Codes and Standards Enhancement (CASE) Initiative

2019 California Building Energy Efficiency Standards

Prescriptive Efficiency Requirements for Cooling Towers – Draft Report

Measure Number**:** 2019-NR-MECH1-D

Nonresidential Mechanical

April 2017

This report was prepared by the California Statewide Codes and Standards Enhancement (CASE) Program that is funded, in part, by California utility customers under the auspices of the California Public Utilities Commission.

Document Information

Category:	Codes and Standards
Keywords:	Statewide CASE, Statewide Codes and Standards Team, Statewide C&S Team, Codes and Standards Enhancements, Title 24, 2019, efficiency, cooling towers, condenser, and standard design
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EXECUTIVE SUMMARY

Introduction

This is a draft report. The Statewide CASE Team encourages readers to provide comments on the proposed code changes and the analyses presented in this version of the report. When possible, provide supporting data and justifications in addition to comments. Readers' suggested revisions will be considered when refining proposals and analyses. The final CASE Report will be submitted to the California Energy Commission in the third quarter of 2017. For this report, the Statewide CASE Team is requesting input on the following:

1. *The estimated incremental costs and if these reflect mature market trends;*
2. *The impact on product manufacturers; and*
3. *The impact on the code compliance documentation process.*

Email comments and suggestions to info@title24stakeholders.com. Comments will not be released for public review or will be anonymized if shared with stakeholders.

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support California Energy Commission's (Energy Commission) efforts to update California's Building Energy Efficiency Standards (2016 Title 24, Part 6 Standards) to include new requirements or to upgrade existing requirements for various technologies. 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 (SoCalGas®) – and two Publicly Owned Utilities (POUs): Los Angeles Department of Water and Power (LADWP) and Sacramento Municipal Utility District (SMUD) – sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to improve energy efficiency and energy performance in California buildings. This report and the code change proposals presented herein is a part of the effort to develop technical and cost-effectiveness information for proposed requirements on building energy efficient design practices and technologies.

The Statewide CASE Team submits code change proposals to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. See the Energy Commission's 2019 Title 24 website for information about the rulemaking schedule and how to participate in the process: http://www.energy.ca.gov/title24/2019standards/.

Measure Description

This measure proposes a prescriptive requirement for higher efficiency axial fan open-circuit cooling towers for newly constructed projects, new systems serving additions, and non-building mounted replacements/alterations. The current 2016 Title 24, Part 6 Standards' mandatory minimum efficiency for axial fan open-circuit cooling towers is 42.1 gallons per minute of condenser water flow per fan horsepower (gpm/hp). The 2016 Alternate Calculation Method Reference Manual assumes an efficiency of 60 gpm/hp for a standard design cooling tower. The intent of this CASE Proposal is to add a prescriptive efficiency requirement of 80 gpm/hp in addition to the mandatory requirement and increase the standard design listed in the Alternate Calculation Method (ACM) Reference Manual to 80 gpm/hp. The measure proposes this prescriptive requirement only for condenser water systems that are rated for 900 gpm (300 tons) or greater.

Currently there is no prescriptive requirement for cooling tower efficiency, only a mandatory requirement. This requirement was first established in 1999 Title 24, Part 6, and was increased by ten percent for 2013 Title 24, Part 6.

Scope of Code Change Proposal

Table 1 summarizes the scope of the proposed changes and which sections of the standards, references appendices, and compliance documents will be modified as a result of the proposed change.

Table 1: Scope of Code Change Proposal

Measure Name	Type of Requirement	Modified Section(s) of 2016 Title 24, Part 6	Modified 2016 Title 24, Part 6 Appendices	Will Compliance Software Be Modified	Modified Compliance Documents(s)
Prescriptive Efficiency Requirements for Cooling Towers	Prescriptive, and/or Performance	140.4	N/A	Yes	NRCC-CXR-04-E NRCC-MCH-02-E NRCC-PRF-01-E

Market Analysis and Regulatory Impact Assessment

Currently about 45 percent of available cooling towers from the major manufacturers meet the new proposed requirement. A few cooling tower models offer 80 gpm/hp or higher efficiency for almost no incremental cost from a current code minimum tower, and more products are available at less than a fifteen percent cost increase. Cooling towers rated below the 80 gpm/hp requirement will still be available for sale in California for both building-mounted alterations and projects using the performance compliance approach.

This proposal is 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.

Cost-Effectiveness

The proposed code change was found to be cost-effective for all climate zones where it is proposed to be required. The benefit-to-cost (B/C) ratio compares the lifecycle benefits (cost savings) to the lifecycle costs. Measures that have a B/C ratio of 1.0 or greater are cost-effective. The larger the B/C ratio, the faster the measure pays for itself from energy savings. The B/C ratio for this measure between 1.35 and 7.94 depending on climate zone. See Section 5 for a detailed description of the cost-effectiveness analysis.

Statewide Energy Impacts

Table 2 shows the estimated energy savings over the first 12 months of implementation of the proposed code change. See Section 6 for more details.

Table 2: Estimated Statewide First-year[1] Energy and Water Savings

First-year Electricity Savings (GWh/yr)	First-year Peak Electrical Demand Reduction (MW)	First-year Water Savings (Million Gallons/yr)	First-year Natural Gas Savings (Million Therms/yr)
1.46	1.45	-	-

1. First year savings from all buildings completed statewide in 2020.

Compliance and Enforcement

The Statewide CASE Team worked with stakeholders to understand impacts on market actors participating in the current compliance and enforcement process for cooling towers. The compliance process and impacts the proposed measure will have on various market actors is described in Section 2.5. Additional detail is provided in Appendix B.

Notable impacts include:

- Market actors need to be made aware of a new prescriptive requirement through outreach, training and resources (such as Energy Code Ace) prior to the implementation date.
- Energy consultants, architects and mechanical designers need to understand how this impacts performance credits and penalties for projects using the performance path to compliance.
- Designers and installers should be made aware that there are cost and size differences for higher efficiency cooling towers.

Although a needs analysis has been conducted with the affected market actors while developing the code change proposal, the code requirements may change between the time the final CASE Report is submitted and the time the 2019 Standards are adopted. The recommended compliance process and compliance documentation may also evolve with the code language. To effectively implement the adopted code requirements, a plan should be developed that identifies potential barriers to compliance when rolling-out the code change and approaches that should be deployed to minimize the barriers.

1. Introduction

This is a draft report. The Statewide CASE Team encourages readers to provide comments on the proposed code changes and the analyses presented in this version of the report. When possible, provide supporting data and justifications in addition to comments. Readers' suggested revisions will be considered when refining proposals and analyses. The final CASE Report will be submitted to the California Energy Commission in the third quarter of 2017. For this report, the Statewide CASE Team is requesting input on the following:

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The Statewide CASE Team submits code change proposals to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. See the Energy Commission's 2019 Title 24 website for information about the rulemaking schedule and how to participate in the process: http://www.energy.ca.gov/title24/2019standards/.

The overall goal of this CASE Report is to propose a code change proposal for Prescriptive Efficiency Requirements for Open-Circuit Cooling Towers in condenser water systems 900 gallons per minute (gpm) or greater. The requirement would apply to newly constructed projects, new systems serving additions, and non-building mounted replacements/alterations. The report contains pertinent information supporting the code change.

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with a number of industry stakeholders including building officials, manufacturers, builders, utility incentive program managers, Title 24 energy analysts, and others involved in the code compliance process. The proposal incorporates feedback received during a public stakeholder workshop that the Statewide CASE Team held on September 26, 2016.

Section 2 of this CASE Report provides a description of the measure and its background. This section also presents a detailed description of how this change is accomplished in the various sections and documents that make up the 2016 Title 24, Part 6 Standards.

Section 3 presents the market analysis, including a review of the current market structure. Section 3.2 describes the feasibility issues associated with the code change, such as whether the proposed measure overlaps or conflicts with other portions of the building standards including fire, seismic, and other safety standards and whether technical, compliance, or enforceability challenges exist.

Section 4 presents the per unit energy, demand, and energy cost savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate energy, demand, and energy cost savings.

Section 5 presents the lifecycle cost and cost-effectiveness analysis. This includes a discussion of additional materials and labor required to implement the measure and a quantification of the incremental cost. It also includes estimates of incremental maintenance costs. That is, equipment lifetime and various periodic costs associated with replacement and maintenance during the period of analysis.

Section 6 presents estimates the statewide energy savings and environmental impacts of the proposed code change for the first-year after the 2019 Standards take effect. This includes the amount of energy that will be saved by California building owners and tenants, statewide greenhouse gas (GHG) reductions associated with reduced energy consumption, and impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic. Statewide water consumption impacts are also considered.

Section 7 concludes the report with specific recommendations with ~~strikeout~~ (deletions) and underlined (additions) language for the Standards, Appendices, Alternate Calculation Method (ACM) Reference Manual, Compliance Manual, and compliance documents.

2. Measure Description

2.1 Measure Overview

This measure proposes a new prescriptive requirement for higher efficiency axial fan open-circuit cooling towers in condenser water systems 900 gpm or greater. This measure would apply to newly constructed projects and new systems serving additions. Alterations would be exempted if the equipment is being mounted to an existing building. The current 2016 Title 24, Part 6 Standards' mandatory minimum efficiency for axial fan cooling towers is 42.1 gallons per minute per horsepower (gpm/hp). The 2016 ACM Reference Manual assumes an efficiency of 60 gpm/hp for a standard design cooling tower. The intent of this CASE Proposal is to add a new prescriptive efficiency requirement of 80 gpm/hp and increase the standard design efficiency used in the compliance software to 80 gpm/hp. The measure proposes this prescriptive requirement only for condenser water systems that are 900 gpm or greater (or serving chilled water plants 300 tons or greater). The proposed code change does not recommend modifications to the existing mandatory minimum efficiency requirements.

The proposal recommends using the existing test procedure and rating conditions to evaluate cooling tower efficiency, which are listed in Table 110.2-G Performance Requirements for Heat Rejection Equipment. These procedures are the Cooling Tower Institute's (CTI) standards: CTI ATC-105 and CTI STD-201 under the standardized conditions of 95°F entering water temperature, 85°F leaving water temperature, and 75°F entering air wet-bulb temperature.

Replacement towers (alterations) are exempted if they are building mounted, but they would have to meet the existing mandatory efficiency requirements in Section 110.2.

The CASE Report measure aims to increase cooling tower efficiencies beyond the ASHRAE 90.1-2016 prescriptive standards.

The key technologies that result in improved cooling tower efficiencies are:

- Increased tower size to provide greater surface area of the water air interface for evaporation to occur and lower pressure drop in air stream.
- Optimized spray performance due to advances in computational and experimental research.
- Low pressure drop high efficiency fans as characterized by induced draft axial fans.
- High efficiency motors.
- High efficiency propellers.
- High efficacy heat transfer membrane.

2.2 Measure History

Cooling tower efficiency was first regulated in 1999. The first requirement was written jointly between ASHRAE 90.1 and ASHRAE Technical Committee (TC) 8.6 – Cooling Towers and Evaporative Condensers. The two committees came to an agreement with the cooling tower industry to establish a mandatory minimum efficiency requirement of 38.2 gpm/hp for open cooling towers with axial fans, as tested by the CTI at 95°F dry-bulb temperature, 85°wet-bulb temperature, and 75° condenser water temperature. At the time of adoption, five percent of the cooling towers available on the market would not meet the forthcoming minimum efficiency requirement. The 2001 Title 24, Part 6 adopted this same requirement.

The ASHRAE 90.1 requirement remained unchanged until the 2013 Title 24, Part 6 Standards code cycle. The Statewide CASE Team developed a CASE Report that proposed new prescriptive requirements for cooling towers to achieve an efficiency beyond 38.2 gpm/hp. Cooling towers were identified as having potential for energy savings since their requirements had not been updated for over ten years, and there are no federal preemption concerns. The Statewide CASE Team found that the cooling towers with efficiencies of 100 gpm/hp were cost-effective over a 15-year period of analysis in all climate zones. ASHRAE TC 8.6 responded to the 100 gpm/hp proposal with criticism as it would require projects to undergo performance method compliance in order to select nearly 90 percent of the cooling tower products available at the time. Additionally, there was concern that more expensive cooling towers (resulting from the increased efficiency) would drive new construction to pursue air-cooled cooling plants instead of water-cooled plants, though the CASE Team noted that since 1999 Title 24, Part 6 prescriptively requires water-cooled cooling plants if the total cooling plant capacity is 300 tons or greater. Due to this response, the CASE Team reduced the proposed requirement to 80 gpm/hp. ASHRAE TC 8.6 was still concerned about the number of cooling tower models that would not meet this requirement, so the measure was dropped from consideration for 2013 Title 24, Part 6 Standards to allow more time for the cooling tower industry to improve the efficiency of product lines.

ASHRAE TC 8.6 did agree that it was appropriate to increase cooling tower efficiencies in both ASHRAE 90.1 and Title 24, Part 6 as the requirement had remained unchanged for over ten years. The ASHRAE TC came to an agreement of increasing ASHRAE 90.1 axial cooling tower efficiency by five percent to 40.1 gpm/hp. Due to Title 24, Part 6 prescriptively requiring water-cooled systems for cooling plants greater than 300 tons, it was agreed that Title 24, Part 6 could increase cooling tower efficiency by ten percent, to 42.1 gpm/hp without having a detrimental effect on the cooling tower industry. This became the new mandatory requirement for cooling towers in 2013 Title 24, Part 6 Standards. The Energy Commission updated the 2013 ACM Reference Manual and compliance software to assume a standard design cooling tower had an efficiency of 60 gpm/hp. The Energy Commission assumed the standard design had an efficiency that exceeded the mandatory minimum requirement because, as presented in the 2013 draft CASE Report, standard practice for cooling towers has moved to more efficient towers.

For the ASHRAE 90.1-2016 Standards cycle, a prescriptive requirement to increase the efficiency of open-circuit cooling towers to 80 gpm/hp whenever these towers are used as part of a waterside economizer was proposed (proposed addendum CX to ASHRAE 90.1-2013). Advocates of this proposed change argued that increased runtime and fan power of waterside economizers helped justify the increased efficiency requirement. This addendum was not approved for ASHRAE 90.1-2016. In 2017, a reformulated version of this addendum was proposed that increased cooling tower efficiency by 30 percent (from 40.2 to 52 gpm/hp) for open-circuit towers attached to waterside economizers. The mandatory requirement was not approved for non-waterside economizer cooling towers and remained unchanged in ASHRAE 90.1-2016.

Cooling tower energy efficiency is being revisited for 2019 Title 24, Part 6 Standards due to the previous studies showing cost-effectiveness of proposed code changes, general market trends towards higher efficiency cooling tower specification, and lack of advancement in cooling tower regulation since 1999. The proposed efficiency requirement now impacts fewer towers on the market as the industry has moved towards higher efficiency towers. In some product classes, all of the cooling towers are more efficient than the required minimum efficiency level of 42 gpm/hp with many cooling towers achieving efficiencies of two times (84 gpm/hp) and even three times (126 gpm/hp) the minimum allowable efficiency.

Cooling tower manufacturers are still concerned that if proposed code changes make water-cooled systems cost more, designers will shift to air-cooled chiller plants, which are less efficient, and would hurt the cooling tower industry. ASHRAE 90.1-2016 does not restrict the use of air-cooled chillers, but the 2016 Title 24, Part 6 Standards includes a prescriptive requirement that cooling plants with a capacity above 300 tons must be water-cooled (Section 140.4(h)). The proposed code change will only apply to cooling towers connected to plants that are over 300 tons. The existing prescriptive requirement that these large plants used water-cooled systems means that in California designers will shift towards air-cooled systems in response to the proposed requirements.

The 300-ton threshold at which the proposed code changes begin to apply is related to two other pieces of 2016 Title 24, Part 6 Standards' requirements, the limitation on air-cooled chillers, and the limitation of centrifugal fan cooling towers.

In order to avoid pushing designers to pursue air-cooled systems in lieu of water-cooled systems due to increased cooling tower costs, the proposed code changes have aligned with existing requirements that air-cooled chillers cannot provide more than 300 tons of cooling in chilled water plants. This limitation has been in place since 2005, though the restriction was more stringent until 2013. Before 2013, the standard limited the amount of cooling provided by air-cooled chillers to 100 tons, if the total cooling plant was 300 tons or greater.

Centrifugal fan cooling towers are a much more compact form of cooling tower than axial fan towers, but these towers are much less efficient, with a minimum efficiency of 20 gpm/hp, less than half of axial fan towers. Title 24, Part 6 prescriptively restricts the use of centrifugal fan towers when the combined capacity is 900 gpm or greater, which corresponds closely to a 300-ton chilled water plant. It is unlikely that centrifugal fan cooling towers exist that could meet the 80 gpm/hp standard, but since these towers are restricted above 300 tons, there is no issue.

2.3 Summary of Proposed Changes to Code Documents

The sections below provide a summary of how each 2016 Title 24, Part 6 Standards' documents will be modified by the proposed change. See Section 7.1 of this report for detailed proposed revisions to code language.

2.3.1 Standards Change Summary

This proposal will modify the following sections of the Building Energy Efficiency Standards as shown below. See Section 7 of this report for the detailed proposed revisions to the code language.

Proposed standards add the following section of code

SECTION 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

(h) Heat Rejection Systems.

6. **Cooling tower efficiency.** Newly installed open-circuit cooling towers serving condenser water loops which total 900 gpm or greater, shall have a rated efficiency of no less than 80 gpm/hp when rated in accordance to the test procedures and rating conditions as listed in Table 110.2-G.

EXCEPTION 1 to Section 140.4(h)6: Replacement of existing cooling towers that are inside an existing building or on an existing roof.

EXCEPTION 2 to Section 140.4(h)6: Buildings in Climate Zone 1 and 16

2.3.2 Reference Appendices Change Summary

The proposed code change will not modify the appendices of the standards.

2.3.3 Alternative Calculation Method (ACM) Reference Manual Change Summary

This proposal will modify the following sections of the ACM Reference Manual as shown below. See Section 7.3 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

5.8.3 Cooling Towers

Cooling Tower Total Fan Horsepower

The proposed code change modifies the standard design horsepower to align with the proposed prescriptive requirements, from 60 gpm/hp to 80 gpm/hp. This aligns the stringency of the performance approach with new prescriptive standards. Note that the 2016 ACM standard design cooling tower fan gpm/hp is 42 percent higher than the required minimum efficiency. For 2019 we are proposing using the same gpm/hp for both prescriptive minimum efficiency and ACM standard design.

2.3.4 Compliance Manual Change Summary

Section 4.2 within Chapter 4 of the Compliance Manual will need to be revised to reflect this prescriptive requirement.

2.3.5 Compliance Documents Change Summary

The following certificate of compliance documents will need to be revised to reflect this new requirement if adopted:

- NRCC-CXR-04-E Commissioning Complex HVAC Systems
- NRCC-MCH-01-E Prescriptive Declarations
- NRCC-PRF-01-E Performance

No installation, acceptance or verification certificates will require revision.

2.4 Regulatory Context

2.4.1 Existing 2016 Title 24, Part 6 Standards

Current Title 24, Part 6 regulations regarding cooling tower efficiency include a mandatory requirement of 42.1 gpm/hp for propeller/axial fan open-circuit towers in Table 110.2-G PERFORMANCE REQUIREMENTS FOR HEAT REJECTION EQUIPMENT.

Additionally, heat rejection systems are prescriptively regulated in section 140.4(h), which restricts centrifugal cooling towers above 900 gpm combined capacity. 140.4(j) contains the air-cooled chiller limitation for chilled water plants above 300 tons.

2.4.2 Relationship to Other Title 24 Requirements

There are no relevant requirements in other parts of Title 24.

2.4.3 Relationship to State or Federal Laws

There are no other state or federal requirements for cooling tower efficiency.

2.4.4 Relationship to Industry Standards

Cooling tower energy efficiency standards are a part of several existing standards, including ASHRAE 90.1 and IECC. Currently these standards treat cooling tower efficiency as a mandatory requirement, with no increase in efficiency requirement for buildings seeking prescriptive compliance.

The CTI is the regulatory body that writes the certification process and acceptance test code for cooling towers. CTI STD-201 contains the testing procedure for cooling tower manufacturers to rate their product lines with the CTI. In addition to manufacturer testing, California requires acceptance testing for cooling towers once they are installed on-site. The acceptance test code written by CTI is ATC-105. These procedures are currently used to ensure cooling towers are both designed and operated to meet the energy standard, and no issues are expected with the increased cooling tower efficiency requirement.

2.5 Compliance and Enforcement

The Statewide CASE Team collected input on what compliance and enforcement issues may be associated with this measure during the stakeholder outreach process. This section summarizes how the proposed code change will modify the code compliance process. Appendix B presents a detailed description of how the proposed code changes could impact various market actors. When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how negative impacts on market actors who are involved in the process could be mitigated or reduced.

This code change proposal will affect buildings that use both the prescriptive and performance approaches to compliance. The key changes to the compliance process are summarized below by project phase:

- **Design Phase**: Table 3 includes roles that may be impacted by this measure during the design phase, and potential impacts.

Table 3: Impact on Market Actors During Design Phase

Role	Potential Impact
Mechanical Designer	May need to use more efficient equipment in design resulting in possible size and cost impacts.
	Would need to be aware of new requirements early in design phase (before document completion) so initial pricing estimates include compliant equipment.
Energy Consultant	Would result in more stringent requirements to meet, potentially meaning less trade-off options under the performance approach.
	Would add a requirement to be aware of and coordinate/ document with project team.
Architect	May require more coordination and space allocation for larger equipment.
	May allow less trade-off options for aesthetic features.

- **Permit Application Phase**: Obtaining a building permit is anticipated to result in only slight changes as there are already mandatory requirements for cooling tower efficiency. The table below includes roles which may be impacted by this measure during the permit application phase, and potential impacts. Table 4 includes roles that may be impacted by this measure during the application phase, and potential impacts.

Table 4: Impact on Market Actors During Permit Application Phase

Role	Potential Impact
Plans Examiner	Would need to be aware of new requirement and its triggers (i.e., not alterations)
	Would need to verify cooling tower efficiency on NRCC-MCH-02-E for new systems using prescriptive compliance path.

- **Construction Phase**: There will be minimal changes to the construction phase of the project, as long as installers are aware of the new efficiency standards for cooling towers, so they do not price or purchase towers that do not meet this requirement. Table 5 includes roles that may be impacted by this measure during the construction phase, and potential impacts.

Table 5: Impact on Market Actors During Construction Phase

Role	Potential Impact
HVAC Contractor/ Installer	Would need to be aware of new requirement and its triggers (i.e., not alterations).
	May require installation of heavier and larger equipment.
	May impact equipment costs.

- **Inspection Phase**: Compliance tasks during the inspection phase will stay largely unchanged, the documents for cooling tower testing will be slightly modified to reflect the new efficiency requirements, but nothing in the proposed code changes will require any additional documents or change in protocol. Table 6 includes roles that may be impacted by this measure during the inspection phase, and potential impacts.

Table 6: Impact on Market Actors During Inspection Phase

Role	Potential Impact
Building Inspector	Would need to be aware of new requirement and its triggers (i.e., not alterations).

Based on the potential impacts to the compliance process described above, there are no insurmountable barriers to compliance and enforcement anticipated for this code change proposal. This is especially true if actions are taken to prepare the market actors prior to implementation. Some suggestions are included in Table 21 with more information on how this code change proposal could impact the compliance and enforcement process.

The Statewide CASE Team has attempted to keep new requirements as simple and straightforward as possible, following the previous requirements that have already been set. A challenge may result from projects that have space constraints, as the new cooling towers will be larger. Projects with tight space constraints have the option of using the performance compliance method to select less efficient towers as long as the energy penalty is traded-off with other efficiency features.

If this code change proposal is adopted, the Statewide CASE Team recommends that information presented in this section, Section 3 and Appendix B be used to develop a plan that minimizes barriers to compliance.

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 actors. 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 stakeholders including utility program staff, Energy Commission staff, and a wide range of industry players who were invited to participate in Utility-Sponsored Stakeholder Meetings held on September 26, 2016 and March 15, 2017.

3.1 Market Structure

Cooling towers are manufactured products, with the majority of rated products coming from three companies: SPX, Evapco, and Baltimore Air Coil. The major manufacturers are identified based on the number of products they have rated and registered with the CTI. These manufacturers design the products and develop technology advancements. They also publish software to aid in the selection of products. The actual sales and selection process is handled by partnering sales representative companies. The selection is done by both the project engineer and sales representative. Currently all three major cooling tower companies provide high-efficiency cooling towers that meet the proposed requirements.

3.2 Technical Feasibility, Market Availability, and Current Practices

While the measure is expected to increase demand for higher efficiency cooling towers, interviews with design engineers show that the market is already demanding higher efficiency towers, with many products lines currently meeting the proposed standards. A survey of the top three manufacturers' product lines revealed that for a 300 ton cooling tower, 45 percent of product lines surveyed currently available will meet the proposed prescriptive requirements. The 45 percent of products that do not meet the proposed requirements will still be available for projects that choose to use performance path compliance. The following chart shows the number of cooling products available and the products corresponding gpm/hp rating for 900 gpm towers available from SPX, Evapco, and Baltimore Air Coil.

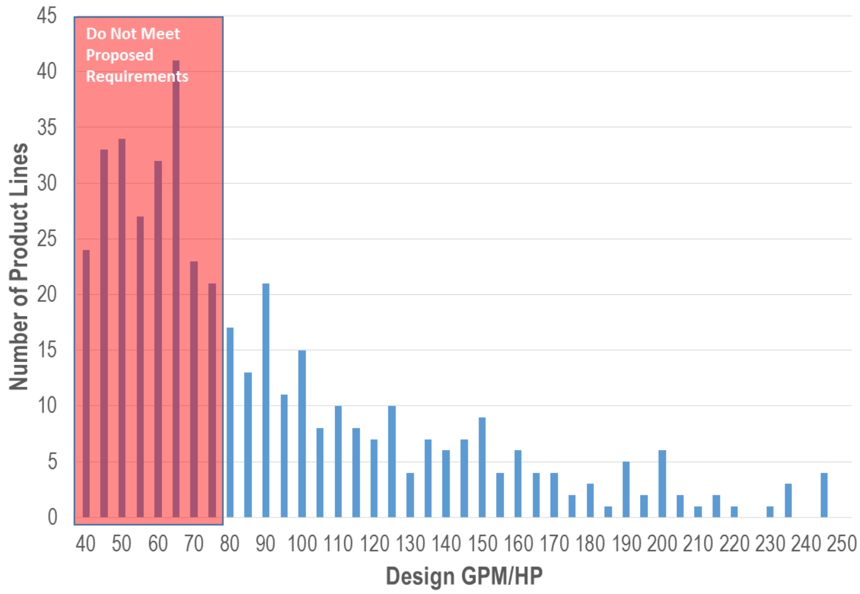

Figure 1: Number of unique units available verses gpm/hp rating for SPX, Evapco, and Baltimore Air Coil.

The Statewide CASE Team does not anticipate issues with constructability or inspection. Based on interviews with design engineers, many projects are selecting more efficient cooling towers due to the good financial payback. The CASE Report from the 2013 Title 24, Part 6 Standards code cycle entitled "Cooling Tower Efficiency and Turndown" also indicated through interviews and project experience that the market is moving towards more efficient cooling towers. No inherent issues with larger and more efficient sized towers have been reported.

Larger towers will take up more space which will constrain the selection of rooftop mounted cooling equipment. Since the measure is prescriptive, space constrained applications can take the performance approach and use smaller-sized cooling towers. Besides the potential for coordination issues, the design process will remain relatively similar. The larger towers may result in aesthetic issues; likely taking more effort to conceal. An advantage of higher efficiency cooling towers is that as the fan power is reduced, the tower will generate less noise, reducing noise concerns.

3.3 Market Impacts and Economic Assessments

3.3.1 Impact on Builders

It is expected that builders will not be impacted significantly by any one proposed code change or the collective effect of all the proposed changes to 2019 Title 24, Part 6 Standards. Builders could be impacted for change in demand for new buildings and by construction costs. Demand for new buildings is driven more by factors such as the overall health of the economy and population growth than the cost of construction. The cost of complying with 2019 Title 24, Part 6 Standards' requirements represents a very small portion of the total building value. Increasing the building cost by a fraction of a percent is not expected to have a significant impact on demand for new buildings or the builders' profits.

Market actors will need to invest in training and education to ensure the workforce, including designers and those working in construction trades, know how to comply with the proposed requirements. Workforce training is not unique to the building industry, and is common in many fields associated with the production of goods and services. Costs associated with workforce training are typically accounted for in long-term financial planning and spread out across the unit price of many units as to avoid price spikes when changes in designs and/or processes are implemented.

Few impacts on builders are expected, as this measure only impacts a small piece of a building. Larger cooling towers may present additional difficulties in the installation process, but there is nothing in the proposed standards that would fundamentally impact the process.

3.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including the California Building code and model national building codes published by the International Code Council, the International Association of Plumbing and Mechanical Officials and ASHRAE 90.) are typically updated on a three-year revision cycles. As discussed in Section 3.3.1, all market actors should (and do) plan for training and education that may be required to adjusting design practices to accommodate compliance with new building codes. As a whole, the measures the Statewide CASE Team is proposing for the 2019 code cycle aim to provide designers and energy consultants with opportunities to comply with code requirements in multiple ways, thereby providing flexibility.

Nothing about the proposed standards will fundamentally change building designer's workflow. The larger towers may cause issues that need to be addressed by architects coordinating with engineers to provide the needed space. Energy consultants should have no issues with the proposed standards. Interviews with a nonresidential building structural engineer confirmed that minimal structural issues would occur with the expected additional weight. The stakeholder engagement process will support a full consideration of the proposed changes.

3.3.3 Impact on Occupational Safety and Health

The proposed code change does not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by the California Department of Occupational Safety and Health (Cal/OSHA). All existing health and safety rules will remain in place. Complying with the proposed code change is not anticipated to have adverse impacts on the safety or health occupants, or those involved with the construction, commissioning, and maintenance of the building.

3.3.4 Impact on Building Owners and Occupants

Building owners and occupants will benefit from lower energy bills. As energy efficiency standards become more stringent, occupants of nonresidential buildings will benefit from energy cost savings. As discussed in Section 3.4.1, when building owners or occupants save on energy bills, they tend to spend it elsewhere in the economy thereby creating jobs and economic growth for the California economy.

Building owners will have about a 15 percent higher first cost for mechanical equipment due to the larger, more efficient towers, but as the analysis in this CASE Report shows, the more efficient towers will pay back within 15 years due to lower energy bills. There are a few cost neutral cooling towers available that can meet proposed standards as well. Occupants will be generally unaffected by the more efficient towers, although lower fan speeds will likely reduce noise which could have minor benefits for occupants.

3.3.5 Impact on Building Component Retailers (Including Manufacturers and Distributors)

The results of this study will cause an increased demand for higher efficiency, more expensive heat rejection equipment. Both manufacturers and distributors of this equipment have expressed some concern about the increased cost affecting the sales of this equipment. More expensive cooling towers may result in design teams foregoing cooling towers for air-cooled equipment. Title 24, Part 6 prescriptively requires chillers to be water-cooled above 300 tons, so only chilled water plants below 300 tons in capacity would be at risk of switching to less efficient air-cooled systems. In response to this concern, the measure has been modified to only apply to chilled water plants that are above 300 tons. Since design jobs are prescriptively required to provide water-cooled systems when the proposed code changes take effect, the code change team expects negligible impact to cooling tower sales, and since the towers sold will be larger and more expensive, there may be an increase in total sales revenue in California.

3.3.6 Impact on Building Inspectors

Building inspectors currently must ensure that cooling towers are meeting code-required efficiencies, so there are no significant issues expected with the proposed code changes.

3.3.7 Impact on Statewide Employment

Section 3.4.1 discusses statewide job creation from the energy efficiency sector in general, including updates to 2019 Title 24, Part 6 Standards.

Generally statewide employment is not expected to be affected. Since cooling towers are required on 300 ton plants, and we are increasing the required size of the plants, it can be presumed that the tower manufacturers will have a slight revenue increase which could be good for employment.

3.4 Economic Impacts

3.4.1 Creation or Elimination of Jobs

In 2015, California's building energy efficiency industry employed more than 321,000 workers who worked at least part time or a fraction of their time on activities related to building efficiency. Employment in the building energy efficiency industry grew six percent between 2014 and 2015 while the overall statewide employment grew three percent (BW Research Partnership 2016). Lawrence Berkeley National Laboratory's 2010 *Characterizing the Energy Efficiency Services Sector* report provides a detail on the types of jobs in the energy efficiency sector that are likely to be supported by revisions to building codes.

Building codes that reduce energy consumption provide jobs through *direct employment*, *indirect employment*, and *induced employment*.[1] 2016 Title 24, Part 6 Standards creates jobs in all three categories with a significant amount created from induced employment, which accounts for the expenditure-induced effects in the general economy due to the economic activity and spending of direct and indirect employees (e.g., non-industry jobs created such as teachers, grocery store clerks, and postal workers). A large portion of the induced jobs from energy efficiency are the jobs created by the energy cost savings due to the energy efficiency measures. Wei et al. (2010) estimates that energy efficiency creates 0.17 to 0.59 net job-years[2] per GWh saved (Wei, Patadia and Kammen 2010). By comparison, they estimate that the coal and natural gas industries create 0.11 net job-years per GWh produced. Using the mid-point for the energy efficiency range (0.38 net job-years per GWh saved) and estimates that this

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[1] The definitions of direct, indirect, and induced jobs vary widely by study. Wei et al (2010) describes the definitions and usage of these categories as follows: "*Direct employment* includes those jobs created in the design, manufacturing, delivery, construction/installation, project management and operation and maintenance of the different components of the technology, or power plant, under consideration. *Indirect employment* refers to the ''supplier effect'' of upstream and downstream suppliers. For example, the task of installing wind turbines is a direct job, whereas manufacturing the steel that is used to build the wind turbine is an indirect job. *Induced employment* accounts for the expenditure-induced effects in the general economy due to the economic activity and spending of direct and indirect employees, e.g. non-industry jobs created such as teachers, grocery store clerks, and postal workers."

[2] One job-year (or ''full-time equivalent'' FTE job) is full time employment for one person for a duration of one year.

proposed code change will result in a statewide first-year savings of 1.91 GWh, this measure will result in approximately 0.73 jobs created per first-year. See Section 6.1 for statewide savings estimates.

No other significant job creation is expected based on the specification and installation of equipment.

3.4.2 Creation or Elimination of Businesses within California

There are approximately 43,000 businesses that play a role in California's advanced energy economy (BW Research Partnership 2016). California's clean economy grew ten times more than the total state economy between 2002 and 2012 (twenty percent compared to two percent). The energy efficiency industry, which is driven in part by recurrent updates to the building code, is the largest component of the core clean economy (Ettenson and Heavey 2015). Adopting cost-effective code changes for the 2019 Title 24, Part 6 Standards code cycle will help maintain the energy efficiency industry.

Table 7 lists industries that will likely benefit from the proposed code change classified by their North American Industry Classification System (NAICS) Code.

Table 7: Industries Receiving Energy Efficiency Related Investment, by North American Industry Classification System (NAICS) Code

Industry	NAICS Code
Nonresidential Building Construction	2362
Roofing Contractors	238160
Electrical Contractors	23821
Plumbing, Heating, and Air-Conditioning Contractors	23822
Boiler and Pipe Insulation Installation	23829
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 Equip. Manf.	3334
Engineering Services	541330
Building Inspection Services	541350
Environmental Consulting Services	541620
Other Scientific and Technical Consulting Services	541690
Advertising and Related Services	5418
Commercial & Industrial Machinery & Equip. (Exc. Auto. & Electronic) Repair & Maint.	811310

3.4.3 Competitive Advantages or Disadvantages for Businesses Within California

In 2014, California's electricity statewide costs were 1.7 percent of the state's gross domestic product (GPD) while electricity costs in the rest of the United States were 2.4 percent of GDP (Thornberg, Chong and Fowler 2016). As a result of spending a smaller portion of overall GDP on electricity relative to other states, Californians and California businesses save billions of dollars in energy costs per year relative to businesses located elsewhere. Money saved on energy costs can otherwise be invested, which provides California businesses with an advantage that will only be strengthened by the adoption of the proposed codes changes that impact nonresidential buildings.

3.4.4 Increase or Decrease of Investments in the State of California

The proposed changes to the building code are not expected to impact investments in California on a macroeconomic scale, nor are they expected to affect investments by individual firms. The allocation of resources for the production of goods in California is not expected to change as a result of this code change proposal.

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

The proposed code changes are not expected to have a significant impact on the California's General Fund, any state special funds, or local government funds. Revenue to these funds comes from taxes levied. The most relevant taxes to consider for this proposed code change are: personal income taxes, corporation taxes, sales and use taxes, and property taxes. The proposed changes for the 2019 Title 24, Part 6 Standards are not expected to result in noteworthy changes to personal or corporate income, so the revenue from personal income taxes or corporate taxes is not expected to change. As discussed, reductions in energy expenditures are expected to increase discretionary income. State and local sales tax revenues may increase if building owners spend their additional discretionary income on taxable items. Although logic indicates there may be changes to sales tax revenue, the impacts that are directly related to revisions to 2019 Title 24, Part 6 Standards have not been quantified. Finally, revenue generated from property taxes is directly linked to the value of the property, which is usually linked to the purchase price of the property. The proposed changes will increase construction costs. As discussed in Section 3.3.1, however, there is no statistical evidence that 2019 Title 24, Part 6 Standards drives construction costs or that construction costs have a significant impact on building price. Since compliance with 2016 Title 24, Part 6 Standards does not have a clear impact on purchase price, it can follow that 2019 Title 24, Part 6 Standards cannot be shown to impact revenues from property taxes.

3.4.5.1 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 2019 Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, 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 2019 Title 24, Part 6 Standards will result in changes to compliance determinations. Local governments will need to train building department staff on the revised Title 24, Part 6 Standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2019 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, including tools, training and resources provided by the IOU codes and standards program (such as Energy Code Ace). As noted in Section 2.5 and Appendix B, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

3.4.6 Impacts on Specific Persons

The proposed changes to 2019 Title 24, Part 6 Standards are not expected to have a differential impact on any groups relative to the state population including migrant workers, commuters or persons by age, race or religion.

4. ENERGY SAVINGS

4.1 Key Assumptions for Energy Savings Analysis

The energy savings analysis for this measure uses energy modeling using the CBECC-Com 2019 prototypical models which were provided by the Energy Commission. Certain aspects of the models required accessing additional EnergyPlus features that were not available in CBECC-Com at this time, so the OpenStudio® models which CBECC-Com generates were manipulated directly. Care was taken to follow the Nonresidential Alternative Calculation Method when editing the models.

The key assumption in the energy model is the fan power of the cooling towers. The cooling tower efficiency as described in this CASE Report is based on the design flowrate of condenser water, and design fan power of the cooling tower. The default value in the prototype, based on the 2016 ACM is 60 gpm/hp. Since this analysis is looking at the energy and cost impacts of increasing the required efficiency in a prescriptive compliance building, the baseline cooling tower efficiency is changed to match the lowest efficiency cooling tower allowed by the 2016 code for prescriptive compliance, which is the mandatory minimum of 42.1 gpm/hp. The cooling tower efficiency of the proposed building is set to 80 gpm/hp to match the proposed code change.

The energy models are otherwise left unchanged from the prototype models, all hard-sized components and equipment is left untouched.

4.2 Energy Savings Methodology

To assess the energy, demand, and energy cost impacts, the Statewide CASE Team compared current design practices to design practices that will comply with the proposed requirements. There is an existing 2016 Title 24, Part 6 Standard that covers the building system in question, so the existing conditions assume a building minimally complies with the 2016 Title 24, Part 6 Standards.

The proposed conditions are defined as the design conditions that will comply with the proposed code change. Specifically, the proposed code change will increase cooling tower efficiencies to 80 gpm/hp.

The Energy Commission provided guidance on the type of prototype buildings that must be modeled. The prototype used in this analysis is the large office. This measure concerns buildings with large cooling plants, and only affects buildings with plants greater than 300 tons.

Note that since most cooling towers on office buildings are building mounted, it’s assumed that this measures only affects new construction office. Large schools typically have ground mounted towers, so alterations of large school buildings are considered as well.

Table 8 presents the details of the prototype building used in the analysis.

Table 8: Prototype Buildings used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype ID	Occupancy Type (Residential, Retail, Office, etc.)	Area (Square Feet)	Number of Stories	Statewide Area (Million Square Feet)
Prototype 1	Office	500,000	13	20.52
Prototype 2	School	210,885	2	6.35

The impacts of this measure are climate specific, since the size and runtime of cooling tower fans varies greatly with the climate. The energy savings and cost-effectiveness of this measure are evaluated for all climate zones.

Energy savings, energy cost savings, and peak demand reductions were calculate using Time Dependent Valuation (TDV) methodology.

4.3 Per Unit Energy Impacts Results

There are no natural gas savings for this measure. Electricity savings and peak demand reductions per unit for new construction and alterations are presented Table 9 show that the per-unit savings for the first-year are expected to range from a high of 0.120 kilowatt hours per square foot per year (kWh/yr) to a low of 0.001 kWh/yr depending upon the climate zone. Demand reductions/increases are expected to range between 3.0E^{-5} kilowatts per square foot (kW/ft^2) and 5.71E-5 kW/ft^2 depending on climate zone.

The peak demand decreases from this measure are sourced from the reduction in cooling tower fan power at peak conditions. As this fan is relatively small in comparison to the electricity demand at full building load, demand savings are modest.

Climate Zone 1 shows dramatically less energy savings than the other buildings. This is due to the fact that the climate is very mild all year, so the airside economizer is nearly always in operation. Airside economizer reduces or eliminates heat rejection requirements, so cooling tower runtime is comparatively low compared to other climates. This suggests that Climate Zone 1 and 16 may be exempted from proposed code changes.

Table 9: First Year Energy Per Square Foot

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	TDV Energy Savings (TDV kBtu/yr)
LARGE OFFICE (new construction)			
1	0.001	3.03E-05	0.03
2	0.032	4.06E-05	1.63
3	0.012	3.69E-05	0.59
4	0.036	4.35E-05	1.78
5	0.012	3.32E-05	0.45
6	0.053	4.40E-05	2.10
7	0.041	4.37E-05	1.80
8	0.054	4.26E-05	2.29
9	0.063	4.58E-05	2.78
10	0.061	5.40E-05	2.78
11	0.058	4.36E-05	2.55
12	0.048	4.27E-05	2.24
13	0.062	4.28E-05	2.63
14	0.046	3.95E-05	2.08
15	0.120	5.71E-05	4.53
16	0.010	3.00E-05	0.33
LARGE SCHOOL (new construction and alterations)			
1	0.000	1.33E-05	0.01
2	0.014	2.55E-05	0.79
3	0.004	2.00E-05	0.24
4	0.016	2.70E-05	0.81
5	0.004	2.01E-05	0.16
6	0.023	2.43E-05	0.96
7	0.017	2.33E-05	0.79
8	0.024	2.45E-05	1.11
9	0.031	2.85E-05	1.52
10	0.028	2.90E-05	1.37
11	0.029	2.76E-05	1.30
12	0.023	2.60E-05	1.14
13	0.031	2.66E-05	1.34
14	0.023	2.49E-05	1.08
15	0.068	3.94E-05	2.70
16	0.004	1.94E-05	0.13

Alterations for office buildings typically fall under the building-mounted cooling tower exception, so the savings are left off in this iteration of analysis. When schools and high-rise residential is added, this table will be revisited.

5. Lifecycle Cost and Cost-Effectiveness

5.1 Energy Cost Savings Methodology

TDV energy is a normalized format for comparing electricity and natural gas cost savings that takes into account the cost of electricity and natural gas consumed during each hour of the year. The TDV values are based on long term discounted costs (thirty years for all residential measures and nonresidential envelope measures and fifteen years for all other nonresidential measures). In this case, the period of analysis used is fifteen years. The TDV cost impacts are presented in 2020 present valued dollars. The TDV energy estimates are based on present-valued cost savings but are normalized in terms of "TDV kBtu." Peak demand reductions are presented in peak power reductions (kW). The Energy Commission derived the 2020 TDV values that were used in the analyses for this report (Energy + Environmental Economics 2016).

All analysis used to quantify energy and demand savings is based on energy models from CBECC-Com. The analysis is relatively simple as the only parameter that changes is the cooling tower fan energy. All analysis completed can be easily reproduced using the existing CBECC-Com software packages, no enhancements are necessary. One note is that the baseline model from CBECC-Com has different cooling tower fan power compared to the minimum requirements set by Title 24. Two models were created in CBECC-Com, representing both the baseline minimum compliant Title 24 model, and the model based on proposed code changes. This analysis made use of OpenStudio models that CBECC-Com generates. In the interest of time savings, the models were manipulated directly in OpenStudio and TDV was then calculated based on OpenStudio results using the latest 2019 TDV available.

5.2 Energy Cost Savings Results

Per unit energy cost savings over the fifteen-year period of analysis are presented in Table 10 for new construction and alterations. It is estimated that the first-year TDV energy savings is 0 to 0.4 TDV kBtu/sf. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. Since cooling tower fans run at their maximum capacity during peak periods, savings are higher during peak periods, though most savings occur throughout the year.

Table 10: TDV Energy Cost Savings Over Fifteen-Year Period of Analysis –Per Square Foot – New Construction Large Office

Climate Zone	15-Year TDV Electricity Cost Savings (2020 PV $)	15-Year TDV Natural Gas Cost Savings (2020 PV $)	Total 15-Year TDV Energy Cost Savings (2020 PV $)
LARGE OFFICE (new construction)			
1	$0.00	-	$0.00
2	$0.15	-	$0.15
3	$0.05	-	$0.05
4	$0.16	-	$0.16
5	$0.04	-	$0.04
6	$0.19	-	$0.19
7	$0.16	-	$0.16
8	$0.20	-	$0.20
9	$0.25	-	$0.25
10	$0.25	-	$0.25
11	$0.23	-	$0.23
12	$0.20	-	$0.20
13	$0.23	-	$0.23
14	$0.19	-	$0.19
15	$0.40	-	$0.40
16	$0.03	-	$0.03
LARGE OFFICE (new construction and alterations)			
1	$0.00	-	$0.00
2	$0.07	-	$0.07
3	$0.02	-	$0.02
4	$0.07	-	$0.07
5	$0.01	-	$0.01
6	$0.09	-	$0.09
7	$0.07	-	$0.07
8	$0.10	-	$0.10
9	$0.14	-	$0.14
10	$0.12	-	$0.12
11	$0.12	-	$0.12
12	$0.10	-	$0.10
13	$0.12	-	$0.12
14	$0.10	-	$0.10
15	$0.24	-	$0.24
16	$0.01	-	$0.01

5.3 Incremental First Cost

The Statewide CASE Team estimated the Current Incremental Construction Costs and Post-Adoption Incremental Construction Costs. The Current Incremental Construction Cost represents the incremental cost of the measure if a building meeting the proposed standard were built today. The Post-Adoption Incremental Construction Cost represents the anticipated cost assuming full market penetration of the measure as a result of the new standards, resulting in possible reduction in unit costs as manufacturing practices improve over time and with increased production volume of qualifying products the year the standard becomes effective.

Incremental costs for cooling towers were sourced based on cooling tower manufacturers' software. The software provides the percent increase in cost from a code minimum baseline tower. To find the cost of a base cooling tower, RS Means 2017 was consulted. It is assumed that the cost increase only affects material costs and that labor will be the same. Cooling tower base costs used $120/ton based on RS-Means. A survey was done of the three major manufactures (Evapco, SPX, and BAC), for each cooling tower size used in the energy analysis. Stakeholders commented that it was important to calculate the cost increase for every size tower used in analysis, since the cost increase to go to 80 gpm/hp for a 500 gpm tower, for example may be different than the cost increase for an 1100 gpm/hp tower. The cost increase was identified to go from a 42.1 gpm/hp tower to an 80 gpm/hp tower for all three manufactures for tower sizes used in all 16 climate zones. The incremental cost increase used consisted of the average incremental cost for the three manufacturers for each specific tower size.

The following table reports the incremental cost multiplier found for each climate zone's cooling tower size. The reported gpm/hp is larger than 80 since the goal was to find the cheapest tower that meets the proposed requirement, which at times resulted in a tower over 100 gpm/hp, providing further evidence that the cooling tower market has shifted towards even higher efficiency towers. The gpm/hp in the table is the average value of what was found between the three manufacturers.

Table 11: Cost Increase for High Efficiency Cooling Towers in Analysis

Large Office Prototype				Large Schools Prototype			
Climate Zone	Flow Rate[1] (gpm)	Percent Cost Increase of Higher-efficiency Towers[2]	Average Actual Efficiency (gpm/hp)	Climate Zone	Flow Rate[1] (gpm)	Percent Cost Increase of Higher-efficiency Towers[2]	Average Actual Efficiency (gpm/hp)
1	1,125	17%	83.2	1	1,076	21%	92.6
2	1,506	21%	88.4	2	943	21%	107.7
3	1,369	18%	95.0	3	740	11%	94.6
4	1,610	16%	81.9	4	1,002	19%	105.7
5	1,231	14%	86.0	5	743	11%	94.6
6	1,627	15%	82.4	6	900	12%	93.4
7	1,619	16%	81.9	7	862	14%	90.9
8	1,579	18%	81.9	8	907	12%	93.4
9	1,696	17%	86.5	9	1,057	22%	100.2
10	2,002	13%	89.2	10	1,075	21%	92.6
11	1,614	16%	81.9	11	1,023	17%	105.7
12	1,581	18%	81.9	12	964	20%	113.2
13	1,585	16%	81.9	13	984	19%	113.2
14	1,464	20%	99.2	14	924	11%	93.4
15	2,115	8%	91.7	15	1,459	20%	99.2
16	1,487	21%	87.4	16	718	12%	100.0

1. Flow rate is for one cooling tower, analysis used two towers per building as per ACM except Large Schools CZ1, so all climate zones have condenser water flow rates >900 gpm cutoff

2. Percent cost increase of 80 gpm/hp tower relative to 42.1 gpm/hp tower.

Higher efficiency cooling towers can be made by both increasing the footprint and increasing the height. While increasing the footprint of the tower will take up more real estate, since designers have the option of making the tower taller instead of increasing the footprint, real estate costs were not included in the analysis for ground mounted cooling towers.

In addition to cooling towers being larger, they will also be heavier. An 80 gpm/hp tower is expected to be around 30 to 40 percent heavier than a 40 gpm/hp tower, based on a survey using cooling tower manufacturer selection software provided by each of the major cooling tower manufacturers. To assess potential structural concerns, Rutherford + Chekene structural engineering firm was interviewed. Since this measure will apply almost exclusively to steel framed construction, the firm gave input on the structural impacts of a 5000 pound cooling tower being increased to 7000 pounds. Their response was that the weight increase would "not have a significant cost impact by any stretch of the imagination", and "if it doubled you could see some impact", perhaps on the order of $2,000 due to around a half ton of extra steel. Overall, Rutherford + Chekene commented that placement is a much more important metric than weight, and placement is usually out of the designer's hands. Additional outreach to structural engineers is currently underway.

Per the Energy Commission's guidance, design costs are not included in the incremental first cost.

5.4 Lifetime Incremental Maintenance Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the period of analysis. The present value of equipment and maintenance costs (savings) was calculated using a three percent discount rate (d), which is consistent with the discount rate used when developing the 2019 TDV. The present value of maintenance costs that occurs in the nth year is calculated as follows (where d is the discount rate of three percent):

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

Cooling towers require similar maintenance to other hydronic equipment, yet have additional complications due to the fact that the loop is open and exposed to the outdoors. Special care needs to be taken to clean filters and check periodically for corrosion. The largest maintenance concern is the water treatment system which needs to be checked monthly to ensure proper operation and reduction of scaling build up. Additional important maintenance steps include spraying of wash media, fan/motor belt replacement, and cleaning of basin. Cooling towers that are properly maintained can have an expected useful life of 20 years according to ASHRAE.

The proposed code changes are not expected to increase maintenance costs.

5.5 Lifecycle Cost-Effectiveness

This measure proposes a prescriptive requirement. As such, a lifecycle cost analysis is required to demonstrate that the measure is cost-effective over the 15-year period of analysis.

The Energy Commission establishes the procedures for calculating lifecycle cost-effectiveness. The Statewide CASE Team collaborated with Energy Commission staff to confirm that the methodology described in this report is consistent with their guidelines, including which costs were included in the analysis. In this case, incremental first cost and incremental maintenance costs over the fifteen-year period of analysis were included. The TDV energy cost savings from electricity savings were also included in the evaluation.

Design costs were not included nor was the incremental cost of code compliance verification.

According to the Energy Commission's definitions, a measure is cost-effective if the Benefit-to-Cost (B/C) ratio is greater than 1.0. The B/C ratio is calculated by dividing the total present lifecycle cost benefits by the present value of the total incremental costs.

Results of the per unit lifecycle cost-effectiveness analyses are presented in Table 12 for new construction and alterations. The proposed measure was found to be cost-effective in fourteen out of sixteen climate zones. Due to the highly climate dependent nature of the measure, a few of the milder climates do not show cost-effectiveness. These climates allow airside economizing for a large number of hours per year. Airside economizer reduces or eliminates the heat rejection from the cooling tower when conditions allow. Climate Zone 1 has a very mild climate which allows airside economizer nearly year round, so the cooling tower has very low usage. This results in a very poor benefit/cost ratio. Climate Zone 16 is the coldest climate zone, so the short cooling season reduces the effectiveness of efficient cooling towers.

Note that the study assumes the 80 gpm/hp cooling tower will cost fifteen percent more than the baseline tower of 42.1 gpm/hp. This allows several models to meet the new proposed standards, but a few options exist which will have five percent or lower added first cost.

The proposed measure was found to be cost-effective in fourteen out of sixteen climate zones. Due to the highly climate dependent nature of the measure, a few of the milder climates do not show cost-effectiveness. These climates allow airside economizing to run for many hours per year. Airside economizer reduces or eliminates the heat rejection from the cooling tower when conditions allow. Climate Zone 1 has a very mild climate which allows airside economizer nearly year-round, so the cooling tower has very low usage. This results in a very poor benefit/cost ratio. Climate Zone 16 is the coldest climate zone, so the short cooling season reduces the effectiveness of efficient cooling towers.

Note that the study assumes the 80 gpm/hp cooling tower will cost 15 percent more than the baseline tower of 42.1 gpm/hp. This allows several models to meet the new proposed standards, but a few options exist which will have five percent or lower added first cost.

Table 12: Lifecycle Cost-Effectiveness Summary Per Square Foot

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[1] (2020 PV $)	Costs Total Incremental Present Valued (PV) Costs[2] (2020 PV $)	Benefit-to-Cost Ratio
LARGE OFFICE (new construction)			
1	$0.00	$0.03	0.08
2	$0.15	$0.05	2.83
3	$0.05	$0.04	1.35
4	$0.16	$0.04	3.93
5	$0.04	$0.03	1.48
6	$0.19	$0.04	4.78
7	$0.16	$0.04	3.94
8	$0.20	$0.05	4.48
9	$0.25	$0.05	5.37
10	$0.25	$0.04	6.11
11	$0.23	$0.04	5.61
12	$0.20	$0.05	4.38
13	$0.23	$0.04	5.88
14	$0.19	$0.05	3.89
15	$0.40	$0.03	14.90
16	$0.03	$0.05	0.58
LARGE SCHOOLS (new construction and alterations)			
1	$0.00	$0.02	0.03
2	$0.07	$0.03	2.18
3	$0.02	$0.01	1.57
4	$0.07	$0.03	2.41
5	$0.01	$0.01	1.08
6	$0.09	$0.02	4.79
7	$0.07	$0.02	3.56
8	$0.10	$0.02	5.54
9	$0.14	$0.04	3.69
10	$0.12	$0.04	3.38

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[1] (2020 PV $)	Costs Total Incremental Present Valued (PV) Costs[2] (2020 PV $)	Benefit-to-Cost Ratio
11	$0.12	$0.03	4.08
12	$0.10	$0.03	3.24
13	$0.12	$0.03	4.07
14	$0.10	$0.02	5.9
15	$0.24	$0.05	5.06
16	$0.01	$0.01	0.83

1. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy Commission 2016, Chapter 5 p.51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.
2. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement and maintenance costs over the period of analysis. Costs are discounted at a real (inflation adjusted) three percent rate. Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If incremental maintenance cost is negative it is treated as a positive benefit. If there are no Total Incremental Present Valued Costs, the Benefit/Cost Ratio is Infinite.

6. First-year Statewide Impacts

6.1 Statewide Energy Savings and Lifecycle Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings by multiplying the per unit savings, which are presented in Section 4.3, by the statewide new construction forecast for 2020 or expected alterations in 2020, which is presented in more detail in Appendix A. The first-year energy impacts represent the first-year annual savings from all buildings that were completed in 2020. The lifecycle energy cost savings represents the energy cost savings over the entire 15-year analysis period. Results are presented in in Table 13 and

Table 14 for new construction and alterations, respectively.

Given data regarding the new construction forecast and expected alterations in 2020, the Statewide CASE Team estimates that the proposed code change will reduce annual statewide electricity use by 1.91 GWh with an associated demand reduction of 1.81 MW. The energy savings for buildings constructed in 2020 are associated with a present valued energy cost savings of approximately PV$7.47 million in (discounted) energy costs over the 15-year period of analysis.

Table 13: Statewide Energy and Energy Cost Impacts – New Construction

Climate Zone	Statewide Construction in 2020 (million square feet)[3]	First-year Electricity Savings (GWh)	First-year Peak Electrical Demand Reduction (MW)	Lifecycle[2] Present Valued Energy Cost Savings (PV $ million)
1	-	-	-	-
2	0.52	0.02	0.02	$0.08
3	3.46	0.04	0.13	$0.18
4	1.17	0.04	0.05	$0.19
5	0.23	0.00	0.01	$0.01
6	2.18	0.12	0.10	$0.41
7	1.10	0.05	0.05	$0.18
8	3.20	0.17	0.14	$0.65
9	4.31	0.27	0.20	$1.07
10	1.09	0.07	0.06	$0.27
11	0.21	0.01	0.01	$0.05
12	2.25	0.11	0.10	$0.45
13	0.39	0.02	0.02	$0.09
14	0.27	0.01	0.01	$0.05
15	0.14	0.02	0.01	$0.05
16	-	-	-	-
TOTAL	**20.52**	**0.95**	**0.88**	**$3.72**

1. First-year savings from all buildings completed statewide in 2020.
2. Energy cost savings from all buildings completed statewide in 2020 accrued during fifteen-year period of analysis.
3. Currently savings for cooling towers measure only incorporates large office, final analysis will include large schools and high rise residential as well.

Table 14: Statewide Energy and Energy Cost Impacts – New Construction Large School

Climate Zone	Statewide Construction in 2020 (million square feet)	First-year Electricity Savings (GWh)	First-year Peak Electrical Demand Reduction (MW)	Lifecycle[2] Present Valued Energy Cost Savings (PV $ million)
1	0.00	-	-	-
2	0.18	0.00	0.00	$0.01
3	0.70	0.00	0.01	$0.01
4	0.41	0.01	0.01	$0.03
5	0.08	0.00	0.00	$0.00
6	0.46	0.01	0.01	$0.04
7	0.46	0.01	0.01	$0.03
8	0.66	0.02	0.02	$0.07
9	0.70	0.02	0.02	$0.09
10	0.83	0.02	0.02	$0.10
11	0.21	0.01	0.01	$0.02
12	0.91	0.02	0.02	$0.09
13	0.46	0.01	0.01	$0.06
14	0.15	0.00	0.00	$0.01
15	0.14	0.01	0.01	$0.03
16	0.00	-	-	-
TOTAL	**6.35**	**0.15**	**0.16**	**$0.61**

1. First-year savings from all alterations completed statewide in 2020.
2. Energy cost savings from all alterations completed statewide in 2020 accrued during fifteen-year period of analysis.

Table 15: Statewide Energy and Energy Cost Impacts – Alterations Large School

Climate Zone	Statewide Construction in 2020 (million square feet)	First-year Electricity Savings (GWh)	First-year Peak Electrical Demand Reduction (MW)	Lifecycle[2] Present Valued Energy Cost Savings (PV $ million)
1	0.00	-	-	$-
2	0.45	0.01	0.01	$0.03
3	1.77	0.01	0.04	$0.04
4	1.02	0.02	0.03	$0.07
5	0.20	0.00	0.00	$0.00
6	1.52	0.03	0.04	$0.13
7	0.99	0.02	0.02	$0.07
8	2.13	0.05	0.05	$0.21
9	2.00	0.06	0.06	$0.27
10	1.81	0.05	0.05	$0.22
11	0.45	0.01	0.01	$0.05
12	1.99	0.04	0.05	$0.20
13	1.00	0.03	0.03	$0.12
14	0.34	0.01	0.01	$0.03
15	0.27	0.02	0.01	$0.06
16	0.00	-	-	$-
TOTAL	**15.95**	**0.36**	**0.41**	**$1.52**

1. First-year savings from all alterations completed statewide in 2020.
2. Energy cost savings from all alterations completed statewide in 2020 accrued during fifteen-year period of analysis.

6.2 Statewide Water Use Impacts

The proposed code change will not result in water savings

6.3 Statewide Material Impacts

The proposed code changes will increase the amount of steel used as more efficient cooling towers are larger and heavier.

Table 16: Impacts of Material Use

	Impact on Material Use (lbs/yr)					
	Mercury	**Lead**	**Copper**	**Steel**	**Plastic**	**Others (Identify)**
Impact (I, D, or NC)[1]				I		
Per Unit Impacts				2,000		
First-year[2] Statewide Impacts				169,000		

1. Material Increase (I), Decrease (D), or No Change (NC) compared to base case (lbs/yr).
2. First-year savings from all buildings completed statewide in 2020.

6.4 Other Non-Energy Impacts

The more efficient cooling towers with lower fan power will create less noise on site.

7. PROPOSED REVISIONS TO CODE LANGUAGE

The proposed changes to the Standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2016 documents are marked with underlining (new language) and ~~strikethroughs~~ (deletions).

7.1 Standards

Proposed standards add the following section of code

SECTION 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

(h) Heat Rejection Systems.

1. **Scope.** Subsection 140.4(h) applies to heat rejection equipment used in comfort cooling systems such as air-cooled condensers, open cooling towers, closed-circuit cooling towers, and evaporative condensers.

2. **Fan Speed Control.** Each fan powered by a motor of 7.5 hp (5.6 kW) or larger shall have the capability to operate that fan at 2/3 of full speed or less, and shall have controls that automatically change the fan speed to control the leaving fluid temperature or condensing temperature or pressure of the heat rejection device.

EXCEPTION 1 to Section 140.4(h)2: Heat rejection devices included as an integral part of the equipment listed in TABLE 110.2-A through TABLE 110.2-I.

EXCEPTION 2 to Section 140.4(h)2: Condenser fans serving multiple refrigerant circuits.

EXCEPTION 3 to Section 140.4(h)2: Condenser fans serving flooded condensers.

EXCEPTION 4 to Section 140.4(h)2: Up to one third of the fans on a condenser or tower with multiple fans where the lead fans comply with the speed control requirement.

3. **Tower Flow Turndown.** Open cooling towers configured with multiple condenser water pumps shall be designed so that all cells can be run in parallel with the larger of:

A. The flow that is produced by the smallest pump; or

B. 50 percent of the design flow for the cell.

4. **Limitation on Centrifugal Fan Cooling Towers.** Open cooling towers with a combined rated capacity of 900 gpm and greater at 95°F condenser water return, 85°F condenser water supply, and 75°F outdoor wet-bulb temperature, shall use propeller fans and shall not use centrifugal fans.

EXCEPTION 1 to Section 140.4(h)4: Cooling towers that are ducted (inlet or discharge) or have an external sound trap that requires external static pressure capability.

EXCEPTION 2 to Section 140.4(h)4: Cooling towers that meet the energy efficiency requirement for propeller fan towers in Section 110.2, TABLE 110.2-G.

5. **Multiple Cell Heat Rejection Equipment.** Multiple cell heat rejection equipment with variable speed fan drives shall:

A. Operate the maximum number of fans allowed that comply with the manufacturer's requirements for all system components, and

B. Control all operating fans to the same speed. Minimum fan speed shall comply with the minimum allowable speed of the fan drive as specified by the manufactures recommendation. Staging of fans is allowed once the fans are at their minimum operating speed.

6. **Cooling tower efficiency.** New or replacement open-circuit cooling towers serving condenser water loops which total 900 gpm or greater, shall have a rated efficiency of no less than 80 gpm/hp when rated in accordance to the test procedures and rating conditions as listed in Table 110.2-G.

EXCEPTION 1 to Section 140.4(h)6: Replacement of existing cooling towers that are inside an existing building or on an existing roof.

EXCEPTION 2 to Section 140.4(h)6: Buildings in Climate Zone 1 and 16

7.2 Reference Appendices

There are no proposed changes to the Reference Appendices.

7.3 ACM Reference Manual

Proposed standards modify the following sections

5.8.3 Cooling Towers

Cooling Tower Total Fan Horse Power

Applicability All cooling towers

Definition The sum of the nameplate rated horsepower (hp) of all fan motors on the cooling tower. Pony motors should not be included.

Units gpm/hp or unit less if energy input ratio (EIR) is specified (if the nominal tons but not the condenser water flow is specified, the condenser design water flow shall be 3.0 gpm per nominal cooling ton.)

Input Restrictions As designed, but the cooling towers shall meet minimum performance requirements in Table 110.2-G.

Standard Design The cooling tower fan horsepower is ~~60~~ 80 gpm/hp.

7.4 Compliance Manuals

Chapter 4, Section 4.2 will be updated to reflect the updated requirements.

7.5 Compliance Documents

The NRCC-CXR-04-E would need to have this requirement added and identified as a prescriptive requirement. In addition, the NRCC-MCH-02-E would need to have this requirement added for verification by the plans examiner. For projects pursuing the performance path to compliance, the NRCC-PRF-01-E should be reviewed to determine if revisions are necessary to aid in simple and quick verification of cooling tower efficiency.

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Appendix A: Statewide Savings Methodology

The projected nonresidential new construction forecast that will be impacted by the proposed code change in 2020 is presented in Table 17. The projected nonresidential existing statewide building stock that will be impacted by the propose code change as a result of additions and alterations in 2020 is presented in Table 18.

The Energy Commission Demand Analysis Office provided the Statewide CASE Team with the nonresidential new construction forecast for 2020, broken out by building type and forecast climate zones (FCZ). The raw data from the Energy Commission is not provided in this report, but can be available upon request.

The Statewide CASE Team completed the following steps to refine the data and develop estimates of statewide floor space that will be impacted by the proposed code changes:

1. Translated data from FCZ data into building climate zones (BCZ). This was completed using the FCZ to BCZ conversion factors provided by the Energy Commission (see Table 19).
2. Redistributed square footage allocated to the "Miscellaneous" building type. The Energy Commission's forecast allocated 18.5 percent of the total square footage from nonresidential new construction in 2020 and the nonresidential existing building stock in 2020 to the miscellaneous building type, which is a category for all space types that do not fit well into another building category. It is likely that the 2019 Title 24, Part 6 Standards' requirements apply to the miscellaneous building types, and savings will be realized from this floor space. The new construction forecast does not provide sufficient information to distribute the miscellaneous square footage into the most likely building type, so the Statewide CASE Team redistributed the miscellaneous square footage into the remaining building types in such a way that the percentage of building floor space in each climate zone, net of the miscellaneous square footage, will remain constant. See Table 21 for an example calculation.
3. Made assumptions about the percentage of nonresidential new construction in 2020 that will be impacted by proposed code change by building type and climate zone. The Statewide CASE Team's assumptions are presented in Table 22 and Table 23 and discussed further below.
4. Made assumptions about the percentage of the total nonresidential building stock in 2020 that will be impacted by the proposed code change (additions and alterations) by building type and climate zone. The Statewide CASE Team's assumptions are presented in Table 22 and Table 23 and discussed further below.
5. Calculated nonresidential floor space that will be impacted by the proposed code change in 2020 by building type and climate zone for both new construction and alterations. Results are presented in Table 17 and Table 18.

The code change only considers new construction as building mounted cooling towers are exempt from new requirements, and most offices feature building mounted cooling towers. Large schools will be added to the analysis and will capture some alterations.

Table 17: Estimated New Nonresidential Construction Impacted by Proposed Code Change in 2020, by Climate Zone and Building Type (Million Square Feet)

Climate Zone	New Construction in 2020 (Million Square Feet)											
	OFF-SMALL	REST	RETAIL	FOOD	NWHSE	RWHSE	SCHOOL	COLLEGE	HOSP	HOTEL	OFF-LRG	TOTAL
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.**0000**
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1319	0.0492	0.0000	0.0000	0.5219	0.**7030**
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.4841	0.2192	0.0000	0.0000	3.4641	**4.1675**
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2980	0.1106	0.0000	0.0000	1.1713	1.**5799**
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0579	0.0215	0.0000	0.0000	0.2274	0.**3068**
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3199	0.1373	0.0000	0.0000	2.1831	**2.6403**
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3442	0.1130	0.0000	0.0000	1.1002	1.**5574**
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.4669	0.1926	0.0000	0.0000	3.1959	**3.8554**
9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.4735	0.2263	0.0000	0.0000	4.3115	**5.0114**
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6613	0.1654	0.0000	0.0000	1.0850	1.**9117**
11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1723	0.0416	0.0000	0.0000	0.2060	0.**4199**
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.7029	0.2027	0.0000	0.0000	2.2520	3.**1576**
13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3812	0.0829	0.0000	0.0000	0.3949	0.**8590**
14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1203	0.0292	0.0000	0.0000	0.2718	0.**4213**
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1215	0.0220	0.0000	0.0000	0.1361	0.**2796**
16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.**0000**
TOTAL	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**4.7359**	**1.6137**	**0.0000**	**0.0000**	**20.5212**	**26.8708**

Table 18: Estimated Existing Nonresidential Floor Space Impacted by Proposed Code Change in 2020 (Alterations), by Climate Zone and Building Type (Million Square Feet)

Climate Zone	Alterations in 2020 (Million Square Feet)											
	OFF-SMALL	REST	RETAIL	FOOD	NWHSE	RWHSE	SCHOOL	COLLEGE	HOSP	HOTEL	OFF-LRG	TOTAL
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.0000**
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3164	0.1293	0.0000	0.0000	0.0000	**0.4457**
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.2286	0.5420	0.0000	0.0000	0.0000	**1.7706**
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.7249	0.2975	0.0000	0.0000	0.0000	**1.0224**
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1408	0.0578	0.0000	0.0000	0.0000	**0.1985**
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0730	0.4510	0.0000	0.0000	0.0000	**1.5240**
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.7045	0.2878	0.0000	0.0000	0.0000	**0.9924**
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.5093	0.6208	0.0000	0.0000	0.0000	**2.1301**
9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.3389	0.6611	0.0000	0.0000	0.0000	**2.0000**
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.3853	0.4278	0.0000	0.0000	0.0000	**1.8131**
11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3476	0.1069	0.0000	0.0000	0.0000	**0.4546**
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.4795	0.5056	0.0000	0.0000	0.0000	**1.9851**
13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.7853	0.2181	0.0000	0.0000	0.0000	**1.0034**
14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2608	0.0765	0.0000	0.0000	0.0000	**0.3373**
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2212	0.0487	0.0000	0.0000	0.0000	**0.2699**
16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.0000**
TOTAL	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**11.5160**	**4.4311**	**0.0000**	**0.0000**	**0.0000**	**15.9471**

Table 19: Translation from Forecast Climate Zone (FCZ) to Building Standards Climate Zone (BCZ)

		Building Climate Zone (BCZ)																
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Total**
Forecast Climate Zone (FCZ)	**1**	22.5%	20.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	9.8%	33.1%	0.2%	0.0%	0.0%	13.8%	100%
	2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	22.0%	75.7%	0.0%	0.0%	0.0%	2.3%	100%
	3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	20.9%	22.8%	54.5%	0.0%	0.0%	1.8%	100%
	4	0.1%	13.7%	8.4%	46.0%	8.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	22.8%	0.0%	0.0%	0.0%	0.0%	100%
	5	0.0%	4.2%	89.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.6%	0.0%	0.0%	0.0%	0.0%	100%
	6	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	100%
	7	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	75.8%	7.1%	0.0%	17.1%	100%
	8	0.0%	0.0%	0.0%	0.0%	0.0%	40.1%	0.0%	50.8%	8.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	100%
	9	0.0%	0.0%	0.0%	0.0%	0.0%	6.4%	0.0%	26.9%	54.8%	0.0%	0.0%	0.0%	0.0%	6.1%	0.0%	5.8%	100%
	10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	74.9%	0.0%	0.0%	0.0%	12.3%	7.9%	4.9%	100%
	11	0.0%	0.0%	0.0%	0.0%	0.0%	27.0%	0.0%	30.6%	42.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100%
	12	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	4.2%	95.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	100%
	13	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	69.6%	0.0%	0.0%	28.8%	0.0%	0.0%	0.0%	1.6%	0.1%	0.0%	100%
	14	2.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	97.1%	100%
	15	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	99.9%	0.0%	100%
	16	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100%

Table 20: Description of Building Types and Sub-types (Prototypes) in Statewide Construction Forecast

Energy Commission Building Type ID	Energy Commission Description	Prototype Description			
		Prototype ID	Floor Area (ft^2)	Stories	Notes
OFF-SMALL	Offices less than 30,000 square feet	Small Office	5,502	1	Five zone office model with unconditioned attic and pitched roof.
REST	Any facility that serves food	Small Restaurant	2,501	1	Similar to a fast food joint with a small kitchen and dining areas.
RETAIL	Retail stores and shopping centers	Stand-Alone Retail	24,563	1	Stand Alone store similar to Walgreens or Banana Republic.
		Large Retail	240,000	1	Big box retail building, similar to a Target or Best Buy store.
		Strip Mall	9,375	1	Four-unit strip mall retail building. West end unit is twice as large as other three.
		Mixed-Use Retail	9,375	1	Four-unit retail representing the ground floor units in a mixed use building. Same as the strip mall with adiabatic ceilings.
FOOD	Any service facility that sells food and or liquor	N/A	N/A	N/A	N/A
NWHSE	Non-refrigerated warehouses	Warehouse	49,495	1	High ceiling warehouse space with small office area.
RWHSE	Refrigerated Warehouses	N/A	N/A	N/A	N/A
SCHOOL	Schools K-12, not including colleges	Small School	24,413	1	Similar to an elementary school with classrooms, support spaces and small dining area.
		Large School	210,886	2	Similar to high school with classrooms, commercial kitchen, auditorium, gymnasium and support spaces.
COLLEGE	Colleges, universities, community colleges	Small Office	5,502	1	Five zone office model with unconditioned attic and pitched roof.
		Medium Office	53,628	3	Five zones per floor office building with plenums on each floor.
		Medium Office/Lab		3	Five zones per floor building with a combination of office and lab spaces.
		Public Assembly		2	TBD
		Large School	210,886	2	Similar to high school with classrooms, commercial kitchen, auditorium, gymnasium and support spaces.
		High Rise Apartment	93,632	10	75 residential units along with common spaces and a penthouse. Multipliers are used to represent typical floors.
HOSP	Hospitals and other health-related facilities	N/A	N/A	N/A	N/A
HOTEL	Hotels and motels	Hotel	42,554	4	Hotel building with common spaces and 77 guest rooms.
MISC	All other space types that do not fit another category	N/A	N/A	N/A	N/A
OFF-LRG	Offices larger than 30,000 square feet	Medium Office	53,628	3	Five zones per floor office building with plenums on each floor.
		Large Office	498,589	12	Five zones per floor office building with plenums on each floor. Middle floors represented using multipliers.

Table 21: Example of Redistribution of Miscellaneous Category - 2020 New Construction in Climate Zone 1

Building Type	**2020 Forecast** (Million Square Feet) **[A]**	**Distribution Excluding Miscellaneous Category** **[B]**	**Redistribution of Miscellaneous Category** (Million Square Feet) **[C] = B × 0.11**	**Revised 2020 Forecast** (Million Square Feet) **[D] = A + C**
Small Office	0.049	12%	0.013	0.062
Restaurant	0.016	4%	0.004	0.021
Retail	0.085	20%	0.022	0.108
Food	0.029	7%	0.008	0.036
Non-Refrigerated Warehouse	0.037	9%	0.010	0.046
Refrigerated warehouse	0.002	1%	0.001	0.003
Schools	0.066	16%	0.017	0.083
College	0.028	7%	0.007	0.035
Hospital	0.031	7%	0.008	0.039
Hotel/motel	0.025	6%	0.007	0.032
Miscellaneous	**0.111**	---	-	---
Large Offices	0.055	13%	0.014	0.069
Total	0.534	100%	**0.111**	0.534

Table 22: Percent of Floor Space Impacted by Proposed Measure, by Building Type

Building Type *Building sub-type*	**Composition of Building Type by Sub-types [1]**	**Percent of Square Footage Impacted [2]**	
		New Construction	**Existing Building Stock (Alterations) [3]**
Small Office		0%	0%
Restaurant		0%	0%
Retail		0%	0%
Stand-Alone Retail	*10%*	0%	0%
Large Retail	*75%*	0%	0%
Strip Mall	*5%*	0%	0%
Mixed-Use Retail	*10%*	0%	0%
Food		0%	0%
Non-Refrigerated Warehouse		0%	0%
Refrigerated Warehouse		0%	0%
Schools		32%	2%
Small School	*60%*	0%	0%
Large School	*40%*	80%	4%
College		24%	1%
Small Office	*5%*	0%	0%
Medium Office	*15%*	0%	0%
Medium Office/Lab	*20%*	0%	0%
Public Assembly	*5%*	0%	0%
Large School	*30%*	80%	4%
High Rise Apartment	*25%*	0%	0%
Hospital		0%	0%
Hotel/Motel		0%	0%
Large Offices		50%	0%
Medium Office	*50%*	0%	0%
Large Office	*50%*	*100%*	0%

1. Presents the assumed composition of the main building type category by the building sub-types. All 2019 CASE Reports assumed the same percentages of building sub-types.
2. When the building type is comprised of multiple sub-types, the overall percentage for the main building category was calculated by weighing the contribution of each sub-type.
3. Percent of existing floor space that will be altered during the first-year the 2019 standards are in effect.

Table 23: Percent of Floor Space Impacted by Proposed Measure, by Climate Zone

Climate Zone	Percent of Square Footage Impacted	
	New Construction	Existing Building Stock (Alterations) [1]
1	0%	0%
2	100%	100%
3	100%	100%
4	100%	100%
5	100%	100%
6	100%	100%
7	100%	100%
8	100%	100%
9	100%	100%
10	100%	100%
11	100%	100%
12	100%	100%
13	100%	100%
14	100%	100%
15	100%	100%
16	0%	0%

1. Percent of existing floor space that will be altered during the first year the 2019 standards are in effect.

Appendix B: Discussion of Impacts of Compliance Process for Market Actors

Appendix B provides detail on how the recommended compliance process could impact various market actors in support of the discussion in Section 2.5. The Statewide CASE Team asked stakeholders for feedback on how the measure will impact various market actors during public stakeholder meetings that were held on September 26th, 2016. The key results from feedback received during stakeholder meetings and other target outreach efforts are detailed below.

Market Actors. Table 24 identifies the market actors who will play a role in complying with the proposed change. The table also includes:

- Tasks for which the market actor is responsible,
- Objectives in completing the tasks,
- How the proposed code change could impact existing work flows, and
- Ways negative impacts could be mitigated.

Workflow. Based on user-input, the compliance process for this measure will fit within the current workflow of the market actors involved since it will not create new tasks or remove existing tasks. The proposed process will not require significant coordination between market actors in addition to currently existing coordination or collaborations.

Education and Outreach. Efforts will be necessary, especially to the building energy consultant and design engineering industries so they understand the change and include it in early pricing estimates. These market actors also need to understand the change within the ACM for performance projects.

Training. Because this is a new prescriptive requirement, training will need to be provided so market actors are aware of the change. Architects could also benefit from training emphasizing how to maintain flexibility for design features within an energy budget. As HVAC requirements become more stringent, there will be less trade-offs available for aesthetic features. Energy Consultants may need training on compliance options and what commonly results in credits or penalties as well as how the modeling software will reflect this requirement, and any relevant modeling criteria. Plans examiners and building inspectors just need to be made aware of the change.

Resources. The plans examiner and building inspector checklists create by the Energy Commission and Energy Code Ace will need to be updated to reflect the prescriptive requirement. In addition, the proposed compliance process will alter existing compliance forms to reflect the code change.

Table 24: Roles of Market Actors in The Proposed Compliance Process

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Building Owner	• Provide funding for building • Provide Owner Project Requirements (OPR)	• Building completed according to OPR • Building passes inspection	May see higher first costs	• Outreach so mechanical designers and contractors include compliant equipment in early pricing estimates
Architects	• Inform load calculations • Coordinate trade-offs with energy consultant (performance path only)	• Satisfy owner desires for aesthetics • Minimal clarifications • Meet project budget	• Additional coordination and space required for mechanical equipment • May allow less trade-off for aesthetic features	• Provide training on design flexibility that does not incur penalties when using performance path
Energy Consultant	• Coordinate Title 24, Part 6 requirements with team • Complete compliance documents • Model (performance path only) •	• Project energy goals and code requirements are met • Compliance documents pass plans examination with minimal correction comments	• More stringent requirements to meet • New code changes and requirements to identify	• Automated verification of compliance on documents • Compliance software improvements to identify standard design requirements • Provide training on compliance options for performance path
Mechanical Designer	• Load calculations • Design mechanical system and details • Specify equipment	• Design to meet Title 24 code • Do this cost-effectively	• Mechanical equipment must be more efficient • May increase equipment cost • New code changes and requirements to identify	• Automated verification of compliance on documents • Outreach so mechanical designers and contractors include compliant equipment in early pricing estimates •
Plans Examiner	• Verifies building is designed to code • Reviews NRCC dcouments • Issues building permit	• Verification is quick and straight forward • Minimal training or specialized knowledge required to verify	• New code changes and requirements to be aware of	• Automate compliance documents to verify if equipment meets code • Include requirement in Energy Code Ace Plans Examiner checklist & training

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
HVAC/ Controls Subcontractor / Installer	• Install HVAC system & controls • Select correct equipment • Coordinate with ATT/CxA	• Meet schedule • Complete within budget • Passes inspection	• Heavier/larger equipment to install • New required items which may be unfamiliar with • May increase equipment cost	• Clear and concise design specifications used for bidding
Building Inspector	• Verifies compliant installation • Reviews NRCI/NRCA documents • Issues Certificate of Occupancy	• Able to field verify compliance quickly • Does not result in additional site inspections • Minimal training or specialized knowledge required to verify	• New code changes and requirements to be aware of	• Require equipment to display Title 24 information on equipment and submittals • Include requirement in Energy Code Ace Building Inspector Checklist & training • Consider adding efficiency verification to acceptance test technician duty
Manufacturer	• Help engineers specify products • Work with distributors • Manufacture compliant products	• Get things right the first time • Satisfy design team requests •	• Some products may not meet new requirements	• Simplify requirements and language so it’s clear what products comply • Conduct outreach to help manufacturers understand requirements
Acceptance Test Technician (ATT)/ Commissioning Agent (CxA)	• Conduct condenser system acceptance test • Witness/ document functional performance testing • Ensure facility manager training	• Quickly and cost-effectively complete acceptance tests or functional performance tests to ensure operation • Quickly and cost-effectively complete documentation required for inspector	• No significant impact on workflow identified	N/A