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
179.2	46.8	1.01

58 California Energy Commission Consultant Report, Impact Analysis: California's 2013 Building Efficiency Standards, CEC-400-2013-008, July 2013. Accessible at http://www.energy.ca.gov/2013publications/CEC-400-2013-008/CEC-400-2013-008.pdf

H.6.c. Evaluation Findings

Unit Energy Savings

Cadmus accepts the CEC impact analysis as the best source for determining UES estimates for standard B82.[59] Consistent with the analysis of other standards based on the CEC impact analysis, we determined that estimating impacts for the building types excluded from the CEC impact analysis was reasonable using building types included in the impact analysis as proxies for excluded building types in most cases. Table 58 lists the evaluated UES estimates, including assumptions for the excluded building types.

The CEC reported the UES estimates by building type and climate zone.[60] To develop UES estimates for a building type excluded from the CEC impact analysis, Cadmus used a proxy building type included in the CEC analysis. We then calculated a weighted average UES for the proxy building type, weighted by the square footage per climate zone for the excluded building type. For example, we used the included large office UES as a proxy for the excluded small office UES. To calculate an average UES for small offices, we averaged the large office UES values for each climate zone together, based on the proportion of small office square footage in each climate zone.

Because the whole building models for each building type included Title 24 requirements for multiple end uses (lighting, HVAC, refrigeration, etc.) when applicable, Cadmus could not determine an ideal proxy building type for every excluded building type. Thus, in many cases we used a weighted average UES among all building types for the excluded building types. We averaged the weighted average UES by climate zone for all 16 climate zones using square footage per climate zone for the excluded building types. For small offices, we used the large office UES as a proxy, and for colleges, Cadmus used the school UES as a proxy.

For the building types included in the CEC analysis, Cadmus' evaluated UES estimates differ slightly from the original CEC UES estimates. This is because the UES estimates per building type are weighted by climate zone, and Cadmus used a more recent (and slightly different) CEC new construction square footage forecast by building type and climate zone than was used in the original CEC analysis. Table 58 summarizes our assumptions.

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59 California Energy Commission Consultant Report, Impact Analysis: California's 2013 Building Efficiency Standards, CEC-400-2013-008, July 2013. Accessible at http://www.energy.ca.gov/2013publications/CEC-400-2013-008/CEC-400-2013-008.pdf

60 A summary of the building model outputs for the CEC impact analysis by CEC forecast building type and climate zone was provided by the IOUs in December 2015 (originally sourced from the CEC). The analysis is not currently publicly available and must be requested from the CEC.

Table 58. Cadmus-Estimated UES by Forecast Building Type

Forecast Building Type	UES (kWh/sq. ft./yr)	UES (W/ sq. ft./yr)	UES (therms/ sq. ft./yr)	Building Type Proxy for UES
Office: small	1.088	0.258	0.003	Used large office UES, weighted by small office square footage by climate zone
Office: large	1.124	0.277	0.003	N/A
Restaurant	3.717	1.404	0.286	N/A
Retail	3.371	0.894	-0.010	N/A
Food	1.466	0.383	0.006	Weighted average of all 11 building types UES estimates
Non-refrigerated warehouse	0.146	-0.027	-0.009	N/A
Refrigerated warehouse	1.466	0.383	0.006	Weighted average of all 11 building types UES estimates
School	0.883	0.262	0.001	N/A
College	0.908	0.270	0.001	Used school UES, weighted by college square footage by climate zone
Hospital	0.000	0.000	0.000	Not included because of the inapplicability of 2013 building efficiency standards
Hotel	0.615	0.120	0.006	N/A
Miscellaneous	1.466	0.383	0.006	Weighted average of all 11 building types UES estimates

Applicable Square Footage

Cadmus based the evaluated square footage estimates by building type and climate zone on updated CEC forecast data for 2014 and 2015 new construction provided by the CEC in September 2015. We averaged 2014 and 2015 data for a more robust estimate of annual new construction.

Table 59 shows the evaluated square footage by building type for standard B82.

Table 59. Evaluated Applicable Square Footage by Forecast Building Type

Forecast Building Type	Total Existing Floor Area—2015 CEC Forecast (Million Sq. ft.)
Office: small	8
Office: large	28
Restaurant	4
Retail	26
Food	7
Non-refrigerated warehouse	24
Refrigerated warehouse	2
School	8
College	4
Hospital	8
Hotel	10
Miscellaneous	29
Total	**151**

Table 60 shows the evaluated savings estimate for this standard. The evaluated savings for standard B82 were used to scale evaluated savings for the standards that overlap with B82, thus no final evaluated savings were assigned to standard B82. See the Interactive Effects section at the beginning of this appendix for more details.

Table 60. Nonresidential Evaluated Annual Potential Energy Savings Estimate: Standard B82

Interactive Effects*	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings without interactive effects	N/A	N/A	N/A
Evaluated savings with interactive effects	220.9	57.8	1.21
Final evaluated savings	0.0	0.0	0.00

* The whole building analysis used to estimate savings only produced whole building impacts. Evaluated savings include interactive effects. For standard B82, evaluated savings were used to scale the evaluated savings for the new construction standards that overlap with standard B82. To avoid double-counting final evaluated savings, Cadmus assigned zero final evaluated savings to standard B82.

H.7. B45: NRNC Lighting-Retail

Table 61 lists the findings Cadmus used to estimate potential energy savings for standard B45: Lighting-Retail.

Table 61. Nonresidential Annual Potential Energy Savings Estimate: Standard B45

Description	IOU Estimate	Evaluated*
Total electric energy savings (GWh/yr)	56.1	41.2
Total demand reduction (MW)	16.6	10.2
Total gas energy savings (MMtherms/yr)	-0.21	0.00
Total applicable units (Million sq. ft.)	32.4	26.2

* Evaluated savings in this table exclude scaled interactive effects. Final evaluated savings include scaled interactive effects.

H.7.a. Standard Description

B45: Lighting-Retail requirements are listed in Section 140.6 of the 2013 Title 24 California Building Energy Efficiency Standards. The CASE report supporting this standard details energy savings between the following baseline and standard cases:

- **Baseline:**[61] Lighting allowances for retail spaces must be in accordance with Section 146 of the 2008 Title 24 California Building Energy Efficiency Standards. Section 146(c) details the calculations and input values for the three methods of determining allowable LPD values for retail spaces: the complete building method, the area category method, and the tailored method.

- **Standard:**[62] The adopted language in Title 24-2013 reduces the space types that are covered under the Tailored Method of compliance. These space types are incorporated into the existing primary function areas under the Area Category Method.

  The allowed lighting power for the 'retail' function area under the Area Category Method is reduced, as well as the allowed additional lighting for specified tasks in the footnotes that correlate to primary function areas. These additional lighting allowances may only be used for the designated primary function areas (Table 104.6-C, 2013 California Building Energy Efficiency Standards) and cannot be swapped for other lighting applications in these spaces. Additionally, the allowed LPDs of Wall Display, Floor display, Valuable Display and Ornamental lighting in the Tailored Method of compliance are reduced by 20% to 30% on average from the current allowances. The final language also reduces the lighting power adjustments for mounting heights and refers to the IES Handbook guidelines for determining the allowed lighting power for specific areas that are not covered in the Tailored Method table.[63]

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[61] 2008 California Building Energy Efficiency Standards. California Energy Commission. December 2008.

[62] 2013 California Building Energy Efficiency Standards. California Energy Commission. May 2012.

[63] 2013 California Building Energy Efficiency Standards: Final Report Indoor Lighting—Retail. California Utilities Statewide Codes and Standards team. June 2013.

The requirements for B45: Lighting-Retail in Section 140.6 of the 2013 Title 24 California Building Energy Efficiency Standards are too lengthy to be quoted here.[64]

H.7.b. IOU-Estimated Potential Energy Savings Estimates

Per-Unit Savings Estimates

The IOUs' final estimated UES is a combination of UES for two methods: the tailored method and the area category method. The CASE report showed the analysis used computer models to determine the UES for each building space. The analysis included jewelry, designer, small store, furniture and kitchen and tableware models (models C, D, E, F and G), all assumed to fall under the tailored method, and the big box and high atrium models (models A and B) were associated with the area category method. Based on an analysis performed for the previous round of code revisions, 7% of retail construction used the tailored method and 93% of retail construction used the area category method. The CASE authors studied each space using a base lighting model that conformed to Title 24 2008. The CASE authors compared the Title 24 2008 models with the best available new luminaire technology design to determine if they would pass the proposed Title 24 2013 standards. The CASE report also shows the analysis relied on the modeling results to determine the electric energy savings.

Statewide Potential Energy Savings Estimate

The CASE report based total nonresidential new construction floor areas on the CEC's 2010 forecast. Table 62 summarizes the savings reported by the IOUs for standard B45: Lighting-Retail.

Table 62. Nonresidential IOU-Estimated Annual Potential Energy Savings: Standard B45

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
56.1	16.6	-0.21

H.7.c. Evaluation Findings

The IOU electric energy savings estimate of 56.14 GWh for this standard differs from the statewide energy savings estimate of 51.0 GWh detailed in the CASE report because of an interactive energy savings factor of 1.10, which was not taken into account in the CASE report. The IOUs provided additional documentation to Cadmus as a result of a data request that reiterates the UES and square footage values used in the CASE report. The CASE report's breakout of 7% and 93% between tailored method and area category method, respectively, may be outdated. The CASE report references the previous round of code revisions, which may be a reference to the 2005 code revisions. Cadmus was unable to find secondary sources to verify or reject the CASE report's area type breakdown between tailored and area category methods. The remaining unit energy savings assumptions appear to be reasonable; however, the study scope did not permit detailed investigation of the assumptions.

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[64] 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012.

Cadmus judges the per-unit savings estimates reported by the IOUs to be reasonable for electric energy (kWh) and demand (kW) for standard B45.

Cadmus used CEC forecast estimates for retail space to determine applicable square footage. The square footage assumptions received from the CEC in September 2015 do not align with the CASE report square footage estimates by building type. The change in square footage is the sole driver behind the difference in reported and evaluated savings. Table 63 shows the final evaluated savings estimate for standard B45: Lighting-Retail.

Table 63. Nonresidential Evaluated Annual Potential Energy Savings Estimate: Standard B45

Interactive Effects	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings without interactive effects	41.2	10.2	0.00
Final evaluated savings with interactive effects	30.2	8.5	0.00

* The interactive effects factors are discussed in the Interactive Effects section at the beginning of this appendix. Final evaluated savings include interactive effects.

H.8. B43: NRNC-Daylighting Controls

Table 64 provides a summary of the IOU-estimated and Cadmus-evaluated potential energy savings for standard B43: NRNC-Daylighting Controls.

Table 64. Nonresidential Annual Potential Energy Savings Estimate: Standard B43

Description	IOU Estimate	Evaluated*
Total electric energy savings (GWh/yr)	104.7	81.8
Total demand reduction (MW)	55.0	36.1
Total gas energy savings (MMtherms/yr)	-0.48	-0.08

* Evaluated savings in this table are not scaled to account for whole building interactions using the whole building scaling factors calculated by Cadmus. Final evaluated savings incorporate the scaling factors.

H.8.a. Standard Description

Standard B43: NRNC-Daylighting Controls requirements are listed in Sections 130.1, 140.3, 140.6, 140.1, and 141.0 of the 2013 Title 24 California Building Energy Efficiency Standards. The CASE report supporting this standard details energy savings between the following baseline (which comes from the

2008 Title 24 California Building Energy Efficiency Standards) and the final code (2013 Title 24 California Building Energy Efficiency Standards).[65]

Note that the applicable sections from the 2008 and 2013 Title 24 California Building Energy Efficiency Standards that serve as the baseline and standard for the B43: NRNC-Daylighting Controls are quite long and encompass many aspects of building designs. Thus, we compiled a small summary of the changes to the baseline and the final standard.

- **Baseline**[66]**:** Section 131(c) defines what daylight areas are. In 2008, these requirements were based on the Effective Aperture method. The 2013 code eliminates this and instead uses wattage requirement in daylit zones (as opposed to calculating daylit areas).
- Section 131(c)2A dictates that controls must control 50 percent of the enclosed daylit spaces.
- Exception 1 to Section 131(c)2B dictates an exception to the use of controls for enclosed daylit spaces less than or equal to 2,500 square feet.
- Section 143(c) sets minimum skylight area requirements for large enclosed spaces greater than 8,000 square feet and says that 50% of the floor area must be in the skylit daylight area.
- **Standard**[67]**:** The final code language requires photocontrols installed in primary sidelit and toplit zones that have at least 120 watts of lighting. The final code also requires photocontrols in secondary daylit zones that have at least 120 watts of lighting. The total floor area that must be daylit has increased from 50% to 75%, and the miniumum area that triggers skylit daylighting has been lowered from 8,000 to 5,000 square feet. Specifically, see:
- Exception 1 to Section 130.1(d)2 sets a mandatory requirement for photocontrols in primary toplit and sidelit zones with more than 120 Watts of installed lighting.
- Exception 1 to Section 140.6(d) sets a mandatory requirement for photocontrols in secondary sidelit zones with more than 120 Watts of installed lighting.
- Section 140.3(c)1 lowers the minimum area for skylit daylighting to 5,000 square feet and increases the amount of area that must be in a skylit daylighting area to 75 percent.

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65 Codes and Standards Enhancement Initiative (CASE), Final Report Daylighting Controls, PGandE, SCE, SoCalGas, and SDGandE, June 2013.

66 2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2008-001-CMF, December 2008.

67 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012.

H.8.b. IOU-Estimated Potential Energy Savings

Unit Energy Savings Estimates

The CASE report presented UES estimates distilled by proposed measure, climate zone, and building type. The CASE authors proposed these five measures (with only three evaluated for savings estimates):

- Adopting the watt calculation method in the Alternative Calculation Manual as an approach to determine energy savings
- Reducing the photocontrol area (now wattage) threshold requirement
- Increasing the minimum skylit area requirement
- Reducing the space area threshold requirements for skylights
- Reducing the ceiling height threshold for skylights[68]

The CASE authors did not submit the first and last proposals into the standard. They did not choose to submit the watt calculation method into the standard because they thought it was too complex. They did not choose to submit the last proposal "due to concern over the availability and applicability of skylight products that cater to dropped ceilings."[69]

The following list summarizes the final B43 measures the CASE authors evaluated and used to calculated UES estimates. (Cadmus changed the language slightly from the previous list to clarify the function of each measure.) We refer to these measures as measure 1, measure 2, and measure 3 in this section of the appendix.

- Measure 1: decreasing the threshold area requirement for photocontrols for sidelighting
- Measure 2: decreasing the threshold area requirement for photocontrols for toplighting
- Measure 3: decreasing the minimum skylight area requirement and threshold

The CASE authors developed the UES estimates via simulations of several building prototypes in certain climate zones using a program called *SkyCalc 3.0* (which runs on Excel). Since the IOUs did not provide these spreadsheets to Cadmus, we were unable to evaluate the model that created the UES estimates in the CASE report.[70] We were also unable to find other studies that corroborate the CASE report assumptions and UES estimates. The CASE report cited a Public Interest Energy Research (PIER) study for some of the UES estimates, although they made adjustments to these (we discuss this later, but the

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68 Codes and Standards Enhancement Initiative (CASE), Final Report Daylighting Controls, PG&E, SCE, SoCalGas, and SDG&E, June 2013.

69 Ibid.

70 Note that we did submit a data request for these files.

PIER study involved existing construction and the CASE authors adjusted some of the results to make them applicable to new construction).[71]

The CASE report lists the major assumptions that went into calculating the UES estimates. Cadmus has reviewed these assumptions and judged them to be reasonable (listed here):[72]

- For measures 1 and 2 (photocontrols for sidelighting and toplighting), the CASE authors used a prototype of an office building (assumed to be a typical office building in California) and a small retail space (again, assumed to be representative of small retail spaces), respectively. The CASE authors applied the UES estimates for these prototype building types to all other building types for each measure; however, they accounted for differences between the prototype building type and other forecast building types by adjusting the applicable square footage of the other building types according to what percentage of the prototype results would apply to the additional building types (see Table 70).
- For measure 3 (decreasing the minimum skylight area requirement and threshold), the CASE authors used two prototypes: a large retail store and a large warehouse. The CASE authors applied the UES estimates for the retail prototype building type to all other forecast building types (besides warehouses) for each measure and applied the UES estimates for the warehouse building type to non-refrigerated and refrigerated warehouses. The analysis accounted for differences between the prototype building type and additional forecast building types by adjusting the applicable square footage of the other forecast building types according to what percentage of the prototype results would apply to the other building types (see Table 70).
- For measures 1 and 2, the CASE authors mapped UES estimates of certain climate zones from the PIER study to all the climate zones in California (see Table 65).

Table 65. CASE Report Climate Zones Mapped with PIER Study

Climate Zones in PIER Study	Mapped Climate Zones in CASE Report
2 (North coastal—heating dominated)	1,3,4,16
6 (South coastal—mild)	5,7,8,9,10
12 (Central valley—intermediate)	11
13 (Sunny inland—cooling dominated)	14,15

- For measures 1 and 2, the CASE authors applied scalar adjustments to the PIER reported UES estimates as the PIER analysis was done for existing construction (specifically, the CASE authors

71 PIER. "Office Daylighting Potential: Task 3 of the PIER Daylighting Plus Research Program." CEC-500-2013-002. January 2013.

72 Again, note that finding secondary sources in order to verify these assumptions proved difficult. However, Cadmus finds the assumptions reasonable.

adjusted the LPD requirement in the PIER study and occupancy sensors in spaces less than 250 square feet).

Table 66, Table 67, Table 68, and Table 69 show the UES estimates reported in the CASE report for the different measures and prototype buildings by climate zone. The following tables represent the output from the model the CASE authors built (using some of the overarching assumptions described earlier) in *SkyCalc 3.0*.

The CASE authors determined the UES for the daylighting measures relative to the square footage of the building modeled. The authors also used UES estimates for the prototype buildings as proxies for the CEC forecast building types not modeled. To account for daylighting comprising a different percentage of total square feet for other building types compared with the prototype building types used as proxies, the authors adjusted the applicable square footage for the building types not modeled. A discussion of these assumptions follows in the statewide estimates section.

Table 66. UES Estimates for Measure 1—Office Sidelit Building Prototype

Climate Zone	Electric Savings (kWh/yr/sq. ft.)	Demand Savings (W/sq. ft.)	Gas Savings* (therms/yr/sq. ft.)
1	0.950	0.410	0.000
2	0.950	0.410	0.000
3	0.950	0.410	0.000
4	0.950	0.410	0.000
5	0.540	0.220	0.000
6	0.540	0.220	0.000
7	0.540	0.220	0.000
8	0.540	0.220	0.000
9	0.540	0.220	0.000
10	0.540	0.220	0.000
11	0.450	0.180	-0.001
12	0.450	0.180	-0.001
13	0.500	0.230	0.000
14	0.500	0.230	0.000
15	0.500	0.230	0.000
16	0.950	0.410	0.000

* All of the gas savings are negative and nonzero, but some of them round to zero.

Table 67. UES Estimates for Measure 2—Small Retail Toplit Building Prototype

Climate Zone	Electric Savings (kWh/yr/sq. ft.)	Demand Savings (W/sq. ft)	Gas Savings (therms/yr/sq. ft.)
1	0.790	0.370	0.000
2	1.060	0.370	0.000
3	1.050	0.370	0.000
4	1.160	0.370	0.000
5	1.130	0.440	0.000
6	1.160	0.440	0.000
7	1.190	0.440	0.000
8	1.200	0.440	0.000
9	1.160	0.440	0.000
10	1.170	0.440	0.000
11	1.100	0.470	0.000
12	1.160	0.470	0.000
13	1.220	0.470	0.000
14	1.210	0.470	0.000
15	1.270	0.470	0.000
16	1.010	0.370	0.000

Table 68. UES Estimates for Measure 3—Large Retail Toplit Prototype

Climate Zone	Electric Savings (kWh/yr/sq. ft.)	Demand Savings (W/yr/sq. ft.)	Gas Savings (therms/yr/sq. ft.)
1	1.500	0.600	-0.009
2	1.500	0.600	-0.009
3	1.500	0.600	-0.009
4	1.500	0.600	-0.009
5	1.690	0.780	-0.001
6	1.690	0.780	-0.001
7	1.690	0.780	-0.001
8	1.690	0.780	-0.001
9	1.690	0.780	-0.001
10	1.510	0.780	-0.006
11	1.390	0.740	-0.010
12	1.390	0.740	-0.010
13	1.500	0.770	-0.008
14	1.500	0.770	-0.008
15	1.500	0.770	-0.008
16	1.500	0.600	-0.009

Table 69. UES Estimates for Measure – Large Warehouse Toplit Prototype

Climate Zone	Electric Savings (kWh/yr/sq. ft.)	Demand Savings (W/yr/sq. ft.)	Gas Savings (therms/yr/sq. ft.)
1	0.770	0.320	0.000
2	0.770	0.320	0.000
3	0.770	0.320	0.000
4	0.770	0.320	0.000
5	0.840	0.390	0.000
6	0.840	0.390	0.000
7	0.840	0.390	0.000
8	0.840	0.390	0.000
9	0.840	0.390	0.000
10	0.810	0.390	0.000
11	0.780	0.420	0.000
12	0.780	0.420	0.000
13	0.880	0.440	0.000
14	0.880	0.440	0.000
15	0.880	0.440	0.000
16	0.770	0.320	0.000

Statewide Potential Energy Savings Estimate

To estimate statewide potential energy savings, the CASE authors multiplied the UES by the forecasted new construction square footage and the adjustment factor that accounts for how similar each real building type is to the modeled building. Or, in the form of an equation:

$$Statewide\ Savings = UES\ \times\ Total\ Building\ Sq.Ft.\ \times\ Sq.Ft.Adjustment\ Factor$$

As stated above, for most building types, the CASE report used a proxy UES based on the prototype building(s) for each measure and adjusted the square footage accordingly. For example, they calculated statewide savings for retail sidelighting (measure 1) by multiplying the UES estimate for offices (proxy savings) by the total square footage for retail, as well as a 50% adjustment factor based on the assumption that retail spaces have 50% of the sidelighting space of offices.

Table 70 lists the applicable square footage adjustment factors used by the CASE report for each building type, along with their reasoning. Cadmus was unable to verify many of the adjustment factor assumptions made by the authors (shown in Table 70). The CASE report did not provide details of the NRNC database for instances where they cite the NRNC database. Additionally, we were unable to find many secondary sources verifying or contradicting those claims. [73] However, Cadmus finds the assumptions for the applicable amount of square feet reasonable and conservative – thus we accept all of their claims. The CASE report also noted that when they were unable to reference the NRNC

[73] We found one relevant article—an old iteration of the same PIER study the CASE authors cited.

database to determine how similar a building was to the prototype, the CASE authors used their best judgement.

Table 70. CASE Report Square Footage Adjustment Factors for Daylighting Measures 1, 2, and 3

Building Type	Measure 1	CASE Report Reasoning	Measure 2	CASE Report Reasoning	Measure 3	CASE Report Reasoning
Office: small	100%	Same as prototype	4%	NRNC database—% "Office" space area with skylights	0%	Not expected to have 5,000 sq. ft. of contiguous space and 15-ft. ceiling
Office: large	100%	Same as prototype	4%	NRNC database—% "Office" space area with skylights	0%	Not expected to have 5,000 sq. ft. of contiguous space and 15-ft. ceiling
Restaurant	50%	Has sidelighting, but layout different from prototype	0%	No or very little toplighting	0%	Not expected to have 5,000 sq. ft. of contiguous space and 15-ft. ceiling
Retail	0%	No or very little sidelighting	0%	Expected to have more than 2,500 sq. ft. of skylit area	27%	NRNC database—% "Single Story Large Retail" from total "Retail" space
Food	0%	No or very little sidelighting	0%	Expected to have more than 2,500 sq. ft. of skylit area	27%	NRNC database—% "Single Story Large Retail" from total "Retail" space
Non-refrigerated warehouse	0%	No or very little sidelighting	0%	Expected to have more than 2,500 sq. ft. of skylit area	100%	Most spaces expected to trigger requirement
Refrigerated warehouse	0%	No or very little sidelighting	0%	Expected to have more than 2,500 sq. ft. of skylit area	100%	Most spaces expected to trigger requirement
School	100%	Similar to prototype	8%	NRNC database—% "Small School" space area with skylights	6%	NRNC database—% "Gymnasium" area from total "School" area
College	100%	Similar to prototype	1%	NRNC database—% "Community College" space area with skylights	6%	NRNC database—% "Gymnasium" area from total "School" area
Hospital	0%	Not required to follow Title 24	0%	Not required to follow Title 24	0%	Not required to follow Title 24
Hotel	25%	Conference rooms and lobby similar to prototype, guest rooms don't have general lighting	0%	No or very little toplighting	0%	No or very little toplighting
Miscellaneous	50%	Community center, assembly spaces, laboratories, etc. have sidelighting, but layout different from prototype	1%	NRNC database—% "Other" space area with skylights	0%	Not expected to have 5,000 sq. ft. of contiguous space and 15-ft. ceiling

To estimate statewide savings, the CASE report used the CEC forecast data available at the time they drafted the report. Table 71 shows the square footage estimates for each building type, summed for all climate zones. The authors used CEC new construction square footage forecasted for the year 2014.

Table 71. CEC 2014 Forecasted Square Footage for All Climate Zones

Building Type	2014 CEC Forecast (sq. ft.)
Office: small	9,088,817
Office: large	27,694,523
Restaurant	5,081,128
Retail	32,440,792
Food	8,509,163
Non-refrigerated warehouse	32,072,195
Refrigerated warehouse	1,752,563
School	9,975,271
College	7,379,956
Hospital	8,585,447
Hotel	9,098,191
Miscellaneous	31,648,020
Total	**183,326,066**

Table 72 summarizes the IOU-estimated savings for standard B43: NRNC-Daylighting Controls.

Table 72. Nonresidential IOU-Estimated Annual Potential Energy Savings: Standard B43

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
104.7	55.0	-0.48

H.8.c. Evaluation Findings

Table 75, at the end of this section, shows the final evaluated savings estimate for this standard

Cadmus accepts the UES estimates from the CASE report for electric energy (kWh), demand (kW), and gas energy (therms) for standard B43. UES assumptions appear to be reasonable; however, Cadmus could not verify estimates in detail because of incomplete information and lack of secondary sources.

When reproducing the CASE report's statewide savings estimates, Cadmus found an error in the way the CASE report applied the two different prototypes of measure 3 to the other building types. We were able to reproduce the savings estimate for electric energy savings and gas energy savings using the mapping assumptions shown below in Table 73. However, we were unable to reproduce the demand savings for measure 3 using these mappings.[74] We believe the assumptions in Table 73 to be reasonable, thus we applied the mappings below to demand savings (as opposed to using the CASE authors' mappings for demand savings).

Table 73. Daylighting Measure 3 Evaluation Assumptions

Building Type*	Mapped Prototype
Retail	Large Retail
Food	Large Retail
Non-refrigerated warehouse	Large Warehouse
Refrigerated warehouse	Large Warehouse
School	Large Retail
College	Large Retail

* Note that the other building types are assumed to have zero percent applicable square feet.

Cadmus used updated construction forecasts provided by the CEC in September 2015 for evaluated statewide savings, averaging 2014 and 2015 forecasted values to estimate annual new construction square footage. Table 74 lists the statewide square footage estimates Cadmus used (for all climate zones) to calculate evaluated savings.

Table 74. CEC 2014-2015 Average Square Footage for All Climate Zones

Building Type	2014-2015 CEC Average (sq. ft.)
Office: small	8,058,982
Office: large	27,865,411
Restaurant	4,457,067
Retail	26,208,936
Food	6,975,515
Non-refrigerated warehouse	24,426,646
Refrigerated warehouse	1,501,932
School	7,948,582
College	4,406,233
Hospital	7,993,934
Hotel	9,508,163
Miscellaneous	29,380,935
Total	**158,732,336**

74 We were never able to determine exactly what the error was. However, being able to recreate the estimates in the CASE report for both electric and gas savings is strong evidence that we mapped the building types correctly in Table 73 and that they should also apply to demand savings.

Table 75 shows the final total evaluated savings for standard B43.

Table 75. Nonresidential Evaluated Annual Potential Energy Savings Estimate: Standard B43

Interactive Effects*	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings without interactive effects	81.8	36.1	-0.08
Final evaluated savings with interactive effects	60.0	30.0	-0.21

* The interactive effects factors are discussed in the Interactive Effects section at the beginning of this appendix. Final evaluated savings include interactive effects.

H.9. B51: NRNC-Lighting-Controllable Lighting

Table 76 provides a summary of the IOU-estimated and Cadmus-evaluated potential energy savings for standard B51: NRNC-Lighting-Controllable Lighting

Table 76. Nonresidential Annual Potential Energy Savings Estimate: Standard B51

Description	IOU Estimate	Evaluated*
Total electric energy savings (GWh/yr)	75.1	60.4
Total demand reduction (MW)	0.0	0.0
Total gas energy savings (MMtherms/yr)	0.00	0.00
Total applicable units (Million sq. ft.)	118.8	105.1

* The interactive effects factors are discussed in the Interactive Effects section at the beginning of this appendix. Final evaluated savings include interactive effects.

H.9.a. Description

Standard B51: NRNC-Lighting-Controllable Lighting requirements are listed in Section 130.1 of the 2013 Title 24 California Building Energy Efficiency Standards. The CASE report supporting this standard details energy savings between the following baseline (via the 2008 Title 24 California Building Energy Efficiency Standards) and final code (from the 2013 Title 24 California Building Energy Efficiency Standards):[75]

- **Baseline**[76]**:** Section 131(b) of the 2008 Title 24 Code details that general lighting of any enclosed space 100 square feet or larger with a connected load that exceeds 0.8 watts per square foot must have multi-level controls.
- **Standard**[77]**:** The current requirements for standard B51: NRNC-Controllable Lighting in Section 130.1 of the 2013 Title 24 California Building Energy Efficiency Standards in section 130.1(b) changes the minimum watts per square foot requirement to 0.5 watts per square foot. The standard also provides an exception for classrooms under 0.7 watts per square foot.

H.9.b. Reported Potential Energy Savings Estimates

Unit Energy Savings Estimates

The CASE authors developed the unit energy savings estimates for controlled lighting by using only the energy saving strategy of tuning (as opposed to user dimming, predictable scheduling, and demand management and response, all described in the CASE report). The CASE report defines tuning as, "a method of controlling light levels from a luminaire by adjusting the power output of the ballast in order to produce the desired quantity of lumens."[78] The CASE report also notes that buildings typically over-light spaces initially to account for lamp lumen depreciation (i.e., the reason why tuning saves energy). The CASE authors conducted an engineering analysis with this measure and a cost-effectiveness analysis (using the 2011 Life-Cycle Cost Methodology provided by the CEC) to estimate unit energy savings.

The CASE authors' engineering analysis involved modeling prototype building types compliant with the 2008 Title 24 code and the 2013 Title 24 code. The CASE report used data from CEUS to estimate the occupancy profile and the 2008 Title 24 code as the allowable LPD to estimate the total lighting load of the building. The CASE report repeated this (using the same CEUS data) with the 2013 Title 24 code as the allowable LPD to estimate the total lighting load for each building type. The CASE authors only estimated kWh savings; they assumed kW and therms savings were not applicable to this measure.

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75 Codes and Standards Enhancement Initiative (CASE), Requirements for Controllable Lighting, SCE, March 2011.

76 2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2008-001-CMF, December 2008.

77 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012.

78 Codes and Standards Enhancement Initiative (CASE), Requirements for Controllable Lighting, SCE, March 2011.

The cost-effectiveness analysis (or the means by which the CASE report estimated kWh savings) involved the following two items:

- Estimating the incremental cost of installing the measures via correspondence with lighting manufacturers[79]
- Determining the cost-benefit breakeven point using the estimated hourly savings and the present value of the savings[80]

We show the results of this analysis from the CASE report in Table 77 (all values left as is).[81]

Table 77. Cost-Effectiveness Results from the CASE Report

Prototype*	Incremental Cost/Square Foot	Cost-Benefit Breakeven Point	Cost-Effective?
Office	$0.61	$0.81	Yes
Retail (ASHRAE Type 1)	$0.56	$1.16	Yes
Retail (ASHRAE Type 2)	$1.04	$1.51	Yes
Retail (ASHRAE Type 3)	$2.00	$3.28	Yes
Foodstore	$0.66	$2.15	Yes
School	$0.65	$0.48	No
School (year-round)	$0.65	$1.01	Yes
Warehouse	$0.37	$0.41	Yes
Hospitality	$0.85	$1.22	Yes

* Note that the CASE authors did not create a prototype of every building type. They made assumptions regarding the similarity of prototype buildings to other building types.

Finally, the CASE authors estimated the UES for each building type prototype by dividing the cost-benefit breakeven point by the conversion factor of the annual kWh savings to present the value of savings for the office prototype (which the CASE authors assumed to be the most conservative approach). The CASE authors estimated the conversion factor to be 2.057 dollars per kWh.

The single UES value reported represents a weighted average of the UES values of each building type and the percentage of estimated total new construction floor area applicable to tuning. We discuss this in the next section.

Statewide Potential Energy Savings Estimate

As stated in the previous section, the CASE authors estimated the statewide potential energy savings by multiplying the UES by the CEC forecasted 2014 new construction square feet and the percent of the

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79 The CASE report notes that the details of this analysis are found in Appendix F of the CASE report. However, Appendix F in the CASE report is blank.

80 Note that Cadmus did not have access to these spreadsheets – we only had access to screenshots of these spreadsheets. Thus, we experienced difficulty following all of the calculations.

81 Codes and Standards Enhancement Initiative (CASE), Requirements for Controllable Lighting, SCE, March 2011.

building type that is able to implement the tuning measure. We show this in Table 78 (along with the UES for each building type).

Table 78. IOU-Estimated Statewide Savings Calculations

Building Type	UES (kWh/sq. ft.	2014 CEC Forecasted New Construction Area (10^3 sq. ft.)	Percentage Implementing Tuning	Applicable Floor Area (10^3 sq. ft.)
Small office	0.394	9,089	90%	8,180
Large office	0.394	27,695	90%	24,925
Restaurant	0.734	5,081	90%	4,573
Retail	0.964	32,441	90%	29,197
Food	1.045	8,509	90%	7,658
Warehouse	0.199	32,072	25%	8,018
Refrigerated warehouse	0.199	1,753	90%	1,577
School	0.233	9,975	25%	2,494
College	0.491	7,380	25%	1,845
Hospital	0.000	8,585	0%	n/a
Hotel	0.593	9,098	20%	1,820
Miscellaneous	0.394	31,648	90%	28,483
Total	**0.575**	**183,326**	**65%**	**118,770**

The CASE authors never explicitly state (in the CASE report or elsewhere) the origin of the percent of the buildings that can implement tuning. The assumptions regarding prototype building type mappings are presented in Table 79.

Table 79. Building Type Prototype Mapping Assumptions

Building Type	Prototype Building
Small office	Office
Large office	Office
Restaurant	Retail (ASHRAE Type 2)
Retail	Average of Retail ASHRAE types 1–3
Food	Foodstore
Warehouse	Warehouse
Refrigerated warehouse	Warehouse
School	School
College	College
Hospital	N/A
Hotel	Hospitality
Miscellaneous	Office

Table 80 summarizes the savings reported by the IOUs for this standard.

Table 80. Nonresidential IOU-Estimated Annual Potential Energy Savings: Standard B51

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
75.1	0.0	-0.28

H.9.c. Evaluation Findings

Cadmus judges the unit energy savings estimates from the CASE report to be reasonable for electric energy (kWh), and we agree that there are no unit savings associated with demand (kW). We do note that there are probably interactive effects in terms of gas energy (therms) which are included in the final evaluated savings, calculated as a function of the GWh/yr savings using the factors discussed in the Interactive Effects section at the beginning of this appendix. We were missing the incremental cost data (not present in the appendix referenced in the CASE report) and the spreadsheets in which the CASE authors made their cost-benefit savings estimates.[82] We judged the estimated percentage of total building square footage able to implement the tuning measure to be reasonable. However, the CASE report does not indicate how these percentages were derived, and we failed to find other secondary research with similar results.

We find the CASE authors' results to be reasonable, and they are consistent with methodologies used in other standards. Cadmus attempted to verify the unit savings using other reports or some other data source, but we were unable to find anything applicable to this standard. Cadmus determined that savings for standard B51 do not overlap with the whole building savings for standard B82. The savings for standard B82 were derived from the California Energy Commission's (CEC's) 2013 Building Efficiency Standards Impact Analysis, and the CEC's report indicates that the only lighting controls included in the CEC new construction building models were occupancy and manual lighting controls.[83] Savings for standard B51 are based on tuning lighting controls.

Cadmus' evaluated statewide savings estimates differ from the reported statewide savings estimate because the CASE authors used the 2014 CEC forecasted new construction data set, and Cadmus used the 2014–2015 CEC average new construction data set.

Table 81 shows the final evaluated savings estimate for this standard.

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82 In a data request, we only received screenshots of the final results of the cost-benefit analysis.

83 CEC. (Consultant Report) *Impact Analysis: California's 2013 Building Efficiency Standards*, page 14. CEC-400-2013-008. July 2013. Available online: http://www.energy.ca.gov/2013publications/CEC-400-2013-008/CEC-400-2013-008.pdf

Table 81. Nonresidential Evaluated Annual Potential Energy Savings Estimate: Standard B51

Interactive Effects*	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings without interactive Effects	60.4	0.0	0.00
Final evaluated savings with interactive effects	44.3	0.0	-0.25

* The interactive effects factors are discussed in the Interactive Effects section at the beginning of this appendix. Final evaluated savings include interactive effects.

H.10. B58: NRNC-HVAC-Fan Control and Economizers

Table 82 lists the IOU-estimated and Cadmus-evaluated potential energy savings for standard B58: NRNC-HVAC-Fan Control and Economizers.

Table 82. Nonresidential Annual Potential Energy Savings Estimate: Standard B58

Description	IOU Estimate	Evaluated*
Total electric energy savings (GWh/yr)	33.7	29.0
Total demand reduction (MW)	0.0	0.0
Total gas energy savings (MMtherms/yr)	-0.02	-0.02
Total applicable units (Million sq. ft.)	12.9	11.1

* Evaluated savings in this table exclude scaled interactive effects. Final evaluated savings include scaled interactive effects.

H.10.a. Standard Description

Standard B58: NRNC-HVAC-Fan Control and Economizers requirements are listed in Section 140.4(m) of the 2013 Title 24 California Building Energy Efficiency Standards. The CASE report supporting this standard details energy savings between the following baseline and standard cases:[84]

- **Baseline[85]:** The baseline is the 2008 Title 24 prescriptive requirement for single zone variable air volume (VAV) equipment: All unitary air conditioning equipment and air-handling units with mechanical cooling capacity at ARI conditions greater than or equal to 110,000 Btu/hr that serve single zones shall be designed for variable supply air volume with their supply fans controlled by two-speed motors, variable speed drives, or equipment that has been demonstrated to the

[84] Codes and Standards Enhancement Initiative (CASE), Final Report: Fan Control and Integrated Economizers, Pacific Gas and Electric Company, Southern California Edison, SoCalGas, SDGandE, July, 2013.

[85] 2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2008-001-CMF, December 2008.

Executive Director to use no more energy. The supply fan controls shall modulate down to a minimum of two-thirds of the full fan speed or lower at low cooling demand.

- **Standard**[86]: The current requirements for NRNC-HVAC-Fan Control and Economizers are detailed in Section 140.4(m) of the 2013 Title 24 California Building Energy Efficiency Standards. This measure extends existing fan control prescriptive requirements to a larger range of equipment sizes and clarifies the definition of an integrated economizer. It extends the current single zone VAV requirement (140.4(m), formerly 144(l)) from 10 tons down to less than 6 tons for DX equipment and down to one-fourth HP for chilled water and evaporator equipment, with an effective starting date of January 1, 2016. Both types of equipment will also have an interim period starting January 1, 2014, that brings the requirement down to 75,000 Btu/hr for DX equipment and 1 HP for chilled water/evaporator equipment. The final code language clarifies the definition of an integrated economizer as a system that is able to modulate cooling capacity (e.g., compressor output) with a minimum of two stages of fan control and cooling capacity.

H.10.b. IOU-Estimated Potential Energy Savings Estimates

The B58 standard actually comprises two measures: expanding the requirements for (direct expansion) DX systems that require single zone VAV (from 110,000 Btu/hr to 65,000 Btu/hr) and down to one-fourth HP for chilled water/evaporator equipment. However, for simplicity and to make a more conservative estimate, the CASE authors only calculated UES estimates for the expanded DX system single zone VAV requirements. Thus, the CASE authors' analysis does not account for chilled water systems savings or improved compressor part-load savings.

The CASE authors estimated statewide savings from the UES and an analysis of AHRI California commercial packaged rooftop unit volume in 2010. The CASE authors found that this standard applies to about 7% of AHRI rooftop units sold, so they assumed that it also applies to units serving about 7% of the new construction square footage in California. Then, the CASE authors multiplied the UES by the estimated applicable new construction square footage to get the statewide savings.

Unit Energy Savings Estimates

The CASE report estimated savings for this measure by simulating a prototype building (specifically a small office) in six California climate zones. Per the CASE report, simulations were run in the following climate zones:[87]

- Climate Zone 3: Oakland
- Climate Zone 4: San Jose
- Climate Zone 6: Torrance
- Climate Zone 9: Pasadena

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86 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012.

87 The CASE report does not explain why the six climate zones were selected and modeled.

- Climate Zone 10: Riverside
- Climate Zone 12: Sacramento

The CASE report lists the specifications of the prototype office (they are too extensive to list here).[88] We note that they follow ASHRAE 90.1 Prototype Building Modeling Specifications. The standard case uses a combination of fan control and integrated economizer for a single zone DX cooling unit to reduce fan speed and fan hours (which results in energy savings).

The CASE report shows an average electric savings (from all six climate zones modeled) of 965 kWh/yr per ton or an average of 2.61 kWh/yr per square foot, which is the UES estimate in Table 82.

The CASE authors calculated the unit gas savings using the same methodology. Per prototype building, the CASE report indicated -8.0 therms/yr or -0.0015 therms/yr per square foot (also Table 82).

Statewide Potential Energy Savings Estimate

The CASE report used AHRI California commercial packaged rooftop 2010 unit volume data to estimate the percentage of all commercial rooftop units in California that this standard affects. The CASE report found that about 7% of all AHRI commercial packaged rooftops units apply to this standard; they then assumed that 7% of all new construction square footage applied to this standard.

Appendix A of the CASE report shows all of the AHRI data in section 7.9; we show the applicable data the CASE authors used to estimate savings in Table 83.

Table 83. Excerpt of AHRI California Commercial Packaged Rooftop 2010 Data

Range (kBtu/hr)		Number of Units	Average Size (kBtu/hr)	Total Capacity per Bin	
Min.	Max.			(kBtu/hr)	tons
65	96.9	4,325	81	350,109	29,176
97	134.9	3,434	116	398,636	33,220

From here, the CASE authors adjusted the AHRI bins to account for the applicable DX unit sizes. They did this in the following manner (recall the minimum size of the unit is now 65,000 Btu/hr and the old minimum was 110,000 Btu/hr):

$$\frac{(110 - 97)kBtu/hr}{(134.9 - 97)kBtu/hr} = 34\%$$

Note that the CASE report assumed an even distribution of units between 97.0 kBtu/hr and 134.9 kBtu/hr. The CASE authors used this percentage to adjust the number of units in this range (from 97 kBtu/hr to 110 kBtu/hr). Table 84 shows these results.

88 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012. Appendix Preliminary CASE Report, Pp. 18, 19, 45, and 46.

Table 84. CASE authors Adjusted AHRI Data

Range (kBtu/hr)		Number of Units	Average Size (kBtu/hr)	Total Capacity per Bin (tons)
Min.	Max.			
65	96.9	4,325	81	29,176
97	110	1,179	104	10,171

The CASE authors then estimated the percentage of new California rooftop units affected by the standard to be the ratio of the sum of the number of units in Table 84 and the total number of units in the AHRI data (not shown here) or 5,504/88,606, which equals 6.21% (note that the CASE authors rounded this to 7% in the CASE report). They then assumed that 7% of all new construction floor area in California is covered by this standard or, using 2014 CEC forecasted new construction data, approximately 12.9 million square feet.

Table 85 lists the IOU-estimated savings for standard B58: NRNC-HVAC-Fan Control and Economizers.

Table 85. Nonresidential IOU-Estimated Annual Potential Energy Savings: Standard B58

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
33.7	0.0	-0.02

H.10.c. Evaluation Findings

Cadmus finds the original UES estimates from the CASE report to be conservative and reasonable. As discussed above, the savings estimates do not include savings for chilled water systems, which results in a more conservative estimate.

Cadmus also finds reasonable the estimate using the AHRI annual package commercial RTU shipment data that about 7% of the total NRNC floor area would be affected by this standard. However, Cadmus did not round when calculating their estimates (so we used 6.21% as opposed to 7%). Cadmus also adjusted the square footage used by the CASE authors (they used forecasted 2014 CEC NRNC square footage which was the only data available at that time) with updated square footage data provided by the CEC. Cadmus averaged the forecasted new construction data from 2014 and 2015 for this evaluation. Table 86 shows the final evaluated savings estimates for standard B58: NRNC-HVAC-Fan Control and Economizers.

Table 86. Nonresidential Evaluated Annual Potential Energy Savings Estimate: Standard B58

Interactive Effects*	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings Without Interactive Effects	25.7	0.0	-0.02
Final Evaluated Savings With Interactive Effects	21.3	0.0	-0.04

* The interactive effects factors are discussed in the Interactive Effects section at the beginning of this appendix. Final evaluated savings include interactive effects.

H.11. B61: NRNC-HVAC-Kitchen Ventilation

Table 87 lists the IOU-estimated and Cadmus-evaluated potential energy savings for standard B61: NRNC-HVAC-Kitchen Ventilation.

Table 87. Nonresidential Annual Potential Energy Savings Estimate: Standard B61

Description	IOU Estimate	Evaluated*
Total electric energy savings (GWh/yr)	30.1	30.1
Total demand reduction (MW)	5.2	5.2
Total gas energy savings (MMtherms/yr)	0.28	0.28
Total applicable units (Million sq. ft.)	0.7	0.7

* Evaluated savings in this table exclude interactive effects. Final evaluated savings include interactive effects.

H.11.a. Standard Description

B61: NRNC-HVAC-Kitchen Ventilation requirements are listed in Section 140.9(b) of the 2013 Title 24 California Building Energy Efficiency Standards. The CASE report supporting this standard details energy savings between the following baseline and standard cases:[89]

- **Baseline:** Mechanical systems serving commercial kitchens were not previously regulated by Title 24.
- **Standard**[90]**:** The current requirements for B61: NRNC-HVAC-Kitchen Ventilation are detailed in Section 140.9(b) of the 2013 Title 24 California Building Energy Efficiency Standards. This measure restricts the common practice use of "short-circuit" hoods where replacement air is injected directly into the hood as opposed to being injected elsewhere in the room. The measure introduces new prescriptive requirements for commercial kitchens that set forth

89 Codes and Standards Enhancement Initiative (CASE), Final Report: Kitchen Ventilation, Pacific Gas and Electric Company, Southern California Edison, SoCalGas, SDGE, August, 2013.

90 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012.

requirements to save energy associated with the exhaust and conditioned makeup air requirements in commercial kitchens. It includes four design elements:

- Direct Replacement of Exhaust Air Limitations
- Type I Exhaust Hood Airflow Limitations
- Makeup and Transfer Air Requirements
- Commercial Kitchen System Efficiency Options

H.11.b. IOU-Estimated Potential Energy Savings Estimates

Unit Energy Savings Estimates

The CASE authors estimated UES of each measure using a combination of secondary studies and spreadsheet analyses. The CASE report based UES estimates on four different measures (these were ultimately rolled up into one UES value):

- Measure 1: direct replacement of exhaust air limitation
- Measure 2: Type I exhaust hood airflow requirements
- Measure 3: makeup and transfer air requirements
- Measure 4: commercial kitchen system efficiency options

To evaluate measure 1 (essentially the "outlawing of short-circuit hoods" as the CASE report states), the CASE authors cited research by the American Gas Association, CEC,[91] and a PIER 2002 paper[92] on how this measure saves energy. The CASE authors also demonstrated that exhaust only hood systems use less energy; however, they indicated that short circuit hoods make up approximately 1% of the California market so the CASE authors did not calculate UES for this measure.

The CASE authors estimated savings for measure 2 by citing the ASHRAE Standard 154 that determined unlisted Type I hoods (or Type I hoods that have not been subject to performance tests) consume 30% more energy than listed Type I hoods.[93] The CASE authors estimated savings for measure 3 by analyzing design options for including transfer air in cooling kitchens and dining rooms (as opposed to simply adding makeup air). The CASE authors modeled their designs in three climate zones and presented their results. Note that Cadmus did not have access to the CASE authors' analysis files, but the authors did list their assumptions in creating the system (which Cadmus believed to be reasonable).

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91 The American Gas Association and CEC citations in the CASE report were vague, as they were not in the bibliography of the preliminary CASE report.

92 Public Interest Energy Research(PIER). 2002. "Makeup air effects on commercial kitchen exhaust system performance (CEC P500-03-007F)." Grant Brohard, PG&E; Richard Swierczyna, Paul Sobiski, Vernon Smith, AEC; Donald Fisher, Fisher-Nickel, Inc.

93 ANSI/ASHRAE Standard 154-2003, Ventilation for Commercial Cooking Operations.

For measure 4, the CASE authors cited data from a 2009 SCE study on demand control ventilation (DCV) systems.[94] DCV systems, as the SCE study notes, produce savings compared to normal kitchen exhaust systems by reading the amount of smoke and heat from the cooking surfaces and adjusting the fan system flow rates. In the SCE study, SCE collected data from five DCV installations and showed the energy savings compared with a normal kitchen exhaust system (which only have an ON/OFF function). In Table 88, we show the UES estimated in the CASE report.

Table 88. CASE Reported UES by Measure for Standard B61

Measure	Units	Electric Energy UES (kWh/yr)	Demand UES (kW/yr)	Gas Energy UES (therms/yr)
1*	Per square foot	N/A	N/A	N/A
2	Per square foot	4.210	0.780	0.000
3	Per square foot	8.020	1.370	0.080
4	Per square foot	31.110	5.360	0.320

* CASE report did not analyze because of small market penetration.

Statewide Potential Energy Savings Estimate

The CASE report authors stated in the CASE report that they used data from the CEUS to determine the percentage of California building stock that would be affected by this measure. In the CASE report, the CASE authors estimated kW per square foot, kWh per square foot, and therms per square foot energy savings and then applied these results to the estimated square footage to calculate the final energy savings (the analysis used 2.314 million square feet of floor area). However, the CASE authors did not state how they derived this square foot estimate.

Cadmus found a difference between the statewide final IOU estimate and the values reported in the CASE report. The UES for electric energy, demand, and gas energy remained the same. However, the applicable floor area changed and no explanation was provided in the materials received from the authors in response to Cadmus' data requests.

Table 89 shows the IOU-estimated savings for standard B61: NRNC-HVAC-Kitchen Ventilation.

94 Southern California Edison. June 30, 2009. "Demand Control Ventilation for Commercial Kitchen Hoods (ET 07.10 Report)" Design & Engineering Services Customer Service Business Unit – Southern California Edison.

Table 89. Nonresidential IOU-Estimated Annual Potential Energy Savings Standard B61

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
30.1	5.2	0.28

H.11.c. Evaluation Findings

Cadmus finds the UES estimated by the IOUs to be reasonable. While we did not have access to their analysis, they generally based their savings on reliable secondary sources. Cadmus was unable to determine why the CASE authors changed the applicable square feet between the preliminary CASE report and the final reported estimate. We searched for other sources estimating the applicable floor area, but we were not able to find any. Even though no documentation was provided on the floor area calculation, we find the UES estimates reasonable and note that the statewide savings seem conservative.

Table 90 shows the final evaluated savings estimate for standard B61: NRNC-HVAC-Kitchen Ventilation.

Table 90. Nonresidential Evaluated Annual Potential Energy Savings Estimate: Standard B61

Interactive Effects*	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings without interactive effects	30.1	5.2	0.28
Final evaluated savings with interactive effects	22.1	4.3	0.73

* The interactive effects factors are discussed in the Interactive Effects section at the beginning of this appendix. Final evaluated savings include interactive effects.

H.12. B63: NRNC-HVAC-Chiller Minimum Efficiency

Table 91 lists the IOU-estimated and Cadmus-evaluated potential energy savings for standard B63: NRNC-HVAC-Chiller Minimum Efficiency.

Table 91. Nonresidential Annual Potential Energy Savings Estimate: Standard B63

Description	IOU Estimate	Evaluated*
Total electric energy savings (GWh/yr)	28.9	1.1
Total demand reduction (MW)	0.0	0.0
Total gas energy savings (MMtherms/yr)	0.00	0.00
Total applicable units (Million sq. ft.)	12.7	n/a

* Evaluated savings in this table exclude interactive effects. Final evaluated savings include interactive effects. No unit energy savings or applicable square feet were included in the evaluated statewide savings calculation. See the Evaluation Findings section for more details.

H.12.a. Standard Description

B63: NRNC-HVAC-Chiller Min Efficiency requirements are listed in Table 110.2-D of the 2013 Title 24 California Building Energy Efficiency Standards. The CASE report supporting this standard details energy savings between the following baseline and standard cases:[95]

- **Baseline:** The baseline is the 2008 Title 24 chiller minimum efficiencies. The baseline applies to Section 144(i) of the 2008 Title 24 California Building Energy Efficiency Standards:[96]

  Section 144(i): Limitation of Air-Cooled Chillers

  1. Chilled water plants with more than 300 tons total capacity shall not have more than 100 tons provided by air-cooled chillers.

  EXCEPTION 1 to Section 144(i): Where the designer demonstrates that the water quality at the building site fails to meet manufacturer's specifications for the use of water-cooled equipment.

  EXCEPTION 2 to Section 144(i): Plants that employ a cooling thermal energy storage system.

  EXCEPTION 3 to Section 144(i): Air cooled chillers with minimum efficiencies approved by the Commission pursuant to Section 10-109(d).

- **Standard:** This measure updates Title 24-2013 to adopt and build on the changes to the chiller efficiency measures new in ASHRAE 90.1-2010. In particular, this includes the new chiller efficiencies in 90.1-2007 Addendum M and the increase in coverage of centrifugal chillers in 90.1-2007 Addenda BL and BT (K-factor adjustment). Addendum M introduced two paths to compliance: Path A for fixed speed chillers and Path B for variable speed chillers. This measure proposes to go beyond 90.1 2010 in that it seeks to choose only one path per chiller category based on life-cycle cost.

Table 92 lists the final requirements for standard B63: NRNC-HVAC-Chiller Min Efficiency as shown in Table 110.2-D of the 2013 Title 24 California Building Energy Efficiency Standards.[97]

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95 Codes and Standards Enhancement Initiative (CASE), Draft Report: Chiller Minimum Efficiency, Pacific Gas and Electric Company, Southern California Edison, SoCalGas, SDG&E, April, 2011.

96 2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2008-001-CMF, December 2008.

97 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012.

Table 92. Water Chilling Packages—Minimum Efficiency Requirements*

Equipment Type	Size Category	Path A Efficiency	Path B Efficiency	Test Procedure
Air-cooled, with condenser electrically operated	< 150 Tons	≥ 9.562 EER ≥ 12.500 IPLV	N/A	AHRI 550/590
	≥ 150 Tons	≥ 9.562 EER ≥ 12.750 IPLV	N/A	
Air-cooled, without condenser electrically operated	All capacities	Air-cooled chillers without condensers must be rated with matching condensers and comply with the air-cooled chiller efficiency requirements.		
Water-cooled, electrically operated, reciprocating (reciprocating)	All capacities	Reciprocating units must comply with the watercooled positive displacement efficiency requirements.		AHRI 550/590
Water-cooled, electrically operated positive displacement	< 75 Tons	≤0.780 kW/ton ≤ 0.630 IPLV	≤ 0.800 kW/ton ≤ 0.600 IPLV	AHRI 550/590
	≥ 75 tons and < 150 tons	≤ 0.775 kW/ton ≤ 0.615 IPLV	≤ 0.790 kW/ton ≤ 0.586 IPLV	
	≥ 150 tons and < 300 tons	≤ 0.680 kW/ton ≤ 0.580 IPLV	≤ 0.718 kW/ton ≤ 0.540 IPLV	
	≥ 300 Tons	≤ 0.620 kW/ton ≤ 0.540 IPLV	≤ 0.639 kW/ton ≤ 0.490 IPLV	
Water-cooled, electrically operated, centrifugal	< 150 Tons	≤ 0.634 kW/ton ≤ 0.596 IPLV	≤ 0.639 kW/ton ≤ 0.450 IPLV	
	≥ 150 tons and < 300 tons	≤ 0.634 kW/ton ≤ 0.596 IPLV	≤ 0.639 kW/ton ≤ 0.450 IPLV	
	≥ 300 tons and < 600 tons	≤ 0.576 kW/ton ≤ 0.549 IPLV	≤ 0.600 kW/ton ≤ 0.400 IPLV	
	≥ 600 Tons	≤ 0.570 kW/ton ≤ 0.539 IPLV	≤ 0.590 kW/ton ≤ 0.400 IPLV	
Air-cooled absorption, single effect	All Capacities	≥0.600 COP	n/a	ANSI/AHRI 560
Water-cooled absorption, single effect	All Capacities	≥ 0.700 COP	n/a	
Absorption double effect, indirect-fired	All Capacities	≥ 1.000 COP ≥ 1.050 IPLV	n/a	

Equipment Type	Size Category	Path A Efficiency	Path B Efficiency	Test Procedure
Absorption double effect, direct-fired	All Capacities	≥ 1.000 COP ≥1.000 IPLV	n/a	
Water-cooled gas engine-driven chiller	All Capacities	≥ 1.2 COP ≥ 2.0 IPLV	n/a	ANSI Z21.40.4A

* The table number refers to the table number given in the 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings document. The content in the table is the same; however, the format has been changed to match this document.

H.12.b. IOU-Estimated Potential Energy Savings

Unit Energy Savings Estimates

The CASE authors estimated the energy savings for this measure with a series of eQUEST simulations using a large office model simulated in multiple climate zones. The CASE authors modeled chillers that comply with the prior 2008 standard, as well as chillers that comply with the new 2013 measure. The models included these inputs:

- 10 floors totaling 100,000 square feet
- Large VAV AHU with chilled water (CHW) and hot water (HW) coils
- HW reheat at the zone VAV boxes
- Two equally sized chillers
- Air-cooled and water-cooled chillers modeled in separate runs
- System fans operate 5:00 a.m. to 8:00 p.m. on Monday through Friday and 5:00 a.m. to 3:00 p.m. on Saturday
- Temperature setpoints in all zones are 74°F cooling and 70°F heating

The CASE report presented estimated unit energy savings by climate zone, chiller type, and chiller size. The CASE report did not explain how these savings estimates were rolled up and converted to the UES estimates reported in ISSM.

Overall, the CASE report was incomplete,[98] and it includes the following in the Analysis and Results section:

> *The analysis presented here was done using the same chiller curves that AHRI and the SSPC 90.1 used to estimate their savings. The curves used were developed by AHRI to just fit the COP and IPLV in each chiller category and path. Unfortunately it was recently discovered that these curves were flawed. This analysis is currently being rerun. What is presented here is indicative of the potential savings but will be updated with the new results when they are completed.*

98 In fact, the CASE report has a “draft” watermark on every page.

Thus, we do not know how the IOUs estimated unit energy savings – and we cannot accept their values.

Statewide Potential Energy Savings Estimate

The CASE report authors did not estimate the statewide potential energy savings. The accompanying post-processing Excel file[99] included a tab called "rough estimate of statewide savings;" however, a comment on this worksheet states, "Old. Needs to be updated." As such, we could not clearly determine how the CASE authors generated the savings estimates reported in ISSM. Table 93 summarizes the IOU-estimated savings for standard B63.

Table 93. Nonresidential IOU-Estimated Annual Potential Energy Savings: Standard B63

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
28.9	0.0	0.00

H.12.c. Evaluation Findings

Because of the incomplete nature of the documentation, we were unable to evaluate this standard. This prevented a review of reasonableness (with regards to the assumptions), and we were unable to find any secondary sources that would help us estimate baseline energy and potential energy savings.

In order to assess some savings (as opposed to zeroing out the savings for this standard), we referenced the following from the CASE report:

> *Under Addenda BL and BT, AHRI calculated that 52% more centrifugal chillers will now be covered by 90.1-2010 compared to 90.1-2007. In other words there are now minimum efficiency requirements for many chillers which previously had no requirements at all. Addenda BL and BT are estimated to save over 24 GWh annually worldwide, with estimated savings of 12 GWh per year in the U.S.*

The context surrounding this is that the CASE authors based their methodology on an analysis done by ASHRAE and AHRI.[100] Now, while the CASE authors believed that their own curves were flawed, we can make a rough and conservative estimate for savings based on the AHRI's estimates for savings in the U.S. If we assume that the ratio of total NRNC spending in California

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99 The file is called "Chiller eff eQuest results.xlsx."

100 The CASE authors' assumptions were more aggressive than ASHRAE's assumptions – so their results end up being different, but we can assume that ASHRAE's analysis is more conservative and applicable to this standard.

to the U.S.[101] is equal to the ratio of California to the U.S. chiller savings[102], then we estimate the savings in California to be 1.142 GWh.

Table 94. Nonresidential Evaluated Annual Potential Energy Savings Estimate: Standard B63

Interactive Effects*	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings without interactive effects	1.1	0.0	0.00
Final evaluated savings with interactive effects	0.8	0.0	0.00

* The interactive effects factors are discussed in the Interactive Effects section at the beginning of this appendix. Final evaluated savings include interactive effects.

H.13. B65: NRNC-HVAC-Laboratory Exhaust

Table 95 summarizes the IOU-estimated and Cadmus-evaluated potential energy savings for B65: NRNC-HVAC-Laboratory Exhaust.

Table 95. Nonresidential Annual Potential Energy Savings Estimate: Standard B65

Description	IOU Estimate	Evaluated*
Total electric energy savings (GWh/yr)	57.0	47.4
Total demand reduction (MW)	14.2	10.2
Total gas energy Savings (MMtherms/yr)	2.26	2.93
Total applicable units (Million sq. ft.)	1.4	1.2

* Evaluated savings in this table exclude interactive effects. Final evaluated savings include interactive effects.

** Indicates that the IOUs evaluated unit savings in terms of kWh or therms per square foot per year, and Cadmus evaluated in unit savings in terms of kWh or therms per laboratory hood per year. See the Evaluation Findings section.

101 United States Census Bureau. Construction Spending. Using 2015 data. Accessed 3/10/2017, https://www.census.gov/construction/c30/historical_data.html.

102 Or, in millions of dollars, the ratio of total NRNC spending in California to the United States equals $51,609/$542,259 which is 9.52%.

H.13.a. Standard Description

Standard B65: NRNC-HVAC-Laboratory Exhaust requirements are listed in Section 140.9(c) of the 2013 Title 24 California Building Energy Efficiency Standards. The CASE report supporting this standard details energy savings between the following baseline and standard cases:[103]

- **Baseline**: The 2008 standard allows supply and exhaust in labs to be constant volume. Most labs are currently designed as 100% outside air to all spaces including non-laboratory support spaces like offices and conference rooms. There are currently no requirements for energy recovery for high ventilation spaces.
- **Standard**[104]**:** This standard comes from sections 140.4 (c) and 140.9(c). This standard introduced new prescriptive requirements for the design of variable air volume systems and energy recovery in laboratories. It added language to the standard that requires most laboratory exhaust systems to be capable of reducing zone exhaust and makeup airflow rates to the regulated minimum circulation values (specifically 10 air changes per hour (ACH) or less), or the minimum required to maintain pressurization relationship requirements, whichever is larger. Additionally, requirements are set forth on using laboratory exhaust air to precondition makeup air through heat recovery.

H.13.b. IOU-Estimated Potential Energy Savings

Unit Energy Savings Estimates

The CASE authors calculated the UES using energy simulations. The authors built the energy model for an actual lab (34,000 square feet in area) on a university campus and calibrated it to three years of utility data. They assumed that the labs can go down to a minimum airflow of six air changes per hour for the analysis. The design peak airflows ranged from six to 18 air changes per hour. The authors used this simulation model to determine a conservative average energy savings per square foot.

The CASE report shows a UES of 41.3 kWh per square foot per year for climate zone 12 for the VAV portion of this code change and 0.62 kWh per square foot per year for the energy recovery portion, for a combined total UES of 41.9 kWh per square foot per year. This number matches the value reported by the IOUs.

The CASE report does not include just one single value for UES, but instead presents the estimated UES by climate zone where the unit savings are in kWh or therms per cubic feet per minute (CFM) per year. The CASE report does not explain how these savings estimates were rolled up and converted to the estimates reported by the IOUs (which were reported in kWh, kW, or therms per square foot per year). In fact, the IOUs' unit savings estimates are simply the single result for climate zone 12 and do not

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[103] Codes and Standards Enhancement Initiative (CASE), Final Report: Laboratory Exhaust and Heat Recovery, Pacific Gas and Electric Company, Southern California Edison, SoCalGas, SDG&E, July, 2013.

[104] 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012.

represent the full extent of the modeling outlined in the CASE report (where eight climate zones were modeled).

Statewide Potential Energy Savings Estimate

The CASE authors calculated statewide energy savings associated with the standard by multiplying the UES estimates by the statewide estimate of new construction in 2014 (based on CEC forecast data available at the time the CASE report was written). The authors estimated energy savings only for climate zones 3, 4, 6, 7, 8, 9, 12, and 13. They assumed the annual savings per square foot for the remaining climate zones was equal to the average savings of the calculated climate zones. They also assumed that 50% of labs would be designed as VAV even without the code change, so the statewide savings estimate was reduced by 50%.

The CASE report did not state what fraction of the statewide new construction would be affected by this measure. Moreover, there was a large discrepancy between the statewide savings estimates in the CASE report and the final estimate reported by the IOUs. As an example, for electric energy savings, the CASE report estimated savings of 96.8 GWh/yr, but the IOUs' final estimate for electric savings was 57.1 GWh.

Cadmus asked the IOUs why there was such a discrepancy between the CASE report and their final reported statewide savings estimates (note that the UES did not change between the CASE report and the final reported savings). The IOUs responded that they believed the applicable square footage estimates to be too large, and, thus, they lowered the estimated applicable square footage from about 11% (for colleges and miscellaneous building types) to about 3.5%.

Table 96 summarizes the IOU-estimated savings for this standard B65: NRNC-HVAC-Laboratory Exhaust.

Table 96. IOU-Estimated Potential Energy Savings: Standard B65

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
57.0	14.2	2.3

H.13.c. Evaluation Findings

Following a November 29, 2016, phone meeting between Cadmus, IOU staff, and consultants, the IOUs provided a spreadsheet to help clarify the discrepancy between the annual statewide savings estimate reported in the CASE report (96.8 GWh per year) and the annual estimate reported in ISSM (57.1 GWh per year). The spreadsheet also includes an alternative calculation method of statewide savings (based on the CFM of the hoods in the labs as opposed to the square footage of the labs). We made some adjustments to this alternative calculation, but, overall, we find it reasonable and the most conservative estimation of savings.

This standard is comprised of two measures – the VAV system and energy recovery system. The CASE authors simulated the standard's requirements in eight climate zones for several different minimum cases of air changes per hour (6 ACH, 10 ACH, and 14 ACH). For the VAV system measure, the CASE authors reported the kWh saved per CFM and the therms saved per CFM for each climate zone and ACH requirement.[105] For the energy recovery system measure, the CASE authors only reported the kWh saved per CFM and the therms saved per CFM for climate zones 3 and 12 and minimum ACH of 10 and 18 (we assume that it would have been quite cumbersome to expand the results completely in the CASE report, so perhaps the CASE authors chose to display only these two climate zones as an example).[106]

In Table 97, we present the average savings in terms of kWh/CFM and therms/CFM of each measure for all climate zones given in the CASE report. Moreover, Table 97 only averages savings for systems with 10 ACH as the code applies to 10 ACH or less – the CASE authors note in the CASE report that 10 ACH systems comprise the majority of lab systems (also this is a more conservative approach as 6 ACH systems receive more savings since each air change requires energy).[107]

Table 97. Average UES for Standard B65

Measure	Average kWh/CFM for 10 ACH System	Average therms/CFM for 10 ACH System
VAV System Requirement	11.504	0.551
Energy Recovery Requirement	-0.355	0.139
Total	**11.149**	**0.690**

First note that the energy recovery system does not save electric energy (but it does save gas energy). The energy recovery system requires a fan to operate, but, as the CASE report notes, it does save money during peak times as it pre-cools the outdoor air requiring less chiller and pump energy.[108]

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105 Codes and Standards Enhancement Initiative (CASE), Final Report: Laboratory Exhaust and Heat Recovery, Pacific Gas and Electric Company, Southern California Edison, SoCalGas, SDG&E, July, 2013. See Table 7.

106 *Ibid*. See Table 12.

107 Table 97 represents the IOUs' alternate methodology, but with Cadmus's adjustments. The IOUs only included VAV system requirements in their calculation of savings (that is, they did not include the energy recovery requirement – Cadmus does). Also note that kW savings per CFM are missing; the CASE authors did not report this value in the CASE report. We address that next.

108 Codes and Standards Enhancement Initiative (CASE), Final Report: Laboratory Exhaust and Heat Recovery, Pacific Gas and Electric Company, Southern California Edison, SoCalGas, SDG&E, July, 2013. See Appendix A. Page xvi.

Next in the IOUs' alternate calculation method, they estimated the number of laboratory hoods in the U.S.,[109] the number of hoods in California,[110] and the number of new hoods per year,[111] and the average CFM per hood.[112] We show these below in Table 98 with sources from the IOUs provided in the preceding footnotes.

Table 98. IOU Assumed Values for Alternate Calculation Method, Standard B65

Variable	Value	Units
No. of fume hoods in U.S.	750,000	hoods
No. of fume hoods in CA	85,000	hoods
Percent added each year	5%	-
No. of hoods added per year in CA	4,250	hoods/yr.
Average CFM per hood	1,000	CFM/hood

Cadmus accepted the values in Table 98 as they are reasonable and, for the most part, cite a reputable source.

Finally, the IOUs multiplied the number of hoods added per year in California by the average CFM per hood and by the unit energy savings per CFM to estimate the statewide savings. In this spreadsheet, the IOUs corroborated their final, submitted estimations with this alternate estimation. This alternate estimation yields savings for electric and gas energy about 14% lower than their final estimated savings. However, they do not address demand savings in this alternate calculation.

Cadmus believed it was unreasonable to adjust the electric and gas energy savings but not the demand savings. Since no estimation of watts saved per CFM was provided in the CASE report, Cadmus adjusted the IOUs' demand savings by square footage and the by percent that our final evaluated electric energy savings estimate differed from the IOUs final electric energy savings estimate. We used the same unit demand savings as the IOUs (in terms of kW per square foot per year) and 3.5% of the CEC forecasted 2014-2015 new construction square footage estimate for colleges and miscellaneous buildings (just as

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109 Lawrence Berkeley National Laboratory (LBNL), Energy Use and Savings Potential for Laboratory Fume Hoods, Evan Mills, Dale Sartor, April 2006.

110 Design and Engineering Services, An Energy Assessment of Fume Hoods with and without Automated Sash Positioning Control Systems at Amgen, Inc., Southern California Edison, July 2007.

111 The IOUs assumed that the number of new hoods added per year is equal to 5% of the current estimated number of laboratory hoods. They do not cite anything, and Cadmus could not find anything to support this claim. However, this seems reasonable and conservative.

112 The IOUs also assumed this value. However, Cadmus found a CASE study by UC Davis where they used the same assumption. Found at: http://wcec.ucdavis.edu/wp-content/uploads/2014/06/Case-Study-SASH_Final.pdf.

the IOUs did when they submitted their final estimates except with 2014 CEC forecasted new construction estimates).[113] This resulted in an applicable square footage of 1.18 million square feet, and a ratio of Cadmus evaluated energy savings to IOU estimated energy savings of 83% – or a final savings calculation of (10.400 W/sq. ft./yr) × (1.18 million sq. ft.) × (83%).

Table 99 shows the final evaluated savings estimate for this standard B65.

Table 99. Nonresidential Evaluated Annual Potential Energy Savings Estimate: Standard B65

Interactive Effects*	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings Without Interactive Effects	47.4	10.2	2.93
Final Evaluated Savings With Interactive Effects	47.4	10.2	2.93

* The interactive effects factors are discussed in the Interactive Effects section at the beginning of this appendix. Final evaluated savings include interactive effects.

H.14. B57: NRNC HVAC Controls and Economizers

Table 100 summarizes the IOU-estimated and Cadmus-evaluated potential energy savings for standard B57: HVAC Controls and Economizers.

Table 100. Nonresidential Annual Potential Energy Savings Estimate: Standard B57

Description	IOU Estimate	Evaluated*
Total electric energy savings (GWh/yr)	68.2	68.2
Total demand reduction (MW)	0.0	0.0
Total gas energy savings (MMtherms/yr)	0.00	0.00

* Evaluated savings in this table exclude interactive effects. Final evaluated savings include interactive effects.

H.14.a. Standard Description

The CASE report supporting this standard details energy savings for the following new requirements:[114]

- Fault detection and diagnostics (FDD) will be a mandatory requirement. Buildings must now detect for the following faults:
- Air temperature sensor failure/fault
- Not economizing when it should

[113] Note that we believe it is acceptable to include the miscellaneous building types because there are some labs not associated with universities.

[114] Final Report HVAC Controls and Economizers, Codes and Standards Enhancement Initiative (Case), July, 2013.

- Economizing when it should not
- Damper not modulating
- Excess outdoor air

- Occupant Sensor Ventilation Control: Multipurpose rooms less than 1000 square feet; classrooms greater than 750 square feet; and conference, convention, auditorium, and meeting center rooms greater than 750 square feet shall be equipped with occupant sensor(s) that will set up the operating cooling temperature setpoint and set back the operating heating temperature setpoint as well as automatically reset the minimum required ventilation rate.
- A thermostat with two stages of cooling will be required for single-zone systems whenever an outside air economizer is present.
- The prescriptive baseline for economizers is reduced from 75,000 Btu/h to 54,000 Btu/h.
- The statewide maximum damper leakage is set at 10 cfm/sf at 1.0 in w.g. in order to be consistent with the ASHRAE 90.1 damper leakage requirement.
- The economizer trade-off table is revised to be consistent with the ASHRAE 90.1 requirements.
- Mandatory performance features are included for economizers, and the current option for manufacturers to apply to the CEC for a certification for a factory-installed and calibrated economizer is expanded and revised to be more rigorous if the economizer is not factory installed and certified.
- The high-limit switch prescriptive requirements revise drybulb high limits and prefer fixed drybulb controls at the setpoint indicated in revised tables for all climate zones. The modeling rules in the Alternate Calculation Method reflect these changes.

The new code requirements are detailed in Sections 120.1, 120.2, 120.5, and 140.4 of the 2013 Title 24 Building Energy Efficiency Standards and the Mechanical and Acceptance Requirements chapter of the Nonresidential Compliance Manual. These sections are updates to the 2008 Title 24 sections 121, 122, 125, and 144.

H.14.b. IOU-Estimated Potential Energy Savings

Unit Energy Savings Estimates

Savings for this standard are distributed across the following seven measures:

- FDD
- Occupancy Sensor to Setback Thermostat
- Two-Stage Thermostat
- Economizer Size Threshold
- Economizer Damper Leakage
- Economizer Reliability
- High-Limit Switch Performance

This section summarizes the methods used to collect data and conduct the analysis for the CASE report. Total savings for this standard is equal to the sum of the savings contributions from each measure.

Fault Detection and Diagnostics

The CASE authors conducted a series of EnergyPro energy simulations and corresponding TDV analysis to estimate the potential energy savings resulting from use of FDD. The model included seven prototypes of fast food, grocery, large and small retail, school, and large and small office buildings and covered a representative sample of California climate zones, including 3, 6, 9, 12, 14, and 16.

The CASE authors used a special version of EnergyPro 5.1 configured to use the 2013 weather files developed for the 16 CEC forecast climate zones by Joe Huang with Whitebox Technologies for the CEC. These climate zone files were intended to serve as the reference data for 2013 code analysis. The version of EnergyPro was configured identically to the version certified for use with the 2008 Title 24 standards, outside of the weather file change.

The total UES potential for this measure is 0.0170 kWh per square foot per year. This estimate is the average of the simulation results for each building type and climate zone combination weighted by the corresponding applicable square footage derived from the 2014 CEC new construction forecasts at the time the CASE report was written.

Occupancy Sensor to Setback Thermostat

The CASE authors completed a series of energy simulations using eQUEST to estimate the potential energy savings resulting from use of occupancy sensors to set up and set back the cooling and heating temperature setpoints and automatically reset the minimum required ventilation rate during unoccupied daytime (standby) periods in classrooms, conference rooms, and multipurpose rooms in schools and large and small office buildings. The simulation used a single space, various numbers of exterior surfaces, a range of setup/setback temperatures, and a range of standby period durations as summarized here:

- Climate zones: 3, 6, 9, 12, 14, 16
- Number of exterior walls: 0, 1, 2, 3
- Duration of the standby period: 1, 2, 4, 10 hours
- Temperature setup and setback: 0°F (base case), 2°F, 4°F, 8°F
- System type: packaged single zone constant volume (CAV) with gas furnace, packaged VAV with a boiler, and a built-up or central plant VAV system

Model assumptions were based on 2008 Title 24. Nominal temperature setpoint schedules were based on the 2008 Nonresidential ACM Approval Method and are listed below:

- Cooling: 73°F (7 a.m. to 6 p.m. Monday to Friday, 81°F all other time)
- Heating: 70°F (7 a.m. to 6 p.m. Monday to Friday, 60°F all other time)

The total energy savings potential for this measure is 0.171 kilowatt-hour per square foot per year. This estimate is the average of the simulation results for each building type and climate zone combination weighted by the corresponding applicable square footage derived from the 2014 CEC new construction forecasts at the time the CASE report was written.

Two-Stage Thermostat

The CASE authors completed a series of energy simulations using eQUEST to estimate the potential energy savings resulting from use of a two-stage thermostat. The current simulation of economizers in DOE 2.2 with the packaged single zone system has a known problem in that, as an hourly simulation, it cannot simulate switching between a single stage DX coil cooling operation (that needs to reduce the outside air to avoid comfort problems and coil freezing) and economizer operation where supply air temperature is not an issue. The present routine exaggerates the savings that will accrue from an economizer in a single-stage cooling unit. The energy savings methodology relies on a work-around to correct the simulation.

The simulation used a three story building based on the medium office from the DOE set of reference building models. This model has five zones plus plenum per floor, a range of window to wall ratios, and a range of occupancy types as summarized here.

- Climate zones: 3, 6, 9, 12, 14, 16
- Window to wall ratio: 10%, 30%, 60%
- Occupancy type: high density office, low density office, retail, primary school
- Economizer operation: one-stage thermostat (base case), two-stage thermostat

The total energy savings potential for this measure is 0.311 kWh per square foot per year. This estimate is the average of the simulation results for each building type and climate zone combination weighted by the corresponding applicable square footage derived from the 2014 CEC new construction forecasts at the time the CASE report was written.

Economizer Size Threshold

To estimate the energy savings of the changes, the IOUs developed a series of DOE-2 prototype models. These are the same base models used for the two-stage thermostat analysis previously described. The only difference in the base models is that, for this measure, the economizer operation base case is no economizer and the measure case is a temperature-based economizer.

The total energy savings potential for this measure is 0.478 kWh per square foot per year. This estimate is the average of the simulation results for each building type and climate zone combination weighted by the corresponding applicable square footage derived from the 2014 CEC new construction forecasts at the time the CASE report was written.

Economizer Damper Leakage

The ASHRAE 90.1 mechanical subcommittee investigated this measure and shared their analysis with the IOU Codes and Standards team. The ASHRAE 90.1 committee’s methodology is outlined here:

- Used the small office building spreadsheet model to calculate the energy loss or gain
- Only considered the unoccupied hours when the fan was running

- Calculated the additional heating and cooling load by taking the leakage air times the difference in enthalpy between the run air and outside air
- Used the leakage per ASHRAE 90.1 damper leakage table with 4 cfm per square foot for ASHRAE climate zones 1, 2, 6, 7, and 8 (Eastern Sierra south of Lake Tahoe). Used 10 cfm per square foot for all other zones (most of California)
- From some testing that Carrier did, used a damper leakage of 25 cfm per square foot for the typical product (base case). Also doubled this value to 50 cfm per square foot to investigate the impact
- Included leakage through the outside air damper and exhaust damper. Outside air damper size was calculated based on a 400 feet per minute face velocity and exhaust was based on 600 feet per minute
- Corrected the leakage to 0.5-inch static as the ratings are based on the AMCA Standard 500, which is at 1 inch of static. (0.5/1.0)^0.5=0.71

The IOUs found that the total energy savings potential per floor area for this measure are insignificant.

Economizer Reliability

The energy savings analysis for this savings component is a spreadsheet-based calculation that relies on the energy simulations performed for the FDD measure. It is also based on the Advanced Rooftop Unit PIER project.[115]

The CASE authors multiplied the total TDV dollar savings per ton by bin tonnage and the percentage of the market share per size bin for units above the proposed minimum tonnage (3.75 tons) associated with this measure. The CASE authors then multiplied this number by the market share to attain the statewide TDV dollar savings.

The total energy savings potential per floor area for this measure is 0.0943 kWh per square foot per year. The electricity savings were estimated by dividing the TDV savings by the TDV $/kWh ratios associated with the economizer threshold measure—$0.134/kWh for first year savings. This estimate is the average of the simulation results for each building type and climate zone combination weighted by the corresponding applicable square footage derived from the 2014 CEC new construction forecasts at the time the CASE report was written.

High Limit Switch Performance

To test the impact on energy usage of the various high limit control options including sensor error, the CASE authors created a DOE- 2.2 model of a typical office building. DOE- 2.2 was used (as opposed to other simulation engines like EnergyPlus) because it is capable of modeling high limit sensor error. Sensor error was assumed to be ±2°F for drybulb sensors and ±4%RH for humidity sensors. Seven high

[115] Architectural Energy Corporation. Advanced Automated HVAC Fault Detection and Diagnostics Commercialization Program. Project 4: Advanced Rooftop Unit. PIER Project for the California Energy Commission. August 2007.

limit controls and combinations were modeled, covering the most common high limit strategies and the options that are allowed prescriptively within Title 24, with the exception of the electronic enthalpy strategy, which cannot be modeled explicitly within eQUEST.

The total energy savings potential for this measure is 0.0284 kWh per square foot per year. This estimate is the average of the simulation results for each building type and climate zone combination weighted by the corresponding applicable square footage derived from the 2014 CEC new construction forecasts at the time the CASE report was written.

Statewide Potential Energy Savings Estimate

The reported statewide annual savings for the first year is 68.2 GWh per year and electrical demand savings are negligible. Square footage assumptions were based on the 2014 CEC new construction forecasts at the time the CASE report was written. Table 101 summarizes the IOU-estimated savings for B57: HVAC Controls and Economizers.

Table 101. IOU-Estimated Potential Energy Savings: Standard B57

Measure	UES Savings (kWh/sq. ft. per year.)	Applicable Square Footage (Million)	Total Electric Energy Savings (GWh/yr)
Fault detection and diagnostics	0.017	92.8	1.6
Occupancy sensor to setback thermostat	0.171	46.8	8.0
Two-stage thermostat	0.311	60.8	18.9
Economizer size threshold	0.478	60.8	29.1
Economizer reliability	0.094	92.8	8.8
High limit switch performance	0.028	67.4	1.9
Total statewide savings			**68.2**

H.14.c. Evaluation Findings

Cadmus finds the UES estimates from the CASE report for electric energy (kWh) to be reasonable based on the information available for this standard.

Although we could not confirm estimates based on assumptions made by the CASE authors in the assessment of applicable square footage, we have reviewed the CEC’s nonresidential construction forecast received in September 2015. The CASE authors’ applicable square footage assumptions, based on an earlier version of the CEC’s forecast, appear to be reasonable. Table 102 shows the final evaluated savings estimate for this standard.

Table 102. Nonresidential Evaluated Annual Potential Energy Savings Estimate: Standard B57

Interactive Effects*	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings without interactive effects	68.2	0.0	0.00
Final evaluated savings with interactive effects	59.1	0.0	0.00

* The interactive effects factors are discussed in the Interactive Effects section at the beginning of this appendix. Final evaluated savings include interactive effects.

H.15. B75: NRNC Supermarket Refrigeration

Table 103 summarizes the IOU-estimated and Cadmus-evaluated potential energy savings for standard B75: Supermarket Refrigeration.

Table 103. Nonresidential Annual Potential Energy Savings Estimate: Standard B75

Description	IOU Estimate	Evaluated*
Total electric energy savings (GWh/yr)	18.0	14.8
Total demand reduction (MW)	1.5	1.3
Total gas energy savings (MMtherms/yr)	1.88	1.55
Total applicable units (Million sq. ft.)	8.5	7.0

*Evaluated savings in this table include interactive effects because of the whole building savings analysis approach.

H.15.a. Standard Description

The CASE report supporting this standard details energy savings for the following new requirements:[116]

- Section 120.6(b)1: Floating head pressure – require controls to float refrigeration system saturated condensing temperature to 70°F during low-ambient temperature conditions, with ambient-following control logic and variable speed condenser fans
- Section 120.6(b)1: Condenser specific efficiency – require a maximum fan power per unit of capacity on air-cooled and evaporative-cooled refrigerant condensers
- Section 120.6(b)2: Floating suction pressure – require controls to reset refrigeration system target suction temperature based on refrigerated display case or walk-in temperature, rather than operating at a fixed suction temperature setpoint
- Section 120.6(b)2: Mechanical subcooling – require liquid refrigerant to be subcooled to 50°F or less for low-temperature loads

116 Final Report Supermarket Refrigeration Energy Efficiency, Codes and Standards Enhancement Initiative (CASE), May, 2013.

- Section 120.6(b)3: Display case lighting control – require automatic controls to turn off display case lights during non-business hours
- Section 120.6(b)4: Refrigeration heat recovery – require equipment and controls to utilize rejected heat from refrigeration system(s) for space heating, with a limited increase in refrigerant charge.

These changes result in new language added in a new section, Section 120.6(b), of the 2013 Title 24 Building Energy Efficiency Standards. Requirements for supermarket refrigeration equipment did not previously exist in Title 24 Standards.

H.15.b. IOU-Estimated Potential Energy Savings

Unit Energy Savings Estimates

The CASE authors developed three prototype models to estimate the UES of the Title 24 supermarket refrigeration standards: a small supermarket, a large supermarket, and a big-box food store using large point-of-sale refrigeration boxes with display doors. The authors developed the prototypes based on typical supermarket footprints and sizes observed from over 10 years of Savings by Design data. They obtained refrigeration system types and equipment, design loads, refrigerants, operating schedules, and control strategies for the analysis from the base case criteria used in the California Savings by Design program. To develop the prototype assumptions, they used requirements for envelope, lighting, HVAC systems, and federal walk-in standards from 2008 Title 24.

The authors used several refrigeration system configurations of the proposed measures, sufficient to cover most of the designs used for supermarkets. They applied each refrigeration measure to each of the three prototypes and developed each prototype with three different condenser types and two different compressor system configurations. The CASE authors analyzed results for the 16 recognized California climate zones.

The CASE authors evaluated the energy usage for each supermarket prototype using DOE-2.2R energy simulation software. The DOE-2.2R version is a sophisticated component-based energy simulation program that can accurately model the building envelope, lighting systems, HVAC systems, and refrigeration systems—including the complex interaction between refrigerated supermarket display cases and the surrounding indoor environment. The 2.2R version is specifically designed to include refrigeration systems, using refrigerant properties, mass flow, and component models to accurately describe refrigeration system operation and controls system effects. Square footage assumptions were based on the 2014 CEC new construction forecasts at the time the CASE report was written. Table 106 shows the reported savings for this standard.

Table 104. Nonresidential IOU-Estimated Annual Potential Energy Savings by Climate Zone: Standard B75

Climate Zone	Applicable Square Footage (Million)	UES (kWh/sq. ft.)	UES (W/sq. ft.)	UES (Therm/sq. ft.)
1	0.015	3.66	0.660	0.512
2	0.095	3.66	0.130	0.512
3	0.297	3.66	0.400	0.512
4	0.237	3.66	0.130	0.512
5	0.046	3.66	0.620	0.512
6	0.397	3.66	0.130	0.512
7	0.551	3.66	0.350	0.512
8	0.486	3.66	0.580	0.272
9	1.046	3.66	0.130	0.272
10	0.304	3.66	0.460	0.272
11	0.180	3.63	0.130	0.374
12	0.704	3.63	0.420	0.374
13	0.390	3.63	0.450	0.374
14	0.074	3.63	0.360	0.374
15	0.026	3.63	0.480	0.374
16	0.087	3.63	0.130	0.374

Statewide Potential Energy Savings Estimate

The CASE authors based the UES estimates on supermarket buildings with total square footage of 4,935,315. When applied to the CEC's forecast "Food" building type with a total square footage of 8,509,163, UES estimates for each application are shown in Table 105.

Table 105. Nonresidential IOU-Estimated Annual Potential Energy Savings by Building: Standard B75

Building Type	Applicable Square Footage (Million)	UES (kWh/sq. ft./year)	UES (W/sq. ft.)	UES (Therm/sq. ft./year)
Supermarket	4.935	3.651	0.314	0.382
Food	8.509	2.118	0.181	0.222

The statewide annual savings for the first year is 18.02 GWh, 1.54 MW, and 1.89 MMtherms per year. Table 106 summarizes the IOU-estimated savings for standard B75: Supermarket Refrigeration.

Table 106. Nonresidential IOU-Estimated Annual Potential Energy Savings: Standard B75

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
18.0	1.5	1.88

H.15.c. Evaluation Findings

Cadmus finds the UES estimates from the CASE report reasonable for electric energy (kWh) and demand (kW) and gas (therms). We attempted to verify the unit savings using other reports or some other data source, but were unable to find anything applicable to this standard. The study scope did not permit further detailed investigation into assumptions. We updated the applicable square footage assumptions using the CEC's nonresidential construction forecast (received in September 2015). The most recent estimate of food building square footage is 6,975,515. Cadmus applied the UES for food buildings to the updated square footage results to calculate the final evaluated savings estimate for standard B75: Supermarket Refrigeration (shown in Table 107).

Table 107. Nonresidential Evaluated Annual Potential Energy Savings Estimate: Standard B75

Interactive Effects*	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings without interactive effects	14.8	1.3	1.55
Final evaluated savings with interactive effects	14.8	1.3	1.55

* The interactive effects factors are discussed in the Interactive Effects section at the beginning of this appendix. Final evaluated savings include interactive effects.

H.16. B78: NRNC Data Centers

Table 108 summarizes the IOU-estimated and Cadmus-evaluated potential energy savings for standard B78: Data Centers.

Table 108. Nonresidential Annual Potential Energy Savings Estimate: Standard B78

Description	IOU Estimate	Evaluated*
Total electric energy savings (GWh/yr)	27.5	27.5
Total demand reduction (MW)	0.8	0.8
Total gas energy savings (MMtherms/yr)	0.00	0.00
Total applicable units (Million sq. ft.)	0.1	0.1

* Evaluated savings in this table exclude interactive effects. Final evaluated savings include interactive effects.

H.16.a. Standard Description

The CASE report supporting this standard details energy savings for the following new requirements:[117]

- Requiring economizers in small computer rooms in buildings that have economizers
- Exempting some computer room expansions from the economizer requirement
- Exempting some new computer rooms in existing buildings from the economizer requirement

[117] 2013 California Building Energy Efficiency Standards, Data Center Energy Efficiency, Codes and Standards Enhancement Initiative (Case)

- Prohibiting reheat in computer rooms
- Prohibiting non-adiabatic humidification in computer rooms
- Limiting power of fan systems serving computer rooms to 27 watts per kBtuh of net sensible cooling capacity
- Requiring variable speed controls on all chilled water fan systems and all direct expansion (DX) systems over five tons serving computer rooms.
- Requiring containment in large, high density data centers with air-cooled computers

There were previously no requirements for computer rooms (per common interpretation). This CASE report also makes it clear that the existing mandatory requirements apply to computer rooms.

H.16.b. IOU-Estimated Potential Energy Savings

Unit Energy Savings Estimates

Different types of data centers can meet the economizer requirements in different ways. The CASE authors evaluated the following four data center scenarios in order to reasonably cover the range of data center types:

- Scenario 1. Small Stand-Alone Computer Room Air Economizer
- Scenario 2. Small Stand-Alone Computer Room Air-to-Air Heat Exchanger
- Scenario 3. Small Computer Room in Office Building VAV Box
- Scenario 4. Large Data Center Water Economizer

Small Stand-Alone Computer Room—Air Economizer and Air-to-Air Heat Exchanger

Title 24-2008 requires economizers for "Each individual cooling fan system that has a design supply capacity over 2,500 cubic feet per minute and a total mechanical cooling capacity over 75,000 Btu/hr,"that is, for any system over 6.25 tons. This measure lowers that threshold to 5 tons and above. The CASE authors used DOE-2 to evaluate energy savings of an airside economizer on a data center with a 5 ton cooling system. The same model was used for the air-to-air heat exchanger with the exception of the additional static pressure in the heat exchanger that the supply fan must overcome.

The baseline is a packaged single zone system without an economizer. Economizers in small packaged units are often not truly integrated because of discrete compressor capacity steps. Therefore, the CASE authors set up the following three parametric runs to investigate full and partial economizing:

- A fully integrated economizer with a differential drybulb high limit switch
- A partially integrated economizer per DOE-2
- A non-integrated economizer with a low fixed drybulb high limit switch of 60°F

The CASE authors averaged the first and second parametric runs to establish the proposed case and used this method to represent a partially integrated economizer in a 5-ton unitary cooling system. Overall, the parametric runs show that adding an economizer saves between one-third and two-thirds of the total HVAC energy when compared to a unitary cooling system without an economizer. Total HVAC energy decreased by about two-fifths with the addition of an air-to-air heat exchanger.

Small Computer Room in Office Building – VAV Box

The base case for this measure is a small computer room in an office building served by a split DX system. In the proposed case the computer room is served by both a split DX system and by a cooling only VAV box off of the central VAV system.

The CASE authors set up a model for the baseline in eQUEST. It is a single zone computer room that is served by a packaged split system with DX cooling and no heating component. The zone has a high process load that varies throughout the year to investigate varying server loads throughout the lifetime of the computer room.

The proposed cases come from two parametric runs that the authors set up in the eQUEST model. Both proposed cases include a fully integrated economizer and lower fan power. When a large central VAV system operates to serve just a small computer it effectively operates as a constant volume system (with very low fan power) with supply air temperature reset. Thus, in the first parametric run, the team modeled the system as a constant volume single zone DX system with an airside economizer.

The authors post-processed the results from the eQUEST runs in spreadsheets by filtering for the hours considered in these three proposed cases:

- Savings during unoccupied hours only
- Savings during unoccupied hours when the economizer is operating
- Savings during all unoccupied hours plus occupied hours when the economizer is operating

In the second proposed case, the cooling for the computer room is provided by free cooling from the VAV economizer and supplemented by the single zone split DX. The authors only investigated savings from unoccupied hours in the first two cases. Thus, these runs are quite conservative since they do not account for savings from serving the computer rooms with VAV boxes during occupied hours. The authors took these hours into consideration in the third case. Total HVAC energy savings for the parametric runs ranged from 77% in case three to 95% in case 2.

Large Data Center—Water Economizer

For very large data centers, waterside economizing is likely to be lower first cost than air-side economizing. Therefore, the CASE authors performed an analysis comparing a large data center without economizing to one with a water-side economizer. The authors modeled a 10,000 square foot single-zone data center building using the eQUEST Design Day version to evaluate annual energy performance of the waterside economizer.

The eQUEST model has a 100-foot by 100-foot floor plan, with a floor to ceiling height of 12 feet and a three-foot plenum space above the ceiling. Model inputs for the building's envelope included R-10 wall with no windows and/or doors, an adiabatic roof, and a floor. Inputs also included zero occupancy and 0.5 watts per square foot of uniform lighting load. The authors simplified the envelope and non-IT cooling load in the energy model because its values were small enough to be negligible when compared to the IT load.

The model included 100 watts per square foot for the space IT equipment load and 24 x 7 for the IT load part-load schedule, with a constant load during each month that varied month to month.

The authors established two base-case models: (1) a constant volume air system and (2) a variable volume air system with a minimum air flow rate of 50% of design flow. In both cases, the models showed approximately 13 to 14% total HVAC savings.

Statewide Potential Energy Savings Estimate

Applicable square footage for standard B78 is not described in the CASE report. For the purpose of having a value, the Cadmus team reverse engineered the applicable square footage from the total electric energy savings and the UES as shown below:

27.5 GWh / 280 kWh/sq. ft. = 98,200 square feet

Table 109 lists the IOU-estimated savings for standard B78: Data Centers.

Table 109. Nonresidential IOU-Estimated Annual Potential Energy Savings Estimate: Standard B78

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
27.5	0.8	0.00

H.16.c. Evaluation Findings

Table 110 shows the final evaluated savings estimate for this standard. Cadmus has reviewed information from the IEEE 802.3bs Task Force that provided an overview of the largest data centers and their power densities, however, small computer rooms were not included and documentation of potential energy savings was not found. Cadmus finds the UES estimates from the CASE report to be reasonable for electric energy (kWh) and demand (kW). UES assumptions appear to be reasonable; however, Cadmus could not verify estimates because of incomplete information. We used CEC forecast estimates to determine applicable square footage. The square footage assumptions used to determine statewide savings appear to be reasonable.

Table 110. Nonresidential Evaluated Annual Potential Energy Savings Estimate: Standard B78

Interactive Effects*	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings without interactive effects	27.5	0.8	0.00
Final evaluated savings with interactive effects	27.5	0.8	0.00

* The interactive effects factors are discussed in the Interactive Effects section at the beginning of this appendix. Final evaluated savings include interactive effects.

H.17. B54: NRNC Office Plug Load Control

Table 111 summarizes the IOU-estimated and Cadmus-evaluated potential energy savings for standard B54: Office Plug Load Control.

Table 111. Nonresidential Annual Potential Energy Savings Estimate: Standard B54

Description	IOU Estimate	Evaluated*
Total electric energy savings (GWh/yr)	34.3	13.7
Total demand reduction (MW)	9.3	3.6
Total gas energy savings (MMtherms/yr)	0.00	0.00
Total applicable units (Million sq. ft.)	84.9	36.9

* Evaluated savings in this table exclude interactive effects. Final evaluated savings include interactive effects.

H.17.a. Standard Description

The 2013 Title 24 code language requires the installation of 120-V receptacles with automatic shut-off controls in all office spaces. In all applicable spaces, as designated in the code, a controlled receptacle must be provided within six feet of each uncontrolled receptacle. Split wired duplex receptacles that have one side that is controlled is a valid compliance option. In open office areas, controlled circuits need to be clearly marked to allow for the proper circuit arrangement and receptacle configurations so that some receptacles in office furniture are controlled. Controlled receptacles are required to have the same shut-off controls as those for general lighting. Controlled receptacles are required to have unique markings so that building occupants can differentiate them from uncontrolled ones.

For time switch control, the CASE authors used the baseline overhead lighting controls per 2008 Title 24 requirements assuming the common practice of using either central lighting control panels or central controllable breaker panels to control general lighting. The 2008 Title 24 requires that office spaces less than 250 sq. ft. should be equipped with occupancy sensor for general lighting shut-off controls. This requirement effectively covers most private offices and conference rooms. The authors used this as the baseline for evaluating occupancy sensor controls for plug load.

H.17.b. IOU-Estimated Potential Energy Savings

Unit Energy Savings Estimates

The CASE authors calculated UES, in terms of energy savings per square foot, using an algorithm that accounts for multiple factors affecting plug load energy uses: plug load density, control schedules, and plug load power status during each control schedule. The authors collected plug load density data for each controllable plug load and developed statistics of plug load power status (active, idle, sleep, standby, and disconnected) based on previous plug load studies and assumptions. They developed occupancy patterns based on assumptions of typical working schedules to determine control schedules. To determine annual peak demand savings, they used the CEC's peak capacity weighting factors for hourly savings.

The CASE authors calculated UES estimates for each of the three levels of control, basing the statewide impacts on the level 2 control (which were proposed and adopted). This level of plug load controls requires occupancy sensor controls in private offices and conference rooms and requires time switch controls in other office areas. Table 112 shows UES for small and large offices as well as other applicable nonresidential building spaces.

Table 112. Nonresidential IOU-Estimated Annual Potential Unit Energy Savings: Standard B54

Building Type	UES (kWh/sq. ft./year)	UES (W/sq. ft)	UES (Therm/sq. ft./year)
Small office	0.49	0.20	0.00
Large office	0.61	0.13	0.00
Other	0.61	0.17	0.00

Statewide Potential Energy Savings Estimate

The CASE authors based statewide square footage estimates on CEC forecasted new construction data available at the time the CASE report was drafted. To estimate statewide energy savings, the authors multiplied UES estimates by the statewide new construction floor areas covered by the proposed code change, which included all office buildings (large and small) and office spaces in other building types. The floor area included 1% of retail buildings, 0.5% of non-refrigerated and refrigerated warehouse buildings, 2% of school buildings, 2% of college buildings, and 1% of miscellaneous buildings.

The analysis provided UES for small and large office prototypes based on the whole building floor area. Office space represents 81% of the whole building area in the small office prototype. The authors calculated UES based on office space area by dividing the UES based on the whole building area by 81% and then applied it to the office spaces in the "other" non-office building types. Table 113 summarizes the IOU-estimated savings for this standard B54: Office Plug Load Control.

Table 113. Nonresidential IOU-Estimated Annual Potential Energy Savings: Standard B54

Building Type	Applicable Square Footage (Million sq. ft.)	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Small office	9.1	3.1	1.3	0.00
Large office	27.7	10.7	2.4	0.00
Other	48.0	20.5	5.6	0.00

H.17.c. Evaluation Findings

The Cadmus team checked the power status and inventory assumptions used in the CASE report against the data presented in the LBNL research study[118] on the extent to which electronic office equipment is turned off or automatically enters a low power state when not in active use and found that the two agree very closely. Cadmus accepts the UES estimates from the CASE report for electric energy (kWh) and demand (kW) and gas (therms). We used updated new construction forecasts provided by the CEC in September 2015 for evaluated statewide savings, averaging 2014 and 2015 forecasted values to estimate annual new construction square footage. We then applied the UES for each building type to the updated square footage results to estimate the evaluated savings for this standard. The Cadmus team used the same assumptions as the CASE authors for total square footage in non-office buildings (deemed as "other" in the docketed CASE report). Table 114 shows evaluated savings by building type, and Table 114 shows the final evaluated savings estimate for this standard.

Table 114. Evaluated Annual Potential Energy Savings by Building Type

Building Type	Applicable Square Footage (Million sq. ft.)	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Small office	8.1	2.8	1.1	0.00
Large office	27.9	10.7	2.4	0.00
Other	0.9	0.3	0.1	0.00

118 LBNL, After-hours Power Status of Office Equipment and Inventory of Miscellaneous Plug-Load Equipment, January 2004

Table 115. Nonresidential Evaluated Annual Potential Energy Savings Estimate: Standard B54

Interactive Effects*	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings without interactive effects	13.7	3.6	0.00
Final evaluated savings with interactive effects	10.1	3.0	-0.06

* The interactive effects factors are discussed in the Interactive Effects section at the beginning of this appendix. Final evaluated savings include interactive effects.

H.18. B56: NRNC Fenestration

Table 116 lists the IOU-estimated and Cadmus-evaluated potential energy savings for standard B56: Fenestration.

Table 116. Nonresidential Annual Potential Energy Savings Estimate: B56

Description	IOU Estimate	Evaluated*
Total electric energy savings (GWh/yr)	85.6	63.4
Total demand reduction (MW)	23.9	17.9
Total gas energy savings (MMtherms/yr)	-0.13	0.00

* Evaluated savings in this table exclude scaled interactive effects. Final evaluated savings include scaled interactive effects.

H.18.a. Standard Description

The CASE report supporting this standard details energy savings for updates to the prescriptive envelope component approach of the standards. The window type categories are fixed, operable, curtain wall/storefront, and glazed doors. The skylight categories remain the same. The base case is the Title 24 2008 fenestration code. The new code language differs from the previous code language in the following ways (See Sections 100.1, 110.6, 140.3, and 141.0 of the 2013 Title 24 document):[119]

- The prescriptive U-factor and SHGC requirements have become more stringent.
- A new visible transmittance requirement will be enforced.
- There are no longer different prescriptive requirements for every climate zone, window-to-wall ratio, and façade orientation.

[119] 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012.

H.18.b. IOU-Estimated Potential Energy Savings Estimates

Unit Energy Savings Estimates

The CASE authors based their UES estimates on a prototype building simulation. The prototype building was a 130-by-130 square foot, single-floor energy model, with Title 24-2008 office occupancy loads and Title 24-2008 minimally compliant walls, roof, and HVAC. The authors used internal loads and schedules from the Title 24-2008 ACM for nonresidential and high-rise residential occupancies, and applied daylighting to capture lighting savings caused by the higher visible transmittance rating requirement. The authors modeled the window-to-wall ratios at 10%, 20%, 30%, and 40% and skylight-to-roof ratios at 2% and 5%. The model used updated weather and TDV files.

Lowering the maximum allowed solar heat gain coefficient reduces the HVAC energy required during peak periods, which typically occur during the summer months in California. The inclusion of a visible transmittance requirement also reduces the lighting energy during peak periods, which affects both the lighting load and the cooling load. Table 117 shows UES for each building classification for standard B56: Fenestration.

Table 117. Nonresidential IOU-Estimated Annual Potential Energy Savings: Standard B56

Building Type	UES (kWh/sq. ft./year)	UES (W/sq. ft.)	UES (Therm/sq. ft./year)
Nonresidential windows	0.254	0.060	-0.00002
High-rise windows	0.176	0.050	-0.00514
Nonresidential glass skylights	0.450	0.180	-0.00025
High-rise glass skylights	0.112	0.050	-0.00135
Nonresidential plastic skylights	0.370	0.120	-0.00047
High-rise plastic skylights	0.071	0.030	-0.00102

Statewide Potential Energy Savings Estimate

To calculate the statewide energy savings associated with standard B56, the CASE authors multiplied the energy savings per square foot by the statewide estimate of new construction in 2014. Table 118 summarizes the savings reported by the CASE authors for this standard.

Table 118. Nonresidential Reported Savings Estimate: Standard B56

Building Type	Applicable Square Footage (Million)	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Nonresidential windows	168.4	42.8	10.1	-0.00
High-rise windows	14.9	2.6	0.7	-0.08
Nonresidential glass skylights	11.9	5.4	2.1	-0.00
High-rise glass skylights	0.1	0.0	0.0	0.00
Nonresidential plastic skylights	73.2	27.1	8.8	-0.03
High-rise plastic skylights	0.4	0.0	0.0	0.00
Total statewide savings		**77.9**	**21.8**	**-0.11**

Note that the final IOU estimated savings values for electric energy, demand, and gas energy include interactive effects. The CASE authors did not adjust for these in the CASE report. Thus the total savings in Table 118 differ from those in Table 116.

H.18.c. Evaluation Findings

In order to verify the UES estimates, Cadmus submitted a data request to the CASE authors for all the files that went into their prototype building model. Cadmus did not receive all of the files involved in creating the prototype building model (specifically the input file). Thus, we were unable to review the model. However, we did conduct a literature review of some of the sources in the CASE report cited as critical to the design of the building prototype model.[120] Specifically, we examined the ASHRAE Standard 90.1-2010 and US Department of Energy commercial reference building models of the National Building Stock. The CASE authors generally followed the methodology described in those two sources. This was difficult to evaluate precisely as the study scope did not permit detailed investigation of the assumptions. However, Cadmus looked for similar components and assumptions between the CASE report and the ASHRAE and DOE documents and accepts the UES estimates as reasonable.

The CASE authors did not explicitly state how they derived the square footage estimates for each of the measures. They provided a table in an appendix to the CASE report that outlined each of the California building types and assumptions made in the DOE reference building model, but the document did not fully explain the steps between this table and the CASE report's applicable square footage for each measure. Thus, Cadmus was unable to recreate the CASE authors' square footage estimates using this table.

Although we do not know exactly what the CASE authors did, we did find an apparent mistake in the CASE authors' methodology. The CASE authors appeared to include hospitals in their square footage estimates – which are excluded from Title 24 requirements – because the applicable square footage for

[120] The CASE authors frequently cited interviews with industry experts and literature such as the California Commercial End-Use Survey as sources of data.

nonresidential and high-rise windows (which, physically, would apply to all building types) sums to the 2014 CEC forecasted new construction square footage (with some small rounding error). See Table 119.

Table 119. Estimated Windows Square Footage and 2014 CEC Forecasted Square Footage

Building Type or Total	Square Footage (Million) Reported by CASE Authors
Nonresidential windows	168.4
High-rise windows	14.9
Nonresidential windows + high-rise windows	183.4
2014 CEC forecasted new construction total	183.3

Theoretically, the fenestration requirements would apply to all building types[121] (which is why one would expect nonresidential and high-rise windows to sum to the total square footage). However, hospitals are exempt from Title 24 requirements, so we would expect the fenestration windows requirements to sum (using the 2014 CEC forecasted numbers used by the CASE authors) to about 174 million square feet (or the total 2014 CEC forecasted new construction square feet minus the forecasted square feet for hospitals).

By using the aforementioned table in the appendix to the CASE report to the extent possible, we adjusted the square footage using the 2014-2015 CEC forecasted average in the following manner (Table 120):

Table 120. Applicable Square Footage Percentage Based on Building Type and Measure

Forecasted Building Type	Nonresidential Building Type Percentage	High-rise Building Type Percentage	Windows Percentage	Skylight Percentage
Office: small	100%	0%	100%	5%
Office: large	100%	0%	100%	25%
Restaurant	100%	0%	100%	5%
Retail	100%	0%	100%	95%
Food	100%	0%	100%	95%
Non-refrigerated warehouse	100%	0%	100%	95%
Refrigerated warehouse	100%	0%	100%	0%
School	100%	0%	100%	25%
College	100%	0%	100%	25%
Hospital*	0%	0%	100%	25%
Hotel	0%	100%	100%	5%
Miscellaneous	13%	87%	100%	5%

121 The skylights, however, only apply to a select portion of each building type. This is reflected in the savings.

The percentages in Table 120 are applied to the total building type new construction square footage as follows:

- Multiply the total building type square footage by the building type square footage percentage applicable to the measure – nonresidential or high-rise
- Multiply the resulting number by the square footage percentage applicable to the measure – windows or skylights[122]

Again, this was our best interpretation of the table presented in the appendix to the CASE report. Using this methodology, we get smaller estimates of applicable square feet than if we were to use the 2014 CEC new construction forecasted square footage. Thus, our methodology is (at the very least) more conservative, and more accurate in the fact that this methodology does not include savings from hospitals. Our final estimates by measure are shown in Table 121. Note that the savings in Table 121 did not adjust for interactive effects. Our final evaluated savings for the standard are shown in Table 122.

Table 121. Evaluated Annual Potential Energy Savings By Measure

Building Type	Applicable Square Footage (million)	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Nonresidential windows	115.6	29.4	6.9	-0.00
High-rise windows	35.1	6.2	1.8	-0.18
Nonresidential glass skylights	9.2	4.1	1.7	-0.00
High-rise glass skylights	0.2	0.0	0.0	0.00
Nonresidential plastic skylights	56.4	20.9	6.8	-0.03
High-rise plastic skylights	1.5	0.1	0.0	-0.00
Total statewide savings		**60.7**	**17.2**	**-0.21**

Table 122. Nonresidential Reported Energy Savings Estimate: Standard B56

Interactive Effects*	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings without interactive effects	63.4	17.9	0.00
Final evaluated savings with interactive effects	46.5	14.9	0.00

* The interactive effects factors are discussed in the Interactive Effects section at the beginning of this appendix. Final evaluated savings include interactive effects.

122 Skylights must be further adjusted by their material – plastic or glass. The CASE report estimates the plastic skylights make up 86% of the market and glass skylights make up 14% of the market.

H.19. B50: NRNC Lighting-Parking Garage

Table 123 summarizes the IOU-estimated and Cadmus-evaluated potential energy savings for standard B50: Lighting-Parking Garage.

Table 123. Nonresidential Annual Potential Energy Savings Estimate: Standard B50

Description	IOU Estimate	Evaluated*
Total electric energy savings (GWh/yr)	27.4	18.7
Total demand reduction (MW)	5.4	1.7
Total gas energy savings (MMtherms/yr)	0.00	0.00
Total applicable units (Million sq. ft.)	24.6	20.8

* Evaluated savings in this table exclude interactive effects. Final evaluated savings include interactive effects factors of 1.0 based on parking garage savings not occurring in an environment where other standards are also implemented.

H.19.a. Standard Description

B50: Lighting-Parking Garage requirements are listed in Section 130.1 of the 2013 Title 24 California Building Energy Efficiency Standards. The CASE report supporting this standard details energy savings between the following baseline and standard cases:[123] [124]

- **Baseline:** Parking garages are not required to have occupant sensing or daylighting controls. There are two parking garage area types with different LPD requirements. Parking areas have an LPD requirement of 0.20 watts per square foot. Ramps and entries have an LPD allowance of 0.60 watts per square foot.
- **Standard:** Parking garages are required to have partial on/off occupant sensing controls having at least one control step between 20% and 50% of design lighting power. Parking garages are also required to have lighting in daylight zones controlled independently by automatic daylighting controls. Daylight controls shall be multi-level, continuous dimming, or on/off.

  Additionally, area definitions and LPD requirements for parking garages have been changed. There are now three designated parking garage area types: parking areas, ramps, and daylight adaptation zones. The LPD requirements for these areas are 0.14, 0.30, and 0.60 watts per square foot, respectively.

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[123] 2013 California Building Energy Efficiency Standards: Final Report Parking Garage Lighting and Controls. California Utilities Statewide Codes and Standards team. May 2013.

[124] 2013 California Building Energy Efficiency Standards: Parking Garage LPD and Controls. February 2011.

The current requirements for B50 – Lighting-Parking Garage are described in Sections 130.1(c)7 and 130.1(d)3 of the 2013 Title 24 California Building Energy Efficiency Standards.[125]

H.19.b. IOU-Estimated Potential Energy Savings Estimates

Unit Energy Savings Estimates

The CASE authors estimated per-unit savings for this standard by applying a percentage savings value to a baseline consumption based on the baseline LPD (in watts per square foot), assumed baseline hours per year, and the conversion from watts to kilowatts. The CASE report states the baseline LPD of 0.30 is weighted by the square footage for each parking garage area type. The CASE authors assumed baseline hours per year are 8,760. The percentage savings has two components: LPD reduction savings and lighting control (occupancy sensing and daylighting) savings. They calculated an LPD reduction savings of 33% by using a percent change formula between the baseline case of 0.30 and the efficient case of 0.20.[126] They calculated the baseline and efficient case using an average of the LPD requirements (2008 code for the baseline and the standard for the efficient case) for each area type, weighted by the square footage for each area type.

To estimate lighting control savings, the authors used the model results for combined daylighting and occupancy sensing of 13.4%. They examined daylight-responsive controls using lighting calculation software AFI32 and occupancy sensing controls using a custom simulation program created in Visual Basic through Microsoft Excel. The reported combined percent savings for the LPD reduction and lighting controls is 42%. The final reported UES is 1.11 kWh per square foot.

Statewide Potential Energy Savings Estimate

The CASE authors based total new construction nonresidential floor areas on the CEC's 2013 forecast for retail, restaurant, office, institutional, and warehouse building types. They used a series of assumptions to calculate parking garage square footage using the CEC's forecast for these building types. First, they assumed a number of parking spaces per 1,000 square feet of building area value for each building type,

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[125] 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012.

[126] Figure 8: Recommended Changes to Parking Garage LPD Values found in Table 146-E; Complete Building Method. 2013 California Building Energy Efficiency Standards: Final Report Parking Garage Lighting and Controls. Page 16. California Utilities Statewide Codes and Standards team. May 2013.

ranging from 1.5 for warehouses to 12.0 for restaurants[127]. Next, they assumed that each parking space was 220 square feet and that interior parking consisted of 20% of all parking spaces.[128]

Table 124 summarizes the IOU-estimated savings for standard B50: Lighting-Parking Garage.

Table 124. Nonresidential IOU-Estimated Annual Potential Energy Savings: Standard B50

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
27.4	5.4	0.00

H.19.c. Evaluation Findings

Cadmus was unable to reproduce the baseline and efficient case LPDs calculated in the CASE report for the UES estimate using the stated method.[129] We agree with the methodology described, but there appears to be an error in the calculation. Cadmus calculated a weighted average of the required LPDs by area type with the associated percent of building square footages for those area types, yielding a baseline case of 0.25 watts per square foot and an efficient case of 0.17 watts per square foot. Table 125 shows the percentage of building square footage and the LPD requirement for the baseline and efficient cases for each area type.[130] Table 126 shows the results of the weighted averages for the baseline and efficient cases as reported in the CASE report and as evaluated by Cadmus.[131]

Table 125. Percentage of Building Area and LPD Requirements by Area Type

Area	Percentage of Total sq. ft.	Title 24-2008 LPD (W/sq. ft.)	Title 24-2013 LPD (W/sq. ft.)
Parking garage—parking area	87%	0.20	0.14
Parking garage—ramps	9%	0.60	0.30
Parking garage—entries (daylight adaptation zones)	4%	0.60	0.60

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127 General requirements for parking spaces per 1,000 square feet were found from minimum municipal requirements from the following cities: Pasadena, Santa Ana, Anaheim, Los Angeles, Oceanside. 2013 California Building Energy Efficiency Standards: Final Report Parking Garage Lighting and Controls. Page 8. California Utilities Statewide Codes and Standards team. May 2013.

128 Table 2: Calculation of Impacted Square Footage for Parking Garage Lighting and Controls. Final Report Parking Garage Lighting and Controls. Page 9. California Utilities Statewide Codes and Standards team. May 2013.

129 Final Report Parking Garage Lighting and Controls. Page 16. May 2013.

130 Figure 7 and text on page 16 of the Final Report Parking Garage Lighting and Controls. May 2013.

131 Reported in Figure 8 of the Final Report Parking Garage Lighting and Controls. May 2013.

Table 126. Weighted Average Results for Baseline and Efficient Cases: Reported vs. Evaluated

Area	LPD Reduction (W/sq. ft.)	Title 24-2008 LPD (W/ sq. ft.)	Title 24-2013 LPD (W/ sq. ft.)
Parking garages—reported	0.10	0.30	0.20
Parking garages—evaluated	0.08	0.25	0.17

Cadmus found the remaining UES assumptions to be reasonable; however, we could not verify estimates because of incomplete information. Cadmus recommends the following revisions to the UES estimates from the CASE report:

- Changing the baseline LPD used in the savings calculation from 0.30 to 0.25, based on the square footage and LPD requirements from Title 24 2008 associated with the two parking garage area types.
- Changing the standard LPD used in the savings calculation from 0.20 to 0.17, based on the square footage and LPD requirements from Title 24 2008 associated with each of the three parking garage area types.

Cadmus used CEC forecast estimates (provided to Cadmus in September 2015) to determine applicable square footage, averaging 2014 and 2015 data. We used the same methodology and assumptions to calculate parking garage square footage using building square footages from the CEC forecast. These assumptions appear to be reasonable; however, Cadmus could not verify estimates because of incomplete information. We used a combination of the college and hospital building types for the "Institutional" building type from the CASE report. The square footage assumptions received from the CEC in September 2015 do not align with the CASE report square footage estimates by building type. The change in square footage is the primary driver behind the difference in reported and evaluated savings. Table 127 shows the final evaluated savings estimate for standard B50: Lighting-Parking Garage.

Table 127. Nonresidential Evaluated Annual Potential Energy Savings Estimate: Standard B50

Interactive Effects*	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings without interactive effects	18.7	1.7	0.00
Final evaluated savings with interactive effects	18.7	1.7	0.00

* The interactive effects factors are discussed in the Interactive Effects section at the beginning of this appendix. Final evaluated savings for this standard include interactive effect factors of 1.0 because no interactions occur between this standard and other building systems.

H.20. B66: NRNC-HVAC Small ECMs (Electrically Commutated Motors)

Table 128 summarizes the IOU-estimated and Cadmus-evaluated potential energy savings for standard B66: NRNC-HVAC Small ECM Motor.

Table 128. Nonresidential Annual Potential Energy Savings Estimate: Standard B66

Description	IOU Estimate	Evaluated*
Total electric energy savings (GWh/yr)	55.2	47.4
Total demand reduction (MW)	0.0	0.0
Total gas energy savings (MMtherms/yr)	0.00	0.00

* Evaluated savings in this table include interactive effects because of the whole building savings analysis approach.

H.20.a. Standard Description

The HVAC Small ECM Motor (or electrically commutated motor) requirements are listed in Section 140.4(c)4 of the 2013 Title 24 California Building Energy Efficiency Standards. The CASE report supporting this standard details energy savings between the following baseline and standard cases:[132]

- **Baseline:** Small ECM motors were not covered in the 2008 Title 24 requirements. Therefore, the IOU-proposed baseline is based on industry standard/market average/typical existing conditions, which is represented by permanent-split capacitor (PSC) motors that have been shipped with fans historically. PSC motors have efficiencies in the range of 15% to 65%; the average efficiency of these motors is 29% according to a recent study.[133]
- **Standard:** The standard requires the average efficiency of fractional HVAC motors to be 70% or to be electronically commutated motors.

HVAC Small ECM Motor requirements are listed in Section 140.4(c)4 of the 2013 Title 24 California Building Energy Efficiency Standards.[134]

H.20.b. IOU Potential Energy Savings Estimates

The CASE report estimated statewide potential energy savings based on applying a percent savings to the proportion that small fractional motors contribute to the overall HVAC motor load in California (using CEUS data). The section below (discussing the UES estimates) outlines how the CASE report derived a percent savings for each fractional motor. The CASE report also includes estimated kWh savings per motor – although ultimately that estimate was inconsequential to the overall analysis as they applied a percent savings to the fractional HVAC motor load. However, they did use the UES per motor to corroborate the submitted estimate.

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132 Draft Title 24 Fractional HVAC Motors. Codes and Standards Program Change Theory. September 2016.

133 ANSI/ASHRAE/IES Standards 90.1-2013 Determination of Energy Savings: Quantitative Analysis (ASHRAE 90.1-2013). U.S. Department of Energy (DOE). August 2014. Accessed (12/20/2016) https://www.energycodes.gov/sites/default/files/documents/901-2013_finalCommercialDeterminationQuantitativeAnalysis_TSD.pdf. See section 5.2.2.4.

134 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012.

Unit Energy Savings Estimates

The CASE report includes per-unit fractional HVAC motor savings estimates by assuming the baseline of each fractional HVAC motor (from 1/12 hp to 3/4 hp)[135] to be a PSC motor with a full load efficiency of 29%. The CASE report states that PSC motors typically have efficiencies in the range of 12% to 45%, with a full load efficiency assumption of 29% the average of that range.

The authors estimated that fractional horsepower electronically commutated motors[136] (ECM) have efficiencies in the range of 65% to 85%.[137] They assumed an efficiency for each fractional horsepower motor of 69%, noting that an assumed efficiency of 69% is very close to the code in ASHRAE 90.1-2013, section 5.2.2.4 which requires fractional horsepower fan motors of series fan-power terminal units to have a minimum efficiency of 70%.[138]

The authors proposed two design cases. Proposed Case A was for a, "fixed speed fan (or pump) that was installed without any balancing," and Proposed Case B was for a, "system that would be balanced in the field."[139] The functional difference between the two proposed cases is that Case B assumes a 20% reduction in fan energy for the efficient motor.

The authors estimated a percent savings for all fractional motor sizes of 58% and 67% (for Case A and Case B, respectively). They estimated the power needed in each motor (the baseline motor and the two proposed motor cases) to deliver its rating by dividing the rated horsepower of the motor (in kW) by the efficiency of the motor (as a percentage), and multiplying that by the percent of fan energy needed to achieve the brake horse power of the motor. Table 129 shows an example from the CASE report based on 1/4 hp motor savings.

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135 Note that the standard applies to motors *less than* 1 hp – so 1 hp motors are not included.

136 Note that these are sometimes called brushless direct current (DC) motors.

137 Physically, ECMs differ from PSC motors because EC motors control the fan in an HVAC or evaporator system using variable speeds. PSC motors have only a binary, ON/OFF mode to control the fan speed. Switching from a PSC motor to ECM results in energy savings.

138 ANSI/ASHRAE/IES Standards 90.1-2013 Determination of Energy Savings: Quantitative Analysis (ASHRAE 90.1-2013). U.S. Department of Energy (DOE). August 2014. Accessed (12/20/2016) https://www.energycodes.gov/sites/default/files/documents/901-2013_finalCommercialDeterminationQuantitativeAnalysis_TSD.pdf.

139 Final Report Fractional HVAC Motors. 2013 California Building Energy Efficiency Standards. August 2013. See Appendix A.

Table 129. CASE Report Savings Table for 1/4 Horsepower Motor*

	Base case	Proposed A	Proposed B
MHP (hp)	1/4	1/4	1/4
Motor	Standard (PSC)	ECM	ECM
Motor efficiency	29%	69%	69%
Percentage of MHP for BHP	100%	100%	80%
MHP (kW)	0.250	0.250	0.200
Fan kW	0.654	0.272	0.218
Delta fan kW		0.382	0.436
Percentage of savings		58%	67%

* *Ibid*

The CASE authors calculated per unit energy savings by multiplying the data in the "Delta Fan kW" row by the estimated operating hours. The authors estimated annual operating hours by averaging all nonresidential operating hours from 2013 ACM Appendices (approximately 6,052 hours).[140] They estimated UES by averaging the savings of Case A and Case B for 1/12, 1/8, and 1/4 hp motors (which assumes an even mix of motor sizes and of balanced and unbalanced motors). Using this method, the CASE authors calculated savings per motor of 1,995 kWh/yr.

Note that CASE authors only evaluated 1/12 hp, 1/8 hp, and 1/4 hp motors. They acknowledged that, as the motors increased in size, there would be more energy savings. They chose to evaluate only the aforementioned sized motors showing the trend that as the motors increase in size they become more cost effective. Also, the CASE authors note that reporting per unit savings based only on the analysis of 1/12, 1/8, and 1/4 hp motors is more conservative.

Statewide Potential Energy Savings Estimate

To estimate the statewide potential energy savings, the CASE authors summed the total energy consumption from HVAC applications using CEUS data. From that data, they estimated that there is an annual use of 3174 GWh. The CASE authors then used the CEUS data to estimate the ratio that fractional horsepower motors contribute to the total installed horsepower in commercial HVAC motors. They averaged all projects and assumed 3% of all horsepower comes from fractional horsepower HVAC motors.

The CASE authors then applied the 3% fractional horsepower to total horsepower ratio to the total annual usage and concluded that 95 GWh of annual usage comes from fractional horsepower motors. Finally, to estimate savings, the CASE authors applied the unit percent savings from Case A (58%; as it was the more conservative option) to the estimated 95 GWh of annual energy usage that fractional horsepower motors contribute to the overall load. The authors did not estimate demand or therm

[140] The CASE authors provided Cadmus this file in a data request. The file is called, "Appendix_5.4B_Schedules.xlsx".

savings from this standard. Table 130 summarizes the IOU-estimated savings for standard B66: NRNC-HVAC Small ECM Motor.

Table 130. Nonresidential IOU-Estimated Annual Potential Energy Savings: Standard B66

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
55.2	0.0	0.00

H.20.c. Evaluation Findings

Cadmus finds the general methodology from the CASE report reasonable for estimating energy savings; however, we recommend minor changes to some of the assumptions.

Cadmus accepts the baseline PSC motor efficiency used by the CASE authors as it is the value used in the ASHRAE 90.1-2013 standard.[141] The CASE report, which was completed before the final code language was adopted, assumes an ECM motor efficiency of 69%—the final code language set the motor efficiency standard at 70%. Thus, Cadmus re-did the analysis with that change. Moreover, there appeared to be rounding errors in the CASE report savings example above. Cadmus corrected this. This change was small (affecting the thousandths place in most cases). The result of the correction changed the percent savings slightly—58.3% vs. 58.5%.[142]

Cadmus does not find the CASE authors' estimated operating hours to be reasonable. The CASE authors cite the average annual operating hours from 2013 ACM Appendices. However, this value for operating hours is about 2,000 hours more than the value used in the 2009 Small Electric Motor Technical Support Document (TSD) (see Table 6.2.9 for fans and blowers).[143] Therefore, we used the DOE's value for operating hours (4,500 hours) as it is based specifically on the application type. This change does not affect the percent savings used in the statewide savings estimation, but it does affect the per-motor savings (however, this is ultimately inconsequential to IOU estimates as the IOUs back-calculated per unit savings from their statewide estimate).

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141 ANSI/ASHRAE/IES Standards 90.1-2013 Determination of Energy Savings: Quantitative Analysis (ASHRAE 90.1-2013). U.S. Department of Energy (DOE). August 2014. Accessed (12/20/2016) https://www.energycodes.gov/sites/default/files/documents/901-2013_finalCommercialDeterminationQuantitativeAnalysis_TSD.pdf. See section 5.2.2.4.

142 Although, note that the percent savings that Cadmus used would round up to 59% (Cadmus, however, did not round). Moreover, when applying this percent savings to the statewide energy consumption, the small changes in percent can make a substantial difference to overall savings.

143 Technical Support Document (TSD): Energy Efficiency Standards for Commercial and Industrial Equipment: Small Electric Motors. U.S. Department of Energy (DOE). 2009. Accessed (12/20/2016) https://www.regulations.gov/document?D=EERE-2007-BT-STD-0007-0034.

When estimating the statewide changes, we accept the methodology used by the CASE authors, but disagree with the final ratio of fractional horsepower to total horsepower. In the spreadsheets provided, the CASE authors summed fractional horsepower components inconsistently. In some projects, they counted motors with a horsepower greater than two, and in others they did not count motors with a horsepower of approximately 0.72. Since the code applies to fractional motors less than 1 hp and 1/12 hp or greater, Cadmus summed fractional motors only if they were 3/4 hp or less.[144] This yields a fractional horsepower to total horsepower ratio of 2.55% and yields the total fractional horsepower motor annual energy savings of 47.36 GWh (assuming a 58.5% savings from the ECM motors).

Cadmus would like to note that the CEUS data are from 2006 and based on existing construction. The CASE authors assumed that the CEUS data were applicable to 2013 new construction (and the statewide savings estimate ultimately comes from these data). We could not find an updated study. However, in an attempt to corroborate their original analysis, the CASE authors used the per unit savings, shipment data from the 2009 Small Electric Motor TSD (Tables 9.3.6, 9.3.7, and 9.3.8), market share for industrial and commercial fans and blowers in the 2009 Small Electric Motor TSD (Table 6.2.7), and the California population multiplier of 12% as an alternate estimate of statewide energy savings.[145]

Using this alternative calculation, the authors estimated that there were approximately 28,023 fractional motors shipped in California and statewide energy savings of 55.9 GWh per year. Using this same alternate methodology, Cadmus estimated 49.1 GWh per year of savings. Note that the CASE authors used the methodology described in section H.20.b to submit their findings.

Table 131 shows the final evaluated savings estimate for standard B66: NRNC-HVAC Small ECM Motor.

Table 131. Nonresidential Evaluated Annual Potential Energy Savings Estimate: Standard B66

Interactive Effects*	Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Energy Savings (MMtherms/yr)
Savings without interactive effects	47.4	0.0	0.00
Final evaluated savings with interactive effects	34.7	0.0	0.00

* The interactive effects factors are discussed in the Interactive Effects section at the beginning of this appendix. Final evaluated savings include interactive effects.

144 Note that this is more conservative than summing fractional motors less than 1 hp. Also note that ASHRAE 90.1-2013 addendum 90.1-2010aj sets the maximum applicable motor bhp at 90% of 3/4 hp and a minimum bhp of 25% of 1/12 hp. However, since that statement is not in the Title 24 code, Cadmus summed the horsepower of fractional motors 3/4 hp or less.

145 The CASE authors provided Cadmus with the spreadsheet titled, "ECM Motor Savings Calcs Final.xlsx". See tab, "Statewide Savings Calculations."

I. Potential Energy Savings - Residential

This appendix summarizes Cadmus' evaluation of potential energy savings for the following residential standards:

- B85: RNC-Envelope-Fenestration
- B90: RNC-HVAC-Duct
- B89: RNC-HVAC-Zoned AC
- B88: RNC-HVAC-Whole House Fans
- B84: RNC-Envelope-Wall Insulation
- B83: RNC-Lighting

I.1. B85: RNC-Envelope-Fenestration

Table 132 provides a summary of the findings Cadmus used to estimate potential energy savings for B85: RNC-Envelope-Fenestration.

Table 132. Residential Savings Estimate: B85: RNC-Envelope-Fenestration

Description	IOU Estimate (ISSM)	Evaluated
Unit Energy Savings (kWh)	639	639
Unit Demand Savings (kW)	1.53	1.53
Unit Gas Savings (therms)	-15	-15
Total Electric Energy Savings (GWh/yr)	14.6	7.81
Total Demand Reduction (MW)	34.8	22.2
Total Gas Savings (MMtherms/yr)	-0.34	-0.19
Total applicable units (dwelling units)	22,795	37,040

I.1.a. Description

B85: RNC-Envelope-Fenestration requirements are listed in Section 150.1(c)3 of the 2013 Title 24 California Building Energy Efficiency Standards. The CASE report supporting this standard details energy savings between the following baseline and proposed standard cases:[146]

Baseline

The baseline case is the 2008 Title 24 requirements for maximum U-factor and maximum Solar Heat Gain Coefficient (SHGC) as shown in the table below.

[146] Codes and Standards Enhancement Initiative (CASE), Final Report: Residential Window Efficiency, Pacific Gas and Electric Company, Southern California Edison, SoCalGas, SDG&E, May 2013.

Proposed Standard

This measure lowers the maximum U-factor and the maximum Solar Heat Gain Coefficient as shown in the table below. These requirements are found in Section 150.1(c)3 of the 2013 Title 24 California Building Energy Efficiency Standards.[147]

Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2008 maximum U-factor	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
2013 maximum U-factor	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
2008 maximum SHGC	NR	0.40	NR	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.35	NR
2013 maximum SHGC	NR	0.25	NR	0.25	NR	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25

I.1.b. Reported Potential Energy Savings Estimates

Per-Unit Savings Estimates

According to the CASE report, "The team ran energy simulations to evaluate potential proposed revisions to the fenestration performance requirements, with the primary goals being high statewide TDV savings and low life cycle costs. The CALRES / MP2013 modeling tool was used to run simulations on prototype single-family and multifamily buildings, with reduced fenestration U-factor and SHGC requirements in the Standards' prescriptive Package D. The prototype buildings were modeled in each of California's 16 climate zones." The Package D requirements are listed in Table 151-C of the 2008 Standards.[148]

The CASE report continues, "The prototype single-family home incorporating the proposed revisions results in simulated TDV savings ranging from 2.1 to 18.6 TDV kBtu/sf (5 - 17%) relative to the same home built per 2008 Package D, depending on climate zone. Factoring in new construction starts weighted by climate zone, this translates to 12.4 TDV kBtu/sf or 14.1% statewide TDV savings per prototype single-family home. The prototype multifamily building incorporating the proposed revisions results in simulated TDV savings ranging from 1.3 – 13.0 TDV kBtu/sf (3 - 13%) relative to the same home built per 2008 Package D, depending on climate zone. Factoring in new construction starts weighted by

[147] 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012.

[148] 2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2008-001-CMF, December 2008.

climate zone, this translates to 8.3 TDV kBtu/sf or 9.1% statewide TDV savings per prototype multifamily building."

Statewide Potential Energy Savings Estimate

According to the CASE report, "Statewide energy savings associated with the CASE proposal are estimated by multiplying the calculated per-building prototype savings by the 2014 new construction forecast for the corresponding residential building type. This is performed for each of the 16 climates zones, and the resulting savings for each climate zone are then summed to determine total savings statewide." The gas savings are negative as a net increase in gas usage occurs. This is because the maximum SHGC decreases from the 2008 to 2013 Standard, thus allowing less solar heat gain into the building through the windows.

Table 133 below summarizes the savings reported by the IOUs for this standard.

Table 133. Residential Reported Energy Savings Estimate: B85: RNC-Envelope-Fenestration

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Savings (MMtherms)
14.6	34.8	-0.34

I.1.c. Evaluation Findings

Cadmus accepts the per-unit savings estimates from the CASE report for electric energy (kWh), demand (kW), and gas (therms).

Unit energy savings assumptions appear to be reasonable; however, Cadmus could not completely confirm estimates due to incomplete information.

Cadmus used historical data from CIRB to determine the applicable number of new construction single-family dwelling units. This value is higher than the CASE report new construction estimates. The savings estimates for all measures included in the whole building measure were then scaled such that the sum of the measure savings matches the whole building savings estimate. The scaling factor is 0.536 for GWh/yr values, 0.638 for MW values, and 0.558 for MMtherms values.[149] The final evaluated savings estimate for this standard are shown in Table 134 below.

Table 134. Residential Evaluated Savings Estimate: B85: RNC-Envelope-Fenestration

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Savings (MMtherms)
7.81	22.2	-0.19

[149] The scaling factor approach is described in the Potential Energy section of the main report.

I.2. B90: RNC-HVAC-Duct

Table 135 provides a summary of the findings Cadmus used to estimate potential energy savings for B90: RNC-HVAC-Duct.

Table 135. Residential Savings Estimate: B90: RNC-HVAC-Duct

Description	IOU Estimate (ISSM)	Evaluated
Unit Energy Savings (kWh)	623	623
Unit Demand Savings (kW)	0.75	0.75
Unit Gas Savings (therms)	21.4	21.4
Total Electric Energy Savings (GWh/yr)	10.2	5.46
Total Demand Reduction (MW)	0.0	0.0
Total Gas Savings (MMtherms)	1.1	0.59
Total applicable units (dwelling units)	22,795	37,040

I.2.a. Description

B90: RNC-HVAC-Duct requirements are listed in Section 150.0(m)11 through 13 of the 2013 Title 24 California Building Energy Efficiency Standards. The CASE report supporting this standard details energy savings between the following baseline and proposed standard cases:[150]

Baseline

The baseline case is the 2008 Title 24 prescriptive requirements for:

- Duct sealing in all climate zones and confirmed through field verification and diagnostic testing
- Cooling airflow greater than 350 CFM/ton of nominal cooling capacity in climate zones 10 through 15
- Fan watt draw less than 0.58 W/cfm in climate zones 10 through 15

Proposed Standard

This proposal changed the 2008 requirements from prescriptive to mandatory.

[150] Codes and Standards Enhancement Initiative (CASE), Final Report: Residential Ducts, Pacific Gas and Electric Company, Southern California Edison, SoCalGas, SDG&E, June 2013.

The current requirements for B90: RNC-HVAC-Duct in Section 150.0(m)11 through 13 of the 2013 Title 24 California Building Energy Efficiency Standards read as follows:[151]

11. **Duct System Sealing and Leakage Testing**. When space conditioning systems utilize forced air duct systems to supply conditioned air to an occupiable space, the ducts shall be sealed, as confirmed through field verification and diagnostic testing, in accordance with all applicable procedures specified in Reference Residential Appendix RA3.1, and the leakage compliance criteria specified in Reference Residential Appendix TABLE RA3.1-2, and conforming to one of the following Subsections A, B, or C as applicable:

    A. For single family dwellings and townhouses with the air-handling unit installed and the ducts connected directly to the air handler, the total leakage of the duct system shall not exceed 6 percent of the nominal system air handler airflow as determined utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.1.

    B. For single family dwellings and townhouses at the rough-in stage of construction prior to installation of the dwelling's interior finishing:

        i. Air-handling unit installed.

        If the air-handling unit is installed and the ducts are connected directly to the air handler, the total leakage of the duct system shall not exceed 6 percent of the nominal system air handler airflow as determined utilizing the procedures in Reference Residential Appendix Sections RA3.1.4.3.2, RA3.1.4.3.2.1 and RA3.1.4.3.3.

        ii. Air-handling unit not yet installed.

        If the air-handling unit is not yet installed, the total leakage of the duct system shall not exceed 4 percent of the nominal system air handler airflow as determined utilizing the procedures in Reference Residential Appendix Sections RA3.1.4.3.2, RA3.1.4.3.2.2 and RA3.1.4.3.3.

    C. For multifamily dwellings with the air-handling unit installed and the ducts connected directly to the air handler, regardless of duct system location,

        i. The total leakage of the duct system shall not exceed 12 percent of the nominal system air handler airflow as determined utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.1, or

        ii. The duct system leakage to outside shall not exceed 6 percent of the nominal system air handler airflow as determined utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.4.

[151] 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012.

13. **Duct System Sizing and Air Filter Grille Sizing.** Space conditioning systems that utilize forced air ducts to supply cooling to an occupiable space shall:

A. Have a hole for the placement of a static pressure probe (HSPP), or a permanently installed static pressure probe (PSPP) in the supply plenum downstream of the air conditioning evaporator coil. The size, location, and labeling of the HSPP or PSPP shall conform to the requirements specified in Reference Residential Appendix RA3.3.1.1 as confirmed by field verification and diagnostic testing; and

EXCEPTION to 150.0(m)13A: Systems that cannot conform to the specifications for hole location in Reference Residential Appendix Figure RA3.3-1 shall not be required to provide holes as described in Figure RA3.3-1.

B. Demonstrate, in every control mode, airflow greater than or equal to 350 CFM per ton of nominal cooling capacity through the return grilles, and an air-handling unit fan efficacy less than or equal to 0.58 W/CFM as confirmed by field verification and diagnostic testing in accordance with the procedures given in Reference Residential Appendix RA3.3.

ALTERNATIVE to Section 150.0(m)13B: Standard ducted systems (systems without zoning dampers) may comply by meeting the applicable requirements in TABLE 150.0-C or 150.0-D as confirmed by field verification and diagnostic testing in accordance with the procedures in Reference Residential Appendix Sections RA3.1.4.4 and RA3.1.4.5. The design clean-filter pressure drop requirements of Section 150.0(m)12C for the system air filter device(s) shall conform to the requirements given in TABLES 150.0-C and 150.0-D.

EXCEPTION to Section 150.0(m)13B: Multispeed compressor systems or variable speed compressor systems shall verify air flow (cfm/ton) and fan efficacy (Watt/cfm) for system operation at the maximum compressor speed and the maximum air handler fan speed.

I.2.b. Reported Potential Energy Savings Estimates

Per-Unit Savings Estimates

According to the CASE report, “Energy benefits for mandatory duct leakage testing are based on improving the HVAC system performance in the base case house. This is done by comparing the prototype house modeled to the current 2008 Prescriptive Package D to the prototype house without duct sealing and testing. The typical base case for proposal evaluation is a prototype meeting all current 2008 prescriptive requirements. However, since the proposal was to change the 2008 requirement from prescriptive to mandatory, the IOU C&S team estimated the energy impact of making the requirement mandatory by setting the duct leakage rate at 22% for the base case (since the house will be built post 2001, from field survey data) and the leakage rate at 6% for the proposed case.”

Statewide Potential Energy Savings Estimate

According to the CASE report, “Cumulative energy impacts are calculated based on all buildings constructed during the measure evaluation period (for this measure, 30 years). Cumulative electricity and gas savings (GWh and MMtherms) account for the lifetime savings (30 years) from the buildings constructed during the first year, plus the lifetime minus one year savings (29 years) from the buildings constructed during the second year, plus the lifetime minus two years savings (28 years) from the buildings constructed during the third year, and so on until the end of the evaluation period. Cumulative demand savings account for the reduction in demand from all buildings constructed during the measure evaluation period. It is assumed that the number of new construction starts will remain constant over time, thus the cumulative demand savings is calculated as the first year demand savings multiplied by the number of years."

Table 136 below summarizes the savings reported by the IOUs for this standard.

Table 136. Residential Reported Energy Savings Estimate: B90: RNC-HVAC-Duct

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Savings (MMtherms)
10.2	0.0	1.1

I.2.c. Evaluation Findings

Cadmus accepts the per-unit savings estimates from the CASE report for electric energy (kWh), demand (kW), and gas (therms).

Unit energy savings assumptions appear to be reasonable; however, Cadmus could not completely confirm estimates due to incomplete information.

Cadmus used historical data from CIRB to determine the applicable number of new construction single-family dwelling units. This value is higher than the CASE report new construction estimates. The savings estimates for all measures included in the whole building measure were then scaled such that the sum of the measure savings matches the whole building savings estimate. The scaling factor is 0.536 for GWh/yr values, 0.638 for MW values, and 0.558 for MMtherms values.[152] The final evaluated savings estimate for this standard are shown in Table 137 below.

Table 137. Residential Evaluated Savings Estimate: B90: RNC-HVAC-Duct

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Savings (MMtherms)
5.46	0.00	0.59

I.3. B89: RNC-HVAC-Zoned AC

Table 138 provides a summary of the findings Cadmus used to estimate potential energy savings for B89: RNC-HVAC-Zoned AC.

Table 138. Residential Savings Estimate: B89: RNC-HVAC-Zoned AC

Description	IOU Estimate (ISSM)	Evaluated
Unit Energy Savings (kWh)	441	441
Unit Demand Savings (kW)	0.61	0.61
Unit Gas Savings (therms)	9.9	9.9
Total Electric Energy Savings (GWh/yr)	10.1	5.38
Total Demand Reduction (MW)	13.9	8.87

[152] The scaling factor approach is described in the Potential Energy section of the main report.

Total Gas Savings (MMtherms)	0.23	0.13
Total applicable units (dwelling units)	22,795	37,040

I.3.a. Description

B89: RNC-HVAC-Zoned AC requirements are listed in Sections 150.0(m)15 and 150.1(c)13 of the 2013 Title 24 California Building Energy Efficiency Standards. The CASE report supporting this standard details energy savings between the following baseline and proposed standard cases:[153]

> *Baseline*
>
> 2008 Title 24 offered an energy compliance credit for zoned air conditioning systems under the performance approach. Other than this credit, Title 24 did not previously regulate these measures for multi-zoned systems.
>
> *Proposed Standard*
>
> According to the CASE report, "This measure adds a mandatory measure for cases when a multi-zoned system is installed, or when a new duct is installed in a multi-zone alteration. The proposal requires air handler system efficiencies of 150 CFM/ton or 350 CFM/ton, depending on if the compressor is single speed or variable speed, respectively. Fan efficacy is required to be below the maximum 0.58 W/CFM, and all efficiencies must be verified on-site by a HERS Rater. The change also eliminates air conditioning from the compliance credit for zoned systems under the performance approach."

The current requirements for B89: RNC-HVAC-Zoned AC in Sections 150.0(m)15 and 150.1(c)13 of the 2013 Title 24 California Building Energy Efficiency Standards read as follows:[154]

Section 150.0(m)15:

[153] Codes and Standards Enhancement Initiative (CASE), Final Report: Residential Zoned Ducted HVAC Systems, Pacific Gas and Electric Company, Southern California Edison, SoCalGas, SDG&E, June 2013.

[154] 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012.

15. **Zonally Controlled Central Forced Air Systems.** Zonally controlled central forced air cooling systems shall be capable of simultaneously delivering, in every zonal control mode, an airflow from the dwelling, through the air handler fan and delivered to the dwelling, of greater than or equal to 350 CFM per ton of nominal cooling capacity, and operating at an air-handling unit fan efficacy of less than or equal to 0.58 W/CFM as confirmed by field verification and diagnostic testing in accordance with the applicable procedures specified in Reference Residential Appendix RA3.3.

EXCEPTION to Section 150.0(m)15: Multispeed compressor systems or variable speed compressor systems, or single speed compressor systems that utilize the performance compliance approach set forth in Section 150.1(b) shall demonstrate compliance for airflow (cfm/ton) and fan efficacy (Watt/cfm) by

operating the system at maximum compressor capacity and maximum system fan speed and with all zones calling for conditioning.

Section 150.1(c)13:

13. **HVAC System Bypass Ducts.** Unless otherwise specified on the Certificate of Compliance, bypass ducts that deliver conditioned supply air directly to the space conditioning system return duct airflow shall not be used. All zonally controlled forced air systems shall be verified by a HERS Rater utilizing the procedure in Reference Residential Appendix Section RA3.1.4.6 to confirm compliance with 150.1(c)13.

I.3.b. Reported Potential Energy Savings Estimates

Per-Unit Savings Estimates

According to the CASE report, "Data are obtained from modeling from the manufacturers' extended data tables, independent laboratory tests at Purdue, laboratory tests at Carrier Corporation, and models promulgated by the Air Conditioning Contractors of America."

Statewide Potential Energy Savings Estimate

The kW/sf, kWh/sf, and therms/sf of estimated energy savings calculated in the CASE Report were applied to the estimated square footage to arrive at the final statewide energy savings.

Table 139 below summarizes the savings reported by the IOUs for this standard.

Table 139. Residential Reported Energy Savings Estimate: B89: RNC-HVAC-Zoned AC

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Savings (MMtherms)
10.1	13.9	0.23

I.3.c. Evaluation Findings

Cadmus accepts the per-unit savings estimates from the CASE report for electric energy (kWh), demand (kW), and gas (therms).

Unit energy savings assumptions appear to be reasonable; however, Cadmus could not completely confirm estimates due to incomplete information.

Cadmus used historical data from CIRB to determine the applicable number of new construction single-family dwelling units. This value is higher than the CASE report new construction estimates. The savings estimates for all measures included in the whole building measure were then scaled such that the sum of the measure savings matches the whole building savings estimate. The scaling factor is 0.536 for GWh/yr values, 0.638 for MW values, and 0.558 for MMtherms values.[155] The final evaluated savings estimate for this standard are shown in Table 140 below.

Table 140. Residential Evaluated Savings Estimate: B89: RNC-HVAC-Zoned AC

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Savings (MMtherms)
5.38	8.87	0.13

I.4. B88: RNC-HVAC-Whole House Fans

Table 141 provides a summary of the findings Cadmus used to estimate potential energy savings for B88: RNC-HVAC-Whole House Fans. The negative values for gas savings indicate an increase in gas consumption. This small gas increase is due to ventilation during mild spring and fall days, leading to minor increases in heating energy use.

Table 141. Residential Savings Estimate: B88: RNC-HVAC-Whole House Fans

Description	IOU Estimate (ISSM)	Evaluated
Unit Energy Savings (kWh)	387	387
Unit Demand Savings (kW)	0.0	0.0
Unit Gas Savings (therms)	-3.54	-3.54
Total Electric Energy Savings (GWh/yr)	8.8	4.72
Total Demand Reduction (MW)	0.0	0.0
Total Gas Savings (MMtherms)	-0.08	-0.05
Total applicable units (dwelling units)	22,795	37,040

I.4.a. Description

B88: RNC-HVAC-Whole House Fans introduces two new prescriptive requirements. Both of these help to shift cooling energy use from on-peak to off-peak hours. The CASE report supporting this change details energy savings between the following baseline and proposed standard cases:[156]

Baseline

[155] The scaling factor approach is described in the Potential Energy section of the main report.

[156] Codes and Standards Enhancement Initiative (CASE), Night Ventilation Cooling Compliance Option, Pacific Gas and Electric Company, Southern California Edison, SoCalGas, SDG&E, September 2011.

This is a new addition to the Standards and the baseline case is no whole house fan installed.

Proposed Standard

As a result of this proposal, there is a new prescriptive requirement in climate zones 8 through 14 for whole house fans designed to provide ventilation cooling. There is a new prescriptive requirement in all climate zones for a central fan integrated night ventilation cooling system.

The current requirements for B88: RNC-HVAC-Whole House Fans in Section 150.1(c)10 and 12 of the 2013 Title 24 California Building Energy Efficiency Standards read as follows:[157]

10. **Central Fan Integrated Ventilation Systems.** Central forced air system fans used in central fan integrated ventilation systems shall demonstrate, in Air Distribution Mode, an air-handling unit fan efficacy less than or equal to 0.58 W/CFM as confirmed through field verification and diagnostic testing in accordance with all applicable procedures specified in Reference Residential Appendix RA3.3.

12. **Ventilation Cooling.** Single family homes shall comply with the Whole House Fan (WHF) requirements shown in TABLE 150.1-A. When a WHF is required, comply with Subsections A. through C. below:

    A. Have installed one or more WHFs whose total Air Flow CFM as listed in the CEC Directory is at least 2 CFM/ft^2 of conditioned floor area; and

    B. Have at least 1 square foot of attic vent free area for each 375 CFM of rated whole house fan Air Flow CFM; and

    C. Provide homeowners who have WHFs with a one page "How to operate your whole house fan" informational sheet.

I.4.b. Reported Potential Energy Savings Estimates

Per-Unit Savings Estimates

According to the CASE report, the team ran energy simulations using the California Simulation Engine with a 2700 sf CEC prototype home. The estimated unit energy savings are shown in Table 141 above.

Statewide Potential Energy Savings Estimate

The CASE report does not provide statewide savings estimates. According to the response to the PG&E Data Request Number 25260, "Using the UES data provided on page 4 of the draft CASE report, the average UES of this CASE measure were estimated to be 387 kWh/unit/year and -3.54 therm/unit/year. Using the annual single family construction rate of 22,795 unit/year provided in the CEC California's 2013 Building Energy Efficiency Standards Impact Analysis report (Table 11), first-year statewide energy savings were estimated to be 8.82 GWh and -0.08 MMTherm."

Table 142 below summarizes the savings reported by the IOUs for this standard.

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[157] 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012.

Table 142. Residential Reported Energy Savings Estimate: B88: RNC-HVAC-Whole House Fans

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Savings (MMtherms)
8.8	0.0	-0.08

I.4.c. Evaluation Findings

Cadmus accepts the per-unit savings estimates from the CASE report for electric energy (kWh), demand (kW), and gas (therms).

Unit energy savings assumptions appear to be reasonable; however, Cadmus could not completely confirm estimates due to incomplete information.

Cadmus used historical data from CIRB to determine the applicable number of new construction single-family dwelling units. This value is higher than the CASE report new construction estimates. The savings estimates for all measures included in the whole building measure were then scaled such that the sum of the measure savings matches the whole building savings estimate. The scaling factor is 0.536 for GWh/yr values, 0.638 for MW values, and 0.558 for MMtherms values.[158] The final evaluated savings estimate for this standard are shown in Table 143 below.

Table 143. Residential Evaluated Savings Estimate: B88: RNC-HVAC-Whole House Fans

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Savings (MMtherms)
4.72	0.00	-0.05

I.5. B84: RNC-Envelope-Wall Insulation

Table 144 provides a summary of the findings Cadmus used to estimate potential energy savings for B84: RNC-Envelope-Wall Insulation.

Table 144. Residential Savings Estimate: B84: RNC-Envelope-Wall Insulation

Description	IOU Estimate (ISSM)	Evaluated
Unit Energy Savings (kWh)	99	99
Unit Demand Savings (kW)	0.08	0.08
Unit Gas Savings (therms)	34	34
Total Electric Energy Savings (GWh/yr)	2.7	1.44
Total Demand Reduction (MW)	3.0	1.91
Total Gas Savings (MMtherms)	0.67	0.38
Total applicable units (dwelling units)	22,795	37,040

[158] The scaling factor approach is described in the Potential Energy section of the main report.

I.5.a. Description

B84: RNC-Envelope-Wall Insulation modifies an existing prescriptive requirement for wood-framed wall assembly U-factor. The CASE report supporting this change details energy savings between the following baseline and proposed standard cases:[159]

Baseline

The baseline case is the 2008 Title 24 requirements for minimum R-values as shown in the table below.

Proposed Standard

This measure modifies the maximum U-factor for 2x4 framed walls as shown in the table below. The original proposal included U-factors that were unique to each climate zone. However, the adopted requirement is a uniform U-factor of 0.065 across all climate zones. This was most likely made for simplification reasons to provide uniformity in the Standards. The adopted maximum U-factor is somewhat of an average value of all the proposed U-factors for different climate zones. This modification will likely cause minimal changes in the estimated statewide energy impacts because the climate zones that now have stricter requirements will balance out the zones that now have more lenient requirements than the proposal.

These requirements are found in Table 150.1-A of the 2013 Title 24 California Building Energy Efficiency Standards.[160]

Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2008 minimum R-value	21	13	13	13	13	13	13	13	13	13	19	19	19	21	21	21
2013 maximum U-factor	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065

I.5.b. Reported Potential Energy Savings Estimates

Per-Unit Savings Estimates

According to the CASE report, the team ran energy simulations using CALRES (MICROPAS 2013) with a 2700 sf CEC prototype home. The estimated unit energy savings are shown in Table 144 above. The per-unit savings vary by climate zone and this is the simple average across all climate zones.

159 Codes and Standards Enhancement Initiative (CASE), Increased Wall Insulation, Pacific Gas and Electric Company, Southern California Edison, SoCalGas, SDG&E, October 2011.

160 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012.

Statewide Potential Energy Savings Estimate

The kW/sf, kWh/sf, and therms/sf of estimated energy savings calculated in the CASE Report were applied to the estimated square footage to arrive at the final statewide energy savings. The first-year statewide energy savings reported in the final CASE report are based on an estimated single family construction rate of 47,400 units/year. The 2013 Building Energy Efficiency Standards Impact Analysis report provided a different estimate of annual single family construction rate of 22,795 units. For savings reporting to the CPUC, the CEC's estimate of annual single family construction rate was used to calculate first-year statewide energy savings. The updated first-year statewide energy savings are 2.7 GWh, 3.0 MW, and 0.67 MMTherm.

Table 145 below summarizes the savings reported by the IOUs for this standard.

Table 145. Residential Reported Energy Savings Estimate: B84: RNC-Envelope-Wall Insulation

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Savings (MMtherms)
2.7	3.0	0.67

I.5.c. Evaluation Findings

Cadmus accepts the per-unit savings estimates from the CASE report for electric energy (kWh), demand (kW), and gas (therms).

Unit energy savings assumptions appear to be reasonable; however, Cadmus could not completely confirm estimates due to incomplete information.

Cadmus used historical data from CIRB to determine the applicable number of new construction single-family dwelling units. This value is higher than the CASE report new construction estimates. The savings estimates for all measures included in the whole building measure were then scaled such that the sum of the measure savings matches the whole building savings estimate. The scaling factor is 0.536 for GWh/yr values, 0.638 for MW values, and 0.558 for MMtherms values.[161] The final evaluated savings estimate for this standard are shown in Table 146 below.

Table 146. Residential Evaluated Savings Estimate: B84: RNC-Envelope-Wall Insulation

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Savings (MMtherms)
1.44	1.91	0.38

[161] The scaling factor approach is described in the Potential Energy section of the main report.

I.6. B83: RNC-Lighting

Table 147 provides a summary of the findings Cadmus used to estimate potential energy savings for B83: RNC-Lighting.

Table 147. Residential Savings Estimate: B83: RNC-Lighting

Description	IOU Estimate (ISSM)	Evaluated
Unit Energy Savings (kWh)	261	105
Unit Demand Savings (kW)	N/A	N/A
Unit Gas Savings (therms)	N/A	N/A
Total Electric Energy Savings (GWh/yr)	2.4	3.9
Total Demand Reduction (MW)	0.0	0.0
Total Gas Savings (MMtherms)	-0.05	0.0016
Total applicable units (dwelling units)	22,795	37,040

I.6.a. Description

B83: RNC-Lighting proposed five recommended revisions to 2008 Title 24, three of which were ultimately adopted for 2013 Title 24. The CASE report supporting this change details energy savings between the following baseline and proposed standard cases:[162]

Baseline

This is a new addition to the Standards and the baseline case is the 2008 Title 24 lighting requirements.

Proposed Standard

The final adopted requirements are:

- Efficacy and controls requirements in bathrooms:
  - Require at least one high efficacy luminaire in each bathroom (§150.0(k)5A)
  - All other lighting in each bathroom shall be high efficacy or controlled by vacancy sensors (§150.0(k)5B)
- Garages, laundry rooms, closets and utility rooms now require all lighting to be high efficacy, and that all lighting is controlled using vacancy controls (§150.0(k)6)
- An additional low efficacy allowance for kitchens is provided for all dwelling units. The allowance is up to 50 watts in kitchens for dwelling units less than or equal to 2,500 square feet, and 100 watts in kitchens for all dwelling units over 2,500 square feet.

[162] Codes and Standards Enhancement Initiative (CASE), Residential Lighting, Pacific Gas and Electric Company, Southern California Edison, SoCalGas, SDG&E, March 2011.

These requirements are found in Section 150.0(k) of the 2013 Title 24 California Building Energy Efficiency Standards.[163]

I.6.b. Reported Potential Energy Savings Estimates

Per-Unit Savings Estimates

According to the CASE report, “Energy savings estimates were calculated based on installed lighting equipment data from the 2010 New Home Energy Survey, and room-by-room hours of use data from the 2010 Upstream Lighting Program Final Report. The 2010 New Home Energy Survey is a representative sample of statewide residential new construction in California, and it represents the most current data on residential lighting practices. The 2010 Upstream Lighting Program contains the most current data on residential lighting hours of use.”

The CASE report continues, “Data from the 2010 New Home Energy Survey was modified to reflect the proposed measures in order to determine the reduction in installed lighting load resulting from these measures. Hours of use data from the 2010 Upstream Lighting Program Final Report were then applied to those reductions in lighting load to determine the energy savings from these measures across the 2010 New Home Energy Survey sample. The energy savings estimated for the 2010 New Home Energy Survey sample was then scaled up to match estimated statewide housing starts for 2013 in order to estimate total statewide energy savings.”

The estimated unit energy savings are shown in Table 147 above. The per-unit savings are for a 2700 sf prototype single-family house.

Statewide Potential Energy Savings Estimate

The CASE author scaled up the estimated unit energy savings to represent the estimated housing starts in 2013. For this lighting measure only, the scaling factor is 1.625 for GWh/yr values and -0.0336 for MMtherms values.[164] In addition, they used the average hours of use profiles for each space to estimate overall statewide savings. Table 148 below summarizes the savings reported by the IOUs for this standard.

Table 148. Residential Reported Energy Savings Estimate: B83: RNC-Lighting

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Savings (MMtherms)
2.4	0.0	-0.05

[163] 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012.

[164] The scaling factor approach is described in the Potential Energy section of the main report.

I.6.c. Evaluation Findings

Cadmus accepts the per-unit savings estimates for electric energy (kWh), although demand (kW) and gas (therms) are not available. Unit energy savings assumptions appear to be reasonable; however, Cadmus could not completely confirm estimates due to incomplete information.

Cadmus used historical data from CIRB to determine the applicable number of new construction single-family dwelling units. This value is higher than the CASE report new construction estimates.

Cadmus adjusted the estimates to account for interactive effects between lighting and HVAC. The unit energy savings and the statewide savings include these interactive effects.

The final evaluated savings estimate for this standard are shown in Table 149 below.

Table 149. Residential Evaluated Savings Estimate: B83: RNC-Lighting

Total Electric Energy Savings (GWh/yr)	Total Demand Reduction (MW)	Total Gas Savings (MMtherms)
3.9	0.0	0.0016

I.7. *B97: Residential New Construction, Whole Building*

Table 150 lists the IOU-estimated and Cadmus-evaluated potential energy savings for standard B97: Residential New Construction, Whole Building.

Table 150. Residential Annual Potential Energy Savings Estimates: Standard B97

Description	IOU Estimate	Evaluated*
Total electric energy savings (GWh/yr)	15.3	24.8
Total demand reduction (MW)	20.3	33.0
Total gas energy savings (MMtherms/yr)	0.53	0.9
Total applicable dwelling units	22,795	37,040

* Evaluated savings in this table include interactive effects based on the whole building savings analysis approach.

I.7.a. Standard Description

Standard B97: Residential New Construction—Whole Building captures many of the 2013 Title 24 requirements for new construction. The IOUs based their estimated potential on the whole building new construction results from CEC's 2013 Building Efficiency Standards Impact Analysis between the following baseline and standard cases:[165]

165 California Energy Commission Consultant Report, Impact Analysis: California's 2013 Building Efficiency Standards, CEC-400-2013-008, July 2013. Accessible at http://www.energy.ca.gov/2013publications/CEC-400-2013-008/CEC-400-2013-008.pdf

- **Baseline**: The baseline scenario covers new construction buildings compliant with the 2008 Title 24 requirements for new construction. [166]
- **Standard:** The standard covers new construction buildings compliant with the 2013 Title 24 requirements for new construction.[167]

  The CEC's 2013 whole building impact analysis only covered adopted measures that could be modeled using CEC's preferred energy modeling software, EnergyPlus Version 6. Note that this does not include the residential lighting requirements defined in standard B83. The residential new construction standards covered by the CEC impact analysis include the following, per a memo submitted to Cadmus and the CPUC by the IOU team:[168]

  - StdB84 RNC-Envelope-Wall Insulation
  - StdB85 RNC-Envelope-Fenestration
  - StdB86 RNC-Envelope-Roof Envelope
  - StdB87 RNC-Envelope-Advanced Envelope
  - StdB88 RNC-HVAC-Whole House Fans
  - StdB89 RNC-HVAC-Zoned AC
  - StdB90 RNC-HVAC-Duct
  - StdB91 RNC-HVAC-Refrigerant Charge
  - StdB92 RNC-SFDHW

I.7.b. Evaluation Findings

Unit Energy Savings

Cadmus accepts the CEC impact analysis as the best source for determining UES estimates for this standard.[169]

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166 2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2008-001-CMF, December 2008. Accessible at http://www.energy.ca.gov/2008publications/CEC-400-2008-001/CEC-400-2008-001-CMF.PDF

167 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, CEC-400-2012-004-CMF-REV2, May 2012. Accessible at http://www.energy.ca.gov/2012publications/CEC-400-2012-004/CEC-400-2012-004-CMF-REV2.pdf

168 Memo submitted by the IOU to the CPUC and Cadmus teams on Thursday, December 22nd, titled *Memo 2013 Title 24 WB and IM Savings 12222016*.

169 California Energy Commission Consultant Report, Impact Analysis: California's 2013 Building Efficiency Standards, CEC-400-2013-008, July 2013. Accessible at http://www.energy.ca.gov/2013publications/CEC-400-2013-008/CEC-400-2013-008.pdf

Applicable Dwelling Units

Cadmus relied on CIRB data to estimate the number of applicable dwelling units. We averaged 2014 and 2015 data for a more robust estimate of annual new construction. This yielded 37,040 dwelling units. This compares to 22,795 dwelling units that the IOUs used in their analysis. We took the ratio of 37,040 dwelling units from CIRB and 22,795 dwelling units from the IOUs to yield a scaling factor of 162%. We then applied this scaling factor to the IOU reported energy savings estimates to produce the evaluated savings estimates.

J. NOMAD Detail

Bass Curve Parameters

The findings of the NOMAD analysis are presented in Table 151. The IOU estimated values are compared to the evaluated parameters obtained from the Delphi panels.

Table 151. Building codes (title 24) RNC, NRA, and NRNC NOMAD parameters

Group	Standard	Description	Evaluated Parameters			IOU Estimates		
			Max Saturation (s)	Leading Behavior (p)	Following Behavior (q)	Max Saturation (s)	Leading Behavior (p)	Following Behavior (q)
NRA	Std B34	Lighting-Alterations-New Measures	45%	0.01	0.18	49%	0.03	0.26
	Std B35	Lighting-Alterations-Existing Measures	41%	0.00	0.27	49%	0.03	0.26
	Std B36	Lighting-Egress Lighting Control	43%	0.01	0.13	49%	0.03	0.26
	Std B37	Lighting-Multifamily Corridors	26%	0.01	0.15	49%	0.03	0.26
	Std B38	Lighting-Hotel Corridors	36%	0.01	0.19	49%	0.03	0.26
	Std B39	Lighting-Warehouses and Libraries	51%	0.01	0.22	49%	0.03	0.26
	Std B40	Compressed Air Systems	74%	0.02	0.20	36%	0.02	0.31
	Std B42	Envelope-Cool Roofs	76%	0.01	0.20	41%	0.01	0.26
	Std B99	SF Whole Building	47%	0.03	0.22	30%	0.02	0.36
NRNC	Std B43	Lighting-Daylighting	41%	0.01	0.16	21%	0.00	0.31
	Std B45	Lighting-Retail	54%	0.00	0.28	49%	0.03	0.26
	Std B46	Lighting-Egress Lighting Control	43%	0.01	0.13	49%	0.03	0.26
	Std B47	Lighting- MF Building Corridors	26%	0.01	0.15	49%	0.03	0.26
	Std B48	Lighting- Hotel Corridors	36%	0.01	0.19	49%	0.03	0.26
	Std B49	Lighting-Warehouses and Libraries	51%	0.01	0.22	49%	0.03	0.26
	Std B50	Lighting-Parking Garage	55%	0.00	0.37	49%	0.03	0.26
	Std B51	Lighting-Controllable Lighting	50%	0.01	0.19	18%	0.00	0.50
	Std B54	Lighting-Office Plug Load Control	36%	0.00	0.21	18%	0.00	0.50

Group	Standard	Description	Evaluated Parameters			IOU Estimates		
			Max Saturation (s)	Leading Behavior (p)	Following Behavior (q)	Max Saturation (s)	Leading Behavior (p)	Following Behavior (q)
	Std B57	HVAC Controls and Economizers	41%	0.00	0.28	41%	0.01	0.26
	Std B58	HVAC-Fan Control & Economizers	53%	0.00	0.28	41%	0.01	0.26
	Std B61	HVAC-Kitchen Ventilation	18%	0.00	0.50	18%	0.00	0.50
	Std B78	Process-Data Centers	41%	0.01	0.26	41%	0.01	0.26
	Std B82	Whole Building	41%	0.01	0.19	49%	0.03	0.26
RNC	Std B88	HVAC Whole House Fans	7%	0.00	0.30	30%	0.02	0.36
	Std B89	HVAC Zoned AC	22%	0.00	0.35	30%	0.02	0.36
	Std B90	HVAC Duct	27%	0.04	0.11	30%	0.02	0.36
	Std B97	Whole House	47%	0.03	0.22	30%	0.02	0.36

In the NOMAD parameter assumptions for the utility savings claim, we used a single set of parameters as the input for standards. For the evaluated parameters for these standards, Cadmus solicited separate panelist input for each standard.

B.2 Bass Curve and Delphi Process Description

The Bass curve approach closely followed the guidelines established for the Delphi method originated and documented by researchers at the RAND Corporation in 1958.[170] The Delphi method is an exercise in group communication among a panel of geographically dispersed experts. Strictly speaking, its elements include (1) structuring of information flow, (2) feedback to the participants, and (3) anonymity for the participants. These characteristics offer distinct advantages over the conventional face-to-face conference as a communication tool. The interactions among panel members are controlled by a panel director or monitor who filters out material not related to the purpose of the group. The usual problems of group dynamics are thus completely bypassed. Clearly, another important advantage is avoiding the costs and logistical challenges involved in bringing experts together in one place.

To apply the benefits of a Delphi process to the NOMAD research, the second round of data collection was implemented as follows. First, features were included in the online application that allowed the experts to see all experts' Bass curves (including their own) plus a simple average of all of these curves on a single graph. In addition to the curves, all the first round comments were provided to each expert. To preserve confidentiality, the curves and comments were not identified by author. Next, the experts were asked to return to the online application. When they did, they were given an opportunity to stay

170 On the Epistemology of the Inexact Sciences, Rand Corp, AD0224126.

with their original estimate, agree with the average estimate, or define a new estimate. In this way, some of the significant gaps between expert opinions were closed and more of a consensus was formed.

The standard Bass curve can be represented by the following equation:

$$F(t) = \frac{1 - e^{-(p+q)t}}{1 + (q/p)e^{-(p+q)t}}$$

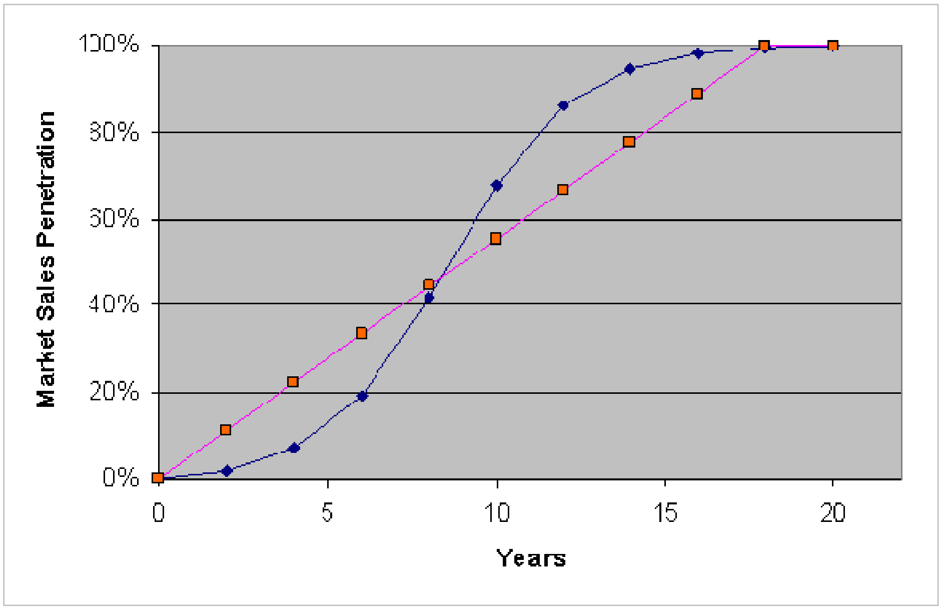
Where:

F(t)	=	the cumulative fraction of adopters,
p	=	coefficient of innovation,
q	=	coefficient of imitation, and
t	=	elapsed time

The coefficient of innovation (p) captures the effect of consumers who are not influenced by the behavior of others and the coefficient of imitation (q) captures the effect of consumers who are influenced by prior adopters. In the literature on this function, innovation is often referred to as "leading" behavior and imitation is described as "following" behavior.

For the purposes of this analysis, the most critical part of the curve to estimate accurately is the initial years immediately following the introduction of the code because the S-shaped nature of the Bass curve can provide more realistic estimates of naturally occurring market adoption rates during those first years, as products gradually increase their market shares. The differences between the linear and S-shaped adoption curves are illustrated in Figure 1, which compares a Bass curve that produces 99% market penetration in 18 years to a linear curve.

Figure 1. Comparison of Typical Bass and Linear Curves for 18-Year Market



In the earliest years, the penetration rates based on the Bass curve are slightly less than those based on the linear curve, while they exceed the linear rates in later years. In this example, the naturally occurring adoption adjustment would be less with the Bass curve for about eight years, and more thereafter.

Mathematically, three of the following five parameters are needed to estimate the Bass curve:

- Time (tmax) when maximum adoption rate will occur
- Maximum adoption rate
- Cumulative adoption at the maximum rate
- Coefficient of innovation (p)
- Coefficient of imitation (q)

B.3 Panelist Selection Process Description

Selection Criteria

The Oxford English Dictionary defines an expert as “a person who has comprehensive and authoritative knowledge of or skill in a particular area.” Cadmus compiled candidate lists for each standard using a combination of sources:

- Published CASE Reports
- Public documents regarding the California Energy Commission (CEC) building and appliance standards regulatory process (e.g., public comments, hearings, and workshops).

- NOMAD expert list compiled by Cadmus during the 2010-2012 Codes and Standards impact evaluation for the California Public Utilities Commission (CPUC).
- Web search of relevant industry associations, energy-related nonprofit organizations, government laboratory research groups, and professional societies

For the purpose of identifying expert candidates for participation in the modified Delphi panel approach, Cadmus used the criteria presented in Table 152, and required an expert panel candidate to meet two or more of these criteria for the specific technology or standard they were being asked to evaluate.

Table 152. NOMAD Expert Selection Criteria

Category	Requirement	Example
Credentials	Has been certified, or has received special training, in a capacity relevant to the technology or standard	• LEED AP • Professional Engineer (P.E.) • Certified Measurement and Verification Professional (CMVP) • Certified Energy Manager (CEM)
Education	Holds an advanced degree in a related field	• MS Mechanical Engineering – Product Design • MS Public Policy
Professional Experience	Has worked for ten or more years in a capacity that would provide knowledge of the technology and market	• 10+ years in product design for GE lighting • 20 years as head of Environmental Energy Technologies Division at LBNL
Publication	Has authored one or more papers or articles for conferences or industry journals on a topic related to the specific technology or standard	• "Reflector Lamp Market Trends and Implications for Regulation of Energy Efficiency"

Approach to Managing Bias

Cadmus recognized that all individuals considered for participation on the Delphi panels were likely to exhibit some degree of bias that could influence their input regarding the naturally occurring market adoption for a specific building code. Cadmus' approach to managing bias followed the approach taken by ASHRAE in its disclosure form for potential project committee members.[171] In it, ASHRAE notes the importance of establishing a balance of interests among committee members and stresses that when all affected interests constructively participate in the consensus opinion, a fair standard will result. On the form, ASHRAE also states: "The question of potential sources of 'bias' ordinarily relates to views stated or positions taken that are largely intellectually motivated or that arise from the close identification or association of an individual with a particular point of view or the positions or perspectives of a particular group. Such potential sources of bias are not disqualifying for purposes of committee service. It is

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[171] ASHRAE. *Potential Sources of Bias/Conflict of Interest*. https://www.ashrae.org/standards-research--technology/standards-forms--procedures. Rev 2/12.

necessary, in order to ensure that a committee is fully competent, to appoint members in such a way as to represent a balance of potentially biasing backgrounds or professional or organizational perspectives."[172]

Consistent with this approach, Cadmus classified candidates by organization type using the following four categories:

- Government
- Manufacturer
- Industry Consultant
- Other (e.g., CEC, ACEEE, NRDC, Universities)

Cadmus reviewed the category mix for experts associated with each building code to ensure that prospective panels were not dominated by a single category type (e.g., manufacturers, consultants). The team summarized the mix of expert candidates recruited for each standard and reviewed the membership mix with the project management team. Cadmus' objective was to assemble expert panels with representation from at least three of the defined categories. In this way, the team expected to achieve a balanced result where the biases of any one group were offset or at least tempered by members of the other groups on the panel.

Additionally, Cadmus reviewed all adoption curves and associated supporting comments. If input was substantially different from all other experts and/or the supporting comments indicated a distinct bias, then we removed that expert's input from the analysis. When this occurred, Cadmus documented the decision and the reasons for it.

Approach to Identifying Conflict of Interest

In Appendix A of ASHRAE's disclosure form, ASHRAE notes that conflict of interest can occur when:

- Committees are not balanced and include individuals with strong personal, financial, or professional interests in seeing that the project produce a particular outcome
- An agency, sponsor, or private organization or company attempts to influence individual committee members or to skew the body of information reviewed by the committee.[173]

In *The Delphi Method: Techniques and Applications*, Chester G. Jones notes concerns are often raised about the credibility of Delphi results as "individual experts may bias their responses so that they are overly favorable toward areas of personal interest." In his examination of several Delphi processes,

172 ASHRAE. *Potential Sources of Bias/Conflict of Interest*. https://www.ashrae.org/standards-research--technology/standards-forms--procedures. Rev 2/12.

173 Ibid.

however, he finds individuals on the panels were able to "rise above the desire to protect personal interests."[174]

Cadmus mitigated potential conflict of interest in several ways. First, in concert with steps to minimize bias, Cadmus endeavored to create balanced panels by recruiting members representing the four interest groups identified above for each building code.

Second, as part of the recruitment process, Cadmus asked all potential panelists whether a conflict of interest would impair their objectivity. We excluded from the panels individuals expressing a declared conflict of interest.

Finally, we provided information about the building codes to be evaluated in summaries in the online data collection tool; the information could be edited only by persons with the appropriate access level. Cadmus developed these summaries from publicly available documents, so it is unlikely that outside bodies would be able to skew the body of information reviewed by the panel members. We also assumed that it is unlikely that individuals or organizations would attempt to pressure individual panel members to provide input skewed in a specific direction; however, in the end, we reviewed each panelist's input in comparison with input from all other panelists and noted input that seemed out of the range of the consensus opinion. Cadmus reserved the option to disregard such input and documented any decisions to do so.

Process Used to Build Expert Panels

Cadmus prioritized recruitment efforts on those building codes that are projected to contribute the most to the overall 2013-2015 gross electricity savings for the Title 24 standards under review during the 2013-2015 evaluation cycle. Table 153 shows the list for Title 24 NRA standards along with estimates of their gross savings.

174 Linstone, Harold A., and Murray Turoff. *The Delphi Method: Techniques and Applications*. Addison-Wesley. 2002. 155-161.

Table 153. NOMAD for 2013 Title 24 NRA Standards

Standard	Description	C&S Start Date	2013–2015 Potential Savings GWh*	2013–2015 Potential Savings MMtherms*	NOMAD
Std B34	Lighting-Alts.-New Measures	7/1/2014	333.1	(1.9)	✓
Std B35	Lighting-Alts.-Existing Measures	7/1/2014	476.1	(1.3)	✓
Std B36	Lighting-Egress Lighting Control	7/1/2014	124.6	-	✓
Std B37	Lighting-MF Building Corridors	7/1/2014	8.5	(0.0)	✓
Std B38	Lighting-Hotel Corridors	7/1/2014	3.1	(0.0)	✓
Std B39	Lighting-Warehouses, Libraries	7/1/2014	90.7	(0.3)	✓
Std B40	Envelope-Cool Roofs	7/1/2014	26.6	(0.1)	✓
Std B41	HVAC-Equipment Efficiency	7/1/2014	144.4	5.5	
Std B42	Process-Air Compressors	7/1/2014	19.1	-	✓

Table 154 shows the list for Title 24 NRNC standards along with estimates of their gross savings. Shading indicates the standards that are included in the whole building analysis.

Table 154. NOMAD for 2013 Title 24 NRNC Standards

Standard	Description	C&S Start Date	2013–2015 Potential Savings GWh*	2013-2015 Potential Savings MMtherms*	NOMAD
StdB43	Lighting-Daylighting	5/1/2015	70.3	(0.3)	✓
StdB44	Lighting-Indoor Lighting Controls	5/1/2015	6.8	(0.0)	
StdB45	Lighting-Retail	5/1/2015	37.7	(0.1)	✓
StdB46	Lighting-Egress Lighting Control	5/1/2015	16.9	-	✓
StdB47	Lighting-MF Building Corridors	5/1/2015	3.6	(0.0)	✓
StdB48	Lighting-Hotel Corridors	5/1/2015	0.6	(0.0)	✓
StdB49	Lighting-Warehouses, Libraries	5/1/2015	20.2	(0.1)	✓
StdB50	Lighting-Parking Garage	5/1/2015	18.4	-	✓
StdB51	Lighting-Controllable Lighting	5/1/2015	50.4	(0.2)	✓
StdB52	Lighting-DR Lighting Controls	5/1/2015	0.5	(0.0)	
StdB53	Lighting-Outdoor Controls	5/1/2015	5.9	-	
StdB54	Lighting-Office Plug Load Control	5/1/2015	11.5	(0.0)	✓
StdB55	Envelope-Cool Roofs	5/1/2015	4.1	(0.0)	
StdB56	Envelope-Fenestration	5/1/2015	57.4	(0.1)	✓
StdB57	HVAC Controls, Economizers	5/1/2015	45.8	-	✓
StdB58	HVAC-Fan Control & Economizers	5/1/2015	22.6	(0.0)	✓
StdB59	HVAC-Reduced Reheat	5/1/2015	0.0	0.1	
StdB60	HVAC-Guest Room OC Controls	5/1/2015	3.0	-	
StdB61	HVAC-Kitchen Ventilation	5/1/2015	20.2	0.2	✓

Standard	Description	C&S Start Date	2013–2015 Potential Savings GWh*	2013-2015 Potential Savings MMtherms*	NOMAD
StdB62	HVAC-Commercial Boilers	5/1/2015	0.3	0.2	
StdB63	HVAC-Chiller Min Efficiency	5/1/2015	19.4	-	✓
StdB64	HVAC-Garage Exhaust	5/1/2015	9.3	-	✓
StdB65	HVAC-Laboratory Exhaust	5/1/2015	38.3	1.5	✓
StdB66	HVAC-Small ECM Motor	5/1/2015	37.1	-	✓
StdB67	HVAC-Water, Space Heat ACM	5/1/2015	0.1	0.2	
StdB68	HVAC-Cooling Towers Water	5/1/2015	0.2	-	
StdB69	HVAC-Occt. Control Smart T'stats.	5/1/2015	0.1	-	
StdB70	HVAC-Low-Temp Radiant Cooling	5/1/2015	-	-	
StdB71	HVAC-Evap Cooling Credit	5/1/2015	-	-	
StdB72	HVAC-Outside Air	5/1/2015	-	-	
StdB73	HVAC-Acceptance Reqmts.	5/1/2015	0.8	-	
StdB74	Refrigeration-Warehouse	5/1/2015	0.7	-	
StdB75	Refrigeration-Supermarket	5/1/2015	12.1	1.3	✓
StdB76	Process-Process Boilers	5/1/2015	0.5	0.7	
StdB77	Process-Air Compressors	5/1/2015	7.1	-	
StdB78	Process-Data Centers	5/1/2015	18.5	-	✓
StdB79	DHW-Hotel DHW Control, Solar	5/1/2015	-	-	
StdB80	DHW-Solar Water Heating	5/1/2015	0.8	0.2	
StdB81	Solar-Solar Ready	5/1/2015	8.5	-	✓
StdB82	Whole Building	5/1/2015	120.3	0.7	✓

We provide a complete list of the RNC and RA line items included in the IOUs' savings estimate in Table 155. Once again, the IOUs relied on the CEC impact analysis for their estimate of savings from RNC. For the residential standards, the IOUs also used the CEC report as the basis for savings from alteration projects. The new construction savings are included as standards 97 and 98 for single-family and multifamily homes, respectively.

In the same memo that detailed the NRNC estimate, the IOUs indicated that the whole building estimates include savings from standards B84–B92. These standards are shaded in Table 155 below to indicate that they are excluded from the total savings from this category.

Table 155. NOMAD for 2013 Title 24 Residential Standards

Standard	Description	C&S Start Year	2013–2015 Potential Savings GWh*	2013–2015 Potential Savings MMtherms*	NOMAD
StdB83	RNC-Lighting	1/1/2015	2.4	(0.0)	
StdB84	RNC-Envelope-Wall Insulation	1/1/2015	2.7	0.7	✓
StdB85	RNC-Envelope-Fenestration	1/1/2015	14.6	(0.3)	✓
StdB86	RNC-Envelope-Roof Envelope	1/1/2015	0.5	0.0	
StdB87	RNC-Envelope-Advanced Envelope	1/1/2015	-	-	
StdB88	RNC-HVAC-Whole House Fans	1/1/2015	8.8	(0.1)	✓
StdB89	RNC-HVAC-Zoned AC	1/1/2015	10.1	0.2	✓
StdB90	RNC-HVAC-Duct	1/1/2015	10.2	1.1	✓
StdB91	RNC-HVAC-Refrigerant Charge	1/1/2015	-	-	
StdB92	RNC-SFDHW	1/1/2015	-	0.3	
StdB93	RNC-MF DHW Control and Solar	4/1/2015	(0.3)	1.1	
StdB94	RNC-DHW-High Eff. Water Heater Ready	1/1/2015	-	0.1	
StdB95	RNC-DHW-Solar for Electric Heat Homes	1/1/2015	0.1	-	
StdB96	RNC-Solar Ready, Oriented Homes	1/1/2015	0.1	0.0	
StdB97	RNC-SF Whole Building	1/1/2015	15.3	0.5	✓
StdB98	RNC-MF Whole Building	4/1/2015	3.1	0.1	
StdB99	Residential Alterations-SF Whole Building	7/1/2014	6.6	0.2	✓
StdB100	Residential Alterations-MF Whole Building	7/1/2014	1.8	0.1	

Cadmus[175] contacted approved candidates by e-mail, explained the Delphi process, and solicited input on specific codes or standards. Within a week of the initial contact, Cadmus followed up with each candidate and asked a short series of questions. Cadmus used potential panelists' responses to these questions to confirm them as a member of an expert panel or to disqualify them from consideration. The questions were as follows:

- What are the main organizations in the [name of technology] field with which you have been affiliated?
- How many years have you worked in the [name of technology] industry?
  Are you currently active in the [name of technology] industry?
  (If not currently active) When were you last active in this industry?

175 Cadmus used a California based call center to contact the candidates, administer the survey, and pay out the incentives.

- How would you describe your role in the [name of technology] industry?
- (To check for conflict of interest) Do you have any financial or other interest that will impair your objectivity in evaluating these standards?

The answers to these questions enabled Cadmus to verify candidates' expert status as well as identify any overt biases or conflicts of interest. In some situations, a candidate was not confirmed. These include:

- The candidate had not been active in the industry for more than four years.
- The candidate declared a conflict of interest.

When these situations arose, interviewers thanked the candidate for their time and explained the reason for their disqualification.

Table 156 presents the number of potential panelists Cadmus identified for each building code and the number of panelists who submitted input in each round. The target for all standards was five submissions. The team focused recruiting efforts on the standards with the greatest GWh savings. In general, we achieved submitted input from approximately 30 – 40% of the identified panelists for each standard.

Cadmus reviewed all adoption curves and associated supporting comments. If it was concluded that a curve and a comment were contradictory or a comment demonstrated that the exercise was misunderstood, then we removed that expert's input from the analysis. These exclusions are the reason for the difference between submitted second round input and the input used for the analysis seen in Table 156. When this occurred, Cadmus documented the decision and the reasons for it.

Table 156. NOMAD targets for submitted input

Group	Standard	Description	Number of Panelists Identified	Submitted First Round Input	Submitted Second Round Input
NRA	Std B34	Lighting-Alterations-New Measures	38	13	13
	Std B35	Lighting-Alterations-Existing Measures	38	13	12
	Std B36	Lighting-Egress Lighting Control	38	12	11
	Std B37	Lighting-Multifamily Corridors	38	12	10
	Std B38	Lighting-Hotel Corridors	38	12	11
	Std B39	Lighting-Warehouses and Libraries	38	12	11
	Std B40	Envelope-Cool Roofs	12	8	8
	Std B42	Process-Air Compressors	17	11	11
	Std B99	SF Whole Building	*Used weighted average NOMAD curve*		
NRNC	Std B43	Lighting-Daylighting	38	5	5
	Std B45	Lighting-Retail	38	5	5
	Std B46	Lighting-Egress Lighting Control	38	12	11
	Std B47	Lighting- MF Building Corridors	38	12	10
	Std B48	Lighting- Hotel Corridors	38	12	11
	Std B49	Lighting-Warehouses and Libraries	38	12	11
	Std B50	Lighting-Parking Garage	38	5	5
	Std B51	Lighting-Controllable Lighting	38	5	5
	Std B54	Lighting-Office Plug Load Control	38	6	5
	Std B57	HVAC Controls and Economizers	12	4	2
	Std B58	HVAC-Fan Control & Economizers	7	3	2
	Std B61	HVAC-Kitchen Ventilation	9	3	0
	Std B78	Process-Data Centers	10	3	0
	Std B82	Whole Building	*Used weighted average NOMAD curve*		
RNC	Std B88	HVAC Whole House Fans	6	3	2
	Std B89	HVAC Zoned AC	7	3	3
	Std B90	HVAC Duct	17	4	3
	Std B97	Whole House	*Used weighted average NOMAD curve*		

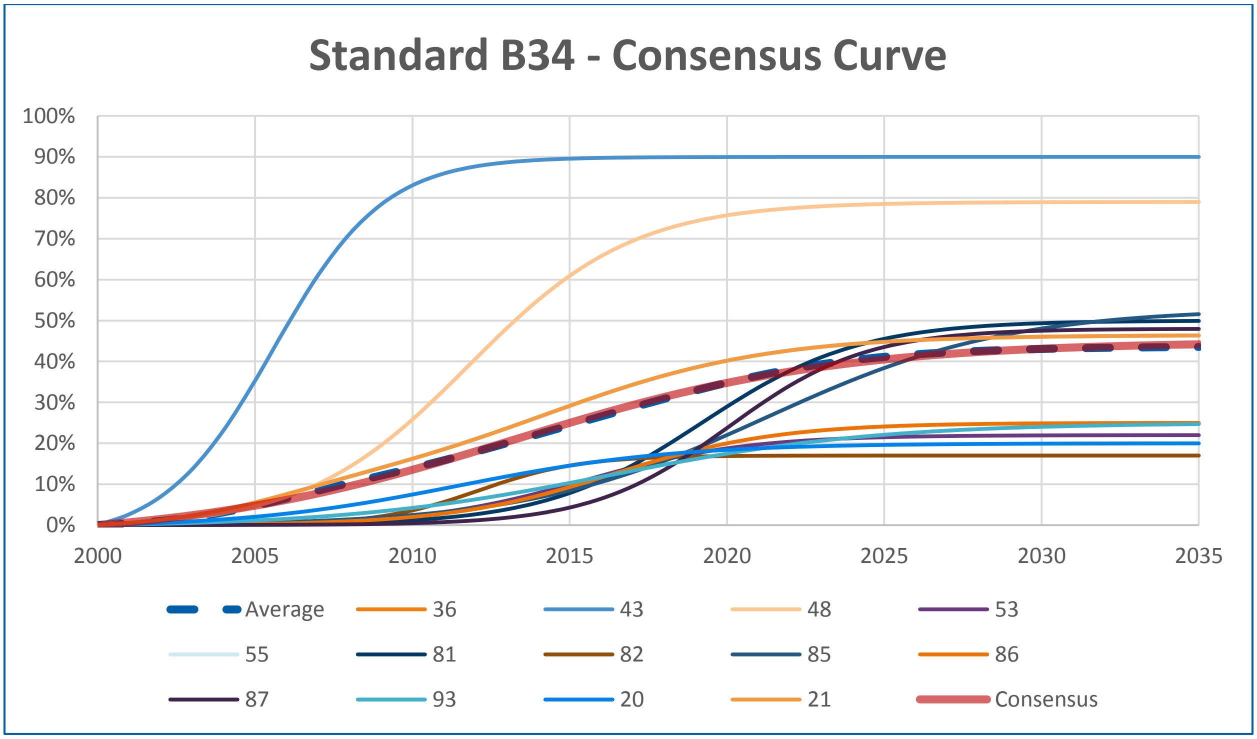
B.4 NOMAD Analysis Details for Building Codes

This section provides additional information on the NOMAD analysis conducted on the Title 24 codes and presents the NOMAD curves that were created for each of the standards analyzed based on the expert inputs solicited for this evaluation.

Lighting – Alterations – New Measures – Standard B34

Figure 2 provides the consensus Bass curve for Lighting – Alterations – New Measures along with the panelist input used to develop it.

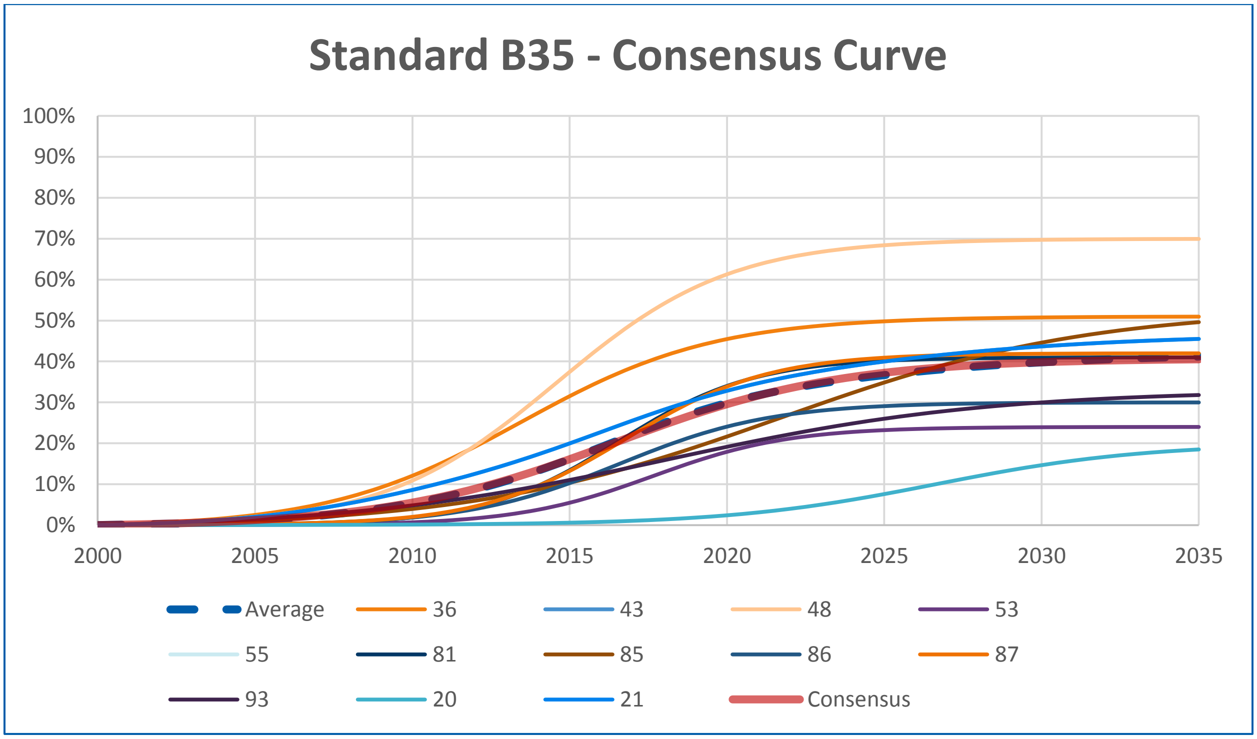
Figure 2. Standard B34 – Lighting – Alterations – New Measures Consensus Curve



Lighting – Alterations – Existing Measures – Standard B35

Figure 3 provides the consensus Bass curve for Lighting – Alterations – Existing Measures along with the panelist input used to develop it.

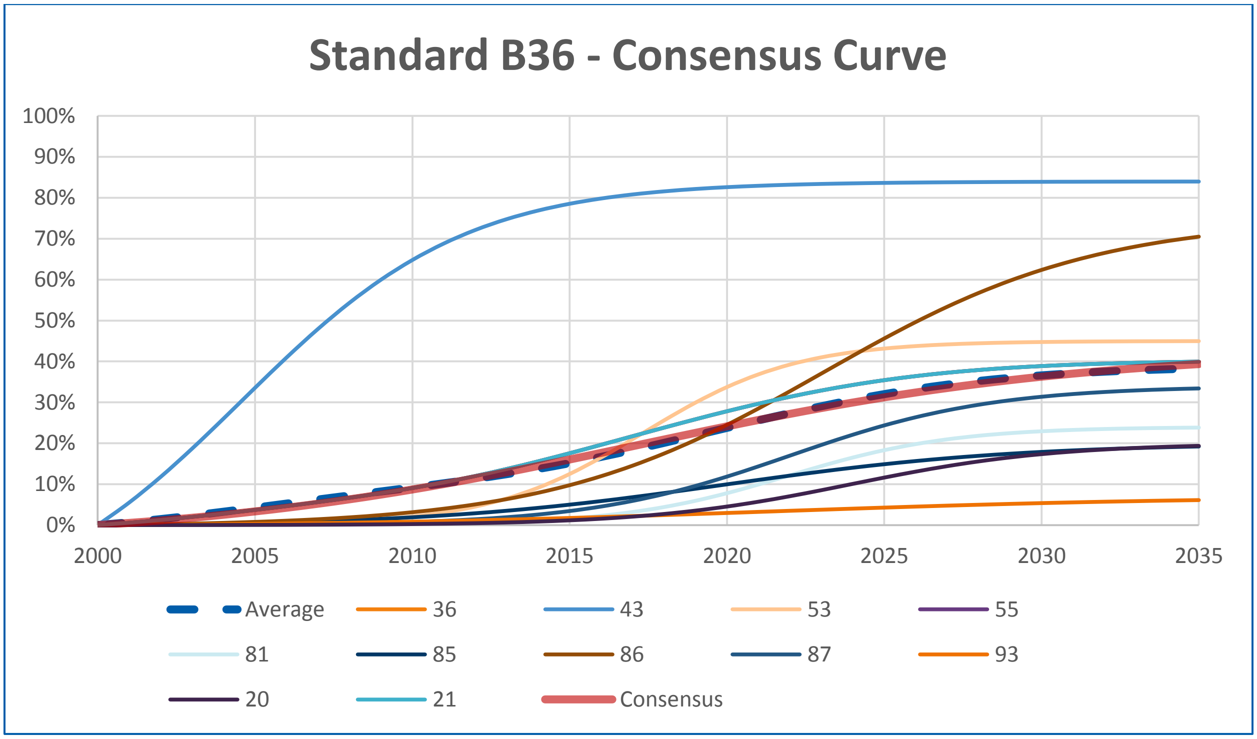
Figure 3. Standard B35 – Lighting – Alterations – Existing Measures Consensus Curve



Lighting – Egress Lighting Controls – Standard B36

Figure 4 provides the consensus Bass curve for Lighting – Egress Lighting Controls along with the panelist input used to develop it.

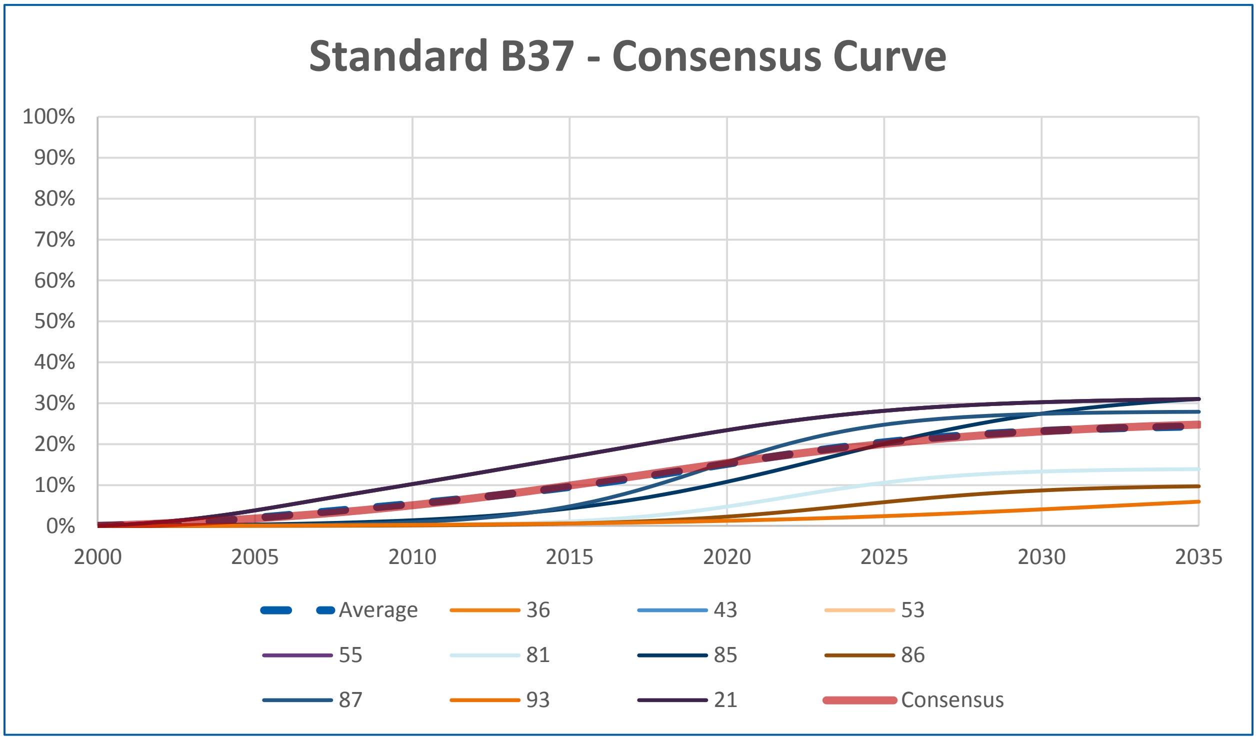
Figure 4. Standard B36 – Lighting – Egress Lighting Controls Consensus Curve



Lighting – Multifamily Corridors – Standard B37

Figure 5 provides the consensus Bass curve for Lighting – Multifamily Corridors along with the panelist input used to develop it.

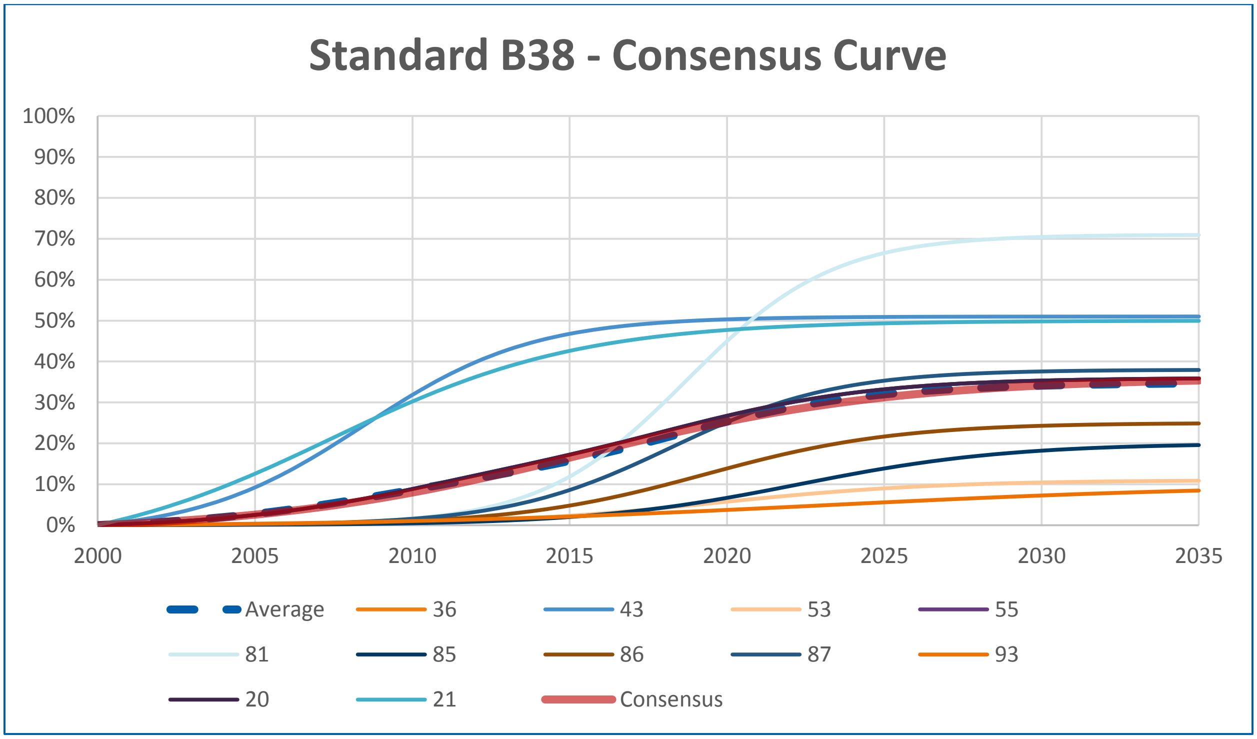
Figure 5. Standard B37 – Lighting – Multifamily Corridors Consensus Curve



Lighting – Hotel Corridors – Standard B38

Figure 6 provides the consensus Bass curve for Lighting – Hotel Corridors along with the panelist input used to develop it.

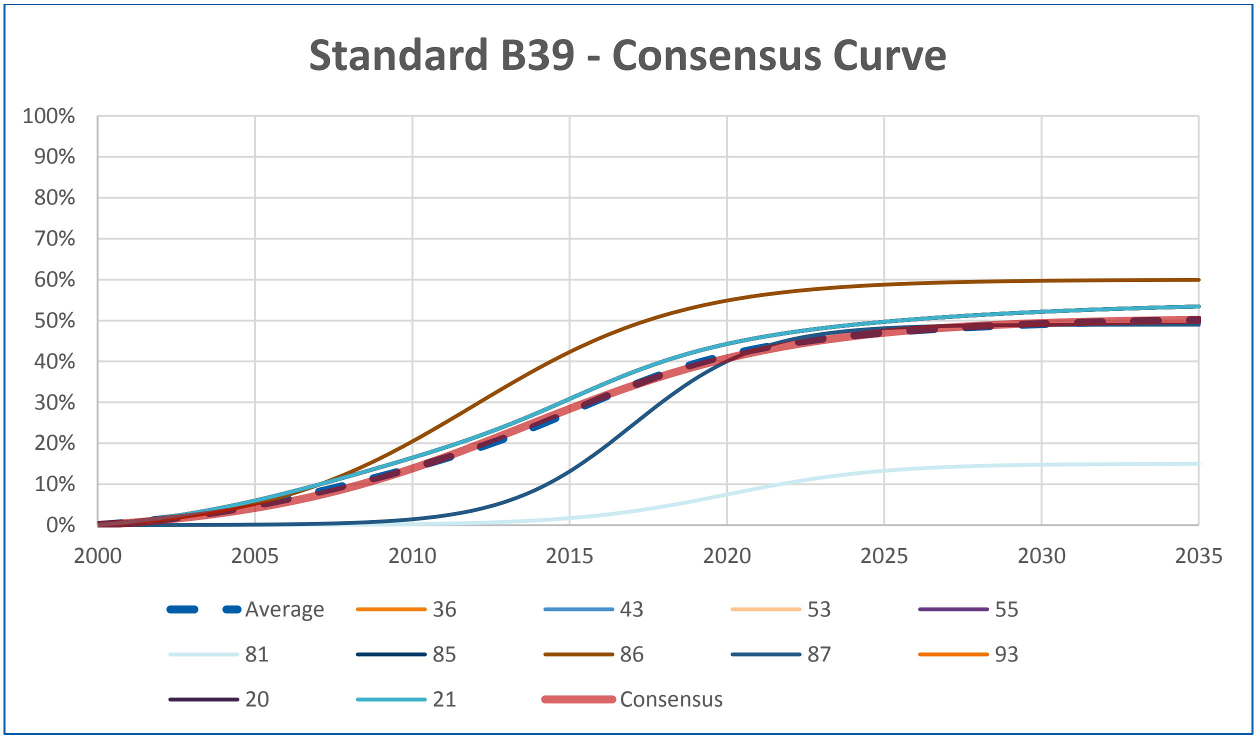
Figure 6. Standard B38 – Lighting – Hotel Corridors Consensus Curve



Lighting – Warehouses and Libraries – Standard B39

Figure 7 provides the consensus Bass curve for Lighting – Warehouses and Libraries along with the panelist input used to develop it.

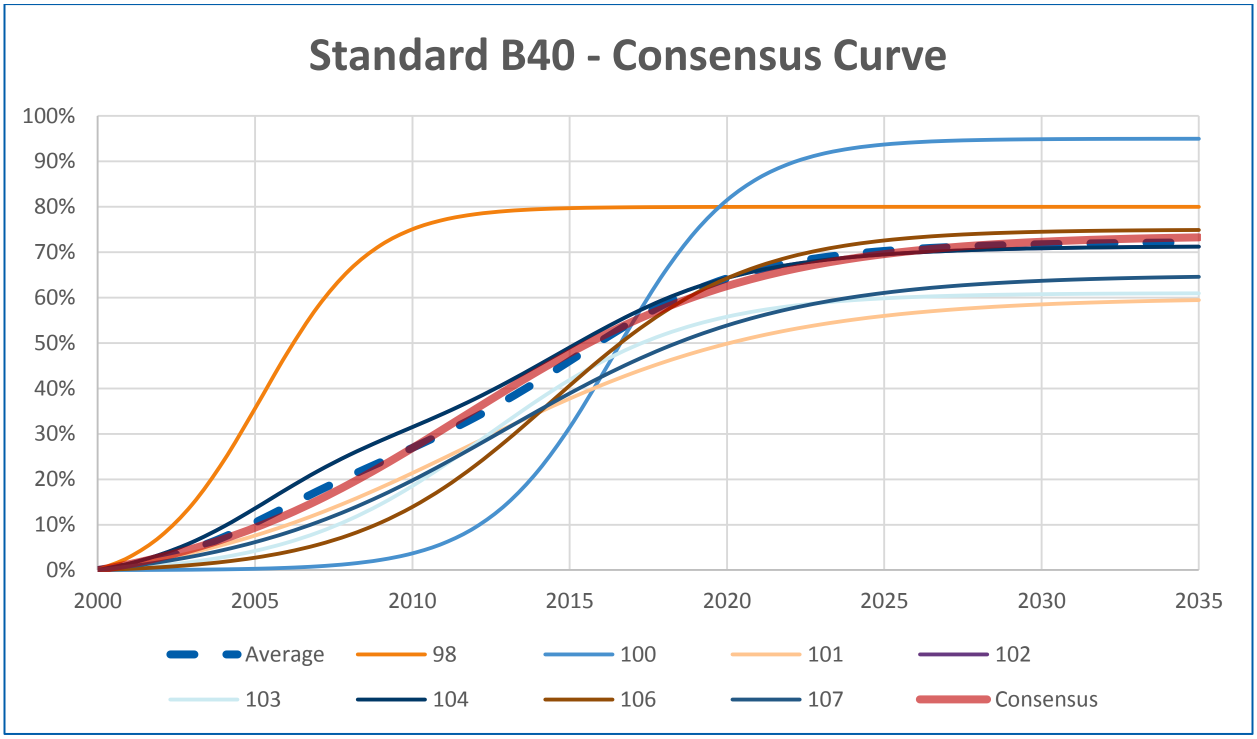
Figure 7. Standard B39 – Lighting – Warehouses and Libraries Consensus Curve



Envelope – Cool Roofs – Standard B40

Figure 8 provides the consensus Bass curve for Envelope – Cool Roofs along with the panelist input used to develop it.

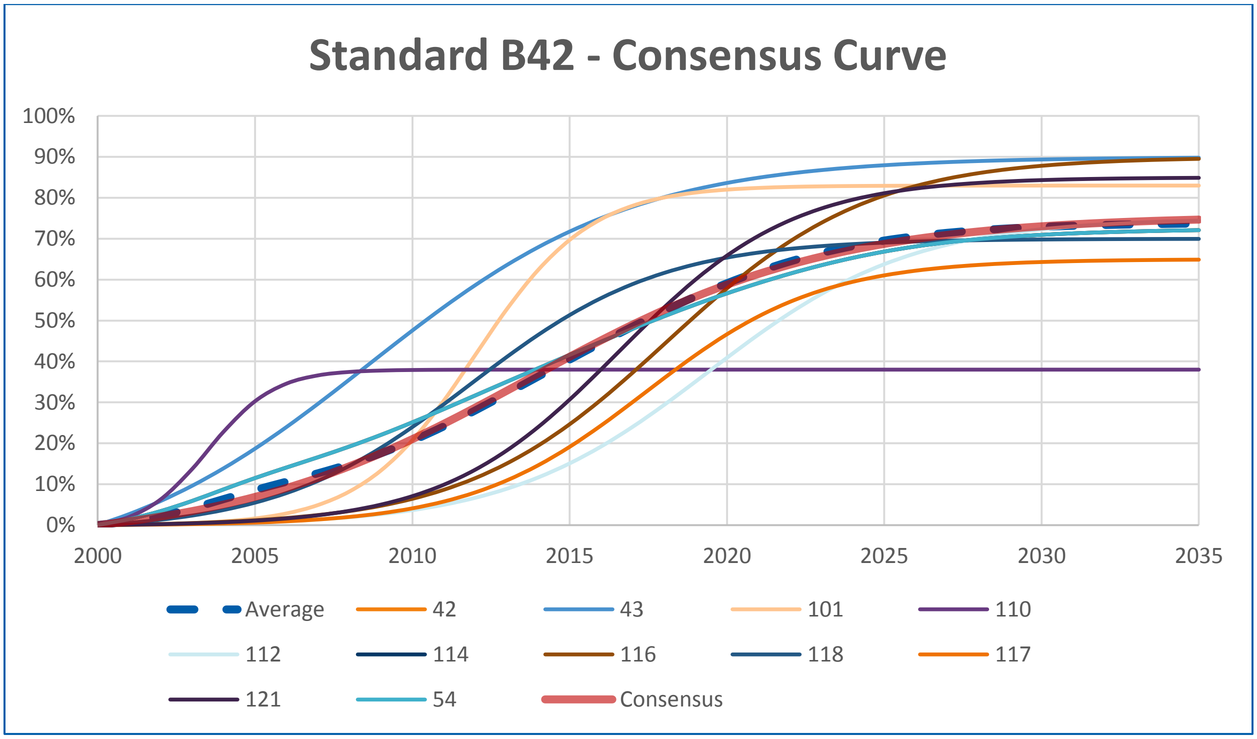
Figure 8. Standard B40 – Envelope – Cool Roofs Consensus Curve



Compressed Air Systems – Standard B42

Figure 9 provides the consensus Bass curve for Compressed Air Systems along with the panelist input used to develop it.

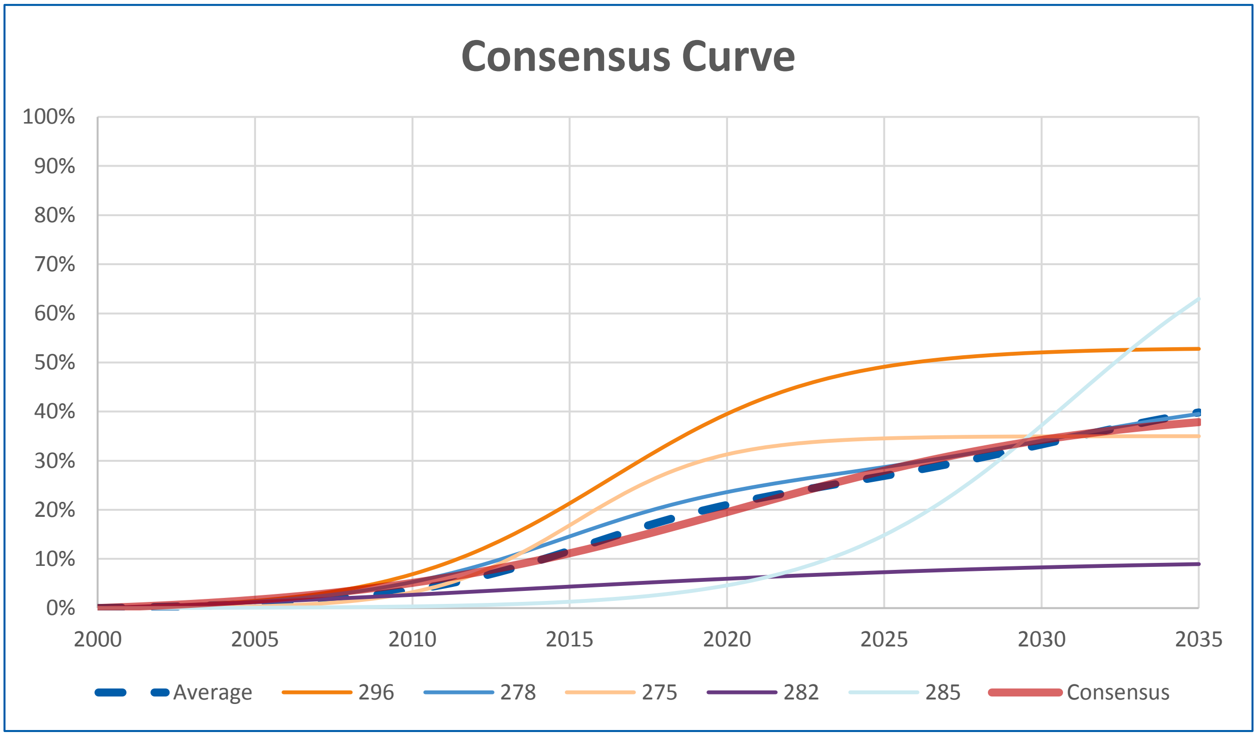
Figure 9. Standard B42 – Compressed Air Systems Consensus Curve



Lighting – Daylighting – Standard B43

Figure 10 provides the consensus Bass curve for Lighting – Daylighting along with the panelist input used to develop it.

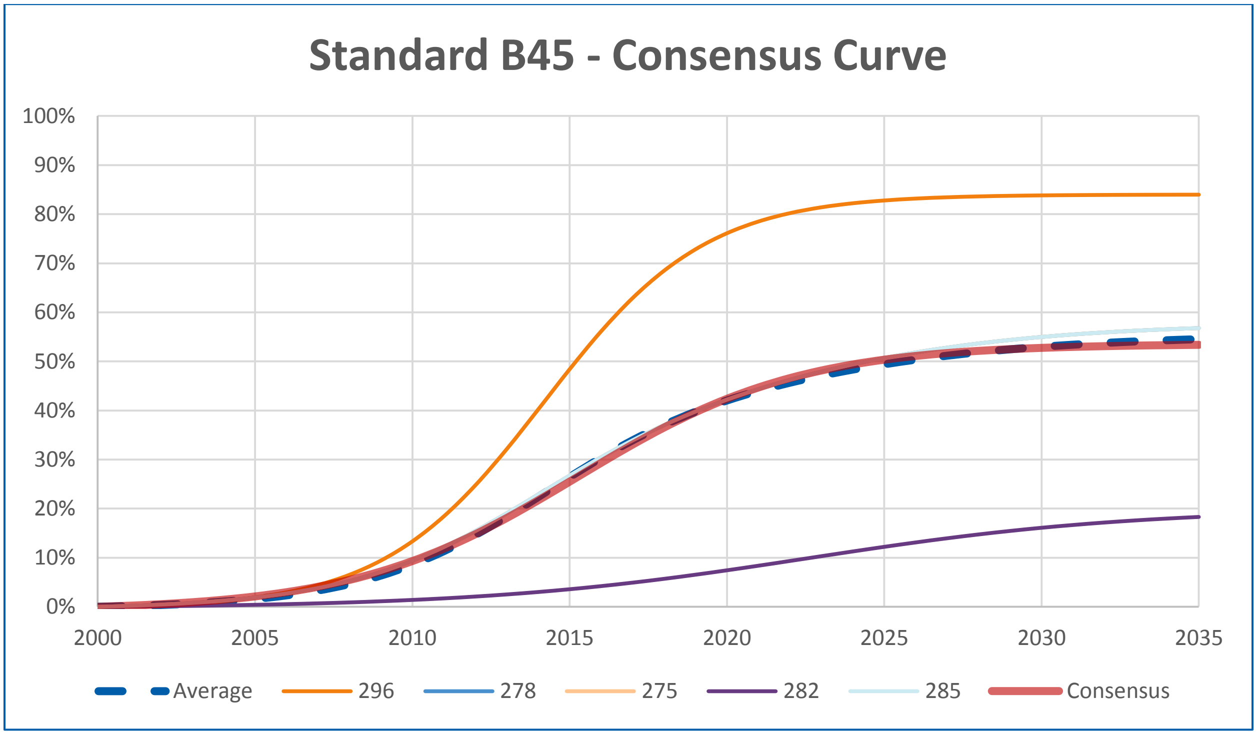
Figure 10. Standard B43 – Lighting – Daylighting Consensus Curve



Lighting – Retail – Standard B45

Figure 10 provides the consensus Bass curve for Lighting – Retail along with the panelist input used to develop it.

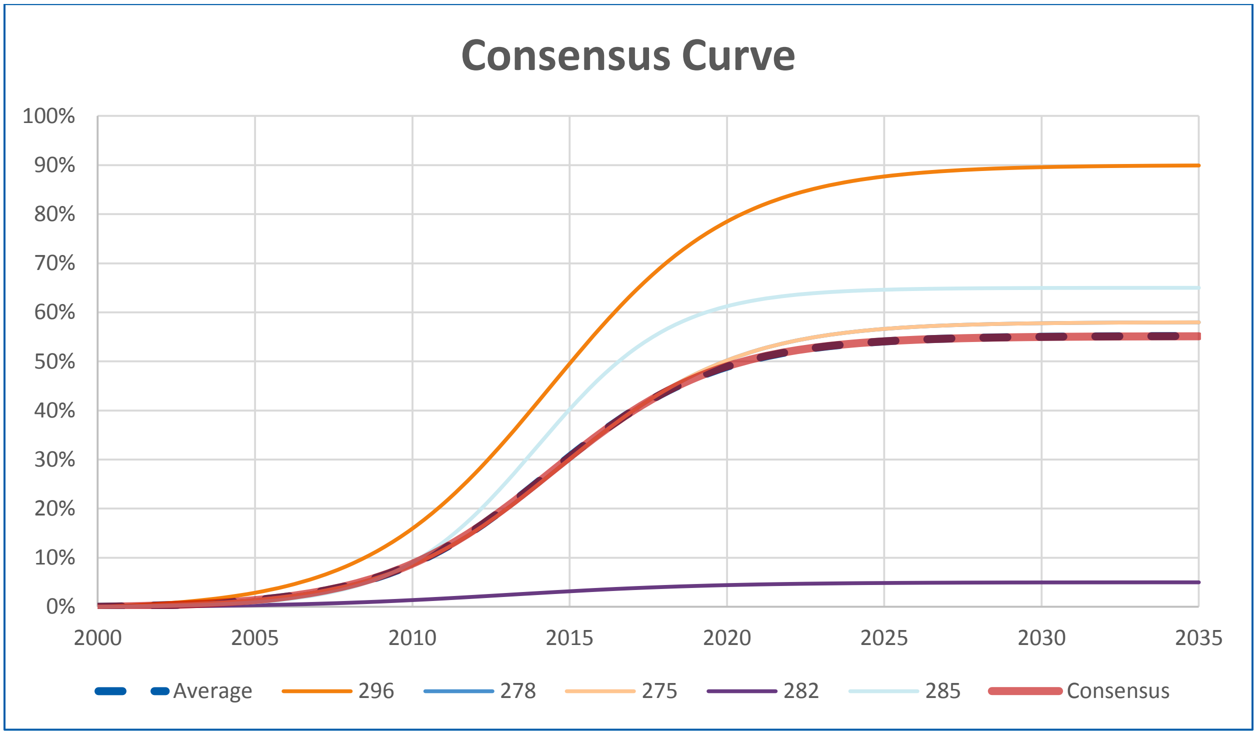
Figure 11. Standard B45 – Lighting – Retail Consensus Curve



Lighting – Parking Garage – Standard B50

Figure 10 provides the consensus Bass curve for Lighting – Parking Garage along with the panelist input used to develop it.

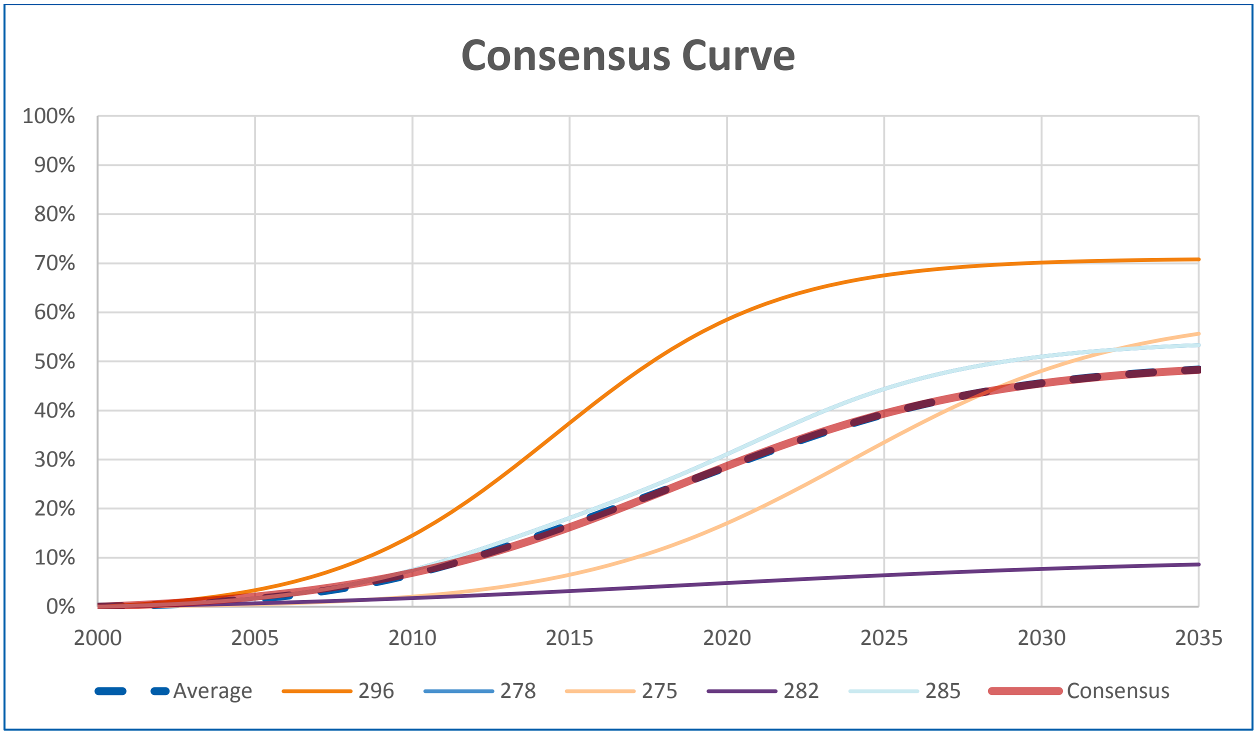
Figure 12. Standard B50 – Lighting – Parking Garage Consensus Curve



Lighting – Controllable Lighting – Standard B51

Figure 10 provides the consensus Bass curve for Lighting – Controllable Lighting along with the panelist input used to develop it.

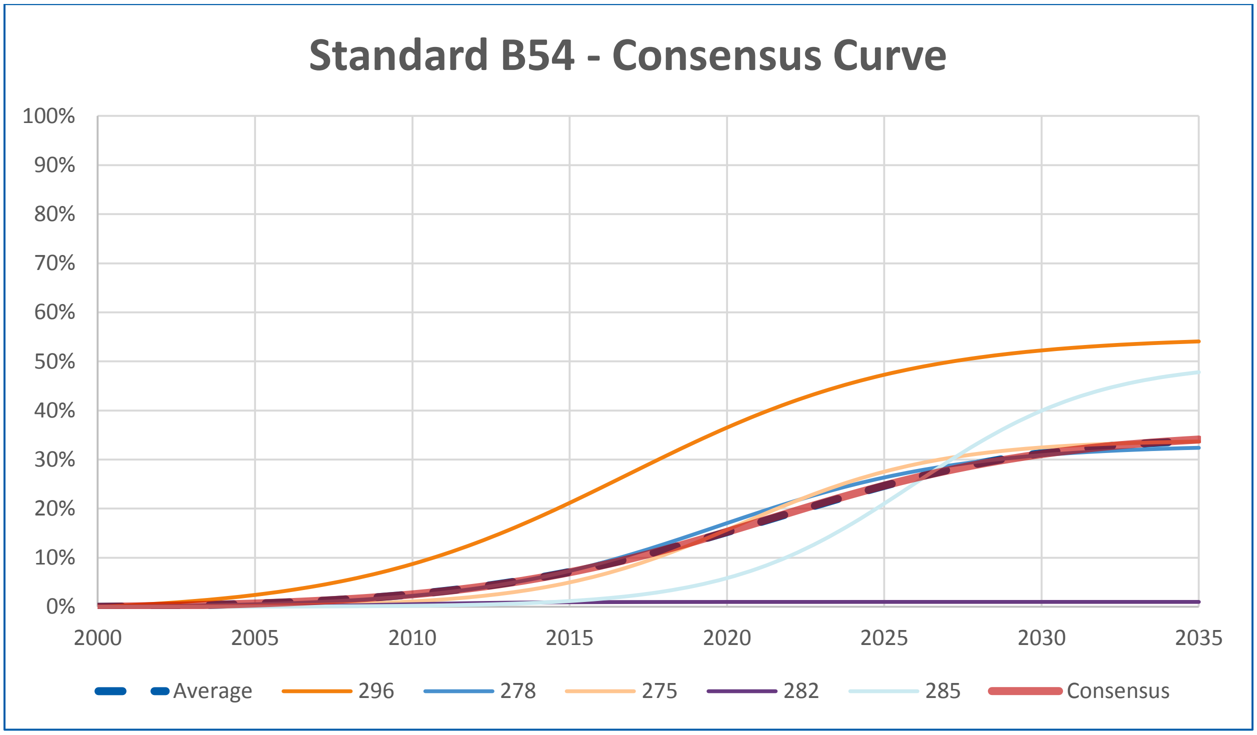
Figure 13. Standard B51 – Lighting – Controllable Lighting Consensus Curve



Lighting – Office Plug Load Control – Standard B54

Figure 10 provides the consensus Bass curve for Lighting – Office Plug Load Control along with the panelist input used to develop it.

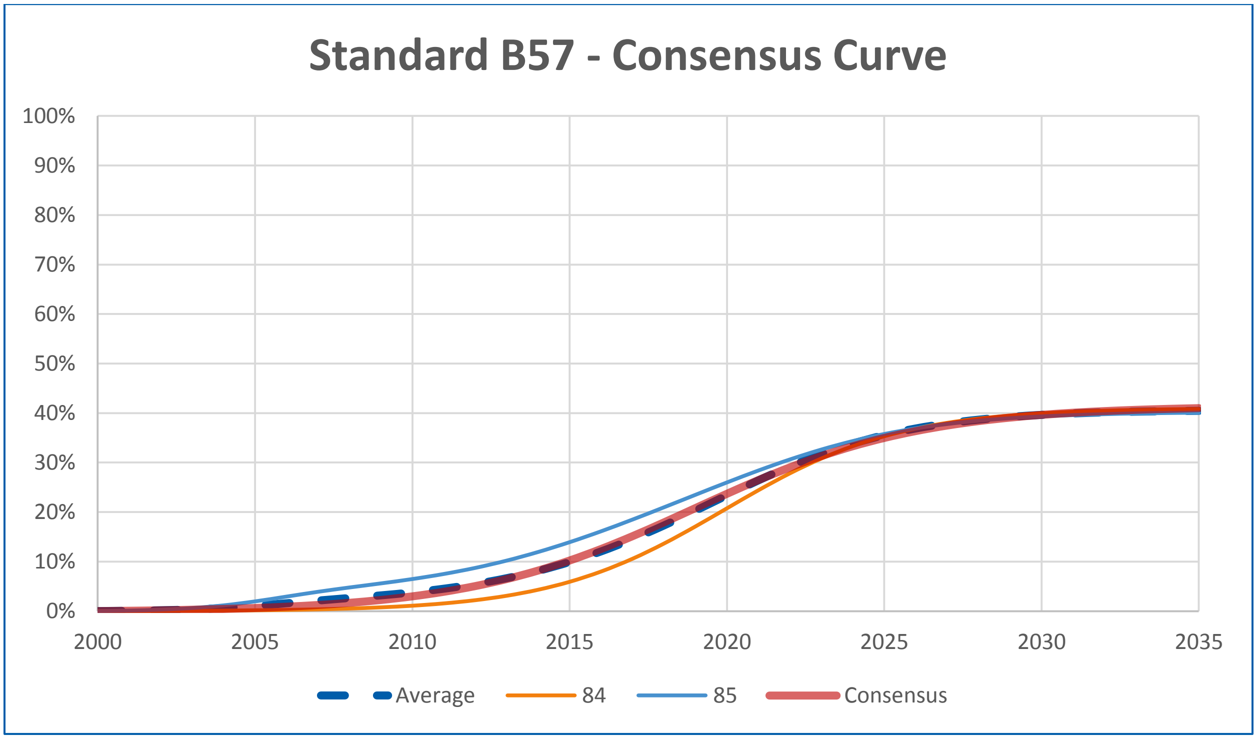
Figure 14. Standard B54 – Lighting – Office Plug Load Control Consensus Curve



HVAC – Controls, Economizers – Standard B57

Figure 10 provides the consensus Bass curve for HVAC – Controls, Economizers along with the panelist input used to develop it.

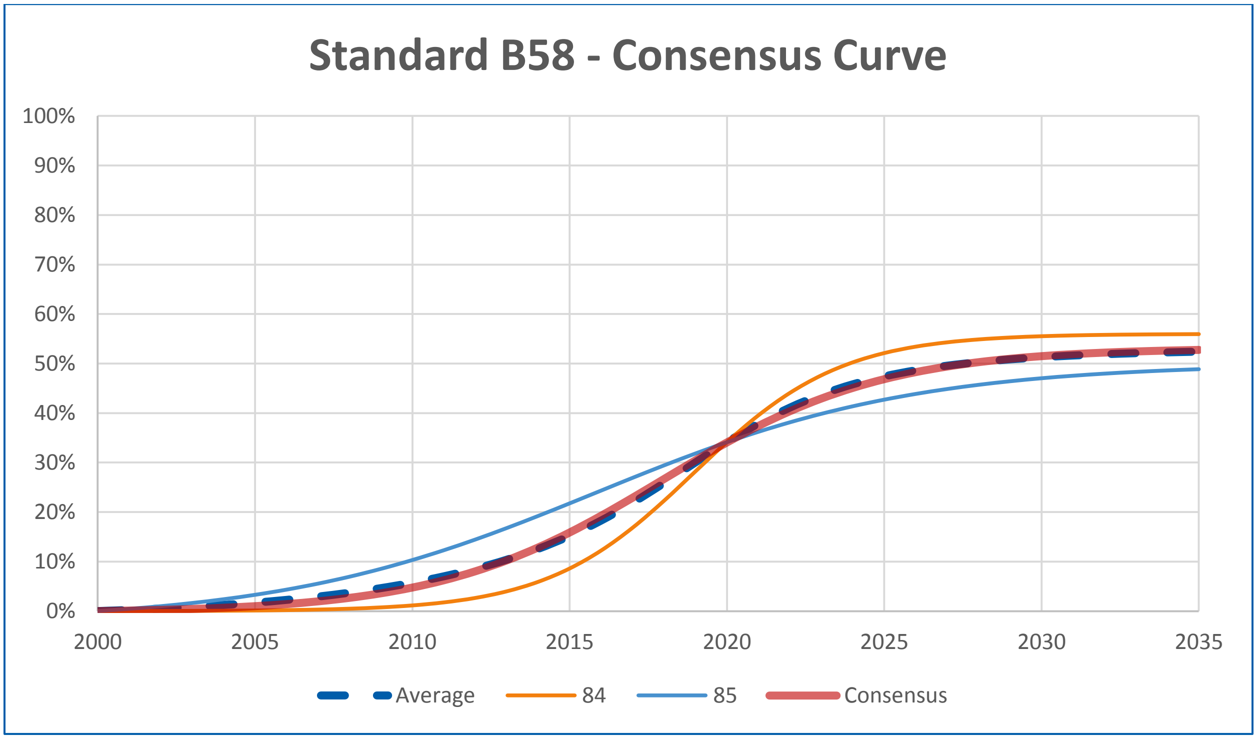
Figure 15. Standard B57 – HVAC – Controls, Economizers Consensus Curve



HVAC – Fan Control & Economizers – Standard B58

Figure 10 provides the consensus Bass curve for HVAC – Fan Control & Economizers along with the panelist input used to develop it.

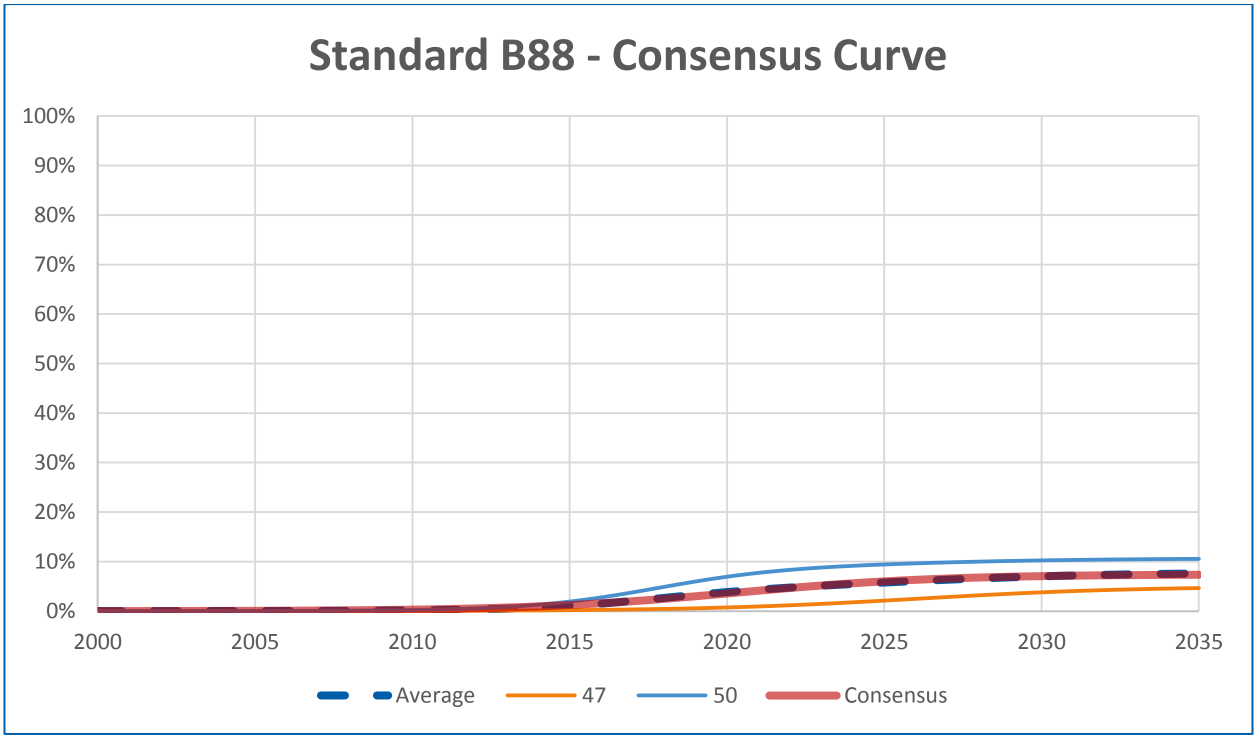
Figure 16. Standard B58 – HVAC – Fan Control & Economizers Consensus Curve



HVAC – Whole House Fans – Standard B88

Figure 10 provides the consensus Bass curve for HVAC – Whole House Fans along with the panelist input used to develop it.

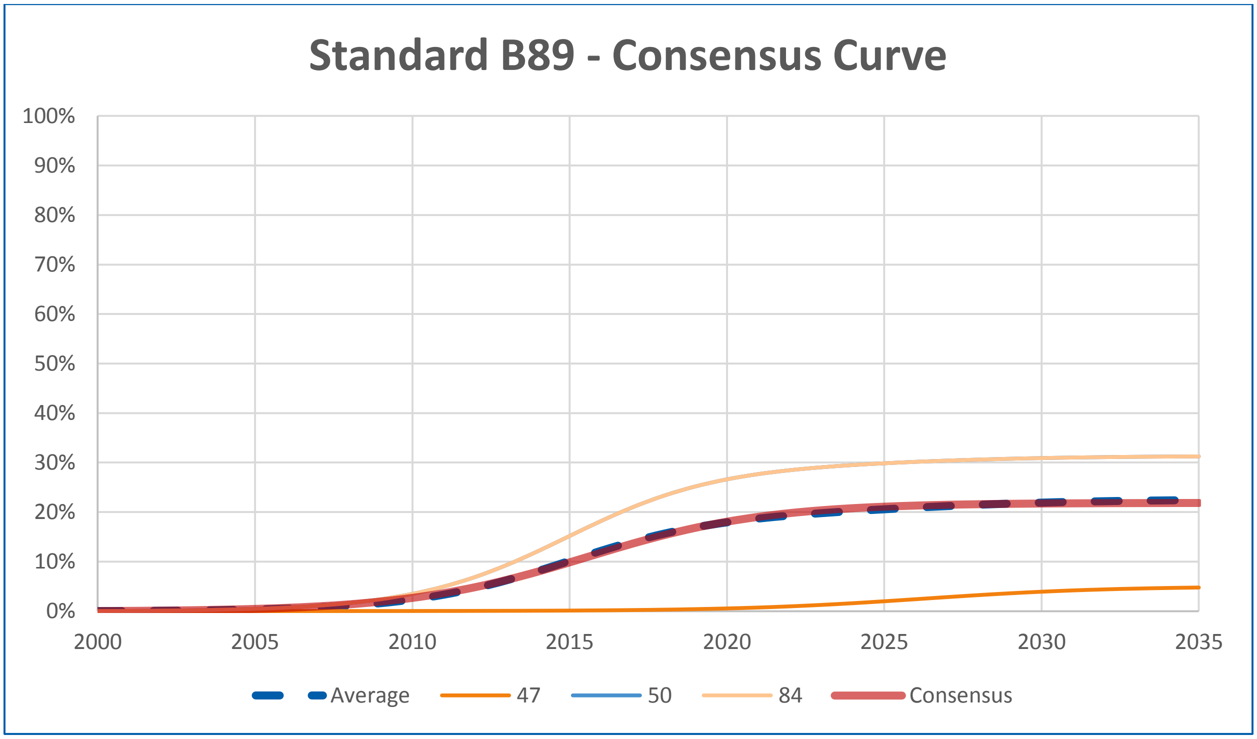
Figure 17. Standard B88 – HVAC – Whole House Fans Consensus Curve



HVAC – Zoned AC – Standard B89

Figure 10 provides the consensus Bass curve for HVAC – Zoned AC along with the panelist input used to develop it.

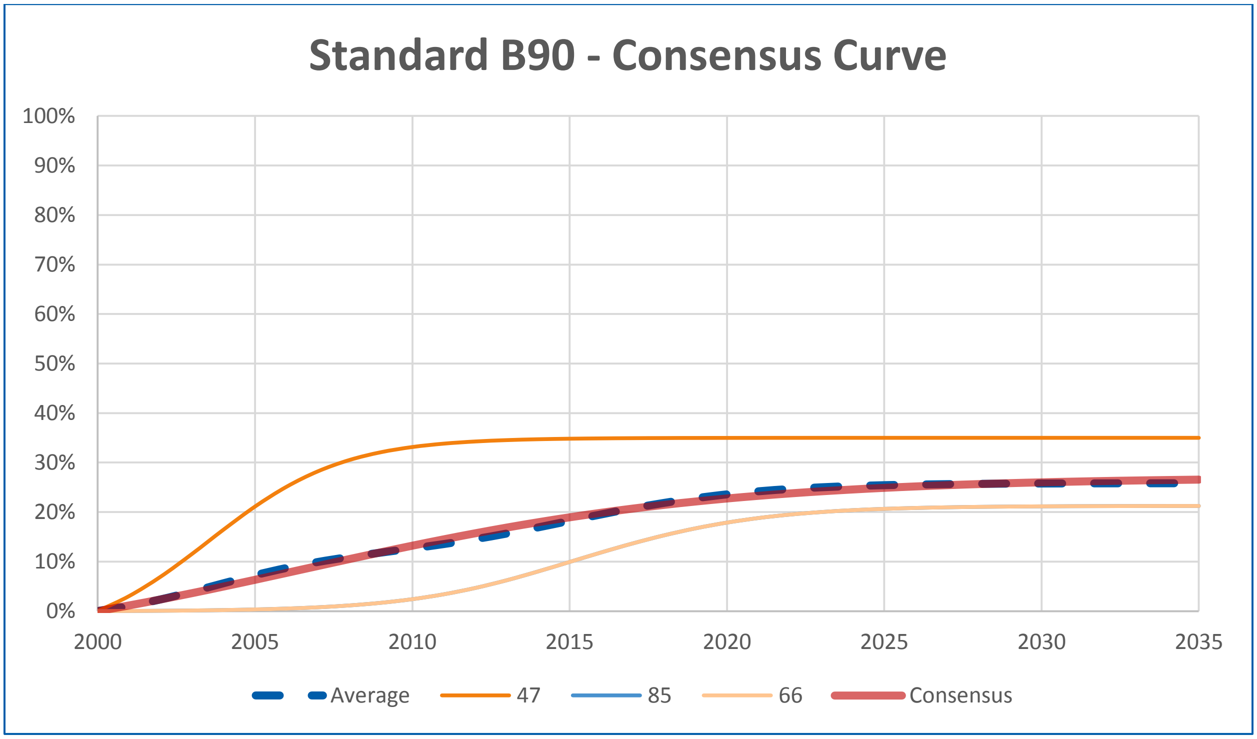
Figure 18. Standard B89 – HVAC – Zoned AC Consensus Curve



HVAC – Duct– Standard B90

Figure 10 provides the consensus Bass curve for HVAC – Duct along with the panelist input used to develop it.

Figure 19. Standard B90 – HVAC – Duct Consensus Curve



K. Additional Detail on NonResidential Alteration (NRA) Standards

We provide the evaluation findings for the four NRA standards that were not included in the main report in this section. Since we prioritized standards based on the IOU estimated potential savings, we did not evaluate the unit energy savings or market size (applicable square footage for the lighting and cool roof standards, air compressors for standard B42). We did update other parameters and this is the reason that evaluation results differ from the IOU estimates.

Standard B37 NRA-Lighting-MF Building Corridors

We applied the ESAF value based on our field study of lighting alteration projects. With this value and the lower NOMAD finding, net program savings are slightly higher than the IOU estimate despite the lower attribution score.

Table 157. Evaluated vs. IOU Estimated Unit Energy Savings for Standard B37

NRA-Lighting-MF Building Corridors	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	0.085	0.00001	0.00000	1.100	1.320	-0.00410
Evaluated	0.085	0.00001	0.00000	1.100	1.320	-0.00410

Table 158. Evaluated vs. IOU Estimated Market Size and Savings for Standard B37

NRA-Lighting-MF Building Corridors	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	30,246,575	2.83	83%	2.35	-25%	1.76	84%	1.48	0.18	(0.006)
	2015	60,000,000	5.62	83%	4.66	-29%	3.32	84%	2.78	0.34	(0.010)
	Total		**8.45**		**7.02**		**5.07**		**4.26**	**0.51**	**(0.016)**
Evaluated	2014	30,246,575	2.83	91%	2.58	-9%	2.35	68%	1.59	0.19	(0.006)
	2015	60,000,000	5.62	91%	5.11	-10%	4.61	68%	3.12	0.37	(0.012)
	Total		**8.45**		**7.69**		**6.96**		**4.72**	**0.56**	**(0.018)**

Standard B38 NRA-Lighting-Hotel Corridors

As with standard B37, we found higher gross energy savings due to the ESAF value, lower NOMAD, and lower attribution with the overall finding of higher net program savings.

Table 159. Evaluated vs. IOU Estimated Unit Energy Savings for Standard B38

NRA-Lighting-Hotel Corridors	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	0.085	0.00001	0.00000	1.100	1.320	-0.00410
Evaluated	0.085	0.00001	0.00000	1.100	1.320	-0.00410

Table 160. Evaluated vs. IOU Estimated Market Size and Savings for Standard B38

NRA-Lighting-Hotel Corridors	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	11,120,658	1.04	83%	0.86	-25%	0.65	84%	0.54	0.07	(0.002)
	2015	22,060,000	2.07	83%	1.71	-29%	1.22	84%	1.02	0.12	(0.004)
	Total		**3.11**		**2.58**		**1.86**		**1.57**	**0.19**	**(0.006)**
Evaluated	2014	11,120,658	1.04	91%	0.95	-15%	0.81	68%	0.55	0.06	(0.002)
	2015	22,060,000	2.07	91%	1.88	-16%	1.57	68%	1.06	0.13	(0.004)
	Total		**3.11**		**2.83**		**2.38**		**1.61**	**0.19**	**(0.006)**

Standard B40 NRA-Envelope-Cool Roofs

For this cool roof standard, Cadmus found a higher NOMAD estimate and lower attribution which when combined produced a lower net program savings.

Table 161. Evaluated vs. IOU Estimated Unit Energy Savings for Standard B40

NRA-Envelope-Cool Roofs	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	0.052	0.00002	-0.00029	1.000	1.000	0.00000
Evaluated	0.052	0.00002	-0.00029	1.000	1.000	0.00000

Table 162. Evaluated vs. IOU Estimated Market Size and Savings for Standard B40

NRA-Envelope-Cool Roofs	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	172,273,739	8.90	83%	7.39	-20%	5.91	76%	4.49	1.57	(0.025)
	2015	341,738,667	17.66	83%	14.66	-23%	11.28	76%	8.57	2.99	(0.048)
	Total		**26.56**		**22.05**		**17.19**		**13.06**	**4.56**	**(0.073)**
Evaluated	2014	172,273,739	8.90	83%	7.39	-44%	4.15	57%	2.37	0.83	(0.013)
	2015	341,738,667	17.66	83%	14.66	-48%	7.66	57%	4.36	1.52	(0.024)
	Total		**26.56**		**22.05**		**11.81**		**6.73**	**2.35**	**(0.038)**

Standard B42 NRA-Process-Air Compressors

As with standard B40, Cadmus found higher NOMAD values and lower attribution and an overall result of lower net program savings.

Table 163. Evaluated vs. IOU Estimated Unit Energy Savings for Standard B42

NRA-Process-Air Compressors	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	325.650	0.00000	0.00000	1.000	1.000	0.00000
Evaluated	325.650	0.00000	0.00000	1.000	1.000	0.00000

Table 164. Evaluated vs. IOU Estimated Market Size and Savings for Standard B42

NRA-Process-Air Compressors	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	19,641	6.40	83%	5.31	-14%	4.57	85%	3.88	-	-
	2015	38,961	12.69	83%	10.53	-17%	8.76	85%	7.45	-	-
	Total		**19.08**		**15.84**		**13.33**		**11.33**	**-**	**-**
Evaluated	2014	19,641	6.40	83%	5.31	-37%	3.34	54%	1.81	-	-
	2015	38,961	12.69	83%	10.53	-41%	6.20	54%	3.35	-	-
	Total		**19.08**		**15.84**		**9.54**		**5.15**	**-**	**-**

L. Additional Detail on NonResidential New Construction (NRNC) Standards

In this section, we selected and presented the standards with the largest savings in each of these three NRNC groups: Lighting, HVAC, and Process/Other.

NRNC Lighting Standards

For some NRNC standards, Cadmus scaled potential savings using the interactive savings factors determined by the ratio between the whole building potential savings and the sum of the potential for the individual measures in the whole building group. This is described in Section 3.1.1 and the values can be found in Table 23 of the main report. We applied this scaling to standards for which we expect interaction with other measures in new buildings. Of the four standard below, we applied the scaling factors to standard B49 and standard B51. We did not apply these adjustments to standards B46 and B50.

Standard B46 NRNC-Lighting-Egress Lighting Control

Table 165. Evaluated vs. IOU Estimated Unit Energy Savings for Standard B46

NRNC-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	0.168	0.00000	0.00000	1.000	1.000	0.00000
Evaluated	0.397	0.00000	0.00000	1.000	1.000	0.00000

Table 166. Evaluated vs. IOU Estimated Market Size and Savings for Standard B46

NRNC-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	2015	100,563,048	16.86	83%	14.00	-29%	9.95	82%	8.13	-	-
Evaluated	2015	84,270,021	33.45	83%	27.76	-9%	25.35	82%	20.72	-	-

Standard B49 NRNC-Lighting-Warehouses and Libraries

Table 167. Evaluated vs. IOU Estimated Unit Energy Savings for Standard B49

NRNC-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	1.100	1.320	-0.00410
Evaluated	0.809	0.00008	0.00000	0.734	0.833	-0.00410

Table 168. Evaluated vs. IOU Estimated Market Size and Savings for Standard B49

NRNC-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	2015	22,733,692	20.23	83%	16.79	-29%	11.93	84%	10.02	1.15	(0.037)
Evaluated	2015	19,535,230	11.59	83%	9.62	-14%	8.29	84%	6.97	0.82	(0.039)

Standard B50 NRNC-Lighting-Parking Garage

Table 169. Evaluated vs. IOU Estimated Unit Energy Savings for Standard B50

NRNC-Lighting-Parking Garage	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	1.111	0.00022	0.00000	1.000	1.000	0.00000
Evaluated	0.899	0.00008	0.00000	1.000	1.000	0.00000

Table 170. Evaluated vs. IOU Estimated Market Size and Savings for Standard B50

NRNC-Lighting-Parking Garage	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	2015	16,542,132	18.37	83%	15.25	-29%	10.84	83%	9.02	1.78	-
Evaluated	2015	15,666,602	14.08	83%	11.69	-31%	8.12	66%	5.32	0.47	-

Standard B51 NRNC-Lighting-Controllable Lighting

Table 171. Evaluated vs. IOU Estimated Unit Energy Savings for Standard B51

NRNC-Lighting-Controllable Lighting	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	0.575	0.00000	0.00000	1.100	1.320	-0.00410
Evaluated	0.575	0.00000	0.00000	0.731	0.833	-0.00410

Table 172. Evaluated vs. IOU Estimated Market Size and Savings for Standard B51

NRNC-Lighting-Controllable Lighting	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	2015	79,722,329	50.39	83%	41.82	-2%	41.08	83%	34.10	-	(0.127)
Evaluated	2015	79,185,823	33.39	83%	27.71	-16%	23.22	72%	16.72	-	(0.093)

NRNC HVAC Standards

Standard B64 NRNC-HVAC-Garage Exhaust

Table 173. Evaluated vs. IOU Estimated Unit Energy Savings for Standard B64

NRNC-HVAC-Garage Exhaust	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	0.925	0.00021	0.00000	1.000	1.000	0.00000
Evaluated	0.925	0.00021	0.00000	1.000	1.000	0.00000

Table 174. Evaluated vs. IOU Estimated Market Size and Savings for Standard B64

NRNC-HVAC-Garage Exhaust	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	2015	10,068,493	9.31	83%	7.73	-2%	7.59	78%	5.94	1.36	-
Evaluated	2015	11,301,370	10.45	83%	8.68	-2%	8.52	78%	6.67	1.52	-

Standard B65 NRNC-HVAC-Laboratory Exhaust

Table 175. Evaluated vs. IOU Estimated Unit Energy Savings for Standard B65

NRNC-HVAC-Laboratory Exhaust	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	41.92	0.0104	1.660	1.000	1.000	0.00000
Evaluated	11,148.8	2.4035	-690.25	1.000	1.000	0.00000

Table 176. Evaluated vs. IOU Estimated Market Size and Savings for Standard B65

NRNC-HVAC-Laboratory Exhaust	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	2015	913,457	38.29	83%	31.78	-2%	31.22	80%	24.90	6.18	0.986
Evaluated	2015	3,202	35.70	83%	29.63	-2%	29.10	55%	16.01	3.45	0.991

Standard B66 NRNC-HVAC-Small ECM Motor

Table 177. Evaluated vs. IOU Estimated Unit Energy Savings for Standard B66

NRNC-HVAC-Small ECM Motor	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	200.83	0.000	0.000	1.000	1.000	0.00000
Evaluated	1,689.9	0.000	0.000	0.731	0.623	0.00000

Table 178. Evaluated vs. IOU Estimated Market Size and Savings for Standard B66

NRNC-HVAC-Small ECM Motor	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	2015	184,492	37.05	83%	30.75	-17%	25.60	82%	20.86	-	-
Evaluated	2015	21,113	26.18	83%	21.73	-17%	18.09	66%	11.98	-	-

NRNC Process and Other Standards

Standard B75 NRNC-Refrigeration-Supermarket

Table 179. Evaluated vs. IOU Estimated Unit Energy Savings for Standard B75

NRNC-Refrigeration-Supermarket	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	2.118	0.00018	0.222	1.000	1.000	0.00000
Evaluated	2.118	0.00018	0.222	1.000	1.000	0.00000

Table 180. Evaluated vs. IOU Estimated Market Size and Savings for Standard B75

NRNC-Refrigeration-Supermarket	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	2015	5,711,630	12.10	83%	10.04	0%	10.02	79%	7.87	0.67	0.823
Evaluated	2015	5,255,525	11.13	83%	9.24	0%	9.22	61%	5.62	0.48	0.590

Standard B78 NRNC-Process-Data Centers

Table 181. Evaluated vs. IOU Estimated Unit Energy Savings for Standard B78

NRNC-Process-Data Centers	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	275.0	0.008	0.000	1.000	1.000	0.00000
Evaluated	280.0	0.008	0.000	1.000	1.000	0.00000

Table 182. Evaluated vs. IOU Estimated Market Size and Savings for Standard B78

NRNC-Process-Data Centers	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	2015	67,123	18.46	83%	15.32	-17%	12.75	68%	8.70	0.25	-
Evaluated	2015	73,997	20.72	83%	17.20	-27%	12.54	69%	8.67	0.25	-

M. Additional Detail on Residential Standards

As noted above, our effort to evaluate residential standards was focused on the single-family codes. We present our findings for single family homes overall in Table 183. We found that single-family construction averaged 37,040 new homes per year, which was 62% greater than the 22,096 annual figure used in the IOU estimate. The potential also reflects larger than expected savings from residential alteration projects in both 2014 and 2015.

Table 183. Findings for Single-Family Construction Lighting B83, New B97, and Alterations B99

	Year	Electric Savings (GWh)							MW	Gas Savings (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	2014	-	n/a	-	n/a	-	n/a	-	-	-
	2015	24.2	83%	20.1	-20%	16.1	72%	11.7	13.9	0.3
	Total	**24.2**	**83%**	**20.1**	**-20%**	**16.1**	**73%**	**11.7**	**13.9**	**0.3**
EVAL	2014	5.4	67%	3.6	-27%	2.6	68%	1.8	2.7	0.1
	2015	39.4	61%	23.8	-36%	15.2	68%	10.3	15.4	0.5
	Total	**44.7**		**27.5**		**17.8**		**12.1**	**18.1**	**0.5**

B98 RNC Whole Building Multifamily

Cadmus did not evaluate this standard so the parameters provided by the IOUs are used as shown in Table 184.

Table 184. Evaluated Vs. IOU-Estimated Savings for Standard B98

RNC-MF Whole Building	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	2015	14,124	3.13	83%	2.59	-20%	2.08	72%	1.50	1.51	0.044
	Total		**3.13**		**2.59**		**2.08**		**1.50**	**1.51**	**0.04**
EVAL	2015	14,124	3.13	83%	2.59	-29%	1.85	72%	1.33	1.34	0.039
	Total		**3.13**		**2.59**		**1.85**		**1.33**	**1.34**	**0.039**

B100 RA Alterations Multifamily

Cadmus changed the start date for this standard to be July 2014, the effective date of the 2013 Title 24 codes. Other parameters were not evaluated and, therefore, the IOU estimate was used as shown in Table 185.

Table 185. Evaluated Vs. IOU-Estimated Savings for Standard B100

RA-MF Whole Building	Year	Units	GWh							MW	MMtherms
			Potential Energy Savings	CAF	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	0.00	N/A	-	-	-
	2015	8,061	1.78	83%	1.48	-20%	1.19	72%	0.85	0.86	0.025
	Total		**1.78**		**1.48**		**1.19**		**0.85**	**0.86**	**0.025**
EVAL	2014	4,064	0.90	83%	0.75	-17%	0.62	72%	0.45	0.45	0.013
	2015	8,061	1.78	83%	1.48	-20%	1.19	72%	0.85	0.86	0.025
	Total		**2.68**		**2.23**		**1.80**		**1.30**	**1.31**	**0.038**

All other Residential Standards: B93, B95, B96

These standards were not evaluated and, therefore, the IOU estimate was used as shown in.

Table 186. Evaluated Vs. IOU-Estimated Savings for Standards B93, 95, and 96

			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	B93	RNC-DHW - MF DHW Control and Solar	24,556	(0.32)	83%	(0.27)	-2%	(0.26)	82%	(0.22)	-	0.74
	B95	RNC-DHW - Solar for Elec. Heated Homes	28	0.08	83%	0.06	-2%	0.06	86%	0.05	0.01	-
	B96	RNC-Solar - Solar Ready & Oriented Homes	370	0.08	83%	0.07	-2%	0.07	70%	0.05	0.06	0.00
		Total		**(0.17)**		**(0.14)**		**(0.14)**		**(0.12)**	**0.07**	**0.74**
EVAL	B93	RNC-DHW - MF DHW Control and Solar	24,556	(0.32)	83%	(0.27)	-2%	(0.26)	82%	(0.22)	-	0.74
	B95	RNC-DHW - Solar for Elec. Heated Homes	28	0.08	83%	0.06	-2%	0.06	86%	0.05	0.0	-
	B96	RNC-Solar - Solar Ready & Oriented Homes	370	0.08	83%	0.07	-2%	0.07	70%	0.05	0.1	0.00
		Total		**(0.17)**		**(0.14)**		**(0.14)**		**(0.12)**	**0.07**	**0.74**

N. Unbounded ESAF Energy and Demand Savings for 2013 Title 24

For the 2013 Title 24, we reported the energy and demand savings in the main report document using ESAF values described as bounded since the ESAF value for any given site was limited to a maximum of 100%. This approach and the reasons for its use are described in Section 1.2.1 of the Phase Two, Volume Two report.

Since unbounded ESAF values were computed we have provided both bounded and unbounded ESAF values in the Phase Two, Volume Two report in Section 3.2 and in Appendix G.

In order to provide additional continuity and comparability between the prior PY 2010-2012 evaluation which used unbounded ESAF values (described as compliance adjustment factors or CAFs in the impact evaluation report) and the present report, we report the 2013 Title 24 energy and demand savings here using unbounded ESAF values.

Table 187. 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 codes	1,226.1	1,017.6	738.9	582.9	1,029.9	1,408.1	1,105.1	672.1
NRNC codes	382.3	317.3	262.0	213.4	403.7	445.0	398.0	268.9
RNC and RA codes	29.0	24.0	19.2	14.0	50.4	32.4	21.5	14.7
2013-2015 Total	**1,637.3**	**1,359.0**	**1,020.1**	**810.3**	**1,484.0**	**1,885.5**	**1,524.5**	**955.7**
Evaluated/IOU Estimated					**91%**	**139%**	**149%**	**118%**

*Values may not sum exactly due to rounding.

Table 188. 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	595.8	481.7	302.0
SCE	32.60%	533.8	443.0	332.6	264.2	483.8	614.7	497.0	311.5
SDG&E	7.40%	121.2	100.6	75.5	60.0	109.8	139.5	112.8	70.7
All IOUs	**71.60%**	**1172.3**	**973.0**	**730.4**	**580.2**	**1062.6**	**1350.0**	**1091.6**	**684.3**
Evaluated/IOU Estimated						**91%**	**139%**	**149%**	**118%**

*Values may not sum exactly due to rounding.

Table 189. 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 codes	320.7	266.2	192.9	149.3	178.8	252.3	194.6	106.7
NRNC codes	56.1	46.5	36.7	29.9	65.1	85.8	78.1	51.8
RNC and RA codes	34.0	28.3	22.6	16.3	60.2	48.0	31.6	21.6
2013-2015 Total	**410.8**	**340.9**	**252.2**	**195.6**	**304.1**	**386.0**	**304.4**	**180.2**
Evaluated/IOU Estimated					**74%**	**113%**	**121%**	**92%**

*Values may not sum exactly due to rounding.

Table 190. 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	107.7	79.7	61.8	96.1	122.0	96.2	56.9
SCE	32.60%	133.9	111.1	82.2	63.8	99.1	125.8	99.2	58.7
SDG&E	7.40%	30.4	25.2	18.7	14.5	22.5	28.6	22.5	13.3
All IOUs	**71.60%**	**294.1**	**244.1**	**180.6**	**140.0**	**217.7**	**276.4**	**217.9**	**129.0**
Evaluated/IOU Estimated						**74%**	**113%**	**121%**	**92%**

*Values may not sum exactly due to rounding.

Table 191. 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 codes	1.73	1.44	1.03	-0.64	1.83	0.23	-0.03	-0.86
NRNC codes	4.27	3.54	3.34	2.66	5.25	4.96	4.79	3.04
RNC and RA codes	2.04	1.70	1.53	1.19	2.70	3.91	2.87	2.08
2013-2015 Total	**8.05**	**6.68**	**5.90**	**3.22**	**9.77**	**9.10**	**7.64**	**4.27**
Evaluated/IOU Estimated					**121%**	**136%**	**129%**	**133%**

*Values may not sum exactly due to rounding.

Table 192. 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 codes	3.46	2.87	2.07	0.24	3.18	2.23	1.61	0.16
NRNC codes	4.59	3.81	3.59	2.87	5.56	5.22	5.02	3.21
RNC and RA codes	2.09	1.73	1.56	1.22	2.78	3.91	2.87	2.08
2013-2015 Total	**10.14**	**8.42**	**7.21**	**4.32**	**11.52**	**11.36**	**9.49**	**5.45**
Evaluated/IOU Estimated					114%	135%	132%	126%

*Values may not sum exactly due to rounding.

Table 193. 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	3.32	2.79	1.56
SCG	58.40%	4.70	3.90	3.45	1.88	5.71	5.32	4.46	2.49
SDG&E	4.10%	0.33	0.27	0.24	0.13	0.40	0.37	0.31	0.17
All IOUs	**99.00%**	**7.97**	**6.61**	**5.85**	**3.19**	**9.68**	**9.01**	**7.56**	**4.22**
Evaluated/IOU Estimated						121%	136%	129%	133%

*Values may not sum exactly due to rounding.

Table 194. 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	4.15	3.46	1.99
SCG	58.40%	5.92	4.92	4.21	2.52	6.73	6.64	5.54	3.19
SDG&E	4.10%	0.42	0.35	0.30	0.18	0.47	0.47	0.39	0.22
All IOUs	**99.00%**	**10.04**	**8.33**	**7.14**	**4.28**	**11.40**	**11.25**	**9.40**	**5.40**
Evaluated/IOU Estimated						114%	135%	132%	126%

*Values may not sum exactly due to rounding.

O. Responses to Comments Received

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
1	text/table disparity	ES/iii-iv	Comment	IOUs	Text shows 72% of IOU estimate; Table ES-2 shows 75%	Yes	Corrected to 81%
2	text/table disparity	ES/iv	Comment	IOUs	Text shows 72% of IOU estimate; Table ES-3 shows 75%	Yes	Corrected to 81%
3	text/table disparity	ES/v	Comment	IOUs	Text shows 36% of IOU estimate; Table ES-4 shows 38%	Yes	Corrected to 59%
4	Conclusion	ES/viii (they have not…)	Question	IOUs	You have stated that the CEC Title 24 savings estimate is inadequate for determining the statewide impact of Title 24. Is this what you meant to say. If so it appears that you are challenging the CEC's estimate of savings used for long-term procurement planning. That statement, combined with the fact that you are using "bounded" savings estimates, suggests that there is no adequate measure of Title 24 savings to be used for procurement planning.	No	The conclusion makes no statement about the use of the CEC estimate for long-term procurement. The report states "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." This conclusion is based only on the needs of the evaluation.
5	Recommen dation	ES/viii (We recommend that…)	Comment	IOUs	Please restate this recommendation to provide more clarity. The suggested whole building analyses would have to be agreed upon by the CEC and CPUC prior to ratepayer monies being spent by the IOUs to document the analyses. A Codes and Standards Enhancement report is not necessarily the most appropriate vehicle for documenting the suggested whole building analyses.	No	The report recommends that the IOUs, CPUC, and CEC collaborate to develop a consistent building simulation approach to estimate Title 24 savings and the CPUC would be the entity to approve IOU expenditures. CASE reports have been the vehicle used to document all Title 24 revisions to date so the recommendation is consistent with the precedents for all other Title 24 changes.
6	Recommen dation	ES/viii (the IOUs research ways to assess…)	Question/ Comment	IOUs	How is this recommendation beneficial and cost efficient if the CPUC managed impact assessment moves to a whole building approach as you suggest? This recommendation is inconsistent with the previous recommendation that suggests moving to a whole building assessment.	No	The IOUs prepare CASE reports to support individual code changes through the CEC adoption process so the recommendation is not for new work. Information on individual code changes is essential in the evaluation to allocate attribution and NOMAD effects across the component codes.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
7	Conclusion	ES/ix (but assumes that…)	Question	IOUs	What is the empirical basis for this assumption?	No	The primary reason for the change is that the 2008 T-24 baseline is minimum requirements and therefore the consistent assumptions must be made for the 2013 T-24 baseline. In addition, absent historic data to support rationale that choices the market makes to select specific building designs are entirely attributable to the C&S program, it seems reasonable to use bounded savings estimates.
8	Recommendation	ES/ix (We recommend that the CPUC …)	Comment	IOUs	The IOUs recommend the CPUC scope a new study in the upcoming EM&V roadmap to look into code compliance in new construction and building alterations. The study should be able to quantify the causes of over/under compliance used as part of the estimation of the energy savings adjustment factor (ESAF). The study would follow the normal public vetting process for EM&V studies.	No	CPUC may consider this suggestion while developing the next version of the C&S research roadmap.
9	Recommendation	ES/x (The CPUC and IOUs should consider conducting...)	Question	IOUs	Please explain how this recommendation will address the challenge listed in the above conclusion: "One challenge faced by the evaluation was identifying buildings that were constructed under the 2013 Title 24."	No	The recommendation will help verify the accuracy of the assumed lags or provide a more accurate estimate.
10	Recommendation	ES/ix (The CPUC and IOUs should consider supplementing...)	Comment	IOUs	The IOUs concur with this recommendation, particularly given the small sample size of the current evaluation.	No	Thank you for your comment.
11	Recommendation	Earlier version of report (We recommend the CPUC consider…)	Question	IOUs	What did CEC staff say about this finding when you discussed it with them?	No	The cited text does not appear in the recommendations in the draft report provided for public review so we are unsure what the comment refers to.
12	Recommendation	ES/x (We recommend that the	Question	IOUs	Can you provide a table of suggested compliance improvement targets, including potential savings from such efforts, so that the IOUs can prioritize their efforts in a cost efficient fashion?	No	This is out of the scope of the current evaluation.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
		IOUs and CEC…)					
13	Bounded ESAF	1.2.1 (First, there is no empirical basis…)	Comment/ Question	IOUs	The IOUs strongly disagree with this statement. Architects will often exceed code requirements so that they do not have to perform redesign if the building is judged to not meet the energy code. Redesign would typically be uncompensated work so over compliance acts as insurance against an uncompensated redesign effort. There is also a situation where the least expensive alternative happened to push the whole building consumption beyond code. The lifecycle cost reduction afforded by LEDs (relative to fluorescents) can cause building alterations (and new construction) to exceed code. Was any adjustment made to NOMAD in order to reflect "over-compliance"? If not, why not given that the over compliance was not due to the standard? Please provide empirical data for the basis to limit the ESAF at 100% including how spill over was accounted for. Also, please provide the percentage of sites that exceeded code, the average percentage those sites exceeded code, and the assumptions that justify limiting savings to 100% when such a large portion of the sites exceeded coded by such a large margin.	No	All the arguments made for why T-24 requirements are exceeded also apply to the baseline. The goal is to determine the difference in energy consumption due to the new code. NOMAD reflects what would have occured in the absence of new codes and standards. Given that the sample size of non residential buildings was 18, there is too much uncertainty to make broad claims that there is a large portion of buildings that exceed the minimum requirements by a large amount.
14	Bounded ESAF	1.2.1 (Second, the calculation of unit savings assumes…)	Comment	IOUs	The IOUs wish to caution the authors that adjustment of the C&S baselines would demand concomitant alterations to DEER values, potential study savings estimates, and baselines defined under D.16-08-019 (Table 1, p. 49) since code baselines would shift if the baseline moved to the typical efficiency level of building built under the prior code. In addition, this approach, in order to be logically consistent, would demand a lower than code baseline for measures that typically did not meet code.	No	Thank you for your comment. The method described in the comment assumes the energy savings are from an "actual" baseline to an "actual" site evaluated new code baseline. This is a more complex approach that the CPUC is not recommending for the 2013-2015 cycle. Future T-24 cycles will need to adjust for changes in the CPUC policy as necessary.
15	Information Gaps	2.1.1/11 (Cadmus found significant gaps…)	Comment	IOUs	PG&E's lead on the data request response explained to Cadmus that certain data could not be retrieved from sub-contractors since key staff had left the firms.	No	Thank you for your comment.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
16	Square footage values	2.1.1/11 (but does not use the square…)	Question	IOUs	How so; please explain and provide more detail on the the estimates are unreliable and what is used instead.	No	The evaluation report indicates that Cadmus was informed by CEC staff that the CEC finds the Dodge square footage data to be unreliable load forecasting results. More details on the unreliability of the Dodge data for this purpose would need to be obtained from the CEC. Cadmus used the CEC's forecasted existing and new construction square footage for evaluated statewide savings, consistent with the IOU's approach which also leveraged CEC forecasted square footage estimates.
17	Formatting	3.1.1/62 (Table 22)	Comment	IOUs	Please Increase significant digits for absolute values smaller than .001.	Yes	The table was revised to show additional digits.
18	Scaling Factor	3.1.1/65 (Table 23)	Question	IOUs	Does the 218.5% value for Mtherms include negative therm interactive effects?	No	Yes, the gas scaling factor includes negative therm interactive effects.
19	Scaling Factor	3.1.2/66 (Cadmus applied Equation 1…)	Question	IOUs	How do these estimates compare with CEC estimates used for forecasting purposes?	No	We do not have the data to answer this question.
20	ESAF	3.2.1/69 (Cadmus found that Therms ESAF…)	Question	IOUs	Is this a reasonable assumption for SoCalGas given they do not include negative therm interactive effects?	No	We believe that this is a reasonable assumption.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
21	Savings estimate	4.1/75 (Table 34)	Question/ Comment	IOUs	What are the major causes for the significant reduction in IOU attribution? Was it across the board or only for specific standards? How many "experts" were employed to determine net program attribution for each standard? IOU involvement in standards development has increased since the last impact study cycle. That fact suggests that either the previous study's attribution panel was biased or the new attribution panel was biased. Alternatively, the "error bounds" on the attribution estimates for both cycles are quite wide and overlap the point estimates for each study.	No	In each evaluation, attribution scores are determined by an independent panel convened for the study. We recruited four experts to serve on the panel for the Title 24 codes. Since the scores in each study are determined by a unique group of panelists, we are not able to explain any apparent trends between scores. However, we compared the scores in the last evaluation to the scores in the current study and found that the simple average of all Title 24 attribution scores was 58% in the 2010-2012 evaluation and is 63% for the current study. In the last study however, six composite for remainder standards (B33a-B33f) received an average score of 10% and all other standards averaged 76%. We are not aware of any bias in either the prior or the current evaluation process or panel. We continue to use a normal distribution with 90% of the values between + and - 20% to evaluate the uncertainty of our overall results.
22	Savings estimate	4.1/76 (Table 36)	Question	IOUs	Was the major reason for this downward adjustment in evaluated savings due to differing definitions of demand savings between the CPUC and CEC?	Yes	The evaluation found larger demand savings for the NRNC and Residential categories than those included in the IOU estimate. For the NRA category, demand savings were found to be 41% of the IOU estimate. The primary reason for this is that demand savings for standard B35 in the IOU estimate of 122.8 MW/year were based on a calculation error. The evaluation found annual savings of 30 MW/year for this standard. Section 4.2.2 and Appendix H.2 were revised to note that the IOU estimated value is based on a calculation error.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
23	Savings estimate	4.1/77 (Table 39)	Question	IOUs	Was the major reason for the reduction due to negative therm interactive effects? If not, what were the major causes for the reductions?	Yes	The draft evaluation report contained incorrect values for some interactive factors (therms/kWh). Once these values were corrected, the overall finding is that evaluated therm savings are greater than the IOU estimated value.
24	Savings estimate	4.5/91 (Table 64)	Question	IOUs	For 2008 T-24 and 2013 T-24 NRNC what causes program net energy savings to be higher than net energy savings? Interactive effect differences?	No	In the final analysis, this situation only occurs for the 2008 Title 24 where net program savings are 15.84 MMtherms and net savings are 14.54 Mmtherms under the condition that interactive effects are included. The commenter is correct--this is the result of differences in interactive effects and attribution values.
25	Conclusions & Recommendations	5/92-95	Question/ Comment	IOUs	Same questions/comments as listed above in the Executive Summary questions/comments	No	See responses to comments 4 through 12 above.
26	Residential whole building methodology			IOUs	The appendices to the California Statewide Codes and Standards Program Impact Evaluation: Volume Two (Impact Evaluation Report) include a full write-up on the methodology used to evaluate the whole-building approach for nonresidential buildings. It would be helpful to see a similar write-up for the whole-building approach for residential buildings in the next iteration of the document.	Yes	A description of the whole building methodology used to evaluate single-family residential buildings (Standard B97) has been added to Appendix I.
27	Appendices K and L			IOUs	The appendices are incomplete. Appendices K and L (pages 170 - 171) state that standard-specific data for four Nonresidential Alterations (NRA) and all the Nonresidential New Construction (NRNC) measures remains to be added. The additional information in those sections would have been helpful to review to better understand how those measures were evaluated, particularly the NRA measures. We look forward to reviewing the additional information in a subsequent draft when it is ready.	No	The IOUs were looking at preliminary documents. The Appendices document posted to the public site included the additonal information.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
28	Standard B34 Daylighting Controls			IOUs	**Nonresidential Lighting Alterations (Standards B34)** Which NRA measure, if any, captures the evaluated energy savings from the daylighting control alterations requirements included in Standard B43: NRNC Daylighting Controls? Standard B43 is listed as a NRNC measure, but it has an alterations component. Are the alterations energy savings from Standard B43 captured as part of the evaluated savings for Nonresidential Lighting Alterations, New Measures (Standard B34)? For the 2013 Title 24, Part 6 standards, a lighting alterations compliance option (Option 2) was introduced that did not require automatic daylighting controls, but set a lower lighting power allowance (LPA). Did the special investigation of the mandatory daylighting controls requirements take the new compliance option into account? The compliance evaluation presented in Section 3.2 of the Impacts Evaluation and Appendix G indicates 49 buildings where surveyed to evaluate compliance with lighting alterations requirements. It appears that a portion of these 49 buildings exceeded the 2013 alteration code; the energy savings adjustment factor (ESAF) is larger than 100% in Table 7 of the appendices document. This suggests that some portion of the evaluated alteration projects in those 49 buildings elected to use Option 2 to comply with the lighting alteration code, which does not require the installation of automatic daylighting controls, and requires a lower LPA (85% of 2013 Title 24, Part 6 LPA). The IOUs request that CPUC reconsider the following conclusions stated in the Impact Evaluation Report about poor compliance with the daylighting control requirements for alteration projects given the existence of Option 2 to comply with the lighting alteration code:	Section 2.2.5 revised to reflect option 2 sites.	**With regard to application of the standard to NRAs:** The alterations savings for daylighting controls are included in the evaluated potential savings for standard B34: Nonresidential Lighting Alterations, New Measures. Both the reported and evaluated potential savings for standard B34 were based on the CEC's impact analysis. The CEC report states on page 14 that daylighting was modeled as part of the 2013 lighting standards (note that while this section is titled Nonresidential Newly Constructed Buildings, the text says that "most requirements apply to new construction, but some requirements have been evaluated for their effect as alterations to existing buildings".) Additionally, the IOUs indicated in email correspondence from Yanda Zhang on 12/3/2015 that the B34 standard savings from the CEC were based on the daylighting CASE report as well as other CASE reports for lighting controls. The special investigation did not affect the findings with regard to potential savings or the ESAF values used to calculate gross savings for the NRA standards. As noted in Table 7 of Appendix F, this control requirement was investigated since it is a mandatory requirement that is not modelled in the EnergyPro software used to determine ESAF values for lighting alteration projects.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
					"Conclusion: Compliance with some specific code requirements was relatively poor… Another example was common failure to meet the mandatory daylighting control requirements in commercial buildings, particularly in alterations, and incorrect calculations" (Impact Evaluation Report, page ix and page 94). "For alteration sites, we determined that 89% (34 of 38) had at least one space with daylighting requirements, of which 26% (9 of 34) were confirmed to have controls installed. However, 3% of alteration sites (1 of 38) had daylighting controls installed even though they were not required to" (Impact Evaluation Report, page 37). "Space-by-space analysis showed similar results with higher installation rates in new construction projects… For the alteration sites, controls were required in 44% (54 of 122) of the spaces and they were installed in 30% (16 of 54) of the spaces where they were required. They were also installed in an additional 14 spaces where they were not required. Overall, controls were installed in 25% (30 of 122) of the alterations spaces" (Impact Evaluation Report, pages 37 and 38).		**With regard to Option 2:** Compliance option data was not collected during the site surveys. After being made aware of Option 2, we have reviewed the analysis and made adjustments. For alteration sites, if the installed lighting power was less than 85% of the allowed value, and the space did not have manual controls, we assumed that compliance Option 2 was selected. After factoring in the (assumed) Option 2 sites, we found that only 25% of the alteration spaces require controls. Of these spaces, only 13% (4/30) had the required controls installed (versus 30% in our previous analysis). The report has beenr revised to reflect these findings. Based on this low rate of compliance, we stand by our conclusion that compliance with the daylighting control requirement is relatively poor.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
					It was not clear if/ how the results of the special investigation on daylighting control compliance were factored into the evaluation of the Net Program Evaluated Savings from the NRA standards. Did the reported foregone savings in the special investigation (Figure 5 of the Impacts Evaluation Report) result in lower Net Program Evaluated Savings for the NRA standards presented in Table ES-2 "Evaluated vs. IOU Estimate: 2013-2015 PY 2013 Title 24 Electricity Savings (GWh)" of the Impact Evaluation Report? If the evaluated savings of the NRA standards were discounted based on the results of the special investigation that found relatively high foregone savings due to low compliance with automatic daylighting controls, then the IOUs request that CPUC confirm that the foregone savings are not inadvertently overstated due to buildings that may have complied with the daylighting alterations requirements using Option 2 (lower lighting power). Specifically, the IOUs are requesting the following clarification about the analysis of the 49 buildings that were surveyed to evaluate compliance with lighting alteration requirements: • Was information collected on the compliance option (Option 1 or Option 2) used to adhere to the daylighting control alterations requirements? What was the distribution of compliance using Option 1 and Option 2? • What was the as-built lighting power by space type for each building? Did the buildings without advanced daylighting controls have lighting power levels that were 85% or lower than the 2013 Title 24, Part 6 LPA requirements?		

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
29	Standard B41 HVAC Efficiency			IOUs	HVAC Equipment Efficiency (Standard B41) The Impact Evaluation Report states that the IOUs were assigned an attribution score of zero percent for the HVAC Equipment Efficiency measure (Standard B41). The report states that "since the California Title 24 standards went into effect on July 1, 2014 Cadmus determined that regardless of IOU contributions, the State of California would have been required by law to adopt the standard" since "DOE mandated that states adopt ASHRAE 90.1-2010 HVAC efficiency requirements by October 2013" (Impact Evaluation Report, page 74). States are not required to adopt any provision in ASHRAE 90.1 into their building codes. As stated in DOE's final determination (dated October 19, 2011), "[s]tates are required to certify that they have reviewed the provisions of their commercial building code regarding energy efficiency, and as necessary, updated their code to meet or exceed Standard 90.1–2010." As can be seen in Figure 1 below, as of January 2017 (seven years after ASHRAE 90.1-2010 was approved) only 13 states have adopted building codes that are as stringent as ASHRAE 90.1-2010. California is one of only three states that has voluntarily adopted a commercial building code that is overall more stringent that the current edition of ASHRAE 90.1 (2013). California was not mandated to adopt the equipment efficiency requirements in ASHRAE 90.1-2010, but voluntarily chose to do so.	Yes. Table 33 and Section 3.4 have beeen revised	Based on the additional information provided, CPUC staff agreed that Cadmus should reconsider attribution for this standard. 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%. The report and the ISSM analysis have been revised to include this attribution value. Note that this adjustment being made is an exception to the usual protocol and does not set a precedent to provide additional documentation after publication of a draft report.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
					Federal law directs the U.S. Department of Energy (DOE) to review the federal minimum efficiency requirements for certain commercial and industrial equipment whenever ASHRAE 90.1 amends its standards for such equipment (42USC 6313(a)(6)(A)). The following equipment is subject to this "ASHRAE Trigger" requirement: • Small, Large, and Very Large Commercial Package Air Conditioning and Heating Equipment • Single Package Vertical Air Conditioners and Heat Pumps • Packaged Terminal Air Conditioners and Heat Pumps • Warm-air Furnaces • Commercial Packaged Boilers • Storage Water Heaters, Instantaneous Water Heaters, and Unfired Hot Water Storage Tanks As a result of the "ASHRAE Trigger" requirements, ASHRAE has taken the lead on establishing more stringent standards for the equipment in question, and DOE typically adopts ASHRAE's equipment efficiency levels. Generally speaking, ASHRAE does not complete a comprehensive market and cost analysis on measures it adopts into ASHRAE 90.1. However, ASHRAE does complete a market and cost effectiveness analysis for the equipment efficiency values. The analysis ASHRAE provides informs the DOE's analysis of the ASHRAE equipment efficiency values and streamlines the adoption of ASHRAE equipment efficiency levels into the federal appliance standards.		

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
					Since the equipment efficiency values that are adopted into ASHRAE 90.1 will mostly likely become the federal minimum efficiency standards, states have a unique opportunity to adopt the equipment efficiency values that appear in ASHRAE 90.1 using a simplified process. The California Energy Commission (Energy Commission) is not obligated to adopt ASHRAE 90.1 equipment efficiency values into Table 110.2 of Title 24, Part 6, but if the Energy Commission chooses to do so it can adopt the equipment efficiency values without conducting a cost-effectiveness analysis. The Energy Commission can adopt the efficiency values before DOE completes their cost-effectiveness analysis and before DOE adopts the standards. Given the DOE rulemaking process is typically slower than the Energy Commission's rulemaking process, this essentially means that California can adopt the equipment efficiency regulations that will become federal law several years earlier than the federal requirements will take effect. In terms of the HVAC equipment efficiency levels in ASHRAE 90.1-2010, the nergy Commission elected to adopt those into Title 24, Part 6 earlier than was required by federal law in large part due to the IOUs' effort and support for early adoption and alignment with ASHRAE 90.1. The process to adopt ASHRAE standards into Title 24, Part 6 is also not automatic; the Energy Commission is still required to conduct a public rulemaking to update the code.		
					The IOUs began work on the HVAC efficiency measure in 2009, which is before ASHRAE 90.1-2010 was approved in October 2010 and before DOE completed its rulemaking to adopt the standards (DOE Final was published in 2012), and invested significant effort and resources into the process to update the HVAC equipment efficiency levels in Title 24, Part 6. This effort included the IOUs' participation in the Energy Commission's public workshops and hearings through both the pre-rulemaking and rulemaking processes, and the development of the HVAC Equipment Efficiency Codes and Standards Enhancement (CASE) Report that involved data collection, market research, a cost-effectiveness analysis, an energy impacts analysis, and stakeholder outreach.		

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
					The IOUs also contributed to the adoption of the ASHRAE 90.1-2010 HVAC efficiency requirements by DOE, as described in the memo entitled, Federal Standards for Small, Large & Very Large Commercial Package Air Conditioners and Computer Room Air Conditioners, that was submitted to CPUC as part of the 2013-2015 C&S Impact Evaluation for the appliance standards. The IOUs were an active participant in DOE's rulemaking process, and specifically collected data, conducted analyses, participated in DOE public meetings, and submitted comment letters to DOE in support of ASHRAE 90.1-2010. The IOUs also worked closely with several national energy advocate organizations such as the Appliance Standards Awareness Project (ASAP) and the Northwest Energy Efficiency Alliance (NEEA) throughout DOE's rulemaking to build support for DOE's adoption of the ASHRAE 90.1 efficiency levels. The IOUs have a history of supporting the adoption of ASHRAE efficiency levels into Title 24, Part 6, (which we continued in the 2016 and 2019 code cycles), and we have invested resources to help the Energy Commission analyze these measures. This helps the Energy Commission ensure that the state's building code is keeping pace with ASHRAE, and results in significant energy savings that otherwise would not be achieved. An attribution score of zero percent for the support of ASHRAE measures is inconsistent with this practice, and suggests that the IOUs should not continue this work. The IOUs would like to request that CPUC reconsider assigning an attribution score of zero percent for our significant involvement in the Energy Commission's rulemaking to adopt the HVAC equipment efficiency measure.		

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
30	Supermarket Refrigeration (Standard B75)			IOUs	In our review of the Impact Evaluation Report and appendices we discovered a discrepancy between the interactive effect factors presented in Table 22 of the report and Table 13 in the appendices for the supermarket refrigeration measure (Standard B75). We believe that savings from process measures should not be scaled to account for interactive effects. We recommend that CPUC update Table 13 in the Appendices document so there are no interactive effects applied to Standard B75.	Yes	We agree with the comment and have revised the analysis inputs, the report, and the appendices such that no interactive effects are applied to standard B75.
31	Conclusions and Recommendations			Carol Yin PhD, Yinsight, Inc.	IESR. Would it be possible for the evaluation team to include an appendix with recommendations presented using the table from the CPUC Energy Division Impact Evaluation Standard Reporting Guidelines? Thank you! — Question by Carol Yin on May 30, 2017	Yes	The requested table is included as an appendix.
	CodeCycle memo dated June 5, 2017			CodeCycle	Note: With regard to the memo *Comments on the "California Statewide Codes and Standards Program Impact Evaluation Volume Two: 2013 Title 24" (Herein, Draft 2013-2015 Evaluation), May 23, 2017* submitted by Dan Suyeyasu and Kim Goodrich of CodeCycle on June 5, 2017, the introduction and section 1 provide an overview of specific comments detailed in Sections 3,4, and 5. Section 2 contains a statement that Codecycle expects to comment on Uncertainty and Precision at a later time. We have responded to the specific comments in Sections 3, 4, and 5 here. From the beginning of section 3 through the end of part 3 a) and again insection 3 d) the memo is focused on a memo Cadmus produced in 2009. This commentary is not relevant to the current evaluation.	N/A	N/A

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
32	CodeCycle memo dated June 5, 2017			CodeCycle	3 b) Taking the Performance Approach Too Far Having adopted a performance method for a limited purpose in the 2006-2008 Evaluation and 2010-2012 Evaluation – ensuring that compliance tradeoffs driven through performance modeling were properly credited – the performance-based evaluation set forth for prescriptive measures has now been extended to all mandatory measures without proper notice or review. In reviewing the Draft 2013-2015 Evaluation, a wide range of mandatory measures are evaluated for energy savings but with compliance numbers derived from the performance modeling process (ESAF). For mandatory measures, the Gross Savings should be merely a product of the Potential Savings and the actual compliance rate (Figure 1: Step 2) of the particular mandatory measure in question. Whether other efficiency measures are installed in the building is irrelevant to determine a percentage installation rate for the target measure (i.e. compliance rate). If the same measure is installed where it is not mandatory, that is also irrelevant.	No	The primary objective of the impact evaluation is to determine the energy savings that will be achieved in construction projects that are required to conform to the 2013 Title 24 energy code. The evaluators used field research to develop estimates of the energy savings realized (gross savings) compared to the energy savings expected (potential savings) at the project level. This estimate is purposefully described as the Energy Savings Adjustment Factor (ESAF) since the focus is on energy savings. Generally, estimates of measure-level compliance were not possible within the project resources.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
33					3 c) The Reason for Using a Performance Model to Account for Interactive Effects in Determining Potential Savings Differs from the Reason to Use a Performance Model to Properly Assess Measure Installation Rates to Determine Gross Savings The Draft 2013-2015 Evaluation is right to note that a whole building model is essential to address interactive effects between measures, but that logic only applies to Figure 1: Step 1-b in the above annotated flow chart. In every context, the 2013-2015 Evaluation should be far more precise in denoting the analytical steps where its arguments in favor of a whole building analysis is specifically targeted (Step 1-b or Step 2?). The arguments for using whole building energy models differ between those steps, and the appropriate application of such models differs as a result. For instance, if the IOUs implemented a more stringent mandatory requirement for primary sidelit controls, the UES for that measure would be reduced by simultaneous Title 24 2013 reductions in allowed LPD in a building (accounted for in Step 1-b). But, whether the savings from the mandatory requirement for primary sidelit controls are realized in a given building is assessed in Step 2. If compliance with the primary sidelit control requirement is 50%, then the 3 Figure 1 is an annotated version of the Draft 2013-2015 Evaluation's Figure 1, pg. 36 gross savings from that measure are half of the potential savings. If a building has an exceptionally low LPD but no daylight controls, that should not impact the gross savings from the primary daylighting control measure because the low LPD lighting was not installed in lieu of the primary daylighting controls. Title 24 does not allow tradeoffs for such controls in the compliance calculation process.		

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
34	CodeCycle memo dated June 5, 2017				3 e) Proposed Clarifications for the 2013-2015 Evaluation The following statements in the Draft 2013-2015 Evaluation should be clarified to reduce ambiguity on these points moving forward: The statement: "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." Should be clarified as follows: "Cadmus agrees that whole building simulation is a better approach to estimating *unit energy savings* for new construction than summing estimates of savings from individual measures in isolation" The statement: "A weakness in the individual code/measure approach is the lack of a method for taking into account interactions among requirements." Should be clarified as follows: "A weakness in the individual code/measure approach in evaluation *Unit Energy Savings* is the lack of a method for taking into account interactions among requirements." The statement: "This factor captures the percent of the energy saving potential that has been realized in the market." Should be clarified as follows: "This factor (ESAF) captures the percent of the energy saving potential that has been realized in the market for prescriptive measures in buildings that complied with Title 24 using the performance path." Another example conflating energy model functions at Step 1-b as compared to Step 2 is evident in this statement: "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."	No	Please see our response to comment 32 above. The proposed clarifications are not consistent with the evaluation approach or the role of ESAF values.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
					3 e) (continued) Energy is an essential part of the analysis at Figure 1: Step 1-b (in terms of UES) and potential energy savings are derived by combining Step 1-a with Step 1-b. Steps 2 through 5 need to produce percent (%) adjustment factors, all of which adjust the potential energy savings coming from Step 1. The CPUC protocols actually require an "evaluation of strict conformance to regulatory requirements" for mandatory measures (and for prescriptive measures when using the performance method), per the 2009 Cadmus memo. An "evaluation of strict conformance to regulatory requirements" will produce the required percent adjustment needed in Step 2, producing the data needed to assess the actual impact of any new mandatory measure. Offsetting energy impacts – positive or negative – from other building systems are simply irrelevant to determining the impact of a new mandatory measure as adjusted at Step 2. Similar clarifications should be made throughout the report to make clear that 1) The need to account for interactive effects happens in Step 1-b and 2) The performance-based assessment of compliance (i.e. ESAF) is only suitable for prescriptive measures in buildings that complied with Title 24 using the performance path.	No	CodeCycle appears to have an alternative approach to the determination of potential energy savings than what the CPUC and evaluators defined and executed. The evaluation was focused on estimation of energy savings expected from projects constructed under the 2013 Title 24 energy code. The evaluation was designed to be conducted within the resources available from the CPUC.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
35					3 f) There are, Generally, Two Types of Energy Models, and their Respective Uses Should be Clearly Defined in the Report Whole building energy models generally come in two varieties: • An assessment of code compliance, with the energy model needing to adhere to a range of strict modeling requirements (e.g. ACM), some inherent to the modeling software and some imposed on modelers through regulation. Such modeling also produces a tightly controlled code baseline model. (Herein, Compliance Modeling) • An assessment of actual energy use, with a modeler allowed to use whatever modeling capabilities at their disposal to achieve the desired estimate. Such modeling does not include a tightly controlled code baseline model. (Herein, Estimation Modeling) In the 2013-2015 Evaluation, Estimation Modeling could be used at Step 1-b to assess Unit Energy Savings. This could be a necessity as Compliance Modeling is not designed to handle mandatory measure compliance. But a Compliance Model should be used at Step 2 to assess the As-Built model. Whenever a building energy model is discussed in the report, the authors should state whether it is a Compliance Model or an Estimation Model. The 2010-2012 Evaluation used an Estimation Model at Step 2, attempting to assign energy savings to the compliance score for measures that a standard compliance model would not evaluate. The Estimation Model was then compared to a code baseline model from the Compliance Modeling framework. This mixing of modeling methodologies – an unconstrained Estimation Model combined with a constrained code baseline model – led to a significant overestimation of compliance levels and CAF levels in the 2010-2012 Evaluation.	No	The terms and definitions offered in this comment are not established in the existing evaluation protocol. The evaluation relied on energy models built within CEC-certified ACM-compliant software (EnergyPro) to determine energy consumption for each project/building in three scenarios: the project just complies with the 2008 code, the project just complies with the 2013 code, and the project as-built. Extra care was taken to ensure that PAFs were only applied when permitted by the 2013 Title 24. This approach produced the ESAF values needed to estimate overall statewide savings.
36					3 g) Example of Applying Performance Compliance Results to a Mandatory Measure	No	The example is offered to illustrate a point about measure-level compliance but this is not relevant to the evaluation approach or results.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
37					3 h) Identifying Mandatory Measures in the Analysis We leave it to Cadmus and the CPUC to identify those measures analyzed in the 2013-2015 Evaluation that are mandatory measures rather than prescriptive measures. Any measures that are incorporated in Title 24 2013 between Subsection 110.0 and Subsection 130.5 are mandatory measures. Some of the broader measures identified in the Draft 2013-2015 Evaluation are composed of mandatory and prescriptive subcomponents. Those subcomponents should have different compliance adjustments applied to them (Figure 1: Step 2) just as different UES values are sometimes applied.		

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
38					4) Remove the Unbounded ESAF from the Report CPUC staff have concluded that the Unbounded ESAF does not reflect energy savings impacts driven by the IOU code advocacy program. The Unbounded ESAF also does not represent a level of code compliance. We strongly recommend that the metric be removed to minimize the prospect of confusion from the metric. If CPUC staff can explain the analytical value provided to decision makers by the Unbounded ESAF, perhaps the Unbounded ESAF should stay in the report. But merely stating how an unbounded ESAF is calculated does not illustrate its value to decision makers. As an example of the possible confusion, the Draft 2013-2015 Evaluation states: "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."11 This statement ends with the clause "the savings", which is unduly ambiguous. Does "the savings" refer to savings driven by the new measures introduced to the code by the IOUs? Does it refer to energy savings delivered by the whole of Title 24, whether developed by the CEC, the IOUs, or other stakeholders (e.g. ASHRAE)? Or does it refer to some other type of savings? In a similar vein, we propose clarifying this statement: "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." As follows: "As discussed earlier, the CPUC staff believe that outside factors, and not the additional measures added to the 2013 code through IOU code advocacy efforts, cause buildings to be more efficient than required by the code at the site level." The 2013-2015 Evaluation is assessing solely the impact of the marginal code improvements added through IOU code advocacy efforts. It is not assessing the impact of the whole of Title 24. It is imperative to minimize ambiguity between those distinct impacts.	No	The evaluation is based on the potential savings from all measures adopted by the CEC that the the IOUs associated with the program advocacy efforts. In this way, the results only reflect the savings associated with the same set of measures. With regard to the bounded and unbounded ESAF values, the CPUC specified that unbounded ESAF values be computed and reported to provide continuity with past evaluation methods. In the 2013-2015 evaluation, the CPUC also specified the approach used to produce bound ESAF values. The evaluation report and appendices includes both sets of values.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
39	Special Investigations Daylighting Controls	Section 2.2.5, P32	Comment	CodeCycle	5 **b) An Analysis of Daylighting Control Compliance** The Special Investigation also looks at compliance with daylighting control requirements. The data presented in that analysis comparing installation instances in spaces where controls are required is quite useful. For the mandatory daylighting controls (Measure B43), that is precisely the type of data that should be used to determine the Step 2 level of non-compliance. The data provided on lighting control installation in spaces where such controls are not required is misleading and is not pertinent to any of the discussions on mandatory control evaluation that has taken place over the past two years. In the following table, the only information that describes compliance with the pertinent Title 24 requirements, and therefore might be tied to IOU code advocacy efforts, are the rows labeled “Required”. (reference to P38 of report, memo includes image of Table 16) The “Not Required” rows are assessing something unrelated to Title 24, as are the “Total” rows, which include the “Not Required” data. This distortion is further illustrated below, where installations in buildings where the controls are not required seems to improve the “Installation Rate of the Required Daylighting Controls.” (reference to p38 of report, memo includes image of Table 17)	Yes	An objective of our field data collection process was to collect and document all elements of each project/building that would impact energy consumption. While we agree that the presence of daylighting controls that are not required does not affect the primary evaluation of whether projects/buildings will deliver the energy savings expected from the 2013 Title 24 code, this information is useful to some stakeholders. We have clarified in the text that the presence of controls that were not required does not affect our conclusions with regard to energy performance relative to the 2013 Title 24 code.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
					5 b) (continued) Determining the "Installation Rate of the Required Daylighting Controls" should involve 1) determining where the measures are required, and then 2) seeing if the measure is actually installed in that location. For buildings using the performance method, some trading between required spaces and non-required spaces would be a suitable component of a broader compliance analysis (consistent with CEC rules), but the 2013-2015 Evaluation's inclusion of installation rates in spaces where measures are "Not Required" goes far beyond that narrow case. This is particularly clear since the bulk of compliance with daylighting control requirements involves primary sidelit areas, which is a mandatory requirement and does not permit tradeoffs. This section should be rewritten, removing any reference to installations in spaces where the controls were "Not Required". Those control installations may save energy, which is good, but they have no relation to Title 24 compliance or the impacts driven by IOU code advocacy efforts.		

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
40	Special Investigations PAF	Section 2.2.6, P41	Comment	CodeCycle	5 **a) An Analysis of PAF Applicability** There are three broad categories of ways to apply PAF credits to a building's lighting system: 1) Apply no PAF credits 2) Apply PAF credits as permitted by Title 24 3) Ignore Title 24 rules in applying PAFs, including assigning PAFs reserved for a given control type (e.g. Partial On Occupancy Sensors) to controls that do not have corresponding PAFs (e.g. a countdown timer) to ensure that the non-PAF-eligible control receives a control credit in the energy model. In reviewing the 2010-2012 Evaluation, we learned that the 2010-2012 Evaluation applied PAFs to buildings using PAF Method 3, ignoring all Title 24 limitations on the usage of PAFs (i.e. control type, space type, space size, and mandatory measures). In the two sample files we analyzed, this led to average PAF values of ~20%, and a likely increase of CAF values of 300% - 500% as compared PAF Method 2. The introduction to the PAF discussion in the Draft 2013-2015 Evaluation suggests that the evaluation responds to CodeCycle's questions about the 2010-2012 Evaluation. But, the Draft 2013-2015 Evaluation reviews the potential difference between PAF Method 1 and PAF Method 2, a delta many times smaller than if Method 3 was compared to Method 2. This result provides no useful information to the concerns CodeCycle has raised regarding the 2010-202 Evaluation and should be removed from the 2013-2015 Evaluation as being misleading. The recommendation related thereto should also be removed. CodeCycle continues to recommend that the CPUC review the actual discrepancies found in the 2010-2012 Evaluation, comparing PAF Method 3 with the proper methodology using PAF Method 2. Further, the Draft 2013-2015 Evaluation should clarify whether PAF Method 1, 2, or 3 was used to calculate the ESAF values in the 2013-2015 Evaluation.	Yes	All of the models used to determine energy savings adjustment factors (ESAFs) for this evaluation were constructed to apply PAF credits as permitted by Title 24 which corresponds to Method 2 in the comment. We modified the description of model quality control in Section 2.2.3 to include the statement "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." For this special investigation, Cadmus modifed five of the site models to find energy consumption if no PAF credits were applied. The modified models correspond to Method 1 in the comment. This analysis and the description of it in our report were done specifically at the request of the CPUC.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
41		Section 4.6	Question	IOUs	"Instead, Cadmus used a Monte Carlo simulation approach to examine the uncertainty around estimates of cumulative savings in 2013-2015." How is a Monte Carlo simulation approach validly employed given a bounded savings estimates protocol being in place?		The MC simulation uses probability distributions and minimum an dmaximum values for all evaluted input parameters. The bounds on ESAF were set to zero and one, reflecting the bounded estimates.
42		Section 4.6.1 Inputs	Comment	IOUs	"For all of the remaining evaluated inputs, Cadmus calculated the standard deviation of the mean (i.e., the standard error) based on plus or minus 20% relative precision at 90% confidence (or precision reported in the previous or current evaluation). " Just an observation, if this were good enough for previous evaluations for a subset of "evaluated inputs" then why not use this "standard deviation" for all the inputs now? Also, using bounded savings shouldn't the "relative precision" be different?		Edited to clarify.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
43		Table 66 Inputs to Uncertainty Analysis	Question	IOUs	Regarding ESAF values: Were bounded savings used throughout? How was a simulation value treated if it caused saving to exceed 100% of the expected savings value? Was it truncated before developing the final distribution, thereby keeping the use of the "bounded" protocol consistent? How can a truncated value be assumed to be normally distributed?		Were bounded savings used throughout? Yes, for reporting ESAF were bounded at the site level. How was a simulation value treated if it caused saving to exceed 100% of the expected savings value? Minimum and maximum values of one and zero were used for the ESAF distribution. Was it truncated before developing the final distribution, thereby keeping the use of the "bounded" protocol consistent? Yes. We limited (truncated) values for individual sites to determine the bounded ESAF values. We then constructed a distribution based upon an assumed range (e.g., +/-20%). In cases where precision values were available for the unbounded values, we used the unbounded precision for the limits of the uncertainty analysis range. This is because the precision of the bounded values can be no worse than the precision of the unbounded values. How can a truncated value be assumed to be normally distributed? Where appropriate, we used a truncated normal distribution.
44		Table 67 Inputs for Standards Responsible for Most (82%) GWh Savings	Question	IOUs	Is this supplemental to cover Phase 2 or both phases? Looks like some measures pertain to Phase 1 report.		This uncertainty analysis covers all Phase 1 appliances and all of the Phase 2 Volume 1 appliances and Volume 2 building codes.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
45		Section 4.6.2 Results	Question	IOUs	What would be the evaluation for the unbounded savings numbers without gas? Is the confidence higher and the ±25% less? Cadmus was asked to run the numbers both ways in the impact report, but it seems they only ran the bounded numbers in the uncertainty analysis report. Is this the case?		Yes, the uncertainty analysis only includes the bounded values. Gas and electric savings are independent, so the electric savings and uncertainty are not impacted by the gas savings.
46		Table 68	Question	IOUs	How should we interpret these results in light of the "bounded" savings protocol? Can we see the code/standard specific results? Do you have results for both bounded and unbounded estimates?		The scope of this evaluation does not include reporting on code/standard specific results. However, the CPUC may decide to request these at a later date.
47		Table 68	Question	IOUs	Is there interaction between the NOMAD adjustment and the bounded ESAF? If so, how is said interaction handled within the Monte Carlo simulation framework?		Per the protocol, the NOMAD adjustment is always applied after the ESAF value. The interaction is the same in the Monte Carlo simulation.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
48			Comment	CodeCycle	1) The Precision Calculation for ESAF Values is Incorrect The research plan for the 2013-2015 Evaluation states that it will follow the protocols used in the 2010-2012 Evaluation, unless noted otherwise. CodeCycle submitted comments on the Research Plan, noting that the formula used to compute precision of compliance estimates in the 2010-2012 Evaluation was incorrect. In response to CodeCycle's comments on the research plan, Cadmus and CPUC reaffirmed the method used in the 2010-2012 Evaluation to calculate precision: "Cadmus statisticians determined the confidence and precision values reported using standard methods. The formulas used in these calculations are included in section 5.2 of the evaluation report. We are unsure whether the formula given for standard error is correct or if it is alternate form. The actual formula used to calculate standard error is given below: SE(CAF) = SE(Total As-Built Savings) / Total 2008 Savings We will continue to include details on formulas and calculations in the report on the 2013-2015 project."1 Notably, the "report on the 2013-2015 project" does not include a formula on how precision was calculated for compliance estimates, as was promised. We presume the precision calculation is based on the standard error formula set forth in the response to comments: SE(CAF) = SE(Total As-Built Savings) / Total 2008 Savings The standard error calculation is incorrect, with a critically misplaced closing parentheses (in red), as explained below. There is also a summing of values within the calculation that is inappropriate, as it is the very nature of the standard deviation (a subset of standard error) to measure the spread between values. Summing the components of the evaluation undermines the ability to measure the spread between those values.		Cadmus calculated the standard error consistent with the sample design and variance estimation for the estimator described in 2013-2015 evaluation report. As described in the report, this is different from the 2010-2012 evaluation.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
			Comment	CodeCycle	The ESAF [i.e. CAF] for a single building, extrapolated to the 2013 standards is: ESAF = As-Built Savings / 2013 Savings And, therefore, a correct standard error calculation would follow this form: SE(ESAF) = SE(As-Built Savings / 2013 Savings) The position of the parentheses to properly calculate the standard error of compliance rates is critical. None of the materials provided in 1) the Draft 2013-2015 Uncertainty Analysis, 2) the Draft 2013-2015 Evaluation, 3) the final 2013-2015 Evaluation Plan, or 4) the 2010-2012 Evaluation explains why it is acceptable to pull "2013 Savings" out of the direct SE analysis and use it as an independent variable when "2013 Savings" is a central component of the ESAF and contributes greatly to the variability in ESAF values between buildings. It would be mathematically permissible to remove "2013 Savings" from inside the parentheses – as was done in the 2013-2015 Evaluation – if two things were true: 1. The "2013 Savings" were a constant, with a fixed value for all projects. 2. The value moved outside of the Standard Error calculation were a per-building value, rather than a sum-total across all buildings: i.e. "Total 2013 Savings". Test 1 fails because the "2013 Savings" per building varies widely by building based both on the specifics of Title 24 requirements applicable to that building (between 2008 and 20013) and based on the overall scale of the building. Because "2013 Savings" is not a constant across all buildings, it must remain inside the parentheses for purposes of calculating the standard error (and subsequent calculation of relative precision).		We use the standard error calculation for a ratio estimator, consistent with the UMP sampling chapter.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
			Comment		Test 2 fails for a number of reasons, but the summing of building values in the denominator is most problematic because it distorts the impact of sample size on the precision calculation. All things being equal, a standard error should be cut in half as the sample size is quadrupled. With the 2013-2015 implementation, the value is reduced to 1/8 for every quadrupling of sample size, with an initial halving driven by the square-root of the sample size (in the standard error formula), but then further dividing by four because the denominator is the sum of "2013 Savings" across four buildings (i.e. "Total 2013 Savings"). The difference between: SE(ESAF) = SE(Total As-Built Savings) / Total 2013 Savings As used in the analysis and the proper calculation: SE(ESAF) = SE(As-Built Savings / 2013 Savings) can be significant. For a sample size of 50, totaling the "2013 Savings" in the denominator instead of using a per building value will produce a value ~50x too small.		See previous.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
49				CodeCycle	2) The Uncertainty Analysis is Incorrect because it Uses Incorrect Precision Estimates for Compliance As discussed above, the 19% estimate of relative precision for lighting alteration ESAF values is incorrect. That 19% value is then used to calculate the overall uncertainty via the Monte Carlo simulations. Once the standard error and relative precision are recalculated with the denominator of each ESAF calculation retained in the overall standard error calculation, the corrected relative precision for lighting alteration ESAF values should be used to rerun the Monte Carlo simulation. The corrected precision and uncertainty numbers are likely to be exceptionally large. This is a direct result of the significant variability found in ESAF values due to the small denominator in the ESAF calculation (e.g. ~5%). A highly variable ESAF will result in a high standard error and high uncertainty.		See previous.

No.	Topic	Section/ Reference	Question or Comment	Source	Question or Comment	Change(s) to Report?	Response
50				CodeCycle	3) The Best Available Estimate of Precision for New Construction Compliance is a Calculation of the Relative Precision Across the 17 New Construction ESAF Values The Draft 2013-2015 Evaluation does not calculate a level of relative precision for the New Construction ESAF values: "Precision for new construction sites was unable to be calculated due to the small number of sites sampled within each jurisdiction."2 We do not understand this, as there are 17 separate ESAF values across which a standard error and relative precision could certainly be estimated. While there may be a desire to analyze the data in smaller groups for weighting purposes, if that cannot be done then a direct evaluation of the 17 available values should be completed. The Draft 2013-2015 Uncertainty Analysis – confronted with no estimate of relative precision for New Construction – uses a value of 20%. There is no obvious need to use a proxy number when a value can be directly calculated. 17 buildings provided the basis for the New Construction savings estimate. The variation in the ESAF values across those 17 buildings should be used to calculate the relative precision of the ESAF for purposes of inputting a value range into the Monte Carlo simulation. That standard error and resulting relative precision from the 17 buildings is the best available data for that input into the Monte Carlo simulations. As with the necessary corrections for calculating Lighting Alteration relative precision, the actual relative precision for the 17 buildings is likely to be far higher than 20%.		Due to data collection challenges, sample sizes within each stratum were too small to reliably estimate standard errors within each stratum. We did not pool unweighted results.

P. Recommendations

Study ID	Study Type	Study Title	Study Manager
ED_CS_1	Impact	California Statewide Codes and Standards Program Impact Evaluation Report Phase Two, Volume One: Appliance Standards	Cadmus

Rec No.	Program or Database	Summary of Findings	Best Practice / Recommendations	Recommendation Recipient
1	Codes and Standards Program	Delivery of program savings estimates, CASE reports, and CCTRs improved, but significant gaps remain in the documentation available to evaluators. Improvements include the following: • Nearly all parameters (except for attribution values of federal standards) were provided at the start of the evaluation in the ISSM format. • Market volume sources were documented, as requested. • CASE reports and CCTRs were delivered as planned and in a shorter time period than previously. • Although no federal attribution values were provided, attribution documentation to support federal standard adoption generally was complete and met the requirements previously identified.	Statewide program administrators and the CPUC should resolve data gap issues before starting the next impact evaluation. The IOUs should update the Code Change Theory Reports or provide other supplementary documentation that reflects the adopted standard.	California IOUs, CPUC

Rec No.	Program or Database	Summary of Findings	Best Practice / Recommendations	Recommendation Recipient
2	Codes and Standards Program	Verifying compliance has become more challenging. This issue includes the following factors: • Increasing complexity of regulations and data needs to assess compliance. For example, Title 20 regulations on battery charger systems used the maximum 24-hour charge and maintenance energy as the performance parameter. This information, however, this information was not readily available in the product literature; and only testing provided a way to determine compliance for products not listed on the CEC list. Similar issues occurred with regulations on swimming pool systems, which changed from pump motor requirements to specific control settings. • Product proliferation. For products such as televisions and battery charger systems, the CEC listing process lagged behind the rapidly changing products available on the market. Measuring compliance requires additional research for unlisted products.	The CPUC and evaluators should consider collaborating with the CEC to efficiently use resources for determining compliance.	CPUC and CEC

Rec No.	Program or Database	Summary of Findings	Best Practice / Recommendations	Recommendation Recipient
3	Codes and Standards Program	Grouping multiple product types/standards in a single CCTR tends to limit the evaluators' ability to assign attribution scores to each standard. The attribution team found insufficient information to calculate factor scores for some individual product types when supporting documentation grouped them with other products. In most instances, products were grouped in a similar manner to the rulemakings themselves. However, in federal standards there are often contributions and discussions based not on the rulemaking as a whole, but rather a specific appliance category or regulation. The extent to which equipment types and contributions to those equipment types can be separated affects the ability of the attribution team to provide a more nuanced and granular attribution score.	Do not group unlike technologies together in a single CCTR.	California IOUs

Rec No.	Program or Database	Summary of Findings	Best Practice / Recommendations	Recommendation Recipient
4	Codes and Standards Program	Evaluating standards that target components (e.g., electric motors) proves challenging. Particularly for small electric motors, concern exists that products manufactured overseas may contain noncompliant parts. Verifying compliance is impossible, short of tearing out the motor. Even if testing offered an option, it would remain challenging to identify whether a product contained a covered product as components specifications are rarely available. Trade associations such as the National Electrical Manufacturers Association (NEMA) may prove useful in obtaining market data on domestic small motor manufacturers, but these statistics would likely not represent a large fraction of foreign suppliers.	Consider reevaluating these standards over time as more market studies are completed. Electric motor and small electric motor compliance also should be reevaluated after completion and application of the Certification, Compliance, Labeling, and Enforcement for Electric Motors and Small Electric Motors Final Rule.	California IOUs, CPUC, CEC, Evaluators

Study ID	Study Type	Study Title	Study Manager
ED_CS_1	Impact	California Statewide Codes and Standards Program Impact Evaluation Report Phase Two, Volume Two: 2013 Title 24	Cadmus

Rec No.	Program or Database	Summary of Findings	Best Practice / Recommendations	Recommendation Recipient
5	Codes and Standards Program	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.	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.	California IOUs, CEC, CPUC

Rec No.	Program or Database	Summary of Findings	Best Practice / Recommendations	Recommendation Recipient
6	Codes and Standards Program	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.	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.	California IOUs, CEC, CPUC
7	Codes and Standards Program	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.	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.	
8	Codes and Standards Program	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.	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.	CPUC

Rec No.	Program or Database	Summary of Findings	Best Practice / Recommendations	Recommendation Recipient
9	Codes and Standards Program	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.	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.	CPUC

Rec No.	Program or Database	Summary of Findings	Best Practice / Recommendations	Recommendation Recipient
10	Codes and Standards Program	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.	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.	CPUC
11	Codes and Standards Program	Our efforts to recruit homes to include in this evaluation were most successful when we worked with the building industry, particularly large builders.	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.	CPUC, Evaluators

Rec No.	Program or Database	Summary of Findings	Best Practice / Recommendations	Recommendation Recipient
12	Codes and Standards Program	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.	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. 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.	CPUC and California IOUs
13	Codes and Standards Program	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.	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.	CPUC

Rec No.	Program or Database	Summary of Findings	Best Practice / Recommendations	Recommendation Recipient
14	Codes and Standards Program	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.	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.	California IOUs and CEC
15	Codes and Standards Program	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.	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.	CPUC