CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Proposals Based on ASHRAE 90.1-2013

Measure Number: 2016-NR-ASHRAE2-F

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2016 CALIFORNIA BUILDING ENERGY EFFICIENCY STANDARDS

California Utilities Statewide Codes and Standards Team September 2014

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EXECUTIVE SUMMARY

Introduction

The Codes and Standards Enhancement (CASE) initiatives present recommendations to support California Energy Commission's (CEC) efforts to update the Title 24 Standards to include or upgrade requirements for various technologies in California's Building Energy Efficiency Standards. The four California Investor Owned Utilities (IOUs) – Pacific Gas and Electric Company, San Diego Gas and Electric, Southern California Edison and Southern California Gas Company – and Los Angeles Department of Water and Power (LADWP) sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to energy efficiency in buildings. This report and the code change proposal presented herein is a part of the effort to develop technical and cost-effectiveness information for proposed regulations on building energy efficient design practices and technologies.

The overall goal of this CASE Report is to propose code change proposals that are based on measures included in the 2013 version of ASHRAE (formerly known as "American Society of Heating, Refrigerating and Air Conditioning Engineers") Standard 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings. There are six sub-measures included in this proposal. This report contains pertinent information that justifies the proposed code changes including:

- Description of the code change proposals, measure history, and existing standards (Section 2);
- Market analysis, including a description of the market structure for specific technologies, market availability, and how the proposed standards will impact building owners and occupants, builders, and equipment manufacturers, distributers, and sellers (Section 3);
- Methodology and assumption used in the analyses energy and electricity demand impacts, cost-effectiveness, and environmental impacts (Section 4);
- Results of energy and electricity demand impacts analysis, Cost-effectiveness Analysis, and environmental impacts analysis (Section 5); and
- Proposed code change language (Section 6).

Scope of Code Change Proposal

The proposed measures will affect the following code documents listed in Table 1.

Table 1: Scope of Code Change Proposal

Measure	Standards Requirements (see note below)	Compliance Option	Appendix	Modeling Algorithms	Simulation Engine	Forms
Elevator	M		Yes			Yes
Escalator	M		Yes			Yes
Direct Digital Control	M					Yes
Door Switch	Ps			Yes	Yes	Yes

Note: An (M) indicates mandatory requirements, (Ps) Prescriptive, (Pm) Performance.

Measure Descriptions

Elevator Ventilation and Cab Lighting Measure

The proposed Elevator Ventilation and Cab Lighting measure would update Title 24 so the California standards are at least as stringent as the standards in ASHRAE 90.1-2013 Section 10.4.3. According to ASHRAE, the lighting in the cab (not including signals and displays) shall not have an efficacy less than 35 lumens per watt (lpw). Cab ventilation fans for elevators without air conditioning shall not consume over 0.33 watts (W) per cubic feet per minute (cfm) at maximum speed. After being unoccupied at rest with the elevator doors shut for over 15 minutes, cab interior lighting and ventilation shall be de-energized until required for operation. In order to promote the use of more efficient lighting, the Statewide CASE Team is proposing that elevators achieve a lighting power density (LPD) of 0.6 watts per square foot (W/SF).

Escalator and Moving Walkway Speed Control Measure:

The Escalator and Moving Walkway Speed Control measure would require escalators and moving walkways to automatically slow down to the minimum permitted speed in accordance with ASME A17.1/CSA B44: Safety Code for Elevators and Escalators, or applicable local code, when not conveying passengers. This measure would conserve energy when these motorized walkways are not in use. The Statewide CASE Team suggests adding an exception to this proposed measure that will exclude escalators and moving walkways that are not located in airports, hotels, or transit areas.

Direct Digital Controls Measure

The Direct Digital Control (DDC) measure would require DDC systems for certain building applications that are currently not required by Title 24. By expanding the scope of applications requiring DDC, energy management data would be more readily available allowing for more efficient systems operations and the implementation of effective energy efficiency strategies. The measure would also specify the minimum capability of such mandated DDC system to ensure the full benefit of DDC for the best energy management practices.

Operable Window/Door Switch Measure

The intent of the Operable Window/Door Switch measure is to prevent unnecessary use of energy for heating or cooling of additional un-tempered air if an operable window or door is left open outside of times when it is beneficial to leave it open. This is accomplished with a simple mechanical interlock that disables heating or cooling when any window or door in the room with the thermostat is left open. It is important to note that mechanical ventilation would not be required to be disabled. For example, this requirement could be met by resetting the active heating setpoint to 50 degrees Fahrenheit (^{o}F) and the active cooling setpoint to 100^{o}F while still providing minimum ventilation to a zone with open windows or doors.

Section 2 of this report provides detailed information about the code change proposals including: ***Section 2.2 Summary of Changes to Code Documents (page 11)*** provides a section-by-section description of the proposed changes to the standards, appendices, alternative compliance manual and other documents that will be modified by the proposed code change. See the following tables for an inventory of sections of each document that will be modified:

- Table 7: Scope of Code Change Proposal (page 12)
- Table 8: Sections of Standards Impacted by Proposed Code Change (page 12)
- Table 9: Appendices Impacted by Proposed Code Change (page 12)
- Table 10: Sections of ACM Impacted by Proposed Code Change (page 13)

Detailed proposed changes to the text of the building efficiency standards, the reference appendices, and are given in ***Section* 6 *Proposed Language*** of this report. This section proposes modifications to language with additions identified with underlined text and deletions identified with ~~struck out~~ text.

Market Analysis and Regulatory Impact Assessment

This proposed code changes are cost effective over the period of analysis. Overall this proposal increases the wealth of the State of California. California consumers and businesses save more money on energy than they do for financing the efficiency measure. As a result this leaves more money available for discretionary and investment purposes.

The expected impacts of the proposed code change on various stakeholders are summarized below:

- **Impact on builders:** The proposed measures will have little to no impact on builders.
- **Impact on building designers:** Building designers may have to take the proposed measures into consideration when designing buildings.

  Impact on occupational safety and health: The Escalator and Moving Walkway Speed Control Measure has a history of safety-related concerns regarding the acceleration rate's effect on passenger stability. California Code of Regulations Title 8 (Chapter 4, Subchapter 6, Group 4, Article 41) states that escalators shall comply with ASME A17.1-2004, an earlier version of the ASME Handbook on Safety Code for Elevators and Escalators that prohibits speed variation of in-use escalators and moving walkways. The 2013 version of ASME A17.1 addresses these historic safety concerns. ASME A17.1-2013 allows escalators to use speed controls, but it also includes specific safety requirements with which escalators with speed controls must comply. There is general consensus that escalators with speed controls that comply with ASME A17.1-2013 are safe. The California Division of Occupational Safety and Health (Cal/OSHA) is in the process of updating Title 8 to refer to ASME A17.1-2013 so Title 8 so it references the newer version of ASME A17.1, which would effectively allow speed controls in California as long as the escalators comply with the safety requirements as specified in ASME A17.1.

The other proposed code changes included in this report do not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by Cal/OSHA. All existing health and safety rules will remain in place. Complying with the proposed code changes is not anticipated to have any impact on the safety or health occupants or those involved with the construction, commissioning, and ongoing maintenance of the building.

- **Impact on building owners and occupants:** Since these measures are cost effective, the building owners who pay their energy bills are reducing their energy costs more than their mortgage costs are for the cost of the measure (i.e. they are experiencing net cost savings). For building occupants who pay their energy bills, the measures save more energy on a monthly basis than the measure costs on the mortgage as experienced by building owners. The pass-through of added mortgage costs into rental costs is less than the energy cost savings experienced by occupants.
- **Impact on equipment retailers (including manufacturers and distributors):** Equipment retailers may benefit from increased sales due to the proposed measures as follows:
  - Elevator Ventilation and Cab Lighting: the proposed measure will result in an increase in sales of occupancy sensors and elevator controls and LED lighting for elevators. Fewer halogen incandescent will be sold for the use in elevators, but elevator lighting is only a small portion of the overall market for halogen lighting.
  - Escalator and Moving Walkway Speed Controls: the proposed measure will result in an increase in sales of escalator and moving walkway systems with the variable speed technology.
  - Direct Digital Controls: The proposed measure will result in an increase in sales for DDC technology. The proposed measure will trigger other sections of Title 24 and require the installation of demand control ventilation and automatic demand shed controls, increasing sales of these technologies as well.
  - Operable Window/Door Switches: The proposed measure will result in an increase in sales of window/door switches.
- **Impact on energy consultants:** The proposed code change is not expected to significantly impact energy consultants.
- **Impact on building inspectors:** As compared to the overall code enforcement effort, these measures have negligible impacts on the effort required to enforce the building codes.
- **Statewide Employment Impacts:** The updates to Title 24 as a whole are expected to result in positive job growth as noted below in Section 3.5. The particular measures proposed in this report are not expected to have an appreciable impact on employment in California.
- **Impacts on the creation or elimination of businesses in California:** In general California businesses would benefit from an overall reduction in energy costs. This could help California businesses gain competitive advantage over businesses operating in other states or countries and an increase in investment in California. The particular measures

proposed in this report are not expected to have an appreciable impact on any specific California business.

- **Impacts on the potential advantages or disadvantages to California businesses:** The proposed measures will have little to no impact on businesses.
- **Impacts on the potential increase or decrease of investments in California:** As described in Section 3.5 of this report, the California Air Resources Board (CARB) economic analysis of greenhouse gas reduction strategies for the State of California indicates that higher levels of energy efficiency and 33% Renewable Portfolio Standard (RPS) will increase investment in California by about 3% in 2020 compared to 20% RPS and lower levels of energy efficiency. After reviewing the CARB analysis, the Statewide CASE Team concluded that the majority of the increased investment of the more aggressive strategy is attributed to the benefits of efficiency (CARB 2010b Figures 7a and 10a). The specific code change proposal presented in this report is not expected to have an appreciable impact on investments in California.
- **Impacts on incentives for innovations in products, materials or processes:** Updating Title 24 standards could encourage innovation through the adoption of new technologies to better manage energy usage and achieve energy savings.
- **Impacts on the State General Fund, Special Funds and local government:** The proposed measure is not expected to have an appreciable impact on the State General Fund, Special Funds, or local government funds.
- **Cost of enforcement to State Government and local governments:** All revisions to Title 24 will result in changes to Title 24 compliance determinations. State and local code officials will be required to learn how buildings can comply with the new provisions included in the 2016 Standards, however the Statewide CASE Team anticipates that the cost of training is part of the regular training activates that occur every time the code is updated.

  The proposed code changes for elevators, escalators, and operable door/windows would require an acceptance test to confirm that the controls systems are installed properly and are functioning as required by the code. These measures would add to the cost of verifying code compliance. The costs to local governments are small when compared to the overall costs savings to society as a result of the code change proposals. Title 24 energy efficiency standards are expected to increase economic growth and income with positive impacts on local revenue.
- **Impacts on migrant workers; persons by age group, race, or religion:** This proposal and all measures adopted by CEC into Title 24 Part 6 do not advantage or discriminate in regards to race, religion or age group.
- **Impact on Homeowners (including potential first time home owners):** The proposal does not impact residential buildings. There is no expected impact on homeowners.
- **Impact on Renters:** The proposed code changes are note expected to have a significant impact on renters. The measure will not impact building comfort or utility. The energy cost savings from the proposed measures might be passed on to tenants, but the cost savings from the proposed measures are not easily attributed to a single building tenant. For example, most elevators and escalators are in common areas that are shared by all

building occupants. Similarly, a DDC system and operable window/door switches would apply to the entire building and would impact the energy use for heating, ventilation, and air conditioning (HVAC) to the entire building.

- **Impact on Commuters:** This proposal and all measures adopted by CEC into Title 24 Part 6 are not expected to have an impact on commuters.

Statewide Energy Impacts

Table 2 shows the estimated energy savings over the first twelve months of implementation of the proposed measures.

Table 2: Estimated First Year Energy Savings

	First Year Statewide Savings			Statewide TDV Savings TDV Energy Savings (Million kBTU)
	Electricity Savings (GWh)	Power Demand Reduction (MW)	Natural Gas Savings (MMtherms)	
Elevator	3.65	0.130	0	39.24
Escalator	0.94	0.004	0	15.65
DDC	10.91	2.391	1.34	272.91
Window/Door Switch	1.36	0	0.20	25.80
TOTAL	16.86	2.556	1.54	353.6

Section 4.6.1 discusses the methodology and Section 5.1.1 shows the results for the per unit energy impact analysis.

Cost-effectiveness

Results per unit Cost-effectiveness Analyses are presented in Tables 3, 4 and 5. The TDV (Time Dependent Valuation) Energy Costs Savings are the present valued energy cost savings over the 15-year period of analysis using CEC's TDV methodology (CEC 2014). The Total Incremental Cost represents the incremental initial construction and maintenance costs of the proposed measures relative to existing conditions (current minimally compliant construction practice when there are existing Title 24 Standards). Costs incurred in the future (such as periodic maintenance costs or replacement costs) are discounted by a 3 percent real discount rate, per CEC's LCC (Lifecycle Cost) Methodology. The Benefit-to-Cost (B/C) Ratio is the incremental TDV Energy Costs Savings divided by the Total Incremental Costs. When the B/C ratio is greater than 1.0, the added cost of the measures is more than offset by the discounted energy cost savings and the measures are deemed to be cost effective. For a detailed description of the Cost-effectiveness Methodology see Section 4.7 of this report.

Table 3: Elevator and Escalator Cost-effectiveness Summary

All Climate Zones	Benefit: TDV Energy Cost Savings + Other Cost Savings (2017 PV $)	Cost: Total Incremental Cost (2017 PV $)	Change in Lifecycle Cost (2017 PV $)	Benefit to Cost Ratio
Elevators	$3,491	$1,478	$(2,012)	2.4
Escalators	$25,324	$4,354	$(20,970)	5.8

Table 4: DDC Cost-effectiveness Summary per Square Foot

Climate Zone	Benefit: TDV Energy Cost Savings (2017 PV $)	Cost: Total Incremental First Cost and Maintenance Cost (2017 PV $)	Change in Lifecycle Cost (2017 PV $)	Planned Benefit to Cost (B/C) Ratio
Climate Zone 1	$2.11	$0.18	$1.93	11.809
Climate Zone 2	$1.28	$0.18	$1.10	7.147
Climate Zone 3	$1.65	$0.18	$1.47	9.254
Climate Zone 4	$1.54	$0.18	$1.36	8.607
Climate Zone 5	$1.31	$0.18	$1.14	7.359
Climate Zone 6	$1.15	$0.18	$0.98	6.466
Climate Zone 7	$1.14	$0.18	$0.96	6.359
Climate Zone 8	$0.93	$0.18	$0.75	5.192
Climate Zone 9	$1.04	$0.18	$0.86	5.815
Climate Zone 10	$0.79	$0.18	$0.62	4.448
Climate Zone 11	$1.34	$0.18	$1.16	7.517
Climate Zone 12	$1.42	$0.18	$1.24	7.934
Climate Zone 13	$1.25	$0.18	$1.07	6.998
Climate Zone 14	$1.12	$0.18	$0.94	6.257
Climate Zone 15	$0.98	$0.18	$0.80	5.481
Climate Zone 16	$1.36	$0.18	$1.18	7.630

Table 5: Door Switch Cost-effectiveness Summary per Square Foot

Climate Zone	Benefit: TDV Energy Cost Savings (2017 PV $)	Cost: Total Incremental First Cost and Maintenance Cost (2017 PV $)	Change in Lifecycle Cost (2017 PV $)	Planned Benefit to Cost (B/C) Ratio
Climate Zone 3	0.54	0.15	0.39	3.6
Climate Zone 6	0.47	0.15	0.32	3.2
Climate Zone 12	0.41	0.15	0.26	2.7
All other Climate Zones	N/A	N/A	N/A	N/A

Section 4.7 discusses the methodology and Section 5.2 shows the results of the Cost-Effectiveness Analysis.

Greenhouse Gas and Water Related Impacts

Please refer to Section 5.3 of this report for a more detailed and extensive analysis of the possible environmental impacts from the implementation of the proposed measures.

Greenhouse Gas Impacts

Table 6 presents the estimated avoided greenhouse gas (GHG) emissions of the proposed code change for the first year the standards are in effect. Assumptions used in developing the GHG savings are provided in Section 4.8.1 of this report.

Table 6: Estimated Statewide Greenhouse Gas Emissions Impacts

	Avoided GHG Emissions ($MTCO_2e$/yr)
Elevator	1,288
Escalator	332
DDC	3,852
Window/ Door Switch	1,590
TOTAL	7,062

Section 4.8.1 discusses the methodology and Section 5.3.1 shows the results of the greenhouse gas emission impacts analysis.

Water Use and Water Quality Impacts

The proposed measures are not expected to have any impacts on water use or water quality, excluding impacts that occur at power plants

1. INTRODUCTION

The Codes and Standards Enhancement (CASE) initiatives present recommendations to support CEC's efforts to update the Title 24 Standards to include or upgrade requirements for various technologies in California's Building Energy Efficiency Standards. The four California Investor Owned Utilities (IOUs) – Pacific Gas and Electric Company (PG&E), San Diego Gas and Electric (SDG&E), Southern California Edison (SCE) and Southern California Gas Company (SCG) – and Los Angeles Department of Water and Power (LADWP) sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to energy efficiency in buildings. This report and the code change proposal presented herein is a part of the effort to develop technical and cost-effectiveness information for proposed regulations on building energy efficiency design practices and technologies.

The overall goal of this CASE Report is to propose code change proposals that are based on measures included in the 2013 version of ASHRAE Standard 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings. There are six sub-measures included in this proposal. The report contains pertinent information that justifies the code change.

Section 2 of this CASE Report provides a description of the measure, how the measure came about, and how the measure helps achieve the state's zero net energy (ZNE) goals. This section presents how the Statewide CASE Team envisions the proposed code change would be enforced and the expected compliance rates. This section also summarizes key issues that the Statewide CASE Team addressed during the CASE development process, including issues discussed during a public stakeholder meeting that the Statewide CASE Team hosted in May 2014.

Section 3 presents the market analysis, including a review of the current market structure, a discussion of product availability, and the useful life and persistence of the proposed measure. This section offers an overview of how the proposed standard will impact various stakeholders including builders, building designers, building occupants, equipment retailers (including manufacturers and distributors), energy consultants, and building inspectors. Finally, this section presents estimates of how the proposed change will impact statewide employment.

Section 4 describes the methodology and approach the Statewide CASE Team used to estimate energy, demand, costs, and environmental impacts. Key assumptions used in the analyses can be also found in Section 4.

Results from the energy, demand, costs, and environmental impacts analysis are presented in Section 5. The Statewide CASE Team calculated energy, demand, and environmental impacts using two metrics: (1) per unit, and (2) statewide impacts during the first year buildings complying with the 2016 Title 24 Standards are in operation. Time Dependent Valuation (TDV) energy impacts, which accounts for the higher value of peak savings, are presented for the first year both per unit and statewide. The incremental costs, relative to existing conditions are presented as are present value of year TDV energy cost savings and the overall cost impacts over the year period of analysis.

The report concludes with specific recommendations for language for the Standards, Appendices, Alternate Calculation Manual (ACM) Reference Manual and Compliance Forms.

2. MEASURE DESCRIPTION

2.1 Measure Overview

2.1.1 Recommended Measure Descriptions

2.1.1.1 Elevator Ventilation and Cab Lighting Measure

The proposed Elevator Ventilation and Cab Lighting measure would update Title 24 so the California standards are at least as stringent as the standards in ASHRAE 90.1-2013 Section 10.4.3. According to ASHRAE, the lighting in the cab (not including signals and displays) shall not have an efficacy less than 35 lumens per watt (lpw). Cab ventilation fans for elevators without air conditioning shall not consume over 0.33 watts (W) per cubic feet per minute (cfm) at maximum speed. After being unoccupied at rest with the elevator doors shut for over 15 minutes, cab interior lighting and ventilation shall be de-energized until required for operation. In order to promote the use of more efficient lighting, the Statewide CASE Team proposes a limit of 0.6 watts per square foot for lighting in elevator cabins to replace the 35 lumens per watt requirement from ASHRAE 90.1-2013. The lighting power density approach allows the lighting designer to consider trade-offs between source efficacy, optical efficacy, surface reflectances and design illuminance to hit the Watts per square foot target.

This proposal will be a mandatory measure and will be added to Section 120.6 Mandatory Requirements for Covered Processes. See Section 6.1.1 of this report for the proposed language. The Nonresidential ACM Reference Manual should be updated to reflect the changes made to the standards. Refer to section 6 of this report for changes to the reference appendices and compliance forms.

2.1.1.2 Escalator and Moving Walkway Speed Control Measure

The Escalator and Moving Walkway Speed Control measure would require escalators and moving walkways to automatically slow down to the minimum permitted speed in accordance with the 2010 version of ASME A17.1/CSA B44: Safety Code for Elevators and Escalators, or applicable local code, when not conveying passengers. This measure would conserve energy when these motorized walkways are not in use. The Statewide CASE Team suggests adding an additional rule that will only apply this measure to certain building types where escalator operation runs day and night, such as airports, hotels, and transit areas.

ASME A17.1/CSA B44 (2010) lists the following requirements for escalators and moving walkways with variable speeds:

- Acceleration and deceleration shall not exceed 1.0 feet per square second (ft/sec^2);
- Rated Speed 100 feet per minute (ft/min) is not exceeded;
- Minimum speed not less than 10 ft/min;
- Passenger Detection provided at both landings;
- Deceleration does not occur until 3 times for passenger transfer between landings;
- Means to detect failure of passenger detection; and
- If failure is detected, run at full rated speed only.

The Title 24 code change proposal will be a mandatory measure and will fall under Section 120.6 – Mandatory Requirements for Covered Processes. See Section 6.1.2 of this report for the proposed language addition. The Nonresidential ACM Reference Manual will be updated to reflect the changes to the prescriptive baseline. Refer to section 6 of this report for changes to the reference appendices and compliance forms.

2.1.1.3 Direct Digital Control Measure

The Direct Digital Control (DDC) Measure would require new buildings, alterations and additions to buildings to install DDC systems. This measure will apply to all HVAC systems of a minimum size to ensure that it is cost effective to incorporate DDC. Requiring DDCs would facilitate various energy saving measures that Title 24 already requires if DDC is installed, including:

- Carbon dioxide (CO_2) demand ventilation controls complying with Section 120.1(c)
- Automatic demand shed controls complying with Section 120.2(h)
- Setpoint Reset controls for Variable Air Volume (VAV) systems with Section 120.4(c)2C

This measure would also include language to require such mandated DDC systems to have a minimum set of capabilities to ensure the full benefits of DDC technology for energy management and savings, including:

- Monitor zone and system demand for fan pressure, pump pressure, heating, and cooling.
- Transfer zone and system demand information from zones to air distribution system controllers and from air distribution systems to heating and cooling plant controllers.
- Automatically detect those zones and systems that may be excessively driving the reset logic and generate an alarm or other indication to the system operator.
- Readily allow operator removal of zone(s) from the reset algorithm.
- For new buildings, the DDC system shall be capable of trending and graphically displaying input and output points
- Additional language will be adopted to require Optimum Start/Stop Controls which ASHRAE 90.1 already mandates.

This proposal will be a mandatory measure and will add a new subsection of code under Section 120.2 – Required Controls For Space-Conditioning Systems and will be titled Section 120.2(j) Direct Digital Controls. See Section 6.1.4 of this report for the proposed language addition. Refer to section 6 of this report for changes to the reference appendices and compliance forms. The compliance forms may be updated to include DDC compliance.

2.1.1.4 Operable Window/Door Switch Measure

The intent of the Operable Window/Door Switch measure is to prevent unnecessary use of energy for heating or cooling of additional un-tempered air if an operable window is left open outside of times when it is beneficial to leave it open. This is accomplished with a simple mechanical interlock that disables heating/cooling when any window in the room with the thermostat is left open. It is important to note that mechanical ventilation would not be required to be disabled. For example, this requirement could be met by resetting the active heating setpoint to 50°F and the active cooling setpoint to 100°F still providing minimum ventilation to a zone with open windows.

This measure will reduce unnecessary heating or cooling demand in spaces with operable windows and doors, which will save not only heating and cooling energy, but fan energy as well. When a building has both mechanical heating/cooling and operable windows it is likely that annual heating/cooling energy will be higher than if the building did not have operable windows. This is because operable windows are often left open when conditions are not favorable, resulting in high infiltration loads on the mechanical system. There are many reasons why windows end up open when it is not favorable, including:

1. Occupant wants more fresh air and does not know or care about heating/cooling energy penalty. This is particularly true when the space temperature can be maintained at setpoint despite the extra infiltration load.
2. Occupant does not know the zone mode (heating/cooling) or outside temperature so cannot gauge if opening the window will reduce or increase energy use.
3. Occupant opened the window under favorable conditions but left the room (with the window open) and conditions changed to unfavorable.
4. Occupant A's office has the thermostat for a zone that includes Occupant B's office. Occupant A opens the window on a brisk day causing the zone to go to full heating. Occupant B is then forced to open the window to prevent from overheating.

2.1.2 Non-recommended Measure Descriptions

2.1.2.1 Fan Efficiency Grade Measure

The Statewide CASE Team explored proposing a Fan Efficiency measure that would recommend using a new metric known as the Fan Efficiency Grade (FEG), a metric that the Air Movement and Control Association (AMCA) developed and that was adopted into ASHRAE 90.1-2013. The Fan Efficiency measure would require a minimum FEG of 67, and the total efficiency of the fan at the design point of operation would have to be within 15 percentage points of the maximum total efficiency of the fan.

This measure would apply to all fans minus the following exceptions:

- Single fans with a motor nameplate horsepower 5 horsepower (hp), or 4 kW, or less;
- Multiple fans in series or parallel (e.g., fan arrays) that have a combined motor nameplate horsepower of 5 hp, or 4 kW, or less and are operated as the functional equivalent of a single fan;
- Fans that are part of equipment listed under Section 6.4.1.1 "Minimum Equipment Efficiencies – Listed Equipment – Standard Rating and Operating Conditions";
- Fans included in equipment bearing a third-party-certified seal for air or energy performance of the equipment package;
- Powered wall/roof ventilators (PRV);
- Fans outside the scope of AMCA 205; and
- Fans that are intended to only operate during emergency conditions.

FEG is a new metric that was created in AMCA (in conjunction with ASHRAE and is defined in AMCA 205-12. A FEG is a numerical rating that classifies fans by their aerodynamic ability to convert mechanical shaft power to air power. A more efficient fan model will have a higher FEG rating. FEGs apply to the efficiency of the fan only and not to the motor and drives (Not wire to air). FEG has been vetted through the ASHRAE 90.1 and ASHRAE TC5.1. Figure 1 shows the FEGs by impeller diameter and total peak efficiency.

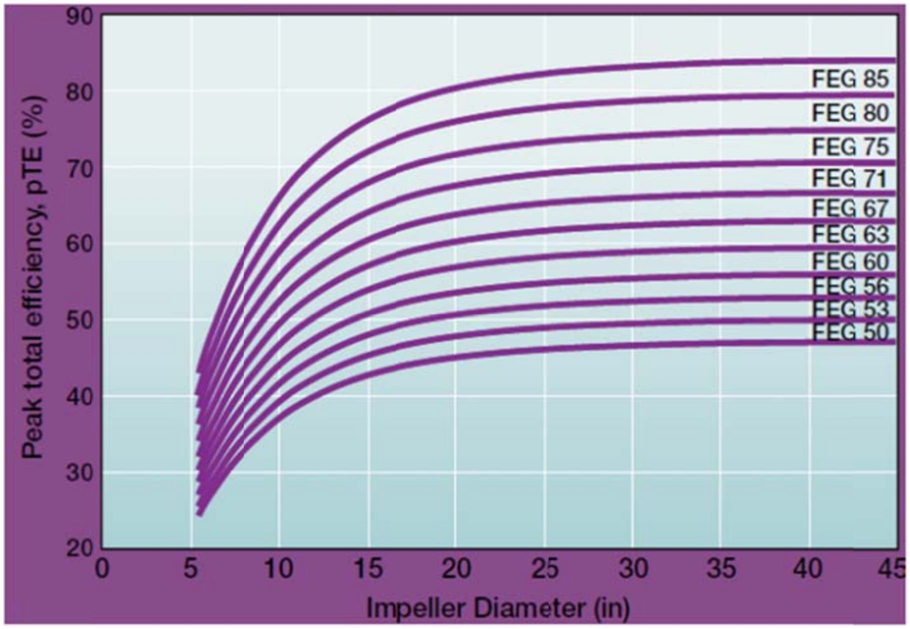

Figure 1: FEG by Impeller Diameter and Peak Total Efficiency

There is still deliberation within industry on whether FEG is the most appropriate metric to use when establishing efficiency standards for fans, or if a standard based on FEG is capable of producing significant energy savings. For larger applications above 5 hp, fans with a FEG rating of 67 are typically already in use. The FEG is only an accurate system for fans in ducted systems, and has multiple scenarios covered in the exceptions of the proposed measure in which it would be unfair to set a FEG requirement.

The Performance Based Efficiency Requirement (PBER) is an alternative to the FEG approach. The PBER is based on air-power equations and is determined based on air flow rates and air pressure. Figure 2 presents the equations used to calculate the PBER. Under the PBER approach, the efficiency requirements are determined by the application, not the equipment. The requirements would start with a base efficiency level that applies to all fans. This base is multiplied by a capacity and application factor. One advantage of the PBER is that the metric would be applicable to the entire fan market whereas the FEG is most applicable to larger fans.

A. For fans *without* a discharge duct, the minimum static efficiency shall be:

$$\textbf{Minimum Static Efficiency} = 60\% \times \left[\frac{CFM}{(250 + CFM)}\right] \times \left[\frac{Ps}{(0.25 + Ps)}\right]$$

B. For fans *with* a discharge duct, the minimum total efficiency shall be:

$$\textbf{Minimum Total Efficiency} = 68\% \times \left[\frac{CFM}{(250 + CFM)}\right] \times \left[\frac{Pt}{(0.25 + Pt)}\right]$$

Figure 2: Performance Based Efficiency Requirement (PBER) Equations

At the time of writing, AMCA is reviewing the PBER approach and is considering moving from the FEG approach to the PBER approach. Greenheck Fan Corporation prefers the PBER approach. The PBER is also being considered for updates to ASHRAE 90.1 and the United States Department of Energy appliance efficiency standards. The PBER is preferable in some aspects, as it covers a larger percentage of the fan market and works better in low pressure applications. While the PBER metric has been gaining traction and it appears that there is momentum to move away from using FEG the PBER approach has not been vetted through the ASHRAE public review process.

The Fan Efficiency Grade Measure was presented at the stakeholder meeting that the Statewide CASE Team held on May 20, 2014 and CEC's pre-rulemaking workshop on June 12, 2014. During both meetings stakeholders commented that the PBER is under review.

Given there is uncertainty about the FEG metric and the ASHRAE 90.1-2013 building efficiency standards that are based on FEG, and the limited time and resources available to proposed changes to for the 2016 Title 24 code change cycle, the Statewide CASE Team has decided not to pursue proposing a code change to Title 24 that would adopt the FEG requirements that appear in ASHRAE 90.1-2013. CEC Staff have indicated that residential building standards are the primary focus of the 2016 Title 24 code change cycle and that CEC Staff does not have the resources to pursue changes to the nonresidential standards that will require significant time and resources to adopt and implement; this was a factor the Statewide CASE Team considered when making the decision not to pursue a fan standard for this code cycle. There is momentum on the national level, but through ASHRAE and the DOE standards setting process, to improve fan efficiency standards. The Statewide CASE Team will monitor the efforts occurring on the national level, and will consider proposing revisions to Title 24 fan efficiency standards during the 2019 Title 24 code change cycle.

2.1.3 Measure History

2.1.3.1 Relationship Between ASHRAE 90.1 and Title 24

Current United States federal law does not require states to adopt building energy efficiency codes for nonresidential buildings. However, if states decide to adopt building efficiency code for nonresidential buildings, those codes must result in energy performance that is equal to or better than the energy performance achieved through the current version of ASHRAE 90.1. In addition, energy performance is evaluated on the code as a whole – not on a measure-by-measure basis. This means that CEC does not have to adopt any one measure in ASHRAE 90.1

as long as the aggregate of all measures in Title 24 result in the same or better energy performance as the aggregate of all measures in ASHRAE 90.1. (42 U.S.C. §6832-6836).

Although California is not required to adopt every measure in ASHRAE 90.1, some of the measures adopted into ASHRAE 90.1 are well-suited for California's building code. California typically reviews revisions to ASHRAE 90.1 on a measure-by-measure basis to identify potential revisions to Title 24. It should be noted that ASHRAE 90.1 Standards are designed for all states. Therefore, some of the measures in ASHRAE 90.1 are not ideally suited for California, and oftentimes the ASHRAE 90.1 Standards that are well-suited for California can be further tailored so they are more appropriate for California.

It is important to note that ASHRAE 90.1 and Title 24 are structured differently. In most cases ASHRAE 90.1 code language cannot be adopted verbatim into Title 24 because there are discrepancies in the existing code structures. For example, ASHRAE 90.1 and Title 24 use different climate zones, so climate zone dependent standards need to be evaluated carefully to ensure that the proposed Title 24 Standards are cost effective in all Title 24 climate zones.

Typically measures that have been vetted through the ASHRAE 90.1 public review process do not receive significant stakeholder opposition when proposed for Title 24. This is, in part, because stakeholders have already participated in ASHRAE's rigorous consensus-building process to develop the ASHRAE 90.1 code language. Despite the fact that a measure has been vetted through the ASHRAE process and has been adopted into ASHRAE 90.1, California must complete an independent analysis of all proposed changes to Title 24 that are based on ASHRAE 90.1 to ensure the measure is cost effective and feasible in the California market.[1] Proposed changes to Title 24 that are based on ASHRAE 90.1-2013 must also be presented at CEC's public workshops. In sum, the information provided in this CASE Report will help inform CEC's determination that the proposed code changes are indeed cost effective and feasible in California.

2.1.3.2 Elevator Ventilation and Cab Lighting Measure

In an attempt to reduce the large amount of energy waste when elevators are idle, ASHRAE 90.1 adopted a measure to shut off ventilation and lighting in an elevator cabin after being unoccupied and not in use after a certain length of time. ASHRAE also set an efficacy requirement, which effectively disallows the use of inefficient fixtures for elevator cabin lighting. There is not any code conflict associated with this measure, and little push back is expected in the implementation to Title 24.

2.1.3.3 Escalator and Moving Walkway Speed Control Measure

ASME A17.1-2010 was the first version of the Safety Code for Elevators and Escalators to allow the speed variation in escalators and moving walkways. ASHRAE 90.1 has adopted this measure from ASME as it is written in ASME A17.1-2010 because it will reduce energy use from escalators and moving walkways.

[1] California can adopt proposed changes to equipment that appear in Table 110.2 of Title 24 without performing a cost-effectiveness analysis if the revised equipment efficiency levels also appear in the most recent version of ASHRAE 90.1.

2.1.3.4 Direct Digital Control Measure

The 2013 version of ASHRAE 90.1 adopted a measure that required DDC for certain applications both in new buildings and retrofits so that these buildings will benefit from energy management tools and energy saving measures. The proposed Title 24 code change proposal would adopt the ASHRAE 90.1-2013 requirements into Title 24 with very little, if any modifications.

As discussed in Section 3 of this report, even though it is not required by code, most new buildings, particularly large and medium sized buildings, are already built with DDC systems. This code change proposal is not recommending changes to standard design practice. Rather, it is updating the code to match what the building industry has already accepted as common practice in medium and large buildings. The proposed code change may result in a change to typical design practices for smaller buildings. The Statewide CASE Team expects minimal resistance to this proposal because it is not modifying existing practices, and the code change has already been through ASHRAE's public review process.

2.1.3.5 Operable Window/Door Switch Measure

In most commercial building types, operable windows and doors are not required by ventilation or building codes but are often included in design as an amenity to give occupants more control over their environment, a greater connection to the outdoors and increased natural ventilation. A common misperception about operable windows and doors in buildings with heating/cooling systems is that they save energy. This is true only if the mechanical system is interlocked with the operable windows/doors. If they are not interlocked then operable windows and doors increase energy use due to the increased outside air heating and cooling load placed on the mechanical system. This has been proven in simulation studies and has been reflected in the utility bills of a number of high profile mixed mode buildings.

Many commercial buildings with operable window/doors now have window/door switches to interlock the windows/doors with the mechanical system. A recent survey of mixed-mode buildings with operable windows conducted by the UC Berkeley found that 7 of 24 buildings with operable windows also had window switches.

The lifecycle cost analysis conducted for this proposal has shown that the window/door switches and associated interlock controls are cost effective and therefore requiring them in the energy code will save energy cost effectively.

This measure was briefly considered by CEC in the development of the 2013 Title 24 code update, but it was introduced late in the process and CEC felt there was not sufficient time to properly solicit and address stakeholder feedback. The measure was included in the 2013 ACM performance modeling rules, which states that "…natural ventilation may only be allowed in the (proposed) model if the building has interlocks on operable windows…", that is, there is an incentive in the modeling rules for including operable windows with window switches but there is no corresponding disincentive for including operable windows without window switches.

As part of this proposal for the 2016 Standards we propose to expand on the modeling rules to include a penalty for operable windows without window switches in the proposed design and to include limitations on the amount of natural ventilation that can be claimed through the operable windows. This is in addition to a proposed change to the prescriptive requirements that requires window switches for operable windows in all buildings not using the performance approach.

2.1.4 Existing Standards

The proposed code changes presented in this report are based on measures that appear in the 2013 version of ASHRAE 90.1. While the code change proposals are based on language in ASHRAE 90.1-2013, the Statewide CASE Team has made some adjustments to the ASHRAE 90.1-2013 standards so the proposed code language is compatible with the existing Title 24 framework.

2.1.4.1 Elevator Ventilation and Cab Lighting Measure

Current Title 24 code requires elevator lighting to be included in the indoor LPD calculations unless the lighting in the elevator meets the requirements of ASHRAE 90.1-2010, which require elevator lighting to be 35 lpw at a minimum. The proposed code change would establish a mandatory requirement of 0.6 W/SF, which is more stringent than the 35 lpw requirement. With the new mandatory requirement in place, elevator lighting systems will no longer be included in the indoor LPD calculations.

There are no existing Title 24 standards that address elevator HVAC or lighting controls.

2.1.4.2 Escalator and Moving Walkway Speed Control Measure

Current state law prohibits escalators and moving walkways from changing speed during operation in the State of California. California Code of Regulations Title 8 (Chapter 4, Subchapter 6, Group 4, Article 41) states that escalators shall comply with ASME A17.1-2004, an earlier version of the ASME safety code that prohibits speed variation of in-use escalators and moving walkways. The California Division of Occupational Safety and Health (DOSH), better known as Cal/OSHA, is responsible for updating the Elevator Safety Orders in Title 8. Cal/OSHA is in the process of updating Title 8 to refer to ASME A17.1-2013 so Title 8 so it references the newer version of ASME A17.1. Staff from the Elevator Unit at Cal/OSHA indicated that the revisions to Title 8 should be adopted by spring 2015. Cal/OSHA will need to adopt the revision to Title 8 prior to CEC’s adoption hearing for this proposed measure.

There have been cases in the past where companies have successfully applied for a variance through Cal/OSHA to install the speed varying technology in California.

The proposed code change does not conflict with any pre-existing code in Part 6 of Title 24, nor are there preemption concerns.

2.1.4.3 Direct Digital Control Measure

Currently Title 24 has various requirements for control logic that apply only to buildings that have DDC installed, however Title 24 does not mandate that DDC be installed. If a building has DDC to the zone level, the DDC system must be programmed to allow automatic centralized demand shed for non-critical zones as specified by Section 120.2(h). Similarly, buildings with multi-zone systems with DDC to the zone level must be programmed to comply with the demand control ventilation requirements in Section 120.1(c)4 and set point reset controls for Variable Air Volume (VAV) systems in Section 140.4(c)2C.

2.1.4.4 Operable Window/Door Switch Measure

An incentive for window switches was added to the performance approach in 2013. Section 5.3.5 of the 2013 Nonresidential ACM includes the following input restriction for compliance software, "When the building has mechanical ventilation and cooling in conjunction with natural ventilation (operable windows), natural ventilation may only be allowed in the model if the building has interlocks on operable windows or other means of automatic controls (automatic window controls)." As discussed, additional detail should be added to the ACM for 2016.

ASHRAE 90.1 was considering adopting the proposed Title 24 code change for the 2013 version of ASHRAE 90.1. The ASHRAE committee released the proposed code change for public review and received two comments expressing a desire to keep operable windows and a concern that the proposal could discourage the use of operable windows. As a result, the ASHRAE Committee limited the scope of the proposed code change and the adopted measure only applies to door switches, not windows and doors.

It is important to understand where operable windows are deemed necessary they are required in the building code, e.g. low rise residential egress windows. Obviously this requirement cannot discourage operable windows in any case where the window is already required to be operable. Where windows are not required to be operable or doors are not required the owner is clearly paying a significant premium to make the window operable or add the door. The incremental cost of the window/door switch is significantly lower than the operable window/door premium. So it is likely that anyone already paying a significant premium will be discouraged by a relatively small incremental cost. Furthermore, the premium for operable windows or adding a door is not likely to decrease significantly as this is a mature market and the cost is driven by the high hardware costs. But the incremental cost of the door/window switch will come down significantly if this measure is adopted because the door/window switch is currently a specialty item that is not included in most operable window/door installation. The hardware costs only a couple dollars. The cost now is mostly extra (non-standard) labor.

If the measure is adopted it will become a standard feature of operable windows and doors and the labor costs will come down, making the incremental cost even less of an issue. Finally, where operable windows/doors are not required; they are an amenity and as such should be used in a responsible manner. Door/window switches are cost effective and therefore constitute responsible use of operable doors/windows.

2.1.5 Alignment with Zero Net Energy Goals

The proposed code changes contribute to California's Zero Net Energy (ZNE) goals by reducing energy use in nonresidential buildings. Many of the proposed code changes presented in this report would require advanced building controls that allow buildings to provide building occupants with the services required while minimizing energy wasted to provide those services when they are not needed. Building controls will play a significant role in attaining the nonresidential ZNE goals.

2.1.6 Relationship to Other Title 24 Measures

2.1.6.1 Elevator Ventilation and Cab Lighting Measure

The prescriptive lighting requirements in Section 140.6.3V of Title 24 states that lighting inside the elevator cab is excluded from indoor LPD calculations if lighting in the cab meets the requirements of ASHRAE/IESNA Standard 90.1-2010, which require elevator lighting to achieve 35 lpw at a minimum. The proposed measure would establish mandatory requirements for elevator lighting. As such, Section 140.6.3V would need to be modified to clarify that elevator lighting compliant with the new proposed code will always be excluded from the indoor LPD calculations and reference the new mandatory requirements for elevator lighting.

2.1.6.2 Escalator and Moving Walkway Speed Control Measure

There is no relation between the proposed measure and other Title 24 measures, nor are there preemption concerns.

2.1.6.3 Direct Digital Control Measure

The mandatory requirements in Section 120.1 (c) of 2013 Title 24 requires demand control ventilation when the building is equipped with DDC to zone level. The proposed measure could trigger this measure, which will require demand control ventilation to be incorporated into the HVAC system.

The mandatory requirements in Section 120.2 (h) of 2013 Title 24 mandates automatic demand shed controls when the building is equipped with DDC to zone level. The proposed measure could trigger this measure, which will require automatic demand shed controls to be incorporated into the HVAC system.

The prescriptive requirements in Section 140.4 (c)2C of 2013 Title 24 requires set point reset for Variable Air Volume (VAV) systems when the building is equipped with DDC to zone level. The proposed measure could trigger this measure, which will require set point reset controls to be incorporated into the HVAC system.

2.1.6.4 Operable Window/Door Switch Measure

This measure is related to natural ventilation requirements in the following Sections:

- 120.1(b) Item 1: Natural Ventilation
- 120.2(e): Shut-off and Reset Controls for Space-conditioning Systems.

2.2 Summary of Changes to Code Documents

The sections below provide a summary of how each Title 24 document will be modified by the proposed change. See Section 6 of this report for detailed proposed revisions to code language.

2.2.1 Catalogue of Proposed Changes

2.2.1.1 Scope

Table 7 identifies the scope of the code change proposal. This measure will impact the following areas (marked by a “Yes”).

Table 7: Scope of Code Change Proposal

Measure	Mandatory	Prescriptive	Performance	Compliance Option	Trade-Off	Modeling Algorithms	Forms
Elevator	Yes						
Escalator	Yes						
DDC	Yes					Yes	Yes
Window/ Door		Yes				Yes	

2.2.1.2 Standards

The proposed code changes will modify the sections of the California Building Energy Efficiency Standards (Title 24, Part 6) identified in Table 8. The requirements for elevator, escalators, and window/doors would add new subsections to the code.

Table 8: Sections of Standards Impacted by Proposed Code Change

Measure	Title 24, Part 6 Section Number	Section Title	Mandatory (M) Prescriptive (Ps) Performance (Pm)	Modify Existing (E) New Section (N)
Elevator	120.6	Mandatory Requirements for Covered Processes	M	N
Escalator	120.6	Mandatory Requirements for Covered Processes	M	N
DDC	120.2	Required Controls for Space-Conditioning Systems	M	N
Window/ Door	140.4	Prescriptive Requirements for Space Conditioning Systems	Ps	N

2.2.1.3 Appendices

The proposed code change will modify the sections of the indicated appendices presented in Table 9.

Table 9: Appendices Impacted by Proposed Code Change

APPENDIX NAME			
Measure	**Section Number**	**Section Title**	**Modify Existing (E) New Section (N)**
Elevator	NA7.14	Elevator Lighting and Ventilation Controls	N
Escalator	NA7.15	Escalator and Moving Walkway Speed Control	N
DDC	N/A	N/A	N/A
Window/Door	N/A	N/A	N/A

2.2.1.4 Nonresidential Alternative Calculation Method (ACM) Reference Manual

The proposed code change will modify the sections of the Nonresidential Alternative Calculation Method References identified in Table 10.

Table 10: Sections of ACM Impacted by Proposed Code Change

Residential Alternative Calculation Method Reference			
Measure	**Section Number**	**Section Title**	**Modify Existing (E) New Section (N)**
Elevator	5.4.8	Elevators, Escalators and Moving Walkways	E
Escalator	5.4.8	Elevators, Escalators and Moving Walkways	E
DDC	5.7.2	System Controls	E
Window/Door	5.3.5	Natural Ventilation	E

Simulation Engine Adaptations

The proposed code changes can be modeled using the current simulation engine. Changes to the simulation engine are not necessary.

2.2.2 Standards Change Summary

This proposal would modify the following sections of the Building Energy Efficiency Standards as shown below. See Section 6.1 of this report for the detailed proposed revisions to the standards language.

2.2.2.1 Changes to Definitions

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

Subsection (b) Definitions: The proposed code changes presented in this report would add new definitions for: “ASME A17.1/CSA B44”, “optimum start controls”, “optimum stop controls”, and “thermostat”.

2.2.2.2 Changes to Mandatory Requirements

SECTION 120.2 – REQUIRED CONTROLS FOR SPACE-CONDITIONING SYSTEMS

Subsection 120.2(j): The proposed code change would add a subsection to Section 120.2 that will require certain buildings to install direct digital controls. The subsection also sets requirements for the capabilities of these control systems.

SECTION 120.6 – MANDATORY REQUIREMENTS FOR COVERED PROCESSES

Subsection 120.6(f): The proposed code change would add a new subsection to Section 120.6 that will set lighting, ventilation, and standby operation requirements for elevators.

Subsection 120.6(g): The proposed regulations add a new mandatory requirement for escalators and moving walkways in airports, hotels, and transit areas. The subsection addresses which escalators and moving walkways will be required to slow down when not in use, as well as the guidelines with which they must comply.

2.2.2.3 Changes to Prescriptive Requirements

SECTION 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

Subsection 140.4(n): The proposed door and window switch control measure would add a new section that would require windows and doors can be opened manually to be equipped with controls that disable mechanical heating and cooling to the zone where the window or door is open. The interlock controls are not required on doors with automatic closing devices, in any space without thermostatic controls, or on alterations to existing buildings.

SECTION 140.6 – PRESCRIPTIVE REQUIREMENTS FOR INDOOR LIGHTING

Subsection 140.6.3V: The proposed elevator lighting and HVAC control measure would modify this subsection so exempts elevator lighting from the prescriptive indoor LPD calculations and that indoor lighting must comply with the new mandatory elevator lighting requirements.

2.2.3 Standards Reference Appendices Change Summary

As discussed in Section 2.3.3 of this report, some of the proposed code changes would require acceptance tests. The reference appendices may need to be updated to explain the required acceptance tests. Proposed changes to the acceptance tests and the reference appendices are included in Section 6.2 of this report.

2.2.4 Nonresidential Alternative Calculation Method (ACM) Reference Manual Change Summary

These proposed changes would modify the following sections of the Nonresidential Alternative Calculation Method (ACM) Reference Manual as shown below. See Section 6.3 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

Section 5.3.5 – Natural Ventilation: The proposed window and door switch control measure would make the following revisions to Section 5.3.5 of the Nonresidential ACM Reference Manual:

- Penalize operable windows without switches by increasing the infiltration rate in the proposed design if operable-window-to-wall ratio greater than 1%. Infiltration rate should only be increased during occupied hours when outdoor air temperatures are between 50^{o}F and 85 ^{o}F. The increased infiltration rate should be fixed at 0.15 cfm/ft2.
- Limit the natural ventilation rate to 1 cfm/ft2 if wind speed below 5 mph and 2 cfm/ft2 above 5 mph. The natural ventilation rate is further limited to 0 cfm/ft2 when the outside air temperature is below 60F, i.e., it is not reasonable to expect occupants to open windows/doors when doing so would result in uncomfortably cold drafts through the window/door. Currently the user can use any natural ventilation rate as long as "Documentation shall be provided supporting the air flow rate for the proposed design".
- Add a definition for "interlocks": Operable window interlocks must be able to automatically disable heating and cooling to any room with operable windows and a thermostat when an operable window in that room is open.
- Fix this typo: The maximum indoor temperature ~~below~~ above which natural ventilation is disabled

Section 5.7.2 – System Controls: The proposed Digital Direct Control measure will result in an update to Section 5.7.2. The update will reflect the new requirement of DDC system for certain building applications and their mandated capabilities.

2.2.5 Compliance Forms Change Summary

For the DDC measure, following compliance forms need to be updated to verify compliance:

- NRCA-MCH-17-F
- NRCA-MCH-18-A

2.2.6 Simulation Engine Adaptations

The simulation engine is capable of modeling the proposed measures.

2.2.7 Other Areas Affected

No other areas will be affected by these measures.

2.3 Code Implementation

2.3.1 Verifying Code Compliance

The proposed code changes that require controls would likely require an acceptance test to verify that the control has been installed and commissioned appropriately. The following code change proposals would require an acceptance test:

- Elevator Ventilation and Cab Lighting Controls
- Escalator and Moving Walkway Speed Controls
- Direct Digital Controls
- Operable Window/Door Switches

Changes to acceptance testing requirements are described in more detail below.

2.3.2 Code Implementation

2.3.2.1 Elevator Ventilation and Cab Lighting Measure

Elevators are not currently regulated under Title 24, so code officials will need to receive training on how to verify compliance with the new requirements.

The measure is now a common industry practice, and almost new construction elevators are already code compliant. As such, industry will not need to adjust their current practices significantly to comply with the proposed code change and the required education and training for industry players will be minimal.

2.3.2.2 Escalator and Moving Walkway Speed Control Measure

Escalators and moving walkways were not previously regulated under Title 24. The measure is not a common industry practice in California, as it has previously been prohibited by California Code of Regulations Title 8, however the technology is mature and escalators with speed controls have been sold, installed and maintaining in Europe for years. While building designers are not familiar with moving walkway controls, building designers are not typically responsible for designing the escalators within buildings. Since the technology is mature, escalator manufacturers should be able to specify compliant escalators without significant lead time. The escalator designer will need to consider pedestrian traffic patterns at each landing of an escalator or moving walkway must be considered to ensure passenger detection will not fail.

This code change proposal would establish the first efficiency requirements escalators. State and local code officials will need to learn about the requirements and how to verify compliance with the newly established code.

2.3.2.3 Direct Digital Control Measure

DDC systems were not previously required by Title 24. The measure is common industry practice for medium and large buildings, and almost all new construction will be code compliant. Most of the savings from this measure will result from new small buildings with additional savings from large and medium buildings being retrofitted. Implementation should not be too difficult since most builders are already installing such systems in medium and large buildings. Compliance testing will be required to verify capabilities and functionality of the DDC system and the required energy efficiency and demand response measures are implemented. These compliance tests already exist in Title 24 if builders voluntarily install DDC systems, so state and local code officials are already familiar with verifying that DDC systems are capable of controlling building systems as required by the code.

2.3.2.4 Operable Window/Door Switch Measure

An acceptable test will be added with the following procedure:

With the window(s) and (door(s) closed, adjust the heating setpoint above the current space temperature.

1. Observe the zone is in heating mode
2. Open a window/door
3. Observe the zone is no longer in heating mode
4. Close the window door
5. Adjust the cooling setpoint below the current space temperature
6. Observe the zone is in cooling mode
7. Open a window/door
8. Observe the zone is no longer in cooling mode or that the outside air temperature is below the space temperature.

2.3.3 Acceptance Testing

The required acceptance tests are described below. The Statewide CASE Team is still developing the code language to describe the acceptance tests. The next version of this report, which will be submitted to CEC in the fall of 2014, will include the proposed code language for the acceptance tests.

2.3.3.1 Elevator Ventilation and Cab Lighting Measure

Acceptance testing will be necessary to verify that the sleep mode function as required by code. The code would require the elevator cabin to shutoff after the cab has been unoccupied and has not received a call signal for over 15 minutes. It is likely that the acceptance test will include verifying that the occupancy sensor work, then manually triggering shutoff to verify that the lighting and ventilation shutoff appropriately. All elevators are already subject to acceptance testing by a certified competent conveyance mechanic and associate safety engineer in accordance with Title 8 and ASME A17.1, 2004, section 8.10. Compliance with the efficiency requirement would be in addition to the Title 8 safety acceptance testing requirements.

2.3.3.2 Escalator and Moving Walkway Speed Control Measure

Acceptance testing will be necessary to verify that the escalator's speed controls meet the code requirements. The test should include measuring both maximum and minimum speeds, the acceleration from minimum speed to maximum speed, and the unoccupied amount of time before the escalator slows down to make sure all are in compliance. The test should also include approaching the escalator in slow speed mode from a variety of angles at an average pace to ensure the passenger detection system speeds up the escalator to max speed before the passenger boards. Finally, it is important to approach the escalator in the wrong direction to verify that the alarm goes off.

All escalators and moving walkways are already subject to acceptance testing by a certified competent conveyance mechanic and associate safety engineer in accordance with Title 8 and ASME A17.1, 2004, section 8.10. The additional tests to verify compliance with Title 24 efficiency requirements could be handled in the same acceptance test.

2.3.3.3 Direct Digital Control Measure

Acceptance testing will be necessary to verify that the DDC system is controlling HVAC equipment and its functionality is fully implemented. The testing would verify that the DDC system is monitoring and controlling the air handlers, chilling and heating plants. The energy efficiency measures would also need to be tested to verify their functionality. This would include demand control ventilation, automatic demand shed controls, and setpoint reset control.

2.3.3.4 Operable Window/Door Switch Measure

This measure requires that during acceptance testing of zone controls, the associated space operable window be opened to verify that heating/cooling is disabled and then closed to verify that heating/cooling is restored.

2.4 Issues Addressed During CASE Development Process

The Statewide CASE Team solicited feedback from a variety of stakeholders when developing the code change proposal presented in this report. In addition to personal outreach to key stakeholders, the Statewide CASE Team conducted a public stakeholder meeting to discuss the proposals. The issues that were addressed during development of the code change proposal are summarized below.

2.4.1 Elevator Ventilation and Cab Lighting Measure

Originally, the Statewide CASE Team was aiming to adopt exactly the same elevator lighting and HVAC requirements that appear in ASHRAE 90.1-2013. ASHRAE 90.1-2013 includes a requirement that lighting in elevators be 35 lpw or higher. This value is significantly less than the efficacy of LEDs, which are typically closer to 70 lpw. During the public stakeholder meeting held on May 20, 2014 stakeholders suggested that California should adopt a lighting efficiency standard that exceeds 35 lpw to achieve more energy savings.

A stakeholder also suggested that a lumen per watt requirement may not be the best metric to evaluate the efficiency of elevator cabin lighting systems. A request was made to look into the possibility of using watts per square foot (W/SF) requirement instead. After analyzing different potential lighting fixtures, lighting patterns, illuminance levels, and other Title 24 W/SF requirements, it was determined that a value of 0.6 W/SF would be an appropriate requirement that would strongly encourage the use of more efficient lighting systems. LED lighting systems are the current target for this code requirement. Based on lumen, foot-candle, and W/SF calculations performed by the Statewide Case Team for various lighting types and elevator sizes, the LED lighting systems should be able to meet the IESNA minimum recommendations of 5 fc and 50 lux for elevators without issue.

When evaluating W/SF requirements, concerns were raised that it may be more difficult for smaller elevators to reach a particular W/SF requirement than larger elevators. The Statewide CASE Team looked at the possibility of adding an extra allowance of watts on top of the W/SF requirement. The proposal was to use a W/SF of 0.50, with an additional 20 W. After comparing the two strategies, it was determined that a straight W/SF requirement would be more appropriate. There were no previous examples of an additional wattage allowance in Title 24.The value of 0.6 W/SF is used in multiple other Title 24 requirements, such as for hallway lighting power density. The Title 24 requirements rarely go below 0.6 W/SF. Hallways have a more beneficial room cavity ratio than elevators. However, because the hallway requirement of 0.6 W/SF can be met by CFLs, the lower room cavity ratio of elevators will encourage the use of LEDs. As a result, the Statewide CASE Team has revised its initial recommendation of 35 lpw for elevator lighting to instead include a lighting power density requirement of 0.6 W/SF.

One concern raised was that elevator lighting and ventilation should remain in operation in the event that the elevator gets stuck with people inside the cab. There are weight sensors that are meant to keep elevator cabins from being overloaded, which can also be used as passenger detection systems to override shut down if someone is still present inside. As a result of this concern, the Statewide CASE Team included language that would require lighting and ventilation to remain operational in event that the elevator gets stuck. Including this language in the code is an extra precaution. Since the elevator lighting and ventilation will be controlled by an occupancy sensor, the lighting and ventilation should remain in operation whenever the cab is occupied, whether the elevator is stuck or not.

2.4.2 Escalator and Moving Walkway Speed Control Measure

An issue that arose during the stakeholder meeting on May 7, 2014, and the pre-rulemaking workshop on June 12th was whether the escalator and moving walkway speed control measure should be a mandatory or prescriptive requirement. The ASHRAE 90.1-2013 requirement is mandatory, and the Statewide CASE Team was originally aiming to propose a mandatory requirement for Title 24, and the measure was presented as a mandatory requirement during the May 7, 2014 stakeholder meeting. However, after discussing the limitations of escalator and moving walkway speed controls in in certain buildings, such as buildings with consistent pedestrian traffic during operating hours or buildings with design constraints that require people to enter the escalator or moving walkway at an abnormal angle, there was discussion amongst stakeholders about the merits of proposing a prescriptive requirement as opposed to a mandatory requirement. If the requirement were prescriptive, if the building is not well suited for speed controls, designer would have the option to use the performance approach and opt out of installing speed controls in favor of other efficiency measures. Moving walkway speed controls are relatively new to the California market and people are not familiar with the technology. Although the ASME requirements have ensured that speed controls are safe, if the code requirement were prescriptive requirement people that do not feel comfortable with the technology would have the option of using the performance approach and opting out of the speed control requirements.

This issue of whether the measure should be mandatory or prescriptive was discussed further during CEC's pre-rulemaking workshop that was held on June 12, 2014. During the pre-rulemaking workshop, stakeholders raised the concern that it is harder to implement a prescriptive requirement than a mandatory requirement. If the measure were prescriptive, the ACM Reference Manual would need to be updated to ensure that the energy use of escalators is modeled correctly, and the code would need to specify how escalator energy use could be traded off against other measure. Neither updating the ACM Reference Manual rule set nor determining appropriate tradeoffs is a straightforward task. The energy savings of speed controls is highly dependent on how the escalator or moving walkway is used, specifically how frequently the escalator is operating but not conveying people. Since occupancy patterns and escalator usage patterns will vary significantly, developing a ruleset for the ACM Reference Manual that accurately predicts energy performance would be challenging. Escalators are not part of any existing regulated building category (e.g., water heating or HVAC). A prescriptive requirement would add these stand-alone systems to the building's energy budget, but the compliance options that could be used to trade off against escalator speed controls would have to come from unrelated building systems like HVAC, envelope, or water heating.

After carefully considering the pros and cons of proposing a mandatory or prescriptive requirement, the Statewide CASE Team is proposing a mandatory requirement that applies to very specific building types (i.e., airports, hotels, and transit areas) that will likely benefit from the speed controls because the typical use patterns of escalator sin these building types are favorable to speed controls. In addition, the Statewide CASE Team has added a requirement that the speed controls be equipped with a manual override option that allows building operators to override the speed control option if they so choose.

The safety of moving walkway controls was discussed during the stakeholder meeting on May 20, 2014. As mentioned previously in this report, ASME has developed design standards for moving walkway controls that address potential safety concerns. The proposed code change would require moving walkways to comply with the ASME safety guidelines. Cal/OSHA is responsible for establishing elevator and escalator safety standards.

2.4.3 Direct Digital Controls Measure

During the stakeholder meeting, the Statewide CASE Team expressed concern for the implementation of triggered energy efficiency measures. Stakeholders stated that since these measures were already being installed for medium and large buildings due to common industry standard practice, the application to small buildings would not impose a significant burden on new construction projects.

2.4.4 Operable Window/Door Switch Measure

The following issues were discussed during the stakeholder meeting:

- Integration with building security systems: One stakeholder asked if the door and window switch controls can be integrated with the building security system. Yes, door and window switch controls can be integrated with the building security system.

  Doors that open and close frequently, such as doors in retail spaces, should not trigger the HVAC system to cycle down. The Statewide CASE Team understands this concern. The proposed code language exempts doors that have automatic closures, which includes most doors in retail spaces.

- One stakeholder questions if the door window switch controls would impact the longevity of the HVAC system. Statewide CASE Team does not expect negative impact on the longevity of HVAC systems.
- Can existing building control systems handle another input, or would this require upgrading control systems? Feedback from the 4 largest packaged air conditioner manufacturers has been positive. None see any problems –e.g. from York/JCI: "I don't see any problem with this. Our TEC controllers have a window sensor input for this very purpose as part of their standard programming, and our FEC controllers can do this as well". Similarly, feedback from DDC vendors including ALC and Honeywell indicates there are no issues implementing this on multiple zone systems such as VAV reheat boxes.
- Buildings with operable windows should have small zones so the full zone receives the benefit of the operable window.

One individual expressed concern that fewer buildings would have operable thus losing some of the non-energy benefits of operable windows. There is a good chance, however, that this measure will have the opposite effect, i.e. it will result in more buildings with operable windows. Many buildings are now required to achieve LEED, CALGreen Code Tier 1 or other energy code that exceed the minimum requirements established by Part 6 of Title 24. Thus giving credit in the ACM for operable windows with switches will be a strong incentive to install operable windows in buildings that otherwise would not have had operable windows.

2.4.5 Fan Efficiency Grade Measure

As discussed in Section 2.1.2, during the CASE development process the Statewide CASE Team decided not to propose a code change that proposed adopting the ASHRAE 90.1-2013 Fan Efficiency Grade requirement. The Fan Efficiency Grade measure was presented ruing the stakeholder meeting on May 20, 2014 and the pre-rulemaking workshop on June 12, 2014. During both public meetings the Statewide CASE Team solicited input on whether FEG was the correct metric and another metric such as PBER was a better metric. After the June 12, 2014 pre-rulemaking workshop, the Statewide CASE Team decided that there was still too much uncertainty about the appropriate metric to propose a code change based on FEG.

3. MARKET ANALYSIS

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. The Statewide CASE Team considered how the proposed standard may impact the market in general and individual market players. The Statewide CASE Team gathered information about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with key stakeholders including utility program staff, CEC, and a wide range of industry players who were invited to participate in stakeholder meetings that the Statewide CASE Team sponsored and held in May 2014.

3.1 Market Structure

3.1.1 Elevator Ventilation and Cab Lighting Measure

The principal elevator manufacturers are Otis, Kone, Schindler, and Thyssenkrupp. Each of these companies has a readily available product capable of fulfilling the requirements of this measure. Each company has multiple branches in California.

3.1.2 Escalator and Moving Walkway Speed Control Measure

The principal escalator and moving walkway manufacturers are Otis, Kone, Schindler, and Thyssenkrupp. Each of these companies has a readily available product capable of fulfilling the requirements of this measure. Each company has multiple branches in California.

3.1.3 Direct Digital Control Measure

The principal manufacturers are Honeywell, Johnson Controls, KMC Controls, and Siemens. Each of these companies has a readily available product capable of fulfilling the requirements of this measure. Each company has multiple branches in California.

3.1.4 Operable Window/Door Switch Measure

This measure is readily available in the market from multiple providers. As discussed above all major packaged unit manufacturers and all major DDC controls manufacturers already have the ability to incorporate this measure into single zone and multiple zone systems. The window switch itself can be packaged with the window or it can a field installed sensor that is hardwired to the HVAC or wireless.

3.2 Market Availability and Current Practices

3.2.1 Elevator Ventilation and Cab Lighting Measure

Elevators that meet the proposed code requirements are common and available from multiple manufacturers, including Kone, Otis, Thyssenkrupp, and Schindler. These manufacturers are already familiar with and produce this technology. This technology is now industry standard practice for new construction elevators.

3.2.2 Escalator and Moving Walkway Speed Control Measure

Escalator and moving walkway manufacturers such as Kone, Otis, Thyssenkrupp, and Schindler are already familiar with and produce this technology in European countries where intermittent speed escalators are more common. These manufacturers should not have any issues meeting the demand once the Standards are effective; the demand in California for 2017 is only projected to be fewer than 300 units based off of the 2005 TIAX Miscellaneous Electricity consumption report (TIAX 2006). Currently California does not allow escalator speed variation, but is expected to once the new Title 8 updates take effect. There are competing products in escalator energy reduction that use power factor correction instead of varying the operating speed, however variable speed technology has been backed by ASME and ASHRAE.

3.2.3 Direct Digital Control Measure

The proposed measure should have little to no issues with market availability, and is available from multiple manufacturers, including Honeywell, Johnson Controls, KMC Controls, and Siemens. These manufacturers are already familiar with and produce this technology.

3.2.4 Operable Window/Door Switch Measure

Window switches and HVAC interlocks are mature technologies that are in widespread use today. There are currently commercially available technologies from multiple manufacturers that can meet the various applications of this measure, including:

- DDC controls - wireless window switches that communicate with wireless receivers at the terminal unit.
- Non-DDC controls – wireless or wired switches that are wired to a relay that interrupts the low-voltage signal from the thermostat to the heating/cooling unit.

A 2007 study of mixed-mode buildings with operable windows conducted by the UC Berkeley CBE found that 7 of 24 buildings with operable windows also had window switches (UC Berkeley 2007).

3.3 Useful Life, Persistence, and Maintenance

The methodology the Statewide CASE Team used to determine the costs associated with incremental maintenance costs, relative to existing conditions, is presented in Section 4.7.1. The incremental maintenance costs of the proposed code change are presented in Section 5.2.1.

3.3.1 Elevator Ventilation and Cab Lighting Measure

The majority of the energy and maintenance savings associated with this measure is created by installing higher-efficiency lamps that meet the efficacy requirement as opposed to installing less efficient halogen or fluorescent lighting. LEDs are preferable, as they not only reduce the energy usage, but also have a lifetime of 50,000 hours, which is roughly 10 times longer than their halogen lamp counterparts and 5 times longer than the fluorescents. In addition to the more efficient lamps, the proposed measure also calls for the lighting to be shut off when the elevator is in standby mode for more than 15 minutes. This means the newer, longer lasting lamps will not be used as frequently as the halogen/fluorescent lamps, which were assumed to run continuously in the baseline. The occupancy sensor control is expected to have a useful life of anywhere between 6 to 10 years. The LCC analysis assumes the first occupancy sensor will be replaced upon burnout within the 15 year period of analysis. Energy savings will persist throughout the life of the measure.

3.3.2 Escalator and Moving Walkway Speed Control Measure

The typical life of an escalator or moving walkway is approximately 25 years. By implementing intermittent speed control on escalator and moving walkway systems, the effective life will typically increase a few years due to a reduction in wear on the motor. This wear reduction as a result of the proposed measure will also reduce the cost and frequency of maintenance. The energy savings will be present throughout the life of the system.

3.3.3 Direct Digital Control Measure

The life, frequency of replacement, and maintenance procedures will, for the most part, remain unchanged when this standard becomes effective. DDC systems may extend the life of HVAC equipment since operation efficiency will be more precise, but probably not significantly.

3.3.4 Operable Window/Door Switch Measure

Energy savings from this measure will persist for the life of the system. Window switches are typically solar powered thus no battery replacements are required. No maintenance is required over the life of the system.

There is a high probability of persistence of savings because the default position is no heating or cooling. Thus if a window switch were damaged or removed for some reason the system would not provide heating/cooling. This would lead to the switch being repaired or replaced in short order.

3.4 Market Impacts and Economic Assessments

3.4.1 Impact on Builders

3.4.1.1 Elevator Ventilation and Cab Lighting Measure

The proposed measure will require elevator installers to set-up the additional controls required to regulate lighting, ventilation, and standby timing.

3.4.1.2 Escalator and Moving Walkway Speed Control Measure

The proposed measure will require escalator or moving walkway installers to install a variable frequency drive motor and means for passenger detection.

3.4.1.3 Direct Digital Control Measure

The proposed measure will more likely impact smaller buildings since it is not common industry practice to install DDC systems. For small, medium and large buildings, the proposed measure will trigger other sections of Title 24 and will require the installation of demand control ventilation and automatic demand shed controls, which may not be common industry practice.

3.4.1.4 Operable Window/Door Switch Measure

Builders will want to make sure the operable windows have the switches integrated with the windows as this will be less expensive than field installing switches.

3.4.2 Impact on Building Designers

3.4.2.1 Elevator Ventilation and Cab Lighting Measure

The proposed measure will have little to no effect on the building designers.

3.4.2.2 Escalator and Moving Walkway Speed Control Measure

The proposed measure will require building designers to pay closer attention to the areas near escalator entrances and exits to ensure approaching passengers will not be able to avoid triggering the passenger detection system.

3.4.2.3 Direct Digital Control Measure

The proposed measure will likely impact smaller buildings since it is not common industry practice to install DDC systems. For small, medium and large buildings, the proposed measure will trigger other sections of Title 24 and require the installation of demand control ventilation, set point reset controls and automatic demand shed controls, which may not be common industry practice.

3.4.2.4 Operable Window/Door Switch Measure

HVAC system designers will need to insure their controls design includes input from the window switch and the appropriate controls action (e.g. reset temperature setpoints when window is open).

3.4.3 Impact on Occupational Safety and Health

The Escalator and Moving Walkway Speed Control Measure has a history of safety-related concerns regarding the impact of acceleration rates on passenger stability. Currently, Title 8 and Cal/OSHA prohibit the variation of escalator and moving walkway speed once operation has begun, by referencing the 2004 ASME A17.1 code. The 2013 ASME A17.1 code permits the variation of escalator and moving walkway speed provided certain requirements are met. These are the same requirements in the suggested code language in Section 6.1 of this report, as the proposed code change from ASHRAE originates from ASME. After discussing the potential code conflict with Cal/OSHA's Elevator Unit, it was learned that Cal/OSHA is in the process of updating Title 8 to refer to the 2013 ASME A17.1, which will allow for the speed variation and is currently expected to go into effect early 2015. The acceptance of this update should occur before Title 24 2016 goes into effect. Stakeholders from Cal/OSHA still express some concern with potential injuries, although the maximum acceleration rate has been deemed safe by ASME.

The other proposed code changes included in this report do not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by Cal/OSHA. All existing health and safety rules will remain in place. Complying with the proposed code changes is not anticipated to have any impact on the safety or health occupants or those involved with the construction, commissioning, and ongoing maintenance of the building.

The Statewide CASE Team met with representatives from Cal/OSHA and the California Air Resources Board (CARB) on Friday, July 11, 2014 to discuss the proposed changes to Title 24 that could impact occupant health and safety. Cal/OSHA requested that we discuss the operable windows/door switch measure during this meeting. After discussing the code change proposal and confirming that the proposal does not impact ventilation within a building with operable windows or doors, Cal/OSHA and CARB articulated that they did not currently have concerns about the code change proposals the Statewide CASE Team was recommending, including the operable windows/doors measure.

3.4.4 Impact on Building Owners and Occupants

3.4.4.1 Elevator Ventilation and Cab Lighting Measure

The proposed measure will reduce energy and maintenance costs for the building owners, and will have little to no effect on the occupants.

3.4.4.2 Escalator and Moving Walkway Speed Control Measure

The proposed measure will reduce energy and maintenance costs for the building owners, but will also potentially increase the likelihood of an injury related lawsuit due to the speed change. If a passenger manages to avoid the passenger detection system and board a slow moving escalator or walkway while a second passenger triggers the speed increase, the acceleration could cause the first passenger to lose his/her balance.

3.4.4.3 Direct Digital Control Measure

The proposed measure will reduce energy costs for the building owners, and will have little to no effect on the occupants.

3.4.4.4 Operable Window/Door Switch Measure

Building occupants will either be told or quickly learn from experience that opening the window disables heating/cooling. Occupants who are environmentally conscious will then be eager to open the window whenever it is tolerable because they know doing so will save HVAC energy.

3.4.5 Impact on Retailers (including manufacturers and distributors)

3.4.5.1 Elevator Ventilation and Cab Lighting Measure

The proposed measure will result in a slight increase in demand for the additional elevator lighting and ventilation control technology.

3.4.5.2 Escalator and Moving Walkway Speed Control Measure

The proposed measure will result in a slight increase in demand for escalator and moving walkway systems that come with the variable speed technology.

3.4.5.3 Direct Digital Control Measure

The proposed measure will result in a slight increase in demand for DDC technology. The proposed measure will trigger other sections of Title 24 and require the installation of demand control ventilation and automatic demand shed controls, increasing demand for both technologies.

3.4.5.4 Operable Window/Door Switch Measure

Operable window/door manufacturers will start including switches as a standard offering in their products. Manufacturers of window/door switches will see an increase in sales.

3.4.6 Impact on Energy Consultants

The proposed measures will have little to no effect on energy consultants.

3.4.7 Impact on Building Inspectors

Each of the proposed measures will require some form of building inspector to verify that the measure has been implemented correctly, but will not result in a significantly longer inspection process than current existing buildings.

3.4.8 Impact on Statewide Employment

The proposed measures will have little to no impact on statewide employment.

3.5 Economic Impacts

The proposed Title 24 code changes, including this measure, are expected to increase job creation, income, and investment in California. As a result of the proposed code changes, it is anticipated that less money will be sent out of state to fund energy imports, and local spending is expected to increase due to higher disposable incomes due to reduced energy costs.[2] In addition, more dollars will be spent in state on improving the energy efficient of new buildings.

These economic impacts of energy efficiency are documented in several resources including the California Air Resources Board's (CARB) Updated Economic Analysis of California's Climate Change Scoping Plan, which compares the economic impacts of several scenario cases (CARB, 2010b). CARB include one case (Case 1) with a 33% renewable portfolio standard (RPS) and higher levels of energy efficiency compared to an alternative case (Case 4) with a 20% RPS and lower levels of energy efficiency. Gross state production (GSP)[3], personal income, and labor demand were between 0.6% and 1.1% higher in the case with the higher RPS and more energy efficiency (CARB 2010b, Table 26). While CARB's analysis does not report the benefits of energy efficiency and the RPS separately, we expect that the benefits of the package of measures are primarily due to energy efficiency. Energy efficiency measures are expected to reduce costs by $2,133 million annually (CARB 2008, pC-117) whereas the RPS implementation is expected to cost $1,782 million annually, not including the benefits of GHG and air pollution reduction (CARB 2008, pC-130).

Macro-economic analysis of past energy efficiency programs and forward-looking analysis of energy efficiency policies and investments similarly show the benefits to California's economy of investments in energy efficiency (Roland-Holst 2008; UC Berkeley 2011).

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[2] Energy efficiency measures may result in reduced power plant construction, both in-state and out-of-state. These plants tend to be highly capital-intensive and often rely on equipment produced out of state, thus we expect that displaced power plant spending will be more than off-set from job growth in other sectors in California.

[3] GSP is the sum of all value added by industries within the state plus taxes on production and imports.

3.5.1 Creation or Elimination of Jobs

CARB's economic analysis of higher levels of energy efficiency and 33% RPS implementation estimates that this scenario would result in a 1.1% increase in statewide labor demand in 2020 compared to 20% RPS and lower levels of energy efficiency (CARB 2010b, Tables 26 and 27). CARB's economic analysis also estimates a 1.3% increase in small business employment levels in 2020 (CARB 2010b, Table 32).

3.5.2 Creation or Elimination of Businesses within California

CARB's economic analysis of higher levels of energy efficiency and 33% RPS implementation (as described above) estimates that this scenario would result in 0.6% additional GSP in 2020 compared to 20% RPS and lower levels of energy efficiency (CARB 2010b, Table ES-2). We expect that higher GSP will drive additional business creation in California. In particular, local small businesses that spend a much larger proportion of revenue on energy than other businesses (CARB 2010b, Figures 13 and 14) should disproportionately benefit from lower energy costs due to energy efficiency standards. Increased labor demand, as noted earlier, is another indication of business creation.

Table 11 below shows California industries that are expected to receive the economic benefit of the proposed Title 24 code changes. It is anticipated that these industries will expand due to an increase in funding as a result of energy efficiency improvements. The list of industries is based on the industries that the University of California, Berkeley identified as being impacted by energy efficiency programs (UC Berkeley 2011 Table 3.8).[4] This list provided below is not specific to one individual code change proposal; rather it is an approximation of the industries that may receive benefit from the 2016 Title 24 code changes. A table listing total expected job creation by industry that is expected in 2015 and 2020 from all investments in California energy efficiency and renewable energy is presented in the Appendix B of this CASE Report.

Table 11: Industries Receiving Energy Efficiency Related Investment, by North American Industry Classification System (NAICS) Code

Industry	NAICS Code
Residential Building Construction	2361
Nonresidential Building Construction	2362
Roofing Contractors	238160
Electrical Contractors	23821
Plumbing, Heating, and Air-Conditioning Contractors	23822
Boiler and Pipe Insulation Installation	23829
Insulation Contractors	23831

4 Table 3.8 of the UC Berkeley report includes industries that will receive benefits of a wide variety of efficiency interventions, including Title 24 standards and efficiency programs. The authors of the UC Berkeley report did not know in 2011 which Title 24 measures would be considered for the 2016 adoption cycle, so the UC Berkeley report was likely conservative in their approximations of industries impacted by Title 24. Statewide CASE Team believes that industries impacted by utilities efficiency programs is a more realistic and reasonable proxy for industries potentially affected by upcoming Title 24 standards. Therefore, the table provided in this CASE Report includes the industries that are listed as benefiting from Title 24 and utility energy efficiency programs.

Window and Door Installation	23835
Asphalt Paving, Roofing, and Saturated Materials	32412
Manufacturing	32412
Other Nonmetallic Mineral Product Manufacturing	3279
Industrial Machinery Manufacturing	3332
Ventilation, Heating, Air-Conditioning, & Commercial Refrigeration Equipment Manufacturing	3334
Computer and Peripheral Equipment Manufacturing	3341
Communications Equipment Manufacturing	3342
Electric Lighting Equipment Manufacturing	3351
Household Appliance Manufacturing	3352
Other Major Household Appliance Manufacturing	335228
Used Household and Office Goods Moving	484210
Engineering Services	541330
Building Inspection Services	541350
Environmental Consulting Services	541620
Other Scientific and Technical Consulting Services	541690
Advertising and Related Services	5418
Corporate, Subsidiary, and Regional Managing Offices	551114
Office Administrative Services	5611
Commercial & Industrial Machinery & Equipment (exc. Auto. & Electronic) Repair & Maintenance	811310

3.5.3 Competitive Advantages or Disadvantages for Businesses within California

California businesses would benefit from an overall reduction in energy costs. This could help California businesses gain competitive advantage over businesses operating in other states or countries and an increase in investment in California, as noted below.

3.5.4 Increase or Decrease of Investments in the State of California

CARB's economic analysis indicate that higher levels of energy efficiency and 33% RPS will increase investment in California by about 3% in 2020 compared to 20% RPS and lower levels of energy efficiency (CARB 2010b Figures 7a and 10a).

3.5.5 Incentives for Innovation in Products, Materials, or Processes

Updating Title 24 standards will encourage innovation through the adoption of new technologies to better manage energy usage and achieve energy savings.

3.5.6 Effects on the State General Fund, State Special Funds and Local Governments

The Statewide CASE Team expects positive overall impacts on state and local government revenues due to higher GSP and personal income resulting in higher tax revenues, as noted earlier. Higher property valuations due to energy efficiency enhancements may also result in positive local property tax revenues. The Statewide CASE Team has not obtained specific data to quantify potential revenue benefits for this measure.

3.5.6.1 Cost of Enforcement

Cost to the State

State government already has budget for code development, education, and compliance enforcement. While state government will be allocating resources to update the Title 24 standards, including updating education and compliance materials and responding to questions about the revised standards, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals.

Cost to Local Governments

All revisions to Title 24 will result in changes to Title 24 compliance determinations. Local governments will need to train permitting staff on the revised Title 24 standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2016 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining. For example, utilities offer compliance training such as "Decoding" talks to provide training and materials to local permitting departments. As noted earlier, although retraining is a cost of the revised standards, Title 24 energy efficiency standards are expected to increase economic growth and income with positive impacts on local revenue.

These new measures would also result in additional on-going compliance costs for plan review and increased inspections. The implementing jurisdictions have authority to recover their costs through permitting and inspection fees. In cases where an additional inspection would be required, it may be automatically covered by service-based fee structures. In other cases, local jurisdictions may be required to raise their fees to recover additional costs or absorb these costs in other ways such as finding other resources, and/or carbon based permitting fees. However, these costs are not expected to be significant compared to overall statewide benefit of enforcing building codes and standards.

3.5.6.2 Impacts on Specific Persons

The proposed changes to Title 24 are not expected to have a differential impact on any of the following groups relative to the state population as a whole:

- Migrant Workers
- Persons by age
- Persons by race
- Persons by religion
- Commuters

The proposed code changes presented in the report do not impact residential buildings, so there are no impacts on homeowners or low-income families.

Renters that pay energy bills will typically benefit from lower energy bills.

4. METHODOLOGY

This section describes the methodology and approach the Statewide CASE Team used to estimate energy, demand, costs, and environmental impacts. The Statewide CASE Team calculated the impacts of the proposed code change by comparing existing conditions to the conditions if the proposed code change is adopted. This section of the CASE Report goes into more detail on the assumptions about the existing and proposed conditions, prototype buildings, and the methodology used to estimate energy, demand, cost, and environmental impacts.

4.1 Existing Conditions

4.1.1 Elevator Ventilation and Cab Lighting Measure

There are no existing Title 24 requirements that cover elevator cab lighting and ventilation. The Statewide CASE Team used current design practices as the existing conditions. It is assumed that sleep mode controls are already industry standard practice in new construction elevators sold currently. Most of the energy savings will come from retrofits, where there are no sleep mode controls and lighting is achieved through less efficient lamps.

4.1.2 Escalator and Moving Walkway Speed Control Measure

There are no existing Title 24 requirements for escalator and moving walkway speed controls. The Statewide CASE Team used current design practices as the existing conditions. The existing condition assumes that all escalators and moving walkways run at a maximum constant speed of 0.5 meters per second during the entire time of operation. The average travel length is assumed to be 10 meters.

4.1.3 Direct Digital Control Measure

There are no existing Title 24 requirements for DDC systems to be installed in buildings. However, if DDC controls are installed voluntarily, Title 24 requirements for automatic demand shed and demand controlled ventilation apply. As discussed in Section 4.6.2, the Statewide CASE Team accounted for the buildings that are already installing DDC systems voluntarily by adjusting the percentage of statewide floor space that would be impacted by the standards.

For buildings that are not voluntarily installing DDC systems, and would therefore be impacted by the standards, the baseline case is defined as a building built to 2013 Title 24 Standards. This is appropriate for new construction, retrofit and replace on burnout installations since if the proposed DDC measure was not adopted, then buildings that are new, being remodeled or HVAC equipment that is being replaced would be required to comply with the current Title 24 standard (2013). The 2013 Title 24 baseline assumes DDC systems are not installed and requirements for demand control ventilation, set point reset controls and automatic demand shed controls are not triggered.

4.1.4 Operable Window/Door Switch Measure

To assess the energy, demand, costs, and environmental impacts, the Statewide CASE Team compared current design practices to design practices that would comply with the proposed requirements.

A total of three simulation runs were performed for each climate zone to establish performance for a building without the operable windows open, performance for when operable windows were open simultaneously with HVAC equipment conditioning the space, and performance for when operable windows were open without HVAC equipment conditioning the space. Hourly output data for these runs were exported to spreadsheets and then compiled into the baseline and proposed measure analysis.

The baseline and proposed models were bounded by the conditions listed in Table 12.

Table 12: Operable Window Use Model Criteria

Scenario	Coldest Acceptable Zone Temperature for Window Open [°F]	Warmest Acceptable Zone Temperature for Window Open [°F]	Highest Acceptable Airflow Through Window [ACH]	Frequency of Operable Window Use During Acceptable Periods [%]
Baseline	68	76	10	25
Proposed	68	76	10	15

The baseline model simulates occupants utilizing operable windows with a non-integrated HVAC system operating to condition the space whenever the criteria listed in Table 4 is satisfied. Note the listed assumption on frequency of window use during acceptable periods. This value represents how often an occupant will open the operable window when acceptable conditions listed in Table 4 are met. For example, in the baseline the window is modeled as closed if opening the window resulting in a space temperature that was too cold or too hot or in an infiltration rate that was too high. The window is only modeled as being open 25% of the time when opening the window would not make it too cold, hot or windy in the space.

When a building is equipped with operable windows and an HVAC system that is not integrated in respect to the use of the windows, it is possible for energy consumption to increase compared to if the building was completely sealed without operable windows. The cause for this potential increase in energy is due to the likelihood of an occupant leaving a window open beyond desirable hours unintentionally. This can be due to numerous reasons such as forgetting to close the window when the occupant leaves the office or not having the correct information on when the optimal time is to open the window.

When an operable window is open, the effect on the space is an increase in the rate of infiltration of un-tempered air. This increases the load on the HVAC system serving the space as a function of temperature differential between the outside air temperature and the space setpoint.

4.2 Proposed Conditions

4.2.1 Elevator Ventilation and Cab Lighting Measure

Under the proposed conditions for elevator cab lighting and ventilation, standby mode will become active when the elevator has been unoccupied and not in use for over 15 minutes. In standby mode, the lighting and ventilation will shut off to conserve energy, and then re-energize when the elevator is called back into action. The proposed condition also includes a LPD requirement of 0.6 W/SF, as well as a ventilation requirement of 0.33W per cubic feet per minute when the cab is moving at maximum speed. To meet the LPD requirement, 3W LEDs replace the 20W halogens and 5W linear fluorescents used in the existing condition assumptions. LEDs not only meet the efficacy requirement, but also have a significantly higher lifecycle. When combined with the fact that the lighting will no longer run 24 hours per day, the cost of maintenance to buy and replace elevator lighting lamps will decrease significantly. The Statewide CASE Team used 3,504 annual hours of unoccupied standby time for an average elevator in the calculations (Engineering Technologies Associated 2012).

4.2.2 Escalator and Moving Walkway Speed Control Measure

Under the proposed conditions for escalators and moving walkway speed control, speed variation will be permitted due to ASME A17.1 (2010) and an expected update to Title 8. After a duration of time equal to three times the length of the typical full ride time with no passengers detected, the escalators and moving walkways will go into an intermittent mode where the speed will ramp down to 10 percent of the maximum speed (i.e., 0.5 m/s to 0.05 m/s) until an approaching passenger is detected again. The decrease in speed will reduce wear on the escalator or moving walkway motor and improve the life expectancy of the system, while simultaneously reducing maintenance and electricity costs. The Statewide CASE Team assumes the average escalator or moving walkway will experience 3 hours of intermittent mode in a typical day.

4.2.3 Direct Digital Control Measure

Under the proposed conditions for DDCs, most buildings would require DDC systems to manage the HVAC systems of the building. They would also require demand control ventilation, set point reset controls and automatic demand shed controls to improve HVAC operations and allow for demand response implementation. For the energy savings calculations, the measure case is defined as a building built to 2016 Title 24 Standards assuming that the proposed DDC measure was adopted. Specifically, it was assumed that DDC systems would be installed and that the above mentioned controls strategies would be deployed.

4.2.4 Operable Window/Door Switch Measure

The proposed conditions are defined as the design conditions that will comply with the proposed code change. The proposed model simulates occupants utilizing operable windows with an integrated HVAC system that is shut off whenever the criteria listed below are satisfied. Note that the assumption for frequency of use is lower in the proposed case to anticipate potential reluctance of occupants to open their windows if they prefer to leave the space HVAC system in operation.

- Criteria under which the window was modeled as open: Simulated open window 18% of the time when all of the following were true:
  - Normal occupied times (no penalty for leaving windows open after hours)
  - Outside temp between 50F and 85F
  - Resultant indoor temp between 68F and 77

4.3 Prototype Building(s)

As discussed in the Energy Impacts Methodology section, the Statewide CASE Team did not model energy use from prototype buildings for the elevator or escalator measures. Rather, the savings estimates were calculated on a per elevator or per escalator basis.

The prototype building used for the DDC and operable windows/doors measures are described below.

4.3.1 Direct Digital Controls

The Statewide CASE Team, using eQUEST, built three prototypes representing retail, colleges and large office space types. These three prototypes represent the majority of new construction in California. These prototypes were based on a generic shape and size of buildings. The new construction prototypes are based on three stories, 40,000 square-foot square floors with 15-foot deep perimeter zones and one interior zone. The total square footage of the prototype buildings' is 120,000 SF. The floor-to-floor height is 13 feet and the plenum height is 4 feet (See Table 13).

Table 13: Prototype Buildings used for Energy, Demand, Cost, and Environmental Impacts Analysis

	Occupancy Type (Residential, Retail, Office, etc.)	Area (Square Feet)	Number of Stories	Relative Weight to Statewide Estimates
Prototype 1	Office	120,000	3	62.8%
Prototype 2	School	120,000	3	13.4%
Prototype 3	Retail	120,000	3	23.8%

Since these three building types do not account for all the building types that are impacted by the DDC measure, the prototype weights were proportionally increased to make up the total impacted square footage.

The retrofit prototype building was modeled as a 12 story high-rise office building with an existing double-duct CAV system using pneumatic controls. These pneumatic controls were upgraded to DDC and the modeled EEMs included both waterside reset measures as well as airside reset EEMs. Demand control ventilation was also added along with optimal central plant operations. This model was then used to scale the results for all retrofit buildings. The scaling is considered applicable due to the fact that large commercial office space makes up the most significant component of the population of retrofit buildings that will be subjected to this measure when and if implemented. Additional modeling can be conducted on all impacted building types and all climate zones, but the results are not expected to be significantly impacted.

4.3.2 Operable Windows/Door Switch

The modeled building is a single-story, 10,000 square-foot square building with 15-foot deep perimeter zones totaling 5,100 square feet and one interior zone totaling 4,900 square feet. The floor-to-floor height is 12 feet and the plenum height is 3 feet. There is a continuous strip of glazing, double pane, and low-e glass for a 50% window-to-wall ratio. There are no skylights and no day lighting controls. The undiversified internal loads include lighting power density of 0.9 watts per square-foot, equipment power density of 1.0 watts per square-foot, and an occupancy density of 200 square foot per person. The internal load schedules are based on default DOE2 values. (For the basis of data post processing to correct for instances where the equivalent space ACH exceeded 6 ACH, the average boiler efficiency is assumed to be 65%). This is based on trend data collected by Taylor Engineering from typical boiler plants (See Table 14).

Table 14: Prototype Buildings used for Energy, Demand, Cost, and Environmental Impacts Analysis – Operable Windows/Doors

	Occupancy Type (Residential, Retail, Office, etc.)	Area (Square Feet)	Number of Stories	Relative Weight to Statewide Estimates	Other Notes
Prototype	Office	100,000	1	100%	50% window to wall ratio and 5,100 square feet of perimeter space. The building is served by a VAV reheat system with DX cooling and hot water reheat.

4.4 Climate Dependent

4.4.1 Elevator Ventilation and Cab Lighting Measure

The impacts of this proposed measure are not climate specific, so it is not necessary to model savings in every climate zone. Statewide average TDV factors were used in the energy and cost analysis.

4.4.2 Escalator and Moving Walkway Speed Control Measure

The impacts of this proposed measure are not climate specific, so it is not necessary to model savings in every climate zone. Statewide average TDV factors were used in the energy and cost analysis.

4.4.3 Direct Digital Control Measure

The impacts of this proposed measure are climate-specific. Impacts were modeled in all 16 California climate zones to illustrate the full range of impacts that are expected statewide.

4.4.4 Operable Window/Door Switch Measure

The impacts of this proposed measure are climate specific. Impacts were modeled in California climate zones 3 (Oakland), 6 (Torrance) and 12 (Sacramento) to illustrate the full range of impacts that are expected statewide.

4.5 Time Dependent Valuation

The TDV of savings is a normalized format for comparing electricity and natural gas savings that takes into account the cost of electricity and natural gas consumed during different times of the day and year. The TDV values are based on long-term discounted costs (30 years for residential measures). The TDV cost impacts are presented in 2017 present value dollars. The TDV energy estimates are based on present-valued cost savings but are normalized in terms of "TDV kBTUs" so that the savings are evaluated in terms of energy units and measures with different periods of analysis can be combined into a single value.

The TDV energy impacts are presented in Section 5.1of this report, and the statewide TDV cost impacts are presented in Section 5.2 of this report.

4.6 Energy Impacts Methodology

The Statewide CASE Team calculated per unit impacts and statewide impacts associated with all new construction, alterations, and additions during the first year buildings complying with the 2016 Title 24 Standards are in operation.

4.6.1 Per Unit Energy Impacts Methodology

4.6.1.1 Elevator Ventilation and Cab Lighting Measure

The Statewide CASE Team estimated the electricity and natural gas savings associated with the proposed code change. The energy savings were calculated on a per elevator basis. The savings were not calculated on a per square foot basis because the energy use associated with elevator lighting and ventilation is independent of the building's size.

Analysis Tools

Energy savings and peak electricity demand reductions were quantified in Microsoft Excel using CEC's Lifecycle Cost (LCC) assumptions and variables obtained from industry experts and studies. CEC's 2013 Nonresidential Compliance Software, CBECC-Com (California Building Energy Code Compliance (for Commercial/Nonresidential buildings) software), is not capable of quantified the energy benefits of elevator lighting and ventilation controls.

Key Assumptions

As mentioned, CEC provided a number of key assumptions to be used in the energy impacts analysis (CEC 2011). Some of the assumptions included in CEC's LCC Methodology include hours of operation, weather data, and prototype building design. The key assumptions used in the per unit energy impacts analysis that are not already included in the assumptions provided in the LCC Methodology are presented in Table 15.

Table 15: Key assumptions for per unit Energy Impacts Analysis - Elevators

Parameter	Assumption	Source	Notes
Lamps per Cabin	8	SDG&E UCSD Study	None
Halogen (W)	20	Norman LED	None
Halogen Life (hrs)	5,000	Norman LED	None
LED (W)	3	Norman LED	None
LED Life (hrs)	50,000	Norman LED	None
CFL (W)	5	Amazon	None
CFL Life (hrs)	10,000	Amazon	None
Existing Halogen vs. Fluorescent %	50% - 50%	Estimate	None
Standby (hrs/yr)	3504	SDG&E UCSD Study	None
Effective Life (yrs)	20	ACEEE 2005	None
Elevator Fan (W)	40	SDG&E UCSD Study	None

4.6.1.2 Escalator and Moving Walkway Speed Control Measure

The Statewide CASE Team estimated the electricity and natural gas savings associated with the proposed code change. The energy savings were calculated on a per unit basis. The savings were not calculated on a per square foot basis because the energy use associated with escalators and moving walkways is independent of the building's size.

Analysis Tools

Energy savings and peak electricity demand reductions were quantified in Microsoft Excel using LCC assumptions and variables obtained from industry experts and studies. CBECC-Com is not capable of calculating the energy impact of this measure.

Key Assumptions

The key assumptions used in the per unit energy impacts analysis that are not already included in the assumptions provided in the LCC Methodology are presented in Table 16.

Table 16: Key assumptions for per unit Energy Impacts Analysis - Escalators

Parameter	Assumption	Source	Notes
Average Escalator Power Requirement (kW)	4.671	TIAX 2006	None
Annual Hours of Operation (hrs/yr)	8,760	None	Note: This measure is being written to only apply to airports, hotels, and transit areas, which are better candidates because they typically run 24/7
Average Incline Length (m)	10	Kone	Average estimate given over phone call with Kone representative
Max rated speed (m/s)	0.5	ASME	None
Min rated speed (m/s)	0.05	ASME	None
Time of delay (s)	60	ASME	Time escalator will continue running at full speed after last person exists before speed is reduced. Assume 3x length of ride.
Average time unloaded (hrs/day)	12.5 h/d	Reasonable Estimate	This value varies drastically per escalator. A rough estimate was calculated
Duration of unloaded period (s)	529	Reasonable Estimate	This value varies drastically per escalator, so a rough estimate was calculated
Effective Life (yrs)	25	Intermittent Escalator Study	None
Percentage of escalators in airports, hotels, and transit areas.	20%	Reasonable Estimate	None

4.6.1.3 Direct Digital Controls Measure

The Statewide CASE Team estimated the electricity and natural gas savings associated with the proposed code change. The energy savings were calculated on a per square foot basis.

To calculate energy savings, the energy simulation tool eQUEST was used to simulate each prototype for both a baseline case (existing conditions) and a DDC measure case (proposed conditions); repeated for all 16 climate zones for each of the three prototype buildings. The difference in energy use between the two cases represents the net energy savings. The savings estimates were calculated per prototype building. To estimate savings per square foot, the net energy savings was normalized by dividing by the square footage of the appropriate prototype building, resulting in energy savings per square foot.

Once the energy savings were simulated for the three prototype building types, and all climate zones, they are combined using the relative weights listed in Table 13 above per the following equation:

$$Energy\ Savings\ [per\ sq\ ft] = OfficeWt\ X\ (Office_{Base} - Office_{Meas}) + SchoolWt\ X\ \left(School_{Base} - School_{Meas)}\right) + RetailWt\ X\ (Retail_{Base} - Retail_{Meas})$$

The resulting weighted average savings per square foot, by climate zone, and can either be kWh/SF or Btu/SF is presented Table 23. Appendix C includes the un-weighted saving per square foot for each of the three prototype buildings.

Analysis Tools

The energy savings for this measure were calculated using a combination of eQUEST simulations and spreadsheets calculations to model the building prototypes and to extrapolate for statewide thermal and utility loads.

4.6.1.4 Operable Window/Door Switch Measure

The Statewide CASE Team estimated the electricity and natural gas savings associated with the proposed code change. The energy savings were calculated on a per square foot basis.

For each climate zone the design zone airflows were determined based on zone peak cooling loads calculated in eQUEST. The zone box minimum was assumed to be the maximum of 10% of the design cooling maximum and the minimum ventilation rate (the maximum of 0.15 cfm/SF and 15 cfm/person).

As mentioned in Section 4.1.4, a total of three simulation runs were performed for each of the three climate zones to establish performance for a building without the operable windows open, performance for when operable windows were open simultaneously with HVAC equipment conditioning the space, and performance for when operable windows were open without HVAC equipment conditioning the space. Hourly output data for these runs were exported to spreadsheets and then compiled into the baseline and proposed measure analysis.

The savings depend on how frequently windows and doors would be open. Figure 3, Figure 5 and Figure 7 show histograms of occupied hours at different outside air temperatures in comparison with hours that operable windows are open for each of the climate zones analyzed. Figure 4, Figure 6 and Figure 8 show the distribution of the hours that operable windows are open in relation to time of day.

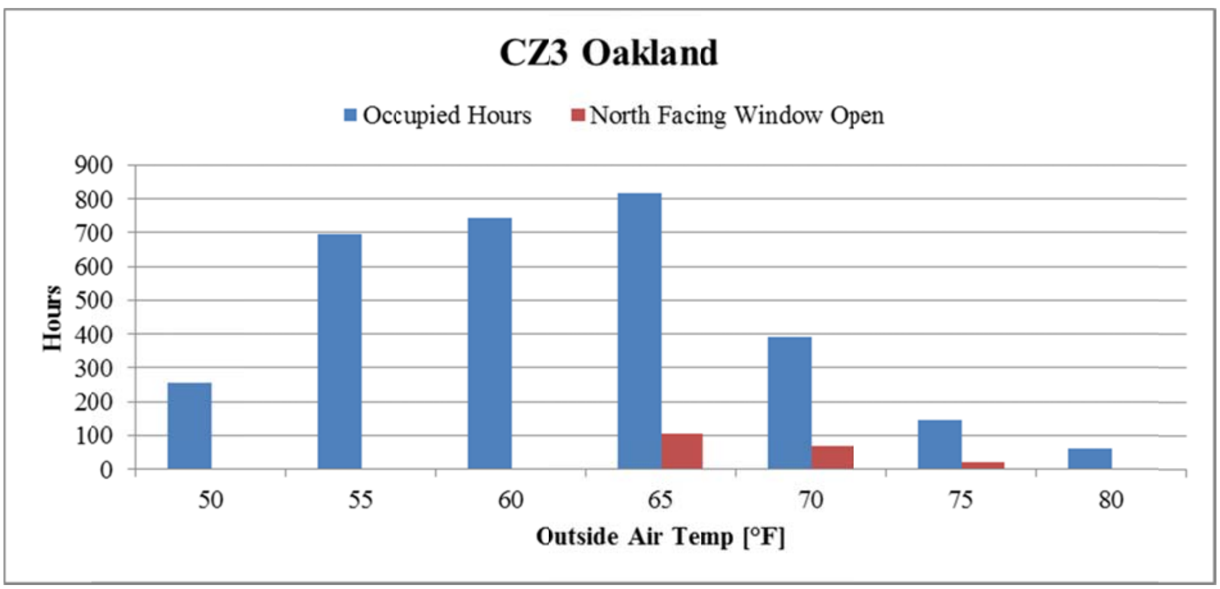

Figure 3: Frequency of occupied hours and North facing operable windows open versus outside air temp

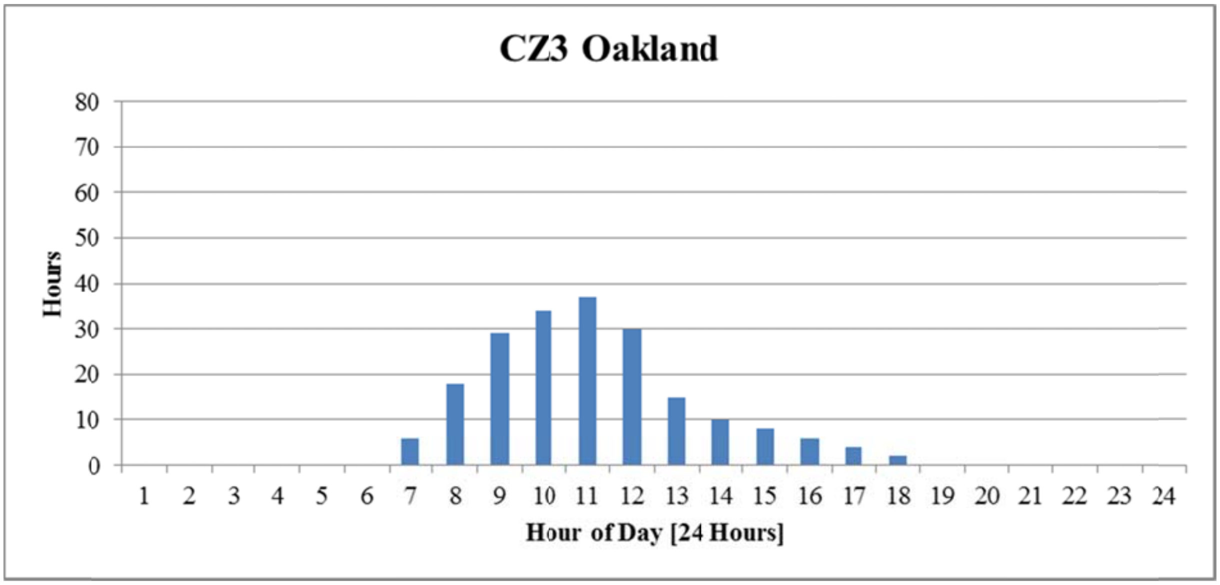

Figure 4: Frequency of North facing operable windows open versus time of day

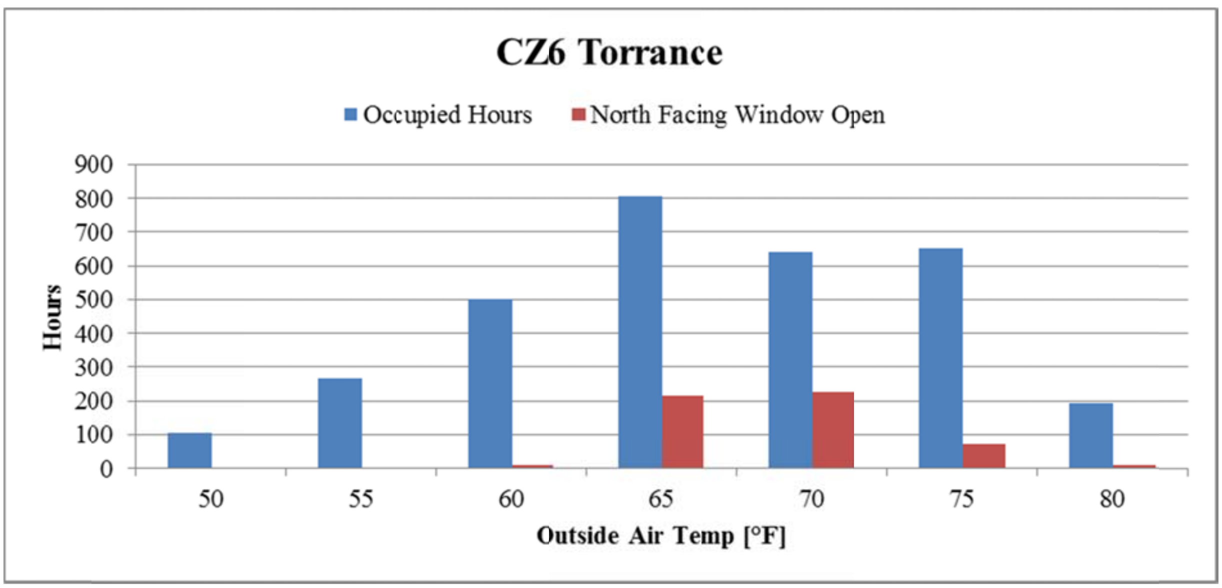

Figure 5: Frequency of occupied hours and North facing operable windows open versus outside air temp

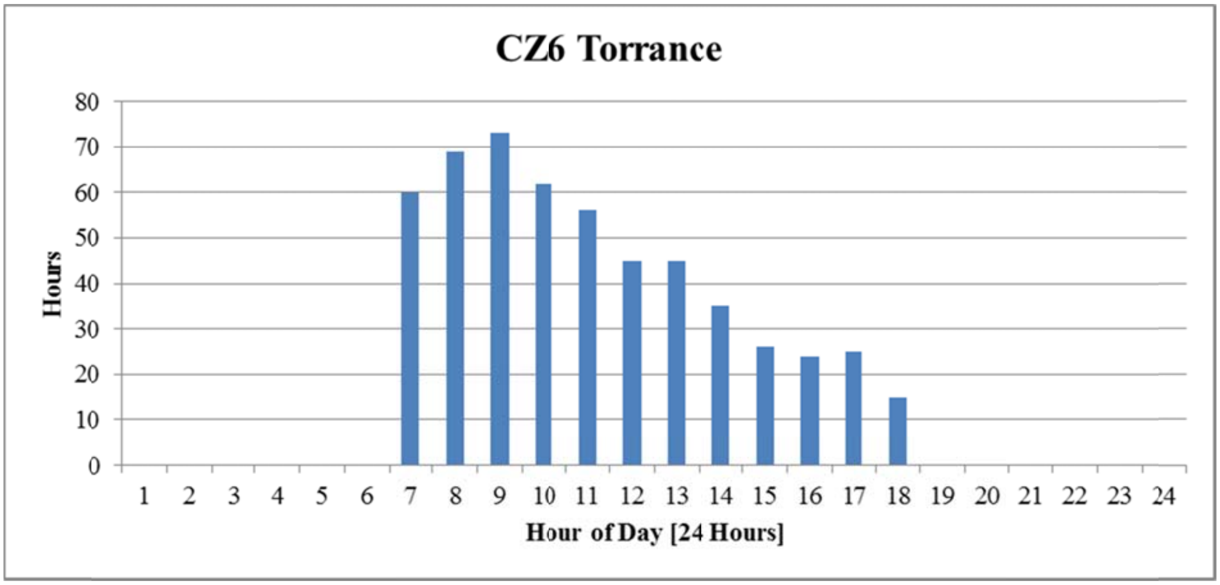

Figure 6: Frequency of North facing operable windows open versus time of day.

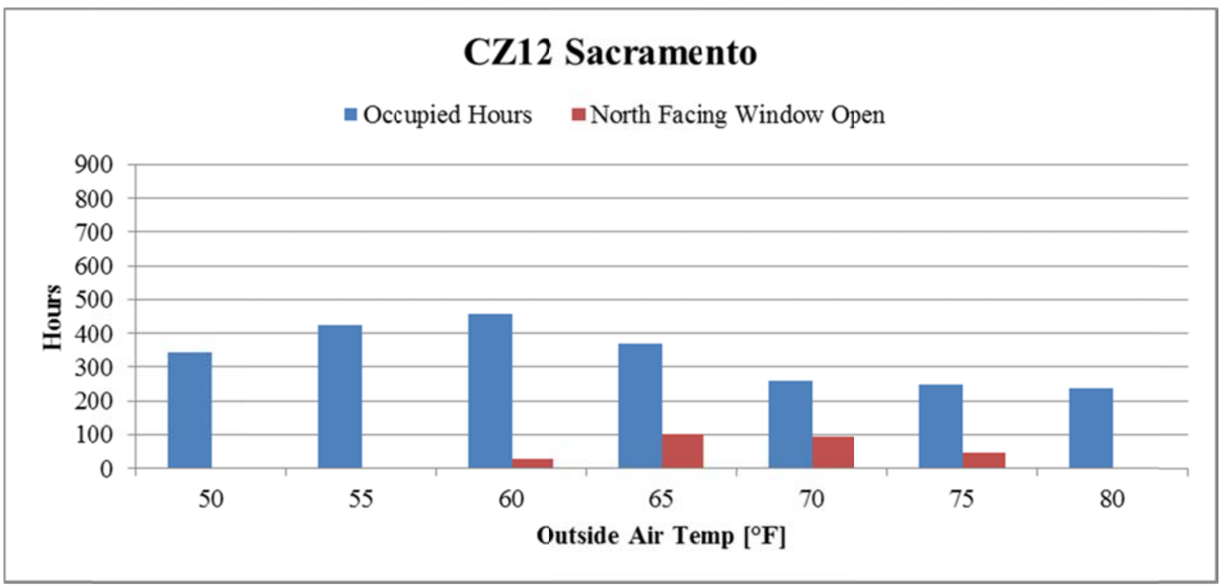

Figure 7: Frequency of occupied hours and North facing operable windows open versus outside air temp

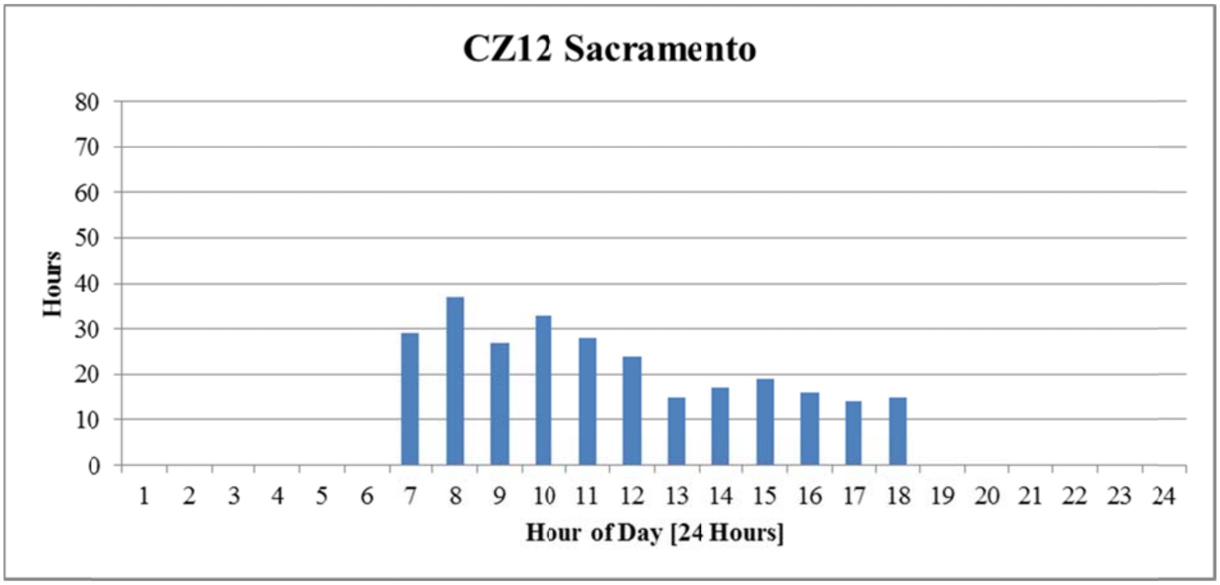

Figure 8: Frequency of North facing operable windows open versus time of day

Analysis Tools

The energy savings for this measure were calculated using a combination of eQUEST simulations and spreadsheets was used to model the prototype building and estimate thermal and utility loads. For the purpose of this analysis, the Sherman-Grimsrud method of infiltration rate calculation was used in the eQUEST model to model operable windows and an infiltration schedule was calibrated against a previous study of operable window and non-integrated HVAC system energy (Daly 2002).

4.6.2 Statewide Energy Impacts Methodology

First Year Statewide Impacts

The Statewide CASE Team estimated statewide impacts for the first year buildings comply with the 2016 Title 24 Standards by multiplying per unit savings estimates by projected 2017 installations.

4.6.2.1 Elevator Ventilation and Cab Lighting Measure

National elevator installation forecasts were determined from the 2006 Commercial and Residential Sector Miscellaneous Electricity Consumption Report written by TIAX LLC. The report assumes a 1.7 percent annual growth rate. The number of expected elevators in 2017 subtracted by the number of expected elevators in 2016 results in the number of expected new construction elevators for 2017 nationally. The national numbers were multiplied by the proportional population of California (12%) to obtain California estimates.

However, because it is now industry standard practice for new construction elevators to meet this proposed requirement, savings only are produced from retrofits that trigger Title 24. The number of retrofits expected in 2017 assumes a 20-year effective life for all elevators. Thus, every year, 5 percent of elevators will require a large retrofit. This results in an expected 2017 retrofit total of 4,344 elevators in the State of California. Multiplying per unit impacts by 4,344 produces the statewide energy impacts.

4.6.2.2 Escalator and Moving Walkway Speed Control Measure

National escalator and moving walkway installation forecasts were determined from the 2006 Commercial and Residential Sector Miscellaneous Electricity Consumption Report written by TIAX LLC. The report assumes a 1.5 percent annual growth rate. The number of expected escalators in 2017 subtracted by the number of expected escalators in 2016 results in the number of expected new construction escalators for 2017 nationally. The national numbers were multiplied by the proportional population of California (12%) to obtain California estimates. California is expected to have approximately 75 new installations in 2017.

The number of retrofits expected in 2017 assumes a 25-year effective life for all escalators. Thus, every year, 4 percent of escalators will require a large retrofit. This results in an expected 2017 retrofit total of 203 escalators in the state of California.

The total number of new construction and retrofit escalators and moving walkways for California in 2017 is 278. However, the Statewide CASE Team has included an addition to the ASHRAE proposal that will only make this measure apply to airports, hotels, and transit areas. Assuming 20 percent of all escalators are in such facilities, the proposed measure will apply to approximately 55 escalators in 2017. Multiplying per unit impacts by 55 produces the statewide energy impacts.

4.6.2.3 Direct Digital Controls Measure

The Statewide CASE Team identified the type of buildings that would be impacted and used data from CEC to estimate the square footage for each building type for new construction in each climate zone in California in the year 2017. Total statewide savings from the proposed DDC measure was calculated by multiplying the per square foot energy savings by the estimates of floor space impacted by the proposed code change.

With ASWB Engineering’s expertise, the Statewide CASE Team estimated the percentages of each building type would be impacted by the proposed code change for both new construction and retrofits. In estimating the new construction percentages, the Statewide CASE Team took into account that many of these building types are already installing DDC technology, as a matter of Industry Standard Practice, and therefore the proposed measure would not produce new DDC installations due to naturally occurring market adoption, and resulting in 0% of the space type being impacted by the code change. Estimates of the square footage of building space impacted by building retrofits took into account the Effective Useful Life (EUL) of HVAC equipment, voluntary replacement of outdated equipment and anything else that would trigger Title 24 and require the installation of DDC technology.

Table 17 presents the percent of floor space impacted by the proposed DDC measure statewide in 2017. See Appendix D for more information on the statewide construction forecast, which was provided by the CEC Demand Analysis Office.

Table 17: Percent of Floor space Impacted by DDC Measure in 2017 Statewide

Building Type	Percent of Newly Constructed Square Footage Impacted by Proposed Measure in 2017	Percent of Retrofitted Square Footage Impacted by Proposed Measure in 2017	Total Percentage Square Footage Impacted by Proposed Measure in 2017
Small office	0%	0%	0%
Restaurant	0%	0%	0%
Retail	10%	5%	15%
Food	0%	0%	0%
Non-refrigerated warehouse	0%	0%	0%
Refrigerated warehouse	0%	0%	0%
Schools	0%	0%	0%
College	25%	20%	45%
Hospital	0%	0%	0%
Hotel/motel	10%	10%	20%
Other	0%	0%	0%
Large offices	25%	15%	40%

4.6.2.4 Operable Window/Door Switch Measure

The Statewide CASE Team estimated statewide impacts for the first year buildings comply with the 2016 Title 24 Standards by multiplying per unit savings estimates by projected 2017 installations. The proposed code change applies to all new commercial construction covered by Title 24 where operable windows or doors (that do not meet the exclusions) are included in the design. Based on the State construction forecasts we estimate that this measure would apply to approximately 12 million ft2 of new construction in the first year. See Appendix D for more information on the statewide construction forecast.

4.7 Cost-effectiveness Methodology

These measures propose both mandatory and prescriptive nonresidential requirements. As such, a lifecycle cost analysis is required to demonstrate that the measure is cost effective over the 15-year period of analysis.

CEC's procedures for calculating lifecycle cost-effectiveness are documented in LCC Methodology. The Statewide CASE Team followed these guidelines when developing the Cost-effectiveness Analysis for this measure. CEC's guidance dictated which costs were included in the analysis. Incremental equipment and maintenance costs over the 15-year period of analysis were included. The TDV energy cost savings from electricity savings were considered. Each of these components is discussed in more detail below.

Neither design costs nor incremental costs of code verification were included.

Incremental Construction Cost Methodology

As requested by CEC, the Statewide CASE Team estimated the Current Incremental Construction Costs and Post-adoption Incremental Construction Costs. The Current Incremental Construction Cost (ΔC_{IC}) represents the cost of the incremental cost of the measure if a building meeting the proposed standard were built today. The Post-adoption Incremental Construction Cost (ΔCI_{PA}) represents the anticipated cost assuming full market penetration of the measure as a result of the new Standards, resulting in mass production of the product and possible reduction in unit costs of the product once market is stabilized.

It is assumed that the ΔCI_{PA} will be equal to the ΔC_{IC}, as the costs are not expected to change much when the proposed standard goes into effect.

Incremental Maintenance Cost Methodology

Maintenance cost is included in the lifecycle cost analysis. The present value (PV) of maintenance costs (savings) was calculated using a 3 percent discount rate (d) as directed in the LCC Methodology. The PV of maintenance costs that occurs in the nth year is calculated as follows (where d is the discount rate):

$$\text{PV Maintenance Cost} = \text{Maintenance Cost} \times \left[\frac{1}{1+d}\right]^n$$

4.7.1 Incremental Cost Methodology

4.7.1.1 Elevator Ventilation and Cab Lighting Measure

Incremental Construction Cost Methodology

The incremental cost of the proposed code change was obtained by using the RS Means catalog data for the costs of the necessary parts and installations. The RS Means catalog does not provide the exact cost, but the Statewide CASE Team has confirmed these numbers to be reasonable with manufacturers.

Key assumptions used to derive cost are presented in Table 17

Table 18: Key Assumptions for per unit Incremental Construction Cost - Elevators

Factor	Assumption	Source	Notes
Cost of lighting and ventilation controls	$1000	RS Means	The actual RS Means total was $837, but this was rounded up to $1,000 to be more conservative.
Occupancy Sensor Replacement	$197	RS Means	This includes part, labor, and overhead. Replaced once on burnout within 15 year analysis.
Cost of LEDs	$19.50 per lamp	Norman LEDs	None
Cost of halogen lamps	$14.95 per lamp	Norman LEDs	None
Cost of CFLs	$6.00 per lamp	Amazon	None
Installation Labor	$15.63 per lamp	Calculated	None

Incremental Maintenance Cost Methodology

Incremental maintenance costs savings were determined by taking into consideration the life cycle of the halogen lamps in the existing conditions, and the life cycle and reduced usage of the LED lamps in the proposed conditions. The LED lamps do not need to be replaced nearly as often as the halogen lamps, which results in a significant maintenance cost savings.

4.7.1.2 Escalator and Moving Walkway Speed Control Measure

Incremental Construction Cost Methodology

The incremental cost of the proposed measure was obtained from a 2005 study by the United States General Services Administration on intermittent escalators. The figure only includes the cost of the motor and sensors, and does not cover design or construction. The study was conducted over 9 ago, and the price may have come down since the study was released and the cost estimates used in the analysis may be conservative.

Key assumptions used to derive cost are presented in Table 18.

Table 19: Key Assumptions for per unit Incremental Construction Cost - Escalators

Factor	Assumption	Source	Notes
Additional cost for new construction	$6000	Kone	Value estimated by Kevin Wigley, Regional Escalator Sales Manager for Kone
Estimated Post Adoption Cost	$5500	Kone	Ballpark estimate provided by Kevin Wigley
Maintenance cost per year	$4800/y	Kone	None
Estimated Maintenance Savings	2%	GSA Intermittent Escalator Study, 2005	None

Incremental Maintenance Cost Methodology

According to the United States General Services Administration's 2005 Intermittent Escalator Study, the maintenance savings costs can be reduced by roughly 2 percent. This number came from a LCC study conducted by RS Means and was confirmed by stakeholders during the May 7, 2014 stakeholder meeting.

4.7.1.3 Direct Digital Control Measure

Incremental Construction Cost Methodology

The incremental cost of the proposed code change was obtained by using the RS Means catalog data for the costs of the necessary parts and installations. The RS Means catalog does not provide the exact cost, but the Statewide CASE Team is confident that the estimate is within a reasonable range.

Key assumptions used to derive cost are presented in Table 19.

Table 20: Key Assumptions for per unit Incremental Construction Cost – DDC

Factor	Assumption	Source	Notes
Additional Cost for New Construction	$0.31 / SF	2014 RS Means Electrical Catalog	None
Estimated Maintenance Savings	$0.0112 / SF per year	SME Los Angeles, Ca.	None

Incremental Maintenance Cost Methodology

The Statewide CASE Team used both RS Means data and empirical data to estimate the incremental the cost of necessary parts and installation. Based on ASWB Engineering's experience designing and specifying controls, the Statewide CASE Team is confident that the estimate is within reasonable range.

4.7.1.4 Operable Window/Door Switch Measure

The incremental cost of $150/zone was provided by controls contractors who have included alternate pricing to include hardware and labor of window/door switches in bids on real projects. These contractors also felt there was no appreciable incremental maintenance cost as the associated hardware and controls are extremely reliable.

4.7.2 Cost Savings Methodology

Energy Cost Savings Methodology

The PV of the energy savings were calculated using the method described in the LCC Methodology. In short, the hourly energy savings estimates for the first year of building operation were multiplied by the 2017 TDV cost values to arrive at the PV of the cost savings over the period of analysis. Climate sensitive measures were calculated in each climate zone using each climate zone's unique TDV values. Non climate sensitive measures were calculated using the population-weighted TDV values.

Other Cost Savings Methodology

This measure does not have any non-energy cost savings.

4.7.3 Cost-effectiveness Methodology

The Statewide CASE Team calculated the cost-effectiveness using the LCC Methodology. According to CEC's definitions, a measure is cost effective if it reduces overall lifecycle cost from the current base case (existing conditions). The LCC Methodology clarifies that absolute lifecycle cost of the proposed measure does not need to be calculated. Rather, it is necessary to calculate the change in lifecycle cost from the existing conditions to the proposed conditions.

If the change in lifecycle cost is negative then the measure is cost-effective, meaning that the present value of TDV energy savings is greater than the cost premium, or the proposed measure reduces the total lifecycle cost as compared to the existing conditions. Propane TDV costs are not used in the evaluation of energy efficiency measures (EEM).

The Planning Benefit-to-Cost (B/C) Ratio is another metric that can be used to evaluate cost-effectiveness. The B/C Ratio is calculated by dividing the total present value TDV energy cost savings (the benefit) by the present value of the total incremental cost (the cost). If the B/C Ratio is greater than 1.0 (i.e. the present valued benefits are greater than the present valued costs over the period of analysis), then the measure is cost effective.

4.8 Environmental Impacts Methodology

4.8.1 Greenhouse Gas Emissions Impacts Methodology

Greenhouse Gas Emissions Impacts Methodology

The Statewide CASE Team calculated avoided GHG emissions assuming an emission factor of 353 metric tons of carbon dioxide equivalents ($MTCO_2e$) per GWh of electricity savings. As described in more detail in Appendix A: Environmental Impacts Methodology, the electricity emission factor represents savings from avoided electricity generation and accounts for the GHG impacts if the state meets the Renewable Portfolio Standard (RPS) goal of 33 percent renewable electricity generation by 2020. Avoided GHG emissions from natural gas savings were calculated using an emission factor of 5,303 $MTCO_2e$/million therms (U.S. EPA 2011).

Greenhouse Gas Emissions Monetization Methodology

The 2017 TDV cost values include the monetary value of avoided GHG emissions, so the Cost-effectiveness Analysis presented in Section 5.2 of this report does include the cost savings from avoided GHG emissions. The monetization for the TDV values includes permit (retail) cost of avoided GHG emissions, but it does not include the social costs of avoided emissions. As evident in the results of the Cost-effectiveness Analysis, the value of avoided GHG emissions is aggregated into the total TDV cost savings and the contribution of GHG emissions is not easily discernible.

4.8.2 Water Use and Water Quality Impacts Methodology

The proposed measures are not expected to have any impacts on water use or water quality, excluding impacts that occur at power plants.

4.8.3 Material Impacts Methodology (Optional)

The proposed measures are not expected to have any impacts on material use.

4.8.4 Other Impacts Methodology

There are no other physical benefits associated with these measures beyond the energy savings and reduced maintenance costs.

5. ANALYSIS AND RESULTS

Results from the energy, demand, cost, and environmental impacts analyses are presented in this section. All of the proposed measures are cost effective in every California climate zone.

5.1 Energy Impacts Results

5.1.1 Per Unit Energy Impacts Results

5.1.1.1 Elevator Ventilation and Cab Lighting Measure

Per unit energy and demand impacts of the proposed measure are presented in Table 21. Per unit savings for the first year are expected to be 839.91 kilowatt-hours per year (kWh/yr), 0 therms/year. Demand savings are expected to be 0.030 kilowatts (kW).

It is estimated that the TDV energy savings over the 15-year period of analysis will be 9,033 kBTU. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. Savings occur from two different sources in this measure. The savings resulting from switching to more efficient lighting occur during all hours of the day. The savings resulting from lighting and ventilation shutting off during standby mode will most likely not occur during peak hours.

Table 21: Energy Impacts per Elevator

Climate Zone	Per Unit First Year Savings[1]			TDV Energy Savings[2] (TDV kBTU)
	Electricity Savings[3] (kWh/yr)	Demand Savings (kW)	Natural Gas Savings (Therms/yr)	
All	839.91	0.030	0	9,033

1. Savings from one elevator for the first year the building is in operation.
2. TDV energy savings for one elevator. Calculated using CEC's 2017 TDV factors and methodology. Includes savings from electricity and natural gas.

5.1.1.2 Escalator and Moving Walkway Speed Control Measure

Per unit energy and demand impacts of the proposed measure are presented in Table 22. Per unit savings for the first year are expected to be 17,124 kWh/yr and 0 therms/year. Peak demand savings are expected to be low (0.074 kW), as sleep mode is not expected to activate during peak hours.

It is estimated that the TDV energy savings over the 15-year period of analysis will be 284,543 kBTU. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. The energy savings associated with this measure are most likely to occur during off-peak hours, as pedestrian traffic is highest in the afternoon. The TDV method might reflect less savings based on the value of peak energy.

Table 22: Energy Impacts per Escalator

Climate Zone	Per Unit First Year Savings[1]			TDV Energy Savings[2] (TDV kBTU)
	Electricity Savings[3] (kWh/yr)	Demand Savings (kW)	Natural Gas Savings (Therms/yr)	
All	17,124	0.074	0	284,543

1. Savings from one escalator for the first year the building is in operation.
2. TDV energy savings for one escalator.
3. Calculated using CEC's 2017 TDV factors and methodology. Includes savings from electricity and natural gas.

5.1.1.3 Direct Digital Controls Measure

Per square foot energy and demand impacts of the proposed measure are presented in Table 23. Per square foot savings for the first year are expected to be 0.55 kWh/yr and 0.07 therms/year. Per square foot demand savings are expected to be 1.2×10^{-4} kW due to that these measures typically save energy outside of demand peak hours (noon to 6 PM).

It is estimated that the TDV energy savings over the 15-year period of analysis will be in the range of 8.92 kBTU to 23.69 kBTU depending on the climate zone. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. The energy savings associated with this measure are most likely to occur during off-peak hours. The TDV method might reflect less savings based on the value of peak energy.

Table 23: Annual Energy Impacts per Square Foot – Direct Digital Controls

Climate Zone	Per Unit First Year Savings[1]			TDV Energy Savings[2] (TDV kBTU)
	Electricity Savings[3] (kWh/yr)	Demand Savings (kW)	Natural Gas Savings (Therms/yr)	
Climate Zone 1	0.853	0.00016	0.134	23.69
Climate Zone 2	0.444	0.00011	0.103	14.34
Climate Zone 3	0.820	0.00011	0.098	18.56
Climate Zone 4	0.640	0.00015	0.087	17.27
Climate Zone 5	0.693	0.00009	0.079	14.76
Climate Zone 6	0.729	0.00011	0.044	12.97
Climate Zone 7	0.657	0.00012	0.037	12.76
Climate Zone 8	0.531	0.00010	0.036	10.42
Climate Zone 9	0.496	0.00015	0.043	11.67
Climate Zone 10	0.371	0.00012	0.034	8.92
Climate Zone 11	0.402	0.00012	0.102	15.08
Climate Zone 12	0.433	0.00012	0.104	15.92
Climate Zone 13	0.411	0.00013	0.071	14.04
Climate Zone 14	0.304	0.00012	0.073	12.55
Climate Zone 15	0.391	0.00016	0.018	11.00
Climate Zone 16	0.223	0.00008	0.166	15.31

1. Savings per square foot for the first year the building is in operation.
2. TDV energy savings per square foot. Calculated using CEC's 2017 TDV factors and methodology. Includes savings from electricity and natural gas.
3. Site electricity savings. Does not include TDV of electricity savings.

5.1.1.4 Operable Window/Door Switch Measure

Per unit energy and demand impacts of the proposed measure are presented in Table 24. Per unit savings for the first year are expected to be in the range of 1,000 to 1,200 kWh/yr and 150 - 200 therms/year depending on the climate zone. Demand savings will be presented in the next version of the report.

It is estimated that the TDV energy savings over the 15-year period of analysis will be in the range of about 19,100 to 24,000 kBTU depending on the climate zone. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

Table 24: Annual Energy Impacts per Prototype Building – Operable Window/Door Switch

Climate Zone	Per Unit First Year Savings[1]			TDV Energy Savings[2] (TDV kBTU)
	Electricity Savings[3] (kWh/yr)	Demand Savings (kW)	Natural Gas Savings (Therms/yr)	
Climate Zone 3	1,070	0	203	23,933
Climate Zone 6	1,130	0	178	21,655
Climate Zone 12	1,189	0	151	19,171

5.1.2 Statewide Energy Impacts Results

First Year Statewide Energy Impacts

The statewide energy impacts of the proposed measures are presented in Table 25. During the first year buildings complying with the 2016 Title 24 Standards are in operation, the proposed measures are expected to reduce annual statewide electricity use by 17 GWh with an associated demand reduction of 0.16 MW. Natural gas use is expected to be reduced by 1.6 MMtherms.

Table 25: First Year[1] Statewide Energy Impacts

	Electricity Savings[3] (GWh)	Power Demand Reduction (MW)	Natural Gas Savings (MMtherms)	TDV Energy Savings Savings[2] (Million kBTU)
Elevator	3.99	0.161	-	45.1
Escalator	0.94	0.004	-	15.7
DDC	10.91	2.391	1.34	272.91
Window/Door Switch	1.35	0	0.21	25.8
TOTAL	**16.86**	**2.556**	**1.55**	**353.6**

1. First year savings from all buildings built statewide during the first year the 2016 Standards are in effect.
2. TDV savings from all buildings built statewide during the first year the 2016 Standards are in effect. Calculated using CEC's 2017 TDV factors and methodology.

All assumptions and calculations used to derive per unit and statewide energy and demand savings are presented in Section 4.6.2 of this report.

5.2 Cost-effectiveness Results

5.2.1 Incremental Cost Results

5.2.1.1 Elevator Ventilation and Cab Lighting Measure

The incremental cost of the proposed measure, relative to existing conditions, is presented in Table 27. The total incremental cost includes the incremental cost during initial construction and the present value of the incremental maintenance cost over the 15-year period of analysis. Each of these components of the incremental cost is discussed below.

Table 26: Incremental Cost of Elevator Measure[1]

Condition	Incremental Initial Construction Cost		Incremental Present Value of Maintenance Cost[3]	Total Incremental Cost[4]
	Current[1]	Post Adoption[2]		
Existing Conditions	$100,000.00	$100,000.00	$3,236.38	$ 103,236.38
Proposed Conditions	$101,478.00	$101,478.00	$549.63	$ 102,027.63
Incremental[1]	$1,478.00	$1,478.00	$ (2,686.74)	$ (1,208.74)

1. Incremental costs equal the difference between existing conditions and proposed conditions. Negative values indicate the Proposed Conditions are less expensive than Existing Conditions.
2. Initial construction cost using current prices; ΔCI_C
3. Initial construction cost using estimated prices after adoption; ΔCI_{PA}
4. Present value of maintenance costs over 15-year period of analysis; ΔCM.
5. Total costs equals incremental cost (post adoption) plus present value of maintenance costs; $\Delta CI_{PA} + \Delta CM$

Incremental Construction Cost Results

The incremental cost is composed of the additional cost for the controls and lamps. The additional controls are approximately an extra $1,000, the cost of installing 8 LED lamps is $281, and there is an additional $197 for the eventual replacement and installation of the occupancy sensor upon burnout. There is no expected difference between current and post adoption costs, as the technology is already industry standard practice.

Incremental Maintenance Cost Results

The difference in maintenance cost is determined from the costs and life cycles of the existing and proposed condition lamps. The halogen and fluorescent lamps have a much shorter life cycle and are in operation at all times of the day. The LED lamps have a life cycle 10 times longer than the halogen lamps, and also benefit from reduced hours of operation due to the standby controls. The LED lamps, while more expensive, will not have to be replaced as often. Over a 15-year period, the maintenance savings are significant.

The maintenance requirements associated with the code change proposal, relative to existing conditions, are described qualitatively in Section 3.3 of this report. The halogen lamps in the existing case need to be replaced every 6-7 months at a cost of roughly $14.95 per lamp. The LED lamps in the proposed case will only need to be replaced every 9.5 years at a cost of roughly $19.50 per lamp (Norman LED).

5.2.1.2 Escalator and Moving Walkway Speed Control Measure

The incremental cost of the proposed measure, relative to existing conditions, is presented in Table 28. The total incremental cost includes the incremental cost during initial construction and the present value of the incremental maintenance cost over the 15-year period of analysis. Each of these components of the incremental cost is discussed below.

Table 27: Incremental Cost of Escalator Measure[1]

Condition	Incremental Initial Construction Cost		Incremental Present Value of Maintenance Cost[3]	Total Incremental Cost[4]
	Current[1]	Post Adoption[2]		
Existing Conditions	$120,000	$120,000	$57,302	$177,302
Proposed Conditions	$126,000	$125,500	$56,156	$181,656
Incremental[1]	$6,000	$5,500	$(1,146)	$4,354

1. Incremental costs equal the difference between existing conditions and proposed conditions. Negative values indicate the Proposed Conditions are less expensive than Existing Conditions.
2. Initial construction cost using current prices; ΔCI_C
3. Initial construction cost using estimated prices after adoption; ΔCI_{PA}
4. Present value of maintenance costs over 15-year period of analysis; ΔCM.
5. Total costs equals incremental cost (post adoption) plus present value of maintenance costs; $\Delta CI_{PA} + \Delta CM$

Incremental Construction Cost Results

According to Kone, the additional cost to install sleep mode technology on a new construction escalator is approximately $6,000. It was also estimated that once the measure is adopted and demand for this technology increases, the additional cost may drop to $5,500.

Incremental Maintenance Cost Results

In 2006, the United States General Services Administration (USGSA) released a comprehensive study that evaluated the feasibility of employing intermittent escalators in the United States. The report stated, "Maintenance costs were provided to the panel by [Washington Metropolitan Area Transit Authority]. The preventive maintenance and ordinary repair costs for the escalators are $3850 per month. An additional $350 is budgeted for repairs due to abuse. As the estimated standby time is approximately 77% for escalators utilizing the slow-down mode, it was estimated by consensus of the industry experts in this study that preventive maintenance and repair costs could be reduced by 2%, i.e., from $3850 to $3773 per month" (USGSA 2006).

The maintenance requirements associated with the code change proposal, relative to existing conditions, are described qualitatively in Section 3.3 of this report.

5.2.1.3 Direct Digital Control Measure

The incremental cost of the proposed measure, relative to existing conditions, is presented in Table 29. The total incremental cost includes the incremental cost during initial construction and the present value of the incremental maintenance cost over the 15-year period of analysis. Each of these components of the incremental cost is discussed below.

Table 28: Incremental Cost of DDC Measure per Square Foot[1]

Condition	Incremental Initial Construction Cost		Incremental Present Value of Maintenance Cost[3]	Total Incremental Cost[4]
	Current[1]	Post Adoption[2]		
Existing Conditions	$0.78	$0.78	$1.21	$2.00
Proposed Conditions	$1.10	$1.10	$1.08	$2.18
Incremental[1]	$0.31	$0.31	($0.13)	$0.18

1. Incremental costs equal the difference between existing conditions and proposed conditions. Negative values indicate the Proposed Conditions are less expensive than Existing Conditions.
2. Initial construction cost using current prices; ΔCI_C
3. Initial construction cost using estimated prices after adoption; ΔCI_{PA}
4. Present value of maintenance costs over 15-year period of analysis; ΔCM.
5. Total costs equals incremental cost (post adoption) plus present value of maintenance costs; $\Delta CI_{PA} + \Delta CM$

Incremental Construction Cost Results

The total incremental cost for new construction is calculated from the baseline case of a pneumatic control system versus the cost of a DDC system which this measure would require. Costing data was obtained from RS Means Electrical Cost Data for both pneumatic and DDC systems. These estimates are based on square footage. Post adoption, the cost for either system is not expected to change.

Incremental Maintenance Cost Results

The difference in maintenance cost between the existing and proposed conditions is due to a drop in maintenance costs for DDC system because of their inherent reliability over pneumatic systems. Table 29 list the assumptions and calculations for incremental cost between base case and measure case.

Table 29: Incremental Present Value Maintenance Cost for DDC systems

	Base Maintenance[1]	Measure Maintenance[1]
HVAC control system	Pneumatic system	DDC system
Technician Working (hours/year)	2080	2080
Hourly Wage ($/hr)	$25	$25
Annual Maintenance Cost (annual gross)	$52,000	$52,000
Percent of Gross Cost for Air System Controls Maintenance	40%	35%
Annual Maintenance Cost for Air System (In-House)	$20,800	$18,200
Outside Contractor Air System Maintenance (hours/year)	200	180
Outside Contractor Air System Maintenance Cost ($/Hr)	$150	$150
Annual Outside Contractor Maintenance Cost for Air System	$30,000	$27,000
Annual Maintenance Cost (In-House + Contractor)	$50,800	$45,200
Normalized per square footage (500,000 sq ft building)	$0.1016/SF	$0.0904/SF
Present value cost for 15 years at 3% discount	$1.21/SF	$1.08/SF

[1] Values obtained from SME interviews with building contractors in Los Angeles County

The maintenance requirements associated with the code change proposal, relative to existing conditions, are described qualitatively in Section 3.3 of this report.

5.2.1.4 Operable Window/Door Switch Measure

The incremental cost of the proposed measure, relative to existing conditions, is presented in Table 30.

Table 30: Incremental Cost of Proposed Measure[1]

Condition	Incremental Initial Construction Cost		Incremental Present Value of Maintenance Cost[3]	Total Incremental Cost[4]
	Current[1]	Post Adoption[2]		
Existing Conditions				
Proposed Conditions	$0.15/ft2	$0.05/ft2		
Incremental[1]	$0.15/ft2	$0.05/ft2	$0	$0.15/ft2

1. Incremental costs equal the difference between existing conditions and proposed conditions. Negative values indicate the Proposed Conditions are less expensive than Existing Conditions.
2. Initial construction cost using current prices; ΔCI_C
3. Initial construction cost using estimated prices after adoption; ΔCI_{PA}
4. Present value of maintenance costs over 15-year period of analysis; ΔCM.
5. Total costs equals incremental cost (post adoption) plus present value of maintenance costs; $\Delta CI_{PA} + \Delta CM$

Incremental Construction Cost Results

The total incremental cost includes the incremental cost during initial construction and the present value of the incremental maintenance cost over the 15-year period of analysis. Each of these components of the incremental cost is discussed below.

The total incremental cost of this measure is $150 per zone. Only perimeter zones have window switches. Interior zones of the prototype buildings are not impacted by the proposed standard (that is, interior zones do not have associated costs for window switches or associated savings). On average, the assumed typical zone size is 500 SF. This is a one-time total installed cost of an operable window switch and associated controls components necessary to disable zone HVAC equipment when the window is open.

Operable window switches are already common and widely available from a number of manufacturers. Typical VAV terminal units from the major manufacturers have controllers that already come standard with an auxiliary input necessary for integration of the operable window switches.

Incremental Maintenance Cost Results

This measure does not have any incremental maintenance costs, i.e. the expected life of the operable window switch exceeds the 15-year analysis period. The maintenance requirements associated with the code change proposal, relative to existing conditions, are described qualitatively in Section 3.3 of this report.

5.2.2 Cost Savings Results

Energy Cost Savings Results

The per unit TDV energy cost savings over the 15-year period of analysis are presented in the tables below. The elevator ventilation and cab lighting measure and the escalator and moving walkway speed control measure are both climate zone independent. Therefore, they are included in a smaller, shared table.

Table 31: Escalator and Elevator TDV Energy Cost Savings Over 15-Year period of Analysis - Per Unit

All Climate Zones	TDV Electricity Cost Savings (2017 PV $)	TDV Natural Gas Cost Savings (2017 PV $)	Total TDV Energy Cost Savings (2017 PV $)
Elevators	$804	$ 0	$ 804
Escalators	$ 25,324	$ 0	$ 25,324

Table 32: DDC TDV Energy Cost Savings Over 15-Year period of Analysis - Per Square Foot

Climate Zone	TDV Electricity Cost Savings (2017 PV $)	TDV Natural Gas Cost Savings (2017 PV $)	Total TDV Energy Cost Savings (2017 PV $)
Climate Zone 1	$ 1.32	$ 0.79	$ 2.11
Climate Zone 2	$ 0.72	$ 0.56	$ 1.28
Climate Zone 3	$ 1.14	$ 0.52	$ 1.65
Climate Zone 4	$ 1.07	$ 0.47	$ 1.54
Climate Zone 5	$ 0.90	$ 0.41	$ 1.31
Climate Zone 6	$ 0.92	$ 0.23	$ 1.15
Climate Zone 7	$ 0.94	$ 0.20	$ 1.14
Climate Zone 8	$ 0.73	$ 0.20	$ 0.93
Climate Zone 9	$ 0.81	$ 0.23	$ 1.04
Climate Zone 10	$ 0.61	$ 0.18	$ 0.79
Climate Zone 11	$ 0.77	$ 0.57	$ 1.34
Climate Zone 12	$ 0.84	$ 0.58	$ 1.42
Climate Zone 13	$ 0.85	$ 0.40	$ 1.25
Climate Zone 14	$ 0.70	$ 0.41	$ 1.12
Climate Zone 15	$ 0.88	$ 0.10	$ 0.98
Climate Zone 16	$ 0.44	$ 0.92	$ 1.36

Table 33: Door Switch TDV Energy Cost Savings Over 15-Year period of Analysis - Per Square Foot

Climate Zone	TDV Electricity Cost Savings (2017 PV $)	TDV Natural Gas Cost Savings (2017 PV $)	TDV Electricity Cost Savings (2017 PV $)
Climate Zone 3	0.25	0.29	0.54
Climate Zone 6	0.22	0.25	0.47
Climate Zone 12	0.19	0.22	0.41
All other Climate Zones	N/A	N/A	N/A

Table 34: Door Switch TDV Energy Cost Savings Over 15-Year period of Analysis - Per Prototype Building

	TDV Electricity Cost Savings (2017 PV $)	TDV Natural Gas Cost Savings (2017 PV $)	TDV Electricity Cost Savings (2017 PV $)
Climate Zone 3 (Oakland)	$817	$2,879	$3,696
Climate Zone 6 (Torrance)	$922	$2,543	$3,465
Climate Zone 12 (Sacramento)	$1,021	$2,204	$3,225
All other Climate Zones	N/A	N/A	N/A

5.2.3 Cost-effectiveness Results

Results per unit lifecycle Cost-effectiveness Analyses are presented in the tables below. The elevator ventilation and cab lighting measure and the escalator and moving walkway speed control measure are both climate zone independent. Therefore, they are included in a smaller, shared table.

Table 35: Elevator and Escalator Cost-effectiveness Summary[1]

All Climate Zones	Benefit: TDV Energy Cost Savings + Other Cost Savings[2] (2017 PV $)	Cost: Total Incremental Cost[3] (2017 PV $)	Change in Lifecycle Cost[4] (2017 PV $)	Benefit to Cost Ratio[5]
Elevators	$3,491	$1478	($2012)	2.4
Escalators	$25,324	$4,354	($20,970)	5.8

1. Relative to existing conditions. All cost values presented in 2017 dollars.
2. Present value of TDV cost savings equals TDV electricity savings plus TDV natural gas savings; ΔTDV$ = ΔTDV$E + ΔTDV$G. For the Elevator measure, maintenance cost savings (i.e., maintenance benefits) were included as benefits rather than an incremental cost to avoid a negative Benefit to Cost Ratio value.
3. Total incremental cost equals incremental construction cost (post adoption) plus present value of incremental maintenance cost; $\Delta C = \Delta CI_{PA} + \Delta CM$. For the Elevator measure, ΔCM was accounted for in the TDV energy cost savings instead.
4. Negative values indicate the measure is cost-effective. Change in lifecycle cost equals cost premium minus TDV energy cost savings; ΔLCC = ΔC – ΔTDV$
5. The benefit to cost ratio is the TDV energy costs savings divided by the total incremental costs; B/C = ΔTDV$ ÷ ΔC. The measure is cost effective if the B/C ratio is greater than 1.0.

Table 36: DDC Cost-effectiveness Summary per Square Foot[1]

Climate Zone	Benefit: TDV Energy Cost Savings + Other Cost Savings[2] (2017 PV $)	Cost: Total Incremental Cost[3] (2017 PV $)	Change in Lifecycle Cost[4] (2017 PV $)	Benefit to Cost Ratio[5]
Climate Zone 1	$2.11	$0.18	($1.93)	11.809
Climate Zone 2	$1.28	$0.18	($1.10)	7.147
Climate Zone 3	$1.65	$0.18	($1.47)	9.254
Climate Zone 4	$1.54	$0.18	($1.36)	8.607
Climate Zone 5	$1.31	$0.18	($1.13)	7.359
Climate Zone 6	$1.15	$0.18	($0.97)	6.466
Climate Zone 7	$1.14	$0.18	($0.96)	6.359
Climate Zone 8	$0.93	$0.18	($0.75)	5.192
Climate Zone 9	$1.04	$0.18	($0.86)	5.815
Climate Zone 10	$0.79	$0.18	($0.61)	4.448
Climate Zone 11	$1.34	$0.18	($1.16)	7.517
Climate Zone 12	$1.42	$0.18	($1.24)	7.934
Climate Zone 13	$1.25	$0.18	($1.07)	6.998
Climate Zone 14	$1.12	$0.18	($0.94)	6.257
Climate Zone 15	$0.98	$0.18	($0.80)	5.481
Climate Zone 16	$1.36	$0.18	($1.18)	7.630

1. Relative to existing conditions. All cost values presented in 2017 dollars.
2. Present value of TDV cost savings equals TDV electricity savings plus TDV natural gas savings; ΔTDV$ = ΔTDV$E + ΔTDV$G.
3. Total incremental cost equals incremental construction cost (post adoption) plus present value of incremental maintenance cost; $\Delta C = \Delta CI_{PA} + \Delta CM$.
4. Negative values indicate the measure is cost-effective. Change in lifecycle cost equals cost premium minus TDV energy cost savings; ΔLCC = ΔC – ΔTDV$
5. The benefit to cost ratio is the TDV energy costs savings divided by the total incremental costs; B/C = ΔTDV$ ÷ ΔC. The measure is cost effective if the B/C ratio is greater than 1.0.
6.

Table 37: Door Switch Cost-effectiveness Summary per Square Foot[1]

Climate Zone	Benefit: TDV Energy Cost Savings + Other Cost Savings[2] (2017 PV $)	Cost: Total Incremental Cost[3] (2017 PV $)	Change in Lifecycle Cost[4] (2017 PV $)	Benefit to Cost Ratio[5]
Climate Zone 3	0.54	0.15	($0.39)	3.6
Climate Zone 6	0.47	0.15	($0.32)	3.2
Climate Zone 12	0.41	0.15	($0.26)	2.7
All other Climate Zones	N/A	N/A	N/A	N/A

1. Relative to existing conditions. All cost values presented in 2017 dollars.
2. Present value of TDV cost savings equals TDV electricity savings plus TDV natural gas savings; ΔTDV$ = ΔTDV$E + ΔTDV$G.
3. Total incremental cost equals incremental construction cost (post adoption) plus present value of incremental maintenance cost; $\Delta C = \Delta CI_{PA} + \Delta CM$.
4. Negative values indicate the measure is cost-effective. Change in lifecycle cost equals cost premium minus TDV energy cost savings; ΔLCC = ΔC – ΔTDV$
5. The benefit to cost ratio is the TDV energy costs savings divided by the total incremental costs; B/C = ΔTDV$ ÷ ΔC. The measure is cost effective if the B/C ratio is greater than 1.0.

5.2.3.1 Window / Door Switch Control

The lifecycle cost of implementing operable window switches are given below in Table 37 for each of the three climate zones analyzed. The cost is the 15-year cost per prototypical building including HVAC energy and the incremental installed cost of the operable window switches. As noted above, there is no incremental annual maintenance.

Table 38: Cost-effectiveness Summary – Operable Window/Door Switch[1]

Climate Zone	Benefit: TDV Energy Cost Savings + Other Cost Savings[2] (2017 PV $)	Cost: Total Incremental Cost[3] (2017 PV $)	Change in Lifecycle Cost[4] (2017 PV $)	Benefit to Cost Ratio[5]
Climate Zone 3	$5372	$1500	-$3872	3.58
Climate Zone 6	$4736	$1500	-$3236	3.16
Climate Zone 12	$4100	$1500	-$2600	2.73
All other Climate Zones	N/A	N/A	N/A	N/A

1. Relative to existing conditions. All cost values presented in 2017 dollars.
2. Present value of TDV cost savings equals TDV electricity savings plus TDV natural gas savings; ΔTDV$ = ΔTDV$E + ΔTDV$G.
3. Total incremental cost equals incremental construction cost (post adoption) plus present value of incremental maintenance cost; $\Delta C = \Delta CI_{PA} + \Delta CM$.
4. Negative values indicate the measure is cost-effective. Change in lifecycle cost equals cost premium minus TDV energy cost savings; ΔLCC = ΔC – ΔTDV$
5. The benefit to cost ratio is the TDV energy costs savings divided by the total incremental costs; B/C = ΔTDV$ ÷ ΔC. The measure is cost effective if the B/C ratio is greater than 1.0.

5.3 Environmental Impacts Results

5.3.1 Greenhouse Gas Emissions Results

Table 38 presents the estimated first year avoided GHG emissions of the proposed code change. During the first year the 2016 Standards are in effect the proposed measure will result in avoided GHG emissions of 14,560 $MTCO_2e$.

Table 39: Statewide Greenhouse Gas Emissions Impacts

	Avoided GHG Emissions[1] ($MTCO_2e$/yr)
Elevator	1,288
Escalator	332
DDC	3,852
Window/Door Switch	1,590
TOTAL	7,062

6. First year savings from buildings built in 2017; assumes 353 $MTCO_2e$/GWh and 5,303 $MTCO_2e$/MMTherms.

5.3.2 Water Use and Water Quality Impacts

The proposed measures will have no impact on water use and water quality.

5.3.3 Material Impacts Results

The impacts of the proposed code change on material use were not evaluated.

5.3.4 Other Impacts Results

Operable Door/Window Switches

Occupants will quickly learn that HVAC is interlocked and thus will feel free to open windows without fear of wasting heating/cooling energy thus resulting in improved air quality and occupant satisfaction. Studies have shown that occupants are willing to accept wider temperature dead-bands in buildings with operable windows.

The ACM rules will encourage architects to include operable windows in their designs. The basecase will not include operable windows. If the windows are operable and have switches then the proposed case will model the windows as open and disable heating/cooling when conditions are favorable. This will result in more buildings with operable windows and thus in improved air quality and occupant satisfaction. Studies have shown that occupants appreciate the personal freedom as well as the fresh air benefits of operable windows.

There are no non-energy benefits associated with the other measures.

6. PROPOSED LANGUAGE

The proposed changes to the Standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2013 documents are marked with underlining (new language) and ~~strikethroughs~~ (deletions).

6.1 Standards

6.1.1 Elevator Ventilation and Cab Lighting Measure

SECTION 120.6 – MANDATORY REQUIREMENTS FOR COVERED PROCESSES

(f) Requirements for Elevators

1. The lighting power density inside the elevator cab, including luminaires in each elevator cab and not including signals and displays shall not exceed 0.6 W/SF.
2. Cab ventilation fans for elevators without air-conditioning shall not consume over 0.33 W/cfm at maximum speed.
3. When stopped and unoccupied with doors closed for over 15 minutes, cab interior lighting and ventilation shall be de-energized until required for operation.
4. Lighting and ventilation shall remain operational in the event that the elevator cabin gets stuck when passengers are in the cabin.

SECTION 140.6 – PRESCRIPTIVE REQUIREMENTS FOR INDOOR LIGHTING

(a) Calculation of Actual Indoor Lighting Power Density

3. Lighting wattage excluded. The watts of the following indoor lighting applications may be excluded from actual indoor Lighting Power Density. (Indoor lighting not listed below shall comply with all applicable nonresidential indoor lighting requirements in Part 6.):

…

V. Lighting in elevators where the lighting meets the requirements in section 120.6(f) ~~of ASHRAE/IESNA Standard 90.1, 2010~~.

6.1.2 Escalator and Moving Walkway Speed Control Measure

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

ASME A17.1/CSA B44 is the American Society of Mechanical Engineers document titled "Handbook on Safety Code for Elevators and Escalators" 2013 (ASME Standard A17.1/CSAB44-2013)

OPTIMUM START CONTROLS are controls that are designed to automatically adjust the start time of an HVAC system each day with the intent of bringing the space to desired occupied temperature levels at the beginning of scheduled occupancy.

OPTIMUM STOP CONTROLS are controls that are designed to setup or setback thermostat setpoints before scheduled unoccupied periods based upon the thermal lag and acceptable drift in space temperature that is within comfort limits.

SECTION 120.6 – MANDATORY REQUIREMENTS FOR COVERED PROCESSES

(g) Mandatory requirements for escalators and moving walkways
Escalators and moving walks located in airports, hotels, and transit areas shall automatically slow to the minimum permitted speed in accordance with ASME A17.1/CSA B44 (2013) when not conveying passengers. The escalators and moving walkways shall have manual override controls that allow for one-speed operation.

6.1.3 Direct Digital Control Measure

SECTION 120.2 REQUIRED CONTROLS FOR SPACE-CONDITIONING SYSTEMS

(j) **Direct Digital Controls (DDC**). Direct Digital Control to the Zone shall be required as follows:

1. DDC to the Zone shall be provided in the applications and qualifications listed in Table 120.2-A.
2. Where DDC is required by Section 120.2(j), the DDC system shall be capable of all of the following, as required, to provide the control logic required in Sections 120.1(c) and 120.2(h):

    A. Monitor zone and system demand for fan pressure, pump pressure, heating, and cooling.

    B. Transfer zone and system demand information (including VAV box damper position and heating or cooling coil valve position) from zones to air distribution system controllers and from air distribution systems to heating and cooling plant controllers.

    C. Automatically detect those zones and systems that may be excessively driving the reset logic and generate an alarm or other indication to the system operator.

    D. Readily allow operator removal of zone(s) from the reset algorithm.

    E. For new buildings, the DDC system shall be capable of trending and graphically displaying input and output points.

F. Capable of resetting heating and cooling setpoints in all non-critical zones upon receipt of a signal from a centralized contact or software point as described in Section 120.2(h).

TABLE 120.2-A DDC to Zone Applications and Qualifications

BUILDING STATUS	APPLICATION	QUALIFICATIONS
New building	Air-handling system and all zones served by the system	Individual air handlers supplying more than three zones and with fan system bhp of 10 hp and larger
New building	Chilled-water plant and all coils and terminal units served by the system	Individual plants supplying more than three zones and with design cooling capacity of 300,000 Btu/h and larger
New building	Hot-water plant and all coils and terminal units served by the system	Individual plants supplying more than three zones and with design heating capacity of 300,000 Btu/h and larger
Alteration or addition	Zone terminal unit such as VAV box	Where existing zones served by the same air-handling, chilled-water, or hot-water system have DDC
Alteration or addition	Air-handling system or fan coil	Where existing air-handling system(s) and fan-coil(s) served by the same chilled- or hot-water plant have DDC
Alteration or addition	New air-handling system and all new zones served by the system	Individual systems with fan system bhp of 10 hp and larger and supplying more than three zones and more than 75% of zones are new
Alteration or addition	New or upgraded chilled-water plant	Where all chillers are new and plant design cooling capacity is 300,000 Btu/h and larger
Alteration or addition	New or upgraded hot-water plant	Where all boilers are new and plant design heating capacity is 300,000 Btu/h and larger

(k) **Optimum Start/Stop Controls**. HVAC systems with DDC to the Zone level shall have optimum start and optimum stop controls. These controls shall have access to space temperature, ambient air temperature and historical thermal lag profiles of each controlled zone.

6.1.4 Operable Window/Door Switch Measure

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

THERMOSTAT is an automatic control device used to maintain temperature at a fixed or adjustable setpoint.

SECTION 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

140.4 (n) Window Switches. Any directly conditioned space with operable wall or roof openings to the outdoors shall be provided with interlock controls that automatically disable *mechanical heating* and *mechanical cooling* to that space (e.g. by resetting the heating setpoint to 50°F and the cooling setpoint to 100°F) when any such opening is open.

EXCEPTION 1 to Section 140.4(n): Interlocks are not required on building exits with automatic closing devices.

EXCEPTION 2 to Section 140.4(n): Any space without a thermostatic controls (thermostat or a space temperature sensor used to control heating or cooling to the space).

EXCEPTION 3 to Section 140.4(n): Alterations to existing buildings.

6.2 Reference Appendices

6.2.1 Elevator Ventilation and Cab Lighting Measure

A new section of Reference Appendix NA7 will be added as follows:

NA7.14 Elevator Lighting and Ventilation Controls

NA7.14.1 Construction Inspection

Verify and document the following prior to functional testing:

(a) Occupancy sensor has been located to minimize false signals
(b) PIR sensor pattern does not enter into elevator lobby
(c) Occupancy sensors do not encounter any obstructions that could adversely affect desired performance
(d) Ultrasonic occupancy sensors do not emit audible sound.

NA7.14.2 Functional Testing

For each elevator cab being tested, confirm the following:

(a) Verify that the lighting and ventilation controlled inside the elevator cab turn off within a maximum of 15 minutes from the start of an unoccupied condition.

(b) Verify that the signal sensitivity is adequate to achieve desired control. The sensor should not detect motion in the elevator lobby.

(c) Verify that lighting and ventilation immediately turn "on" when an unoccupied condition becomes occupied.

(d) Verify that the lighting and ventilation will not shut off when occupied. Stand in the elevator with the door closed and wait 15 minutes to confirm that the lighting and ventilation remain on.

6.2.2 Escalator and Moving Walkway Speed Control Measure

A new section of Reference Appendix NA7 will be added as follows:

NA7.15 Escalator and Moving Walkway Speed Control

NA7.15.1 Construction Inspection

Verify and document the following prior to functional testing:

(a) Variable speed drive is installed on the escalator

(b) Occupancy sensor has been located to minimize false signals
(c) Occupancy sensors do not trigger from pedestrians on adjacent escalators
(d) Occupancy sensors do not encounter any obstructions that could adversely affect desired performance
(e) Ultrasonic occupancy sensors do not emit audible sound.

NA7.15.2 Functional Testing

For each escalator or moving walkway being tested, confirm the following:

(a) Verify the amount of time necessary to ride the entire length of the escalator while standing still
(b) Stand away from the escalator. After being in an unoccupied condition for more than three times the length of time for a full ride, the escalator should slow down.
(c) Approach the escalator entrance while in an unoccupied condition from multiple angles to ensure passenger detection cannot be bypassed.
(d) Verify the slow speed setting is above 10 ft/min (0.05 m/s).
(e) Verify the full speed setting is below 100 ft/min (0.5 m/s).
(f) Verify the acceleration and deceleration of speed changes. This acceleration shall not exceed 1 ft/s^2 (0.3 $m/s^{2)}$
(g) Approach the escalator in an unoccupied condition at an average walking pace. The escalator should reach full speed before boarding.
(h) Approach the escalator in an unoccupied condition at an average walking pace. The escalator should reach full speed before boarding. An alarm should signal to alert that the pedestrian is approaching in the wrong direction.

6.2.3 Direct Digital Control Measure

There are no proposed changes to the Reference Appendices.

6.2.4 Operable Window/Door Switch Measure

There are no proposed changes to the Reference Appendices.

6.3 ACM Reference Manual

6.3.1 Elevator Ventilation and Cab Lighting Measure

Section 5.4.8: Elevators, Escalators and Moving Walkways

Elevator/Escalator Power

Definition: The power for elevators, escalators and moving walkways for different modes of operation. Elevators typically operate in three modes: active (when the car is moving passengers), ready (when the lighting and ventilation systems are active but the car is not moving), and standby (when the lights and ventilation systems are required to be off). Escalators and moving walkways ~~are either active or turned off~~ can be active, turned off, or in a reduced speed sleep mode.

6.3.2 Escalator and Moving Walkway Speed Control Measure

Refer to 6.3.1 above.

Table 12 – Unit Energy Consumption Data for Elevators, Escalators and Moving Walkways in Section 5.4.8 of the ACM Reference Manual will need to be updated to include sleep mode power and hours of operation for escalators and moving walkways.

6.3.3 Direct Digital Control Measure

There are no proposed changes to the ACM Reference Manual.

6.3.4 Operable Window/Door Switch Measure

The baseline mode will not have operable windows.

If the proposed design includes operable windows or doors that do not meet the exceptions and do not have switches and the operable area of such windows/doors exceeds 1% of the wall area then those windows/doors are modeled as open in the proposed model if:

- Zone is scheduled to be occupied, and either:
  - Outside air temperature is above 62^{o}F and below 70^{o}F and zone is in heating, or.
  - Outside air temperature is above 75^{o}F and below 80^{o}F.

Windows/doors are modeled as open with the following assumptions: the normal infiltration rate for the zone is increased by 0.15 cfm/ft2 of zone area.

If the proposed design includes operable windows or operable doors that do not meet one of the exceptions and all such windows/doors have window switches then the proposed design may include a proposed manual natural ventilation control strategy with the following limitations:

- the manual natural ventilation rate shall not exceed 0.15 cfm/ft2
- the manual natural ventilation rate shall be 0 cfm/ft2 when the outside air temperature is below 60F or the zone is not scheduled to be occupied.

The inclusion of a manual natural ventilation control strategy does not preclude the inclusion of an automated natural ventilation control strategy using automatically controlled openings as described elsewhere in the ACM.

6.4 Compliance Manuals

6.4.1 Elevator Ventilation and Cab Lighting Measure

A new section for Passenger Conveyance Systems will need to be added to the 2013 Nonresidential Compliance Manual. A new form will be necessary to verify that elevator lighting and ventilation characteristics in an inspected elevator cabin are in compliance with the standards.

6.4.2 Escalator and Moving Walkway Speed Control Measure

Refer to Section 6.4.1above. A new form will be necessary to verify that the escalator intermittent speed control characteristics in an inspected escalator are in compliance with the Standards.

6.4.3 Direct Digital Control Measure

A new section for Direct Digital Control systems will need to be added to the 2013 Nonresidential Compliance Manual.

For compliance forms, the current Energy Management Control System form NRCA-MCH-18-F, will need to include provisions for Direct Digital Control Systems.

6.4.4 Operable Window/Door Switch Measure

A new section on operable window/door switches will be added to the Compliance Manual.

Forms will be added where the designer needs to indicate if there are any operable windows/doors that do not meet the exceptions and do not have HVAC interlocks. If this is the case then the building cannot comply prescriptively and must use the performance approach. The form will also be used to indicate if there are required switches on any operable windows/doors so that the inspector will know to ask for the appropriate acceptance test documentation.

6.5 Compliance Forms

New forms will be necessary to verify that elevator lighting and ventilation characteristics in an inspected elevator cabin are in compliance with the standards, and to verify that escalator and moving walkway controls have been inspected and are in compliance with the standards.

7. References and Other Research

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7.4 References for Operable Window/Door Switch Measure

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7.5 References for Fan Efficiency Grade Measure

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7.6 General References

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APPENDIX A: ENVIRONMENTAL IMPACTS METHODOLOGY

Greenhouse Gas Emissions Impacts Methodology

The avoided GHG emissions were calculated assuming an emission factor of 353 metric tons of carbon dioxide equivalents ($MTCO_2e$) per GWh of electricity savings. The Statewide CASE Team calculated air quality impacts associated with the electricity savings from the proposed measure using emission factors that indicate emissions per GWh of electricity generated.[5] When evaluating the impact of increasing the Renewable Portfolio Standard (RPS) from 20 percent renewables by 2020 to 33 percent renewables by 2020, California Air Resources Board (CARB) published data on expected air pollution emissions for various future electricity generation scenarios (CARB 2010). The Statewide CASE Team used data from CARB's analysis to inform the air quality analysis presented in this report.

The GHG emissions factor is a projection for 2020 assuming the state will meet the 33 percent RPS goal. CARB calculated the emissions for two scenarios: (1) a high load scenario in which load continues at the same rate; and (2) a low load rate that assumes the state will successfully implement energy efficiency strategies outlined in the AB32 scoping plan thereby reducing overall electricity load in the state.

To be conservative, the Statewide CASE Team calculated the emissions factors of the incremental electricity between the low and high load scenarios. These emission factors are intended to provide a benchmark of emission reductions attributable to energy efficiency measures that could help achieve the low load scenario. The incremental emissions were calculated by dividing the difference between California emissions in the high and low generation forecasts by the difference between total electricity generated in those two scenarios. While emission rates may change over time, 2020 was considered a representative year for this measure.

Avoided GHG emissions from natural gas savings were calculated using an emission factor of 5,303 $MTCO_2e$/million therms (U.S. EPA 2011).

Water Use and Water Quality Impacts Methodology

There are no water use or quality impacts associated with these measures.

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[5] California power plants are subject to a GHG cap and trade program and linked offset programs until 2020 and potentially beyond.

APPENDIX B: JOB CREATION BY INDUSTRY

Table 39 shows total job creation by industry that is expected from all investments in California energy efficiency and renewable energy (Source: UC Berkeley 2010b, Appendix D). While it is not specific to codes and standards, this data indicates the industries that generally will receive the greatest job growth from energy efficiency programs.

Table 39: Job Creation by Industry

NAICS	Industry Description	Direct Jobs	
		2015	2020
23822	Plumbing, Heating, and Air-Conditioning Contractors	8,695	13,243
2361	Residential Building Construction	5,072	7,104
2362	Nonresidential Building Construction	5,345	6,922
5611	Office Administrative Services	2,848	4,785
23821	Electrical Contractors	3,375	4,705
551114	Corporate, Subsidiary, and Regional Managing Offices	1,794	3,014
54133	Engineering Services	1,644	2,825
5418	Advertising and Related Services	1,232	2,070
334413	Semiconductor and Related Device Manufacturing	1,598	1,598
541690	Other Scientific and Technical Consulting Services	796	1,382
23831	Drywall and Insulation Contractors	943	1,331
3334	Ventilation, Heating, Air-Conditioning, & Commercial Refrigeration Equipment Manufacturing	453	792
3351	Electric Lighting Equipment Manufacturing	351	613
926130	Regulation and Administration of Communications, Electric, Gas, Other Utilities	322	319
23816	Roofing Contractors	275	277
54162	Environmental Consulting Services	151	261
484210	Used Household and Office Goods Moving	137	239
23835	Finish Carpentry Contractors	120	120
23829	Other Building Equipment Contractors	119	113
3352	Household Appliance Manufacturing	63	110
Other	Other	454	547
	Total	**35,788**	**52,369**

APPENDIX C: ENERGY AND COST SAVINGS OF DDC MEASURE FOR THREE PROTOTYPE BUILDINGS

The following three tables present the estimated per square foot savings of the DDC measure for the three prototype buildings: office, college, and retail. The statewide savings estimates were derived using the weighted average savings from these three prototype buildings.

Table 40: First Year Energy Impacts per Square Foot Office Building Prototype – Direct Digital Controls

Climate Zone	Per Unit First Year Savings[1]			TDV Energy Savings[2] (TDV kBTU)	TDV Cost Savings over 15-year (2017$)
	Electricity Savings[3] (kWh/yr)	Demand Savings (kW)	Natural Gas Savings (Therms/yr)		
Climate Zone 1	0.668		0.062	28.28	$2.52
Climate Zone 2	0.337		0.043	16.42	$1.46
Climate Zone 3	0.605		0.044	21.38	$1.90
Climate Zone 4	0.477		0.038	19.89	$1.77
Climate Zone 5	0.516		0.036	17.06	$1.52
Climate Zone 6	0.580		0.025	16.80	$1.50
Climate Zone 7	0.537		0.023	16.83	$1.50
Climate Zone 8	0.429		0.021	13.75	$1.22
Climate Zone 9	0.385		0.022	14.08	$1.25
Climate Zone 10	0.331		0.020	12.43	$1.11
Climate Zone 11	0.329		0.043	18.93	$1.68
Climate Zone 12	0.337		0.044	19.13	$1.70
Climate Zone 13	0.343		0.033	19.26	$1.71
Climate Zone 14	0.258		0.027	15.71	$1.40
Climate Zone 15	0.295		0.012	15.58	$1.39
Climate Zone 16	0.183		0.054	15.33	$1.36

1. Savings per square foot for the first year the building is in operation.
2. TDV energy savings per square foot. Calculated using CEC's 2017 TDV factors and methodology. Includes savings from electricity and natural gas.
3. Site electricity savings. Does not include TDV of electricity savings.

Table 41: First Year Energy Impacts per Square Foot College Prototype – Direct Digital Controls

Climate Zone	Per Unit First Year Savings[1]			TDV Energy Savings[2] (TDV kBTU)	TDV Cost Savings over 15-year (2017$)
	Electricity Savings[3] (kWh/yr)	Demand Savings (kW)	Natural Gas Savings (Therms/yr)		
Climate Zone 1	0.166		0.019	8.66	$0.77
Climate Zone 2	0.155		0.014	9.76	$0.87
Climate Zone 3	0.192		0.012	8.95	$0.80
Climate Zone 4	0.194		0.011	11.52	$1.03
Climate Zone 5	0.140		0.011	7.39	$0.66
Climate Zone 6	0.157		0.006	6.92	$0.62
Climate Zone 7	0.180		0.005	8.60	$0.77
Climate Zone 8	0.168		0.005	8.35	$0.74
Climate Zone 9	0.181		0.005	10.47	$0.93
Climate Zone 10	0.165		0.005	11.52	$1.03
Climate Zone 11	0.173		0.012	11.11	$0.99
Climate Zone 12	0.177		0.012	11.35	$1.01
Climate Zone 13	0.203		0.009	12.78	$1.14
Climate Zone 14	0.154		0.009	11.73	$1.04
Climate Zone 15	0.267		0.002	15.01	$1.34
Climate Zone 16	0.089		0.026	10.92	$0.97

1. Savings per square foot for the first year the building is in operation.
2. TDV energy savings per square foot. Calculated using CEC's 2017 TDV factors and methodology. Includes savings from electricity and natural gas.
3. Site electricity savings. Does not include TDV of electricity savings.

Table 42: First Year Energy Impacts per Square Foot Retail Store Prototype – Direct Digital Controls

Climate Zone	Per Unit First Year Savings[1]			TDV Energy Savings[2] (TDV kBTU)	TDV Cost Savings over 15-year (2017$)
	Electricity Savings[3] (kWh/yr)	Demand Savings (kW)	Natural Gas Savings (Therms/yr)		
Climate Zone 1	0.677		0.047	23.24	$2.07
Climate Zone 2	0.214		0.042	7.86	$0.70
Climate Zone 3	0.521		0.024	11.99	$1.07
Climate Zone 4	0.364		0.027	8.77	$0.78
Climate Zone 5	0.454		0.018	9.12	$0.81
Climate Zone 6	0.516		0.006	9.29	$0.83
Climate Zone 7	0.453		0.004	7.85	$0.70
Climate Zone 8	0.329		0.006	5.11	$0.45
Climate Zone 9	0.255		0.004	3.47	$0.31
Climate Zone 10	0.186		0.008	2.75	$0.24
Climate Zone 11	0.197		0.046	9.12	$0.81
Climate Zone 12	0.189		0.041	7.39	$0.66
Climate Zone 13	0.234		0.031	7.87	$0.70
Climate Zone 14	0.132		0.039	7.10	$0.63
Climate Zone 15	0.221		0.003	4.01	$0.36
Climate Zone 16	0.124		0.110	18.44	$1.64

1. Savings per square foot for the first year the building is in operation.
2. TDV energy savings per square foot. Calculated using CEC's 2017 TDV factors and methodology. Includes savings from electricity and natural gas.
3. Site electricity savings. Does not include TDV of electricity savings.

APPENDIX D: NEW CONSTRUCTION FORECAST

The Statewide CASE Team calculated the statewide savings in 2017 (the first year the standards take effect) by multiplying the per unit savings, which are presented in Section 5.1.1, by the statewide new construction forecast for 2017.

CEC Demand Analysis Office provided the Statewide CASE Team with the nonresidential new construction forecast for 2017, which is presented in Table 45. Table 43 provides a more complete definition of the various space types used in the forecast, and Table 44 presents the assumed percent of new construction that would be impacted by the proposed code change.

Table 43: Description of Space Types used in the Nonresidential New Construction Forecast

OFF-SMALL	Offices less than 30,000 ft^2
OFF-LRG	Offices larger than 30,000 ft^2
REST	Any facility that serves food
RETAIL	Retail stores and shopping centers
FOOD	Any service facility that sells food and or liquor
NWHSE	Nonrefrigerated warehouses
RWHSE	Refrigerated Warehouses
SCHOOL	Schools K-12, not including colleges
COLLEGE	Colleges, universities, community colleges
HOSP	Hospitals and other health-related facilities
HOTEL	Hotels and motels
MISC	All other space types that do not fit another category

Table 44: Percent of New Construction Impacted by DDC Measure

Space Type	Percent of New Construction in 2017 Impacted by Proposed Code Change	Climate Zones Impacted by Proposed Code Change
OFF-SMALL	0%	Climate Zones 1 - 16
OFF-LRG	15%	Climate Zones 1 - 16
REST	0%	Climate Zones 1 - 16
RETAIL	0%	Climate Zones 1 - 16
FOOD	0%	Climate Zones 1 - 16
NWHSE	0%	Climate Zones 1 - 16
RWHSE	0%	Climate Zones 1 - 16
SCHOOL	0%	Climate Zones 1 - 16
COLLEGE	0%	Climate Zones 1 - 16
HOSP	0%	Climate Zones 1 - 16
HOTEL	0%	Climate Zones 1 - 16
MISC	0%	Climate Zones 1 - 16

Table 45: Estimated New Nonresidential Construction in 2017 by Climate Zone and Building Type (Million Square Feet)

Source: CEC Demand Analysis Office

Climate Zone	New Construction in 2017 (Million Square Feet)												
	OFF-SMALL	REST	RETAIL	FOOD	NWHSE	RWHSE	SCHOOL	COLLEGE	HOSP	HOTEL	MISC	OFF-LRG	TOTAL
1	0.058482	0.015769	0.040937	0.013995	0.04007	0.002371	0.045703	0.01828	0.027753	0.030543	0.094263	0.068857	0.457023
2	0.226801	0.088369	0.630464	0.163219	0.326702	0.031262	0.244488	0.163417	0.200483	0.349571	0.741643	1.13955	4.305969
3	0.727817	0.408193	2.913304	0.677174	2.517827	0.182815	0.999855	0.624782	0.728856	1.400191	3.893847	4.95172	20.02638
4	0.483775	0.190288	1.586102	0.412521	0.594754	0.071208	0.541267	0.408194	0.489989	0.88999	1.6412	2.935241	10.24453
5	0.093959	0.036958	0.308055	0.08012	0.115514	0.01383	0.105125	0.07928	0.095166	0.172855	0.318756	0.570086	1.989704
6	0.810506	0.825085	3.071567	0.755923	2.648899	0.12231	0.658921	0.64918	0.508382	0.571497	4.144311	2.263747	17.03033
7	0.959442	0.300456	1.634842	0.501873	1.004372	0.012519	0.772492	0.44818	0.32452	1.05876	3.07717	1.252596	11.34722
8	1.077735	1.106258	4.240566	1.033501	3.588133	0.161622	0.855833	0.931472	0.773248	0.87192	5.860016	3.185764	23.68607
9	0.970961	0.915966	3.975362	0.937434	3.28658	0.118707	0.600395	1.094797	1.126944	1.329387	5.375798	5.675382	25.40771
10	1.372005	0.706559	2.995247	0.839311	2.629586	0.074012	0.883246	0.579892	0.527765	1.056115	8.010305	1.496342	21.17039
11	0.332653	0.087536	0.770031	0.268455	0.875277	0.08922	0.503537	0.156352	0.238787	0.197257	0.737278	0.629	4.885385
12	1.7096	0.502362	3.655505	1.014374	3.156848	0.201819	1.686889	0.678263	1.048493	1.480384	3.637341	4.720634	23.49251
13	0.667734	0.204941	1.606109	0.544176	1.706442	0.286473	1.401011	0.389818	0.520143	0.35945	1.883592	0.817316	10.3872
14	0.22447	0.137983	0.608865	0.161672	0.526854	0.02523	0.156291	0.127638	0.114613	0.185086	1.471572	0.431212	4.171487
15	0.349197	0.096162	0.674793	0.238372	0.7605	0.021959	0.191897	0.098322	0.133017	0.204004	1.122613	0.288874	4.17971
16	0.198815	0.10592	0.506106	0.142191	0.449193	0.041763	0.205229	0.122253	0.125255	0.144237	0.931211	0.39447	3.366645
TOTAL	10.26395	5.728808	29.21785	7.784311	24.22755	1.457119	9.852179	6.570121	6.983418	10.30125	42.94092	30.82079	186.1483