California Energy Commission

STAFF REPORT

ENERGY EFFICIENCY COMPARISON

California's *Building Energy Efficiency Standards* and the International Energy Conservation Code and American Society of Heating, Refrigerating and Air-Conditioning Engineers and Illuminating Engineering Society of North America Standard 90.1

CALIFORNIA
ENERGY COMMISSION

Edmund G. Brown Jr., Governor

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ABSTRACT

The federal Energy Policy Act of 1992 requires each state to certify that it has reviewed and considered adopting the national model energy standard. All states must determine if its energy code meets or exceeds the current federal reference code and certify to the Secretary of the U.S. Department of Energy (DOE) its determination. The federal reference energy code for residential buildings is the International Energy Conservation Code, and for commercial buildings the reference standard is American Society of Heating, Refrigerating and Air-Conditioning Engineers and Illuminating Engineering Society (ASHRAE) Standard 90.1.

States must reevaluate the efficiency requirements of their code against those of the new federal building efficiency reference codes. This report documents the California Energy Commission's response to this federal law by providing a comparison of the energy savings effects between California's Title 24, Part 6, 2008 and 2013 *Building Energy Efficiency Standards* to the residential energy requirements of the 2009 and 2012 International Energy Conservation Code and to the nonresidential energy requirements of the American Society of Heating, Refrigerating and Air-Conditioning Engineers and Illuminating Engineering Society of North America *(ASHRAE/IESNA) Standard 90.1-2007 and 2010*.

This report concludes that California's *Building Energy Efficiency Standards* exceed the energy savings expected from requirements in residential Chapter 4 of the *2009 and 2012 International Energy Conservation Code* and from the commercial building requirements of *ASHRAE/IESNA Standard 90.1-2007 and 2010*. While significant improvements have been made to the energy stringency levels of the national reference energy codes, California's residential and nonresidential energy standards contain building measures and building performance operation impacts that are more rigorous, resulting in higher efficiency levels for new residential and nonresidential construction than expected to occur from efficiency requirements of the federal reference energy codes.

Keywords: California Energy Commission, *Building Energy Efficiency Standards*, International Energy Conservation Code, ASHRAE 90.1, energy comparison

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CHAPTER 1: Introduction

States are required by federal law to adopt an energy code that is at least as energy-efficient as the federal reference model energy code. When a new national model energy code is adopted, the U.S. Department of Energy (DOE) is required to determine whether the newly adopted code is more stringent than its predecessor. States have two years after the publication of this determination to certify that it has reviewed the provisions of its residential and nonresidential building code regarding energy efficiency and to report its findings as to whether it is appropriate for that state to revise its energy code requirements to meet or exceed the newly adopted reference national model energy code. The federal reference energy code for residential buildings is the *2009 and 2012 International Energy Conservation Code* (IECC); and for nonresidential buildings the federal reference energy code is the American Society of Heating, Refrigerating and Air-Conditioning Engineers and Illuminating Engineering Society of North America *(ASHRAE/IESNA) Standard 90.1-2007 and 2010*.

This California Energy Commission staff analysis compares the estimated energy savings for residential and nonresidential building energy efficiency measures of the *2008* and *2013 Building Energy Efficiency Standards* to the residential requirements of the *2009* and *2012 IECC*, and the nonresidential requirements of *ASHRAE/IESNA Standard 90.1-2007 and 2010*.

Building Energy Efficiency Standards

The Energy Commission first adopted energy standards for new buildings in 1977 and continues to revise these requirements in response to legislative mandates, changes and improvements to building systems and designs, and to improve compliance and enforcement. Overall, the Energy Commission's revisions to the residential and nonresidential standards have resulted in significant statewide energy savings and remain a cornerstone of state policy to reduce statewide energy use and greenhouse gas emissions. The *Building Energy Efficiency Standards* are contained in Part 6 of Title 24, California Code of Regulations, and often referred to simply as "Title 24."

The standards are separated into two parts: low-rise residential buildings of three stories or less, and nonresidential buildings, which also include high-rise residential buildings four stories or higher and hotel/motel occupancies. The standards prescribe minimum mandatory energy efficiency measures that must be met regardless of building type and additional energy efficiency measures that are dependent on building type. There are two methods of demonstrating compliance: prescriptive and performance. In all, the standards set the maximum energy allowance, expressed in terms of energy consumption per square foot of floor area per year that cannot be exceeded.

With the prescriptive method of compliance, every measure listed in the residential or nonresidential component package must be met or exceeded for the building to be in compliance.

Residential buildings must meet the prescriptive requirements prescribed in Table 151-C, Component Package D of the *2008 Building Energy Efficiency Standards*, and Table 150.1-A Component Package A of the *2013 Building Energy Efficiency Standards*[1].

Nonresidential buildings must meet the prescriptive requirements prescribed in Tables 143-A and B of the *2008 Building Energy Efficiency Standards,* and Tables 140.3-B and C of the *2013 Building Energy Efficiency Standards*.

When the performance approach is used, the energy effects of building features are analyzed to determine their overall effect on the total energy use of the building. Individual energy efficiency measures of the building can be less efficient than measures listed in the prescriptive tables so long as other more energy-efficient measures are used in other areas and the resulting building energy use is less than the maximum energy allowance level established by the standards. The performance approach uses alternative calculation method compliance software approved by the Energy Commission.

Reference Model Energy Codes

Building energy codes are minimum requirements affecting energy-efficient design and construction for new and renovated residential and commercial buildings. On the whole, building regulations govern all aspects of the design and construction of buildings, and building energy codes set an energy-efficiency baseline for the building envelope, building systems, and operating equipment. Improving these minimum requirements or broadening the scope of energy codes helps soften the environmental impact of buildings and result in additional energy and cost savings over the life cycle of a building.

Prior to passage of the 1992 Energy Policy Act, the federal government applied little pressure on states to improve the efficiency of buildings, although equipment improvements were federally mandated that set minimum efficiency levels for manufacturers of space-conditioning and water-heating equipment. With passage of the 1992 Energy Policy Act, a stronger consistent reference point was established for all states against which to adopt, modify, and/or compare their energy code.

The DOE is required by law (the Energy Conservation and Production Act, as amended [ECPA]) to issue a determination as to whether the latest version of the *International Energy Conservation Code* (for low-rise residential buildings) and the latest edition of *ASHRAE/IESNA Standard 90.1* (for commercial buildings and multifamily high-rise residential buildings) will improve energy efficiency compared to the previous edition of the corresponding code or standard. The DOE has one year to publish a determination in the *Federal Register* after each new edition of the code or standard is published, and states have two years from the determination date to respond to the DOE regarding the equivalency of their own energy code.

[1] http://www.energy.ca.gov/title24/

The IECC is developed under the auspices of the International Code Council (ICC) using a government consensus process. This process allows all interested parties to participate, but the final vote on the content of the codes is made by individuals associated with federal, state, or local governments who are also members of the ICC. The IECC is one of 14 model codes developed under the auspices of the ICC that, combined, provide the foundation for a complete set of building regulations covering all aspects of construction: plumbing, electrical, fire protection, fuel gas, energy, mechanical, and so forth. The ICC codes are updated every three years, providing a model that states and local jurisdictions can adopt as is or modify as necessary to reflect regional building practices or state-specific energy efficiency goals. California uses the ICC codes as the primary foundation for establishing the requirements of the *California Building Code*, except for energy efficiency, which are promulgated by the California Energy Commission's regulations encompassed in the *Building Energy Efficiency Standards*.

ASHRAE/IESNA Standard 90.1 is developed under the auspices of the American Society of Heating, Refrigerating and Air-Conditioning Engineers and the Illuminating Engineering Society of North America, using the consensus process of the American National Standards Institute (ANSI), which requires a balance of stakeholder interests. All interested parties can participate by addressing various ASHRAE technical committees during deliberations, participating in subcommittees, or commenting during the public review process. The final vote of the standards project committee includes members from a balance of all stakeholders and is not limited to government representatives, as is the case in the ICC's final vote process. Revisions in the development and maintenance of the standard occur on an ongoing basis and are not approved without achieving consensus from materially affected interest parties. Once an ASHRAE standard is adopted, states and local governments may adopt that standard as their own or make changes to reflect regional building practices or state-specific energy efficiency goals.

CHAPTER 2:
Energy Comparison Analysis

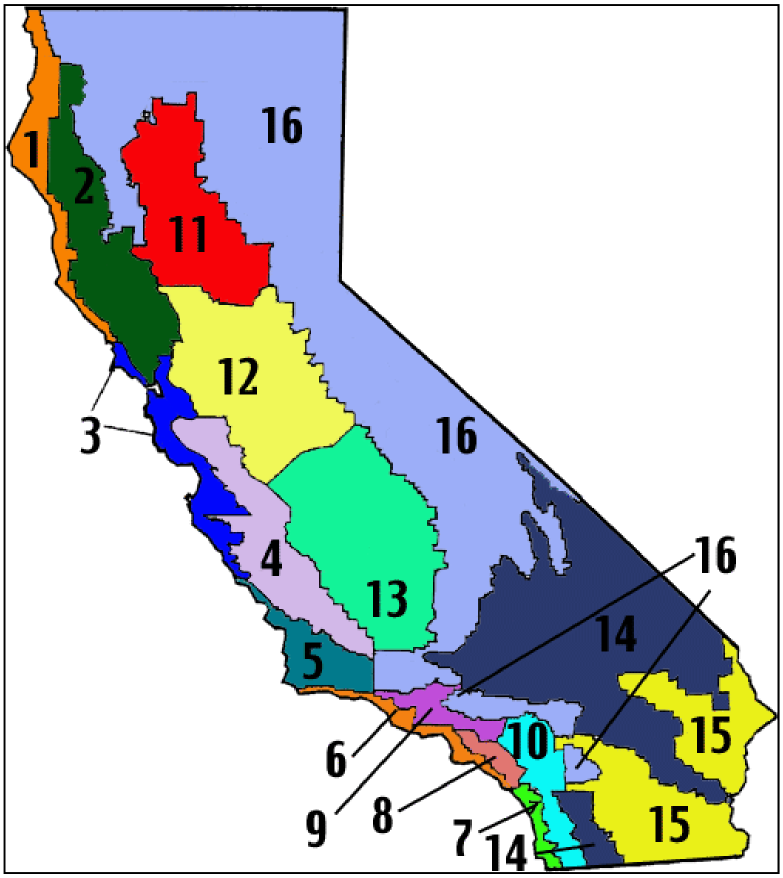
The residential and nonresidential energy codes of California and those of the national model energy codes are relatively identical in their scope—each code establishes minimum energy efficiency levels for space heating, space cooling, water heating, and lighting. However, they differ considerably in the efficiency levels of individual building components, operating conditions, space and water heating system effects, and lighting allowances and control measures, all of which can lead to differences in the overall stringency between the two sets of energy codes.

The required maximum energy threshold for building energy use depends on three key variables: 1) the climate zone where construction is to occur; (2) baseline building efficiency measures encompassed by the energy code or standard; and (3) building-dependent operating and modeling assumptions used for compliance purposes. The interaction of these variables can result in different estimated energy uses for a given building regardless of mandatory measure requirements and whether compliance is shown using either the prescriptive or performance method.

Climate Variables

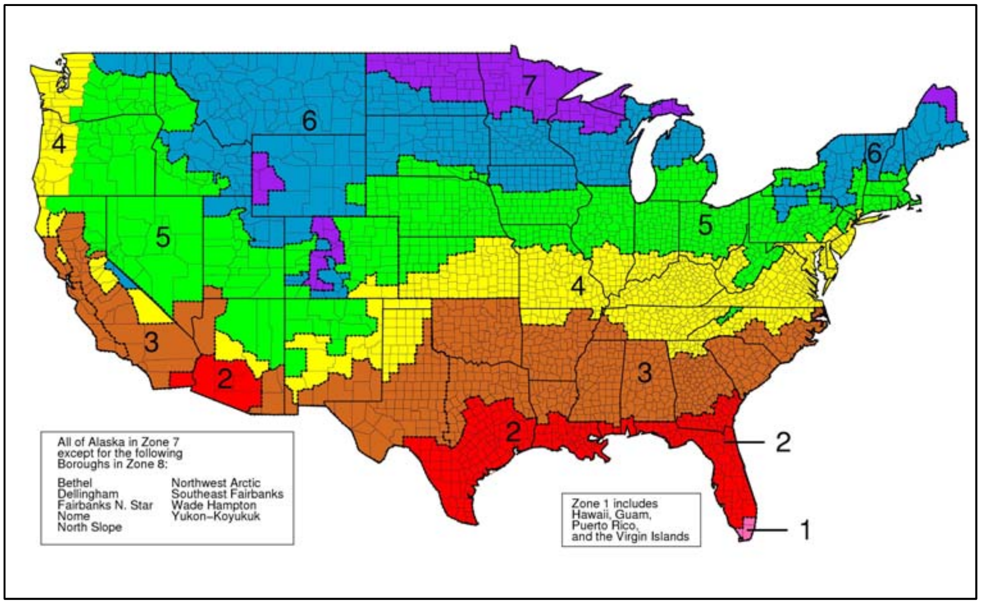
For building energy efficiency purposes, California's *Building Energy Efficiency Standards* divide the state into 16 climate zones. On the other hand, the national model energy codes have established eight distinct climate regions for the nation. Five of these climate regions are within California. (See Figures 1, 2 and 3.) Figure 1 shows the 16 climate zones use for the state's *Building Energy Efficiency Standards*; Figure 2 shows the climate regions designated across the United States for use with the national energy codes of the IECC and *ASHRAE/IESNA Standard 90.1*; and Figure 3 displays the climate zones of the IECC and *ASHRAE/IESNA Standard 90.1* as they would apply specifically to California. Five of the eight IECC and *ASHRAE/IESNA Standard 90.1* national climates zones are represented in California—IECC and *ASHRAE/IESNA Standard 90.1* Climate Zones 2-6. The majority of the state is represented by IECC and *ASHRAE/IESNA Standard 90.1* Climate Zone 3.

Figure 1: California Climate Zones—*Building Energy Efficiency Standards*



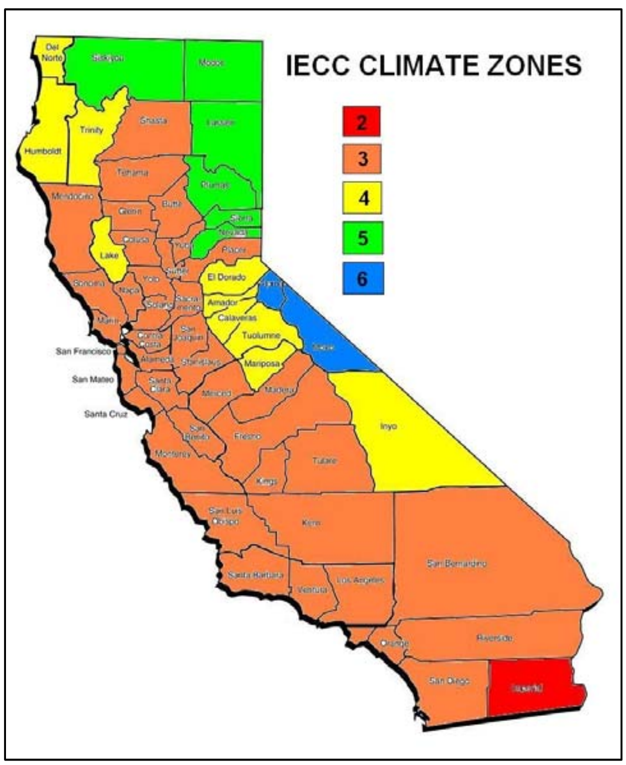
Source: California Energy Commission

Figure 2: IECC and ASHRAE/IESNA Standard 90.1 National Climate Zones



Source: U.S. Department of Energy, Building Energy Codes Program

Figure 3: Climate Zones of the Building Energy Efficiency Standards and IECC and ASHRAE/IESNA Standard 90.1



Source: California Energy Commission

Table 1 shows a breakdown of the individual national climate zones within the 16 climate designations of California's *Building Energy Efficiency Standards*. The national climate zones are further aggregated into three subcategories that have specific efficiency measure requirements that can vary for Climate Zones 4 and 5 based on whether the zone is "A" moist, "B" dry, or "C" marine. The national climate regions are drawn based on county lines, whereas California's 16 climate zones are drawn based on the results of climate data analysis, where some climate lines may coincide with boundaries of individual cities or counties. Hence, when showing compliance with California's *Building Energy Efficiency Standards,* an individual California city or county could have several climate designations within the same jurisdiction, whereas, this does not occur with climate zones of the IECC and *ASHRAE/IESNA Standard 90.1*.

Table 1: Comparison of Climate Designations

California Climate Zones	IECC/ASHRAE 90.1 Climate Zones
1	3c
	4c
2	3b
	3c
	4b
	4c
3	3b
	3c
4	3c
5	3c
6	3b
	3c
7	3b
8	3b
9	3b
	3c
10	3b
11	3b
	5b
12	3b
	3c
	4b
13	3b
14	3b
	4b
15	2b
	3b
16	3b
	4b
	5b
	6b

Source: California Energy Commission

Energy use estimates of building energy features for the respective energy code are affected by climate dynamics. For comparative analysis of the two sets of energy codes, energy use estimates were based on climate designations for California's standards, and building measures were altered based on the requirements specific to the respective national energy code.

Separate modeling analysis was conducted for each IECC and *ASHRAE/IESNA Standard 90.1* climate condition for California, illustrated by Table 1.

Building Efficiency Measures

For homes, the estimated energy use from building measures described in the prescriptive requirements of Table 151-C, Component Package D of the *2008 Building Energy Efficiency Standards,* and Table 150.1-A Component Package A of the *2013 Building Energy Efficiency Standards* were compared against similar requirements of the *2009 and 2012 IECC*, Chapter 4, Table R402.1.1.

Residential performance modeling analysis was performed assuming a two-story, 1,761-square-foot building for the *2008Building Energy Efficiency Standards* energy comparison and a single-story, 2,100-square-foot building for comparing the energy use of *2013 Building Energy Efficiency Standards*. The analysis compared California's *2008 Building Energy Efficiency Standards* to those of the *2009 IECC* using the 2008 California Residential (CALRES) public domain computer program. For residential performance modeling analysis of California's *2013 Building Energy Efficiency Standards* to those of the *2012 IECC*, the building performance analysis program California Building Energy Code Compliance (CBECC) was used. Building measures prescribed by California's requirements for each climate zone represent features of the standard design building against which the estimated annual energy use of the proposed building is compared. For this analysis, building measures of the IECC are described as features of the proposed design building, and the overall estimated energy use from the compliance software program is compared against the energy use of the standard design building. Compliance margins are automatically calculated by the modeling program, where negative numbers indicate that the estimated energy use of the proposed design building is greater than the standard design building.

Nonresidential performance modeling analysis used a similar analytical approach as that for residential buildings. However, several nonresidential prototype buildings were used.[2] Architectural Energy Corporation performed this energy analysis using the Energy Plus performance modeling program, and the full explanation of the approach is contained in two reports:

- ENERGY EFFICIENCY COMPARISON, California's *Building Energy Efficiency Standards and ASHRAE/IESNA Standard 90.1-2010,* June 2013 (CEC-400-2013-007).
- IMPACT ANALYSIS, California's *2013 Building Energy Efficiency Standards,* June 2013 (CEC-400-2013-008).

2 Prototype buildings are described in the *Nonresidential Alternative Calculation Manual (ACM) Approval Method,* December 2008, CEC-400-2008-003-CMF.

For comparative energy analysis of nonresidential buildings, the prescriptive requirements prescribed in Tables 143-A and B of the *2008 Building Energy Efficiency Standards*; and Tables 140.3-B and C of the *2013 Building Energy Efficiency Standards* were used to establish the energy baseline of the standard design building used within the modeling program. Features of the proposed design building were altered, depending on building prototype, to match building measures required by *ASHRAE/IESNA Standard 90.1-2007 and 2010* respectively.

Operating Conditions and Modeling Assumptions

Differences in assumed building operating conditions, schedules, and modeling assumptions used for building features can significantly affect a comparative analysis of the stringency of the two sets of energy codes. For this reason, building operating conditions for this analysis were assumed to be those of California's standards. Examples of differences in operating conditions and building measure assumptions used for California's residential standards and those of the national model energy code are shown in Table 2.

For the nonresidential analysis, ASHRAE/IESNA prototype buildings were slightly modified in some cases to better simulate energy measures included specifically for the California standards. For example, the standards require occupancy sensors to control lights and thermostat setpoints in a number of space types, and to control minimum ventilation rates in others. To evaluate the estimated energy savings for these measures, occupancy schedules had to be defined that allowed the building to be "occupied" part of the day. For California's standards, occupancy, lighting, thermostat, and minimum ventilation rate schedules were modified accordingly. The same occupancy schedules were applied to the same zones of the ASHRAE/IESNA prototype building models to accurately compare the two sets of standards.

Table 2: Residential Energy Code Modeling Comparison—2008 Energy Commission vs. 2009 IECC

Modeling Component	CEC (Standard Design)	IECC (Proposed Design)	Modeling Assumption Used
Weather data	CEC weather data	Same	CEC
TDV	TDV	Source energy use	CEC
Ground reflectivity	20% summer & winter	None	CEC
CFA	2100 single story	Same	CEC
Building	Wood frame	Same	Same
-slab	-3.5”, HC=7 Btu/F-Ft2	None	CEC
-walls	-distributed equally	Same	Same
-roof	-distributed equally	Same	Same
-attic ventilation	- 1/150 for CZs w/RB + 30% vent area 2ft from highest point; or 1/300 for CZs wo/RB + no high vents	None	CEC
R-values	Pkg reqm’t by CZ	Pkg reqm’t by CZ	IECC
Fenestration	Pkg reqm’t @ 20% by CZ	Pkg reqm’t @ 15% by CZ	CEC
-free ventilation	!0% rough opening		
-skylights	None	None	Same
-doors	Same as proposed	40sf	IECC
T-stats	24 hour schedule—Htg- 68F; Clg-78F; Vnt-77F	No schedule—Htg-72F; Clg-75F	CEC
Internal gains -seasonal modifiers	(20,000 Btu/day)+(15 Btu/day*CFA) -monthly (0.80-1.21)	(17,900 Btu/day)+(23.8 Btu/day*CFA)+4104 -none	CEC CEC
Air leakage -air barrier	ELA (2008) None, ACH50 (2013) @ 5 ACH	SLA (2009) Yes, ACH50 (2012) @ 3 ACH	CEC IECC @ 3 ACH
HVAC system -air distribution -refrigerant chrg.	Min. NAECA standard Sealed & tested Tested	Min. NAECA standard 0.88 distribution effic. None	Same CEC CEC
Water heating -water distribution	Min. NAECA standard Std. distribution, insul. pipes	Min. NAECA standard None	Same CEC

Source: California Energy Commission

CHAPTER 3:
Energy Comparison Results

California's metric for building energy use is Time Dependent Valuation (TDV). TDV is the net present value of the time-varying energy used by the building to provide space conditioning, water heating, and specified lighting of buildings. This metric is an alternative to source energy, which is the energy that is used at a site and consumed in producing and in delivering energy to a site, including, but not limited to, power generation, transmission, and distribution losses, and that is used to perform a specific function, such as space conditioning , lighting, or water heating. TDV is used by Energy Commission-approved performance compliance modeling software to depict estimated building energy use. Unlike source energy, TDV accounts for the time when energy is used. As a consequence, building features that save more energy during high electricity peak usage periods are weighted more heavily than during nonpeak periods. Building measures that save energy during periods when TDV is high will be credited more than measures that save energy when TDV is low. For electricity, TDV is high during hot summer afternoons and low under colder temperatures, typically at night. TDV is intended to represent real-time electricity prices. Buildings optimized under TDV tend to be less expensive to operate since more energy would be saved during periods when prices are high.[3]

Residential Energy Use Estimates

Tables 3 and 4 display modeling results that compare the estimated annual energy savings between the *2008 Building Energy Efficiency Standards* and the *2009 IECC,* and *2013 Building Energy Efficiency Standards* and the *2012 IECC,* respectively. Energy modeling for the *2008 Standards* used a 1,761 sf., two-story building, and the *2013 Building Energy Efficiency Standards* used a 2,100 sf., single-story building. Annual estimates of energy use have been weighted by housing starts for each climate zone. Prototype building descriptions and housing starts are based on 2006 and 2011 data from the Construction Industry Research Board (CIRB), and information is taken from two reports:

- *Impact Analysis: 2008 Update to the California Energy Efficiency Standards for Residential and Nonresidential Buildings, November 7, 2007*
- *California's 2013 Building Energy Efficiency Standards Impact Analysis: California's 2013 Building Energy Efficiency Standards (CEC-400-2013-008).*

3 Details of TDV for the *2013 Building Energy Efficiency Standards* are provided in the report: *Time Dependent Valuation of Energy for Developing Building Efficiency Standards, 2013 Time Dependent Valuation (TDV) Data Sources and Inputs,* February 2011 (http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/general_cec_documents/Title24_2013_TDV_Methodology_Report_23Feb2011.pdf).

Table 3: Annual Energy Use—*2008 Building Energy Efficiency Standards* and the *2009 IECC*

1761 2-Story	kTDV/sf-yr				
Climate Zones	**2008 T24 Standard Design Energy Use**	**2009 IECC Proposed Design Energy Use**	**Energy Diff.**	**Weighted Energy Diff.**	**Construction Starts**
1	24.11	29.22	-5.11	-0.02	422
2	46.11	38.43	7.68	0.17	2,351
3	19.87	21.48	-1.61	-0.05	3,485
4	27.53	24.69	2.84	0.08	3,081
5	19.8	20.45	-0.65	-0.01	996
6	9.15	8.94	0.21	0.01	3,103
7	13.77	9.16	4.61	0.12	2,805
8	23.62	18.35	5.27	0.22	4,454
9	30.27	23.8	6.47	0.25	4,226
10	42.21	44.37	-2.16	-0.37	18,661
11	65.58	70.4	-4.82	-0.29	6,433
12	47.55	53.14	-5.59	-0.96	18,641
13	63.19	71.01	-7.82	-1.02	14,095
14	67.28	81.54	-14.26	-1.62	12,300
15	84.73	102.19	-17.46	-1.53	9472
16	70.91	60.47	10.44	0.34	3494
	655.68	677.64			108,019
Statewide Savings	655.68	677.64	21.96	3.2%	

Source: California Energy Commission

Table 4: Annual Energy Use—2013 Building Energy Efficiency Standards and the 2012 IECC

2100 1-story	Total kTDV/sf-yr				
Climate Zone	**2013 T24 Standard Design Energy Use**	**2012 IECC Proposed Design Energy Use**	**Energy Diff.**	**Weighted Energy Diff.**	**Construction**
1	36.04	38.71	-2.67	-0.01	65
2	25.18	23.20	1.98	0.05	579
3	14.37	24.04	-9.67	-0.69	1,636
4	14.37	24.04	-9.67	-0.65	1,541
5	11.83	24.70	-12.87	-0.17	299
6	7.93	8.74	-0.82	-0.07	2,034
7	2.08	3.02	-0.94	-0.09	2,062
8	15.38	12.36	3.02	0.37	2,765
9	29.43	25.42	4.01	0.58	3,280
10	30.44	28.50	1.94	0.21	2,484
11	61.58	66.91	-5.34	-0.15	621
12	38.78	40.33	-1.55	-0.18	2,665
13	65.38	64.32	1.06	0.06	1,380
14	56.77	55.27	1.50	0.03	493
15	101.34	102.03	-0.69	-0.01	494
16	53.57	49.63	3.93	0.07	398
	564.47	591.22			22,796
Statewide Savings	564.47	591.22	26.75	4.5%	

Source: California Energy Commission

Nonresidential Energy Use Estimates

Tables 5 and 6 display modeling results that compare the estimated annual energy savings between the *2008 Building Energy Efficiency Standards* and *ASHRAE/IESNA Standard 90.1-2007*, and the *2013 Building Energy Efficiency Standards* and *ASHRAE/IESNA Standard 90.1-2010,* respectively. Annual estimates of energy use have been weighted by construction starts for each climate zone. Prototype building descriptions and construction starts are based on 2006 and 2011 data from the CIRB, and analysis information is taken from three reports:

- *Impact Analysis: 2008 Update to the California Energy Efficiency Standards for Residential and Nonresidential Buildings,* November 7, 2007

- *ENERGY EFFICIENCY COMPARISON, California's* Building Energy Efficiency Standards and ASHRAE/IESNA Standard 90.1-2010, July 2013 (CEC-400-2013 -XXX)
- *California's 2013 Building Energy Efficiency Standards Impact Analysis: California's 2013 Building Energy Efficiency Standards* (CEC-400-2013-008)

Table 5: Statewide Annual Energy Use—2008 Building Energy Efficiency Standards and ASHRAE/IESNA Standard 90.1-2007

Energy Code/Standard	TDV Energy (GBtu)	Electricity (GWh)	Natural Gas (Mtherm)
90.1-2007	33,060	1,226	20.3
Title 24-2008	32,920	1,233	21
Savings	140	-7	-0.7
Savings	.0.4%	-.06%	-3%

Source: California Energy Commission

Table 6: Statewide Annual Energy Use—2013 Building Energy Efficiency Standards and ASHRAE/IESNA Standard 90.1-2010

Energy Code/Standard	TDV Energy (GBtu)	Electricity (GWh)	Natural Gas (Mtherm)	Site Energy (GBtu)
90.1-2010	31,486	1,168	19.3	5,915
Title 24-2013	27,804	1,012	18.0	5,253
Savings	3,682	156	1.3	662
Savings	12%	13%	7%	11%

Source: California Energy Commission

CHAPTER 4: Conclusion

California's 2008 and 2013 *Building Energy Efficiency Standards* exceed the energy savings expected from requirements in residential Chapter 4 of the *2009 and 2012 International Energy Conservation Code* and from the commercial building requirements of *ASHRAE/IESNA 90.1-2007 and 2010*. While improvements in the energy stringency levels of the national reference energy codes continues, California's residential and nonresidential energy standards contain building measures and building performance operation impacts that are more rigorous, resulting in higher efficiency levels for new residential and nonresidential construction than expected to occur from efficiency requirements of the federal reference energy codes.