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Codes and Standards Enhancement (CASE) Initiative

2019 California Building Energy Efficiency Standards

Prescriptive Efficiency Requirements for Cooling Towers – Final Report

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

Nonresidential Mechanical

August 2017

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Introduction

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, San Diego Gas and Electric, Southern California Edison, and SoCalGas® – and two Publicly Owned Utilities (POUs) – Los Angeles Department of Water and Power and Sacramento Municipal Utility District – 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 are 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 that serve 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 proposal is to add a prescriptive efficiency requirement of 80 gpm/hp in addition to the mandatory requirement and to increase the standard design listed in the Alternative 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.

There is currently 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 15 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 is between 1.35 and 7.94 depending on climate zone. See Section a 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[a] Energy and Water Savings

Construction Type	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)
New Construction	1.10	1.04	N/A	N/A
Alteration	0.36	0.41	N/A	N/A
Total	**1.46**	**1.45**	**N/A**	**N/A**

a. 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 that 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 and the approaches that should be deployed to minimize these barriers.

1. INTRODUCTION

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, San Diego Gas and Electric, Southern California Edison, and SoCalGas® – and two Publicly Owned Utilities (POUs) – Los Angeles Department of Water and Power and Sacramento Municipal Utility District – sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to energy efficiency in buildings. This report and the code change proposal presented herein is a part of the effort to develop technical and cost-effectiveness information for proposed 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/.

The overall goal of this CASE Report is to provide a code change proposal for prescriptive efficiency requirements for open-circuit cooling towers with condenser water systems 900 gallons per minute (gpm) or greater. The requirement will 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 and March 15, 2017.

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, meaning equipment lifetime and various periodic costs associated with replacement and maintenance during the period of analysis.

Section 6 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, and impacts (increases or reductions) on materials 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, Reference Appendices, Alternative 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 will 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 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. ASHRAE is a voluntary, professional engineer organization whose committees are composed of stakeholders interested in the subject being covered. Professional consensus is required for adoption of standards. There is no requirement for a rigorous cost-effectiveness analysis to approve ASHRAE standards as is the case for standards adopted by the United States Department of Energy or the California Energy Commission. ASHRAE standards are important to consider but the Energy Commission must do additional analysis to determine the appropriate efficiency requirements for California. The history of ASHRAE cooling tower standards illustrates how stakeholders impact committee deliberations. 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, only 5 percent of the cooling towers available on the market would not meet the forthcoming minimum efficiency requirement. The original ASHRAE standards were adopted into Title 24, Part 6 for the 2001 code cycle.

During the 2005 code cycle, a new prescriptive requirement was added that limited the use of centrifugal cooling towers on condenser waters systems with flow rates greater than 900 gallons per minute (gpm). Cooling towers are typically used with axial-propeller fans, due to this systems' low cost and high efficiency relative to other configurations. Centrifugal fan towers are an alternative design that is more compact, yet more expensive and less efficient, with an efficiency requirement around half that of axial fan towers. This code change restricted the use of less efficient centrifugal fan towers on larger chilled water plants. Note that industry standard design practice for sizing condenser water systems is 3 gpm per ton, resulting in this centrifugal cooling tower limitation corresponding to cooling plants that are 300 tons or greater in capacity. In other words, if complying with the standards prescriptively, cooling plants over 300 tons must be water-cooled.

The ASHRAE 90.1 requirement remained unchanged until changes were considered during the 2013 Title 24, Part 6 Standards code cycle. The Statewide CASE Team developed this CASE Report to propose 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 were 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 concern that 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. Due to the committee opposition to the 100 gpm/hp efficiency requirement proposal, the Statewide 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 8.6 came to an agreement of increasing ASHRAE 90.1 axial cooling tower efficiency by 5 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, including inadvertently encouraging larger towers to be air-cooled as opposed to water-cooled. This became the new mandatory requirement for cooling towers in 2013 Title 24, Part 6 Standards. In addition to updating mandatory minimum efficiency requirement to 42.1 gpm/hp, the Energy Commission updated the 2013 ACM Reference Manual and compliance software to assume that 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, a prescriptive requirement was proposed to increase the efficiency of open-circuit cooling towers to 80 gpm/hp whenever these towers are used as part of a waterside economizer (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 due to manufacturer opposition. 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. This requirement was not approved for waterside economizer cooling towers and remained unchanged in ASHRAE 90.1-2016. Discussions with the proposal author revealed that cooling tower industry would only accept marginal efficiency increases for systems with waterside economizer, and the author dropped the proposal since it was felt the marginal increase was too little to make meaningful difference.

Cooling tower energy efficiency is being revisited for 2019 Title 24, Part 6 Standards due to previous studies showing cost-effectiveness of proposed code changes, general market trends towards higher efficiency cooling tower specification, and the lack of advancement in cooling tower regulation, beyond a very small efficiency improvement in the 2013 code cycle, since 1999. The proposed efficiency requirement impacts fewer towers on the market than it did when the measure was considered during the 2013 code cycle 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) or 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 use water-cooled systems means that in California, designers will not shift towards air-cooled systems in response to the proposed requirements.

The 300-ton/900-gpm threshold at which the proposed code changes require a higher cooling tower efficiency was chosen to align with two other cooling tower requirements, the limitation on air-cooled chillers above 300 tons (140.4(j)), and the limitation on centrifugal fan cooling towers above 900 gpm condenser water systems (140.4(h)4).

To avoid pushing designers to pursue air-cooled systems in lieu of water-cooled systems, the proposed code changes have aligned with existing requirements that air-cooled chillers cannot provide more than 300 tons of cooling to chilled water plants. This limitation has been in place since 2005, though the language was revised in 2013. Before 2013, the standards stated that for cooling plants greater than 300 tons, only up to 100 tons could be provided by air-cooled chillers. This made for a confusing standard since cooling plants up to 299 tons could be 100 percent air-cooled, but at 300 tons total capacity, only 100 tons would be allowed to be air-cooled. The 2013 code simplified and clarified the requirement, putting a hard limit of 300 tons of cooling provided by air-cooled chillers, regardless of total cooling plant size.

Centrifugal fan cooling towers are a much more compact form of cooling tower than axial fan towers, but these towers have a minimum efficiency of 20 gpm/hp—less than half the efficiency 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 Title 24, Part 6 restricts these towers above 300 tons, , there should not be a situation where a project is trying to prescriptively comply with the cooling tower standard using a centrifugal cooling tower.

An additional uniqueness of Title 24, Part 6 compared to other energy codes is the highly-developed performance path available through Title 24, Part 6. The state has sponsored development of an official energy compliance tool, CBECC-Com (California Building Energy Code Compliance for Commercial Buildings Software), which is available for free. Since the proposed code changes are prescriptive, projects with space constraints that have issues meeting the proposed requirements for cooling towers can use energy modeling to make energy tradeoffs with other measures. Projects that comply through the performance path only need to follow the mandatory requirement for cooling tower efficiency.

2.3 Summary of Proposed Changes to Code Documents

The sections below provide a summary of how each 2016 Title 24, Part 6 documents will be modified by the proposed change. See Section 7 of this report for detailed proposed revisions to code language.

2.3.1 Standards Change Summary

This proposal modifies Section 140.4(h) of the Building Energy Efficiency Standards. The proposed code change adds a new prescriptive requirement for the minimum efficiency of cooling towers serving large condensing water loops (above 900 gpm). Currently, cooling towers only follow the mandatory requirement of 42.1 gpm/hp in Title 24, Part 6 110.2-G. See Section 7 of this report for the detailed proposed revisions to the code language.

2.3.2 Reference Appendices Change Summary

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

2.3.3 Alternative Calculation Method (ACM) Reference Manual Change Summary

The proposed code change modifies Section 5.8.3 of the ACM Reference Manual. Specifically, the Standard Design horsepower is changed 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, the Statewide CASE Team is proposing to use the same gpm/hp for both prescriptive minimum efficiency and ACM Standard Design.

See Section 7.3 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

2.3.4 Compliance Manual Change Summary

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

2.3.5 Compliance Documents Change Summary

If adopted, the following certificate of compliance documents will need to be revised to reflect this new requirement:

- 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

Currently, Title 24, Part 6 includes a mandatory minimum efficiency requirement for propeller/axial fan open-circuit towers. These cooling tower must have a minimum efficiency of 42.1 gpm/hp. These requirements are presented in Table 110.2-G Performance Requirements for Heat Rejection Equipment.

Two other sections of Title 24, Part 6 are related to this code change proposal. The first is section 140.4(j), which reads: “Chilled water plants shall not have more than 300 tons provided by air-cooled chillers.” This is especially related to the current proposal. There is a fear among cooling tower industry that increasing efficiency requirements will lead to more expensive cooling towers, which in turn will drive projects to choose air-cooled systems instead of water-cooled systems. Since the proposed efficiency requirements only apply to cooling plants above 300 tons, these projects would not be allowed to install air-cooled chillers anyway and industry would not have the option of shifting to air-cooled systems.

The other relevant section is 140.4(h)4, which reads “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.” Condenser waters systems rated at 900 gpm are typically sized for 300 ton cooling plants, so this requirement aligns with the air-cooled chiller limitation. Centrifugal cooling towers are a less efficient cooling tower than more typical axial fan types. There are few if any centrifugal products that would comply with proposed code language, but this is not expected to be a problem since the 80 gpm/hp requirement will only affect condenser water plants that are already are subject to restrictions on the use of centrifugal cooling towers.

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 the International Energy Conservation Code (IECC). These standards currently treat cooling tower efficiency as a mandatory requirement, with no increase in efficiency requirements for buildings seeking prescriptive compliance.

The Cooling Technology Institute (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 that cooling towers are both designed and operated to meet the energy standard. No issues are expected with the increased cooling tower efficiency requirement.

2.5 Compliance and Enforcement

The Statewide CASE Team collected input during the stakeholder outreach process on what compliance and enforcement issues may be associated with these measures. 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 describes the roles that may be impacted by this measure during the design phase.

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.
	Will need to be aware of new requirements early in design phase (before document completion) so initial pricing estimates include compliant equipment.
Energy Consultant	Will result in more stringent requirements to meet, potentially meaning less trade-off options under the performance approach.
	Will 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 expected 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 describes the roles that may be impacted by this measure during the application phase.

Table 4: Impact on Market Actors During Permit Application Phase

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

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

Table 5: Impact on Market Actors During Construction Phase

Role	Potential Impact
HVAC Contractor/ Installer	Will 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 describes the roles that may be impacted by this measure during the inspection phase.

Table 6: Impact on Market Actors During Inspection Phase

Role	Potential Impact
Building Inspector	Will 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 27 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. 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. An example of the increased chiller efficiency required to offset meeting the prescriptive cooling tower requirement is presented in Section 4.3 of this report.

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, develop technology advancements, and also publish software to aid in the selection of products. The actual sales and selection process is handled by partnering sales representative companies. No sales and installation data is publicly available due to its proprietary nature. 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 and that many product lines already meet 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 55 percent of products that do not meet the proposed requirements will still be available for projects that choose to use performance path compliance. Figure 1 below 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.

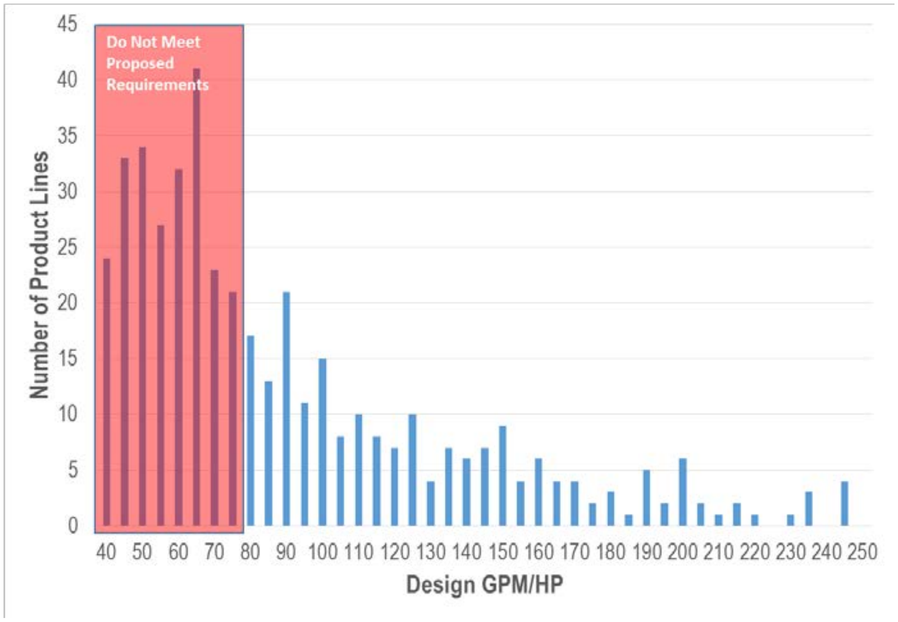

Figure 1: Number of unique units available versus gpm/hp rating for SPX, Evapco, and Baltimore Air Coil.

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 that will likely take 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, thereby 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 that 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 will 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 90.1, 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 that 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, though additional cost may result from weight increases of around 5,000 lbs or more due to additional structural steel required. 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 Division of Occupational Safety and Health. 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 of occupants, or to 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 money elsewhere, thereby creating jobs and economic growth for the California economy. The Statewide CASE Team does not expect the proposed code change for the 2019 code cycle to impact building owners or occupants adversely.

Building owners will have about a 15 to 20 percent higher first cost for the cooling tower due to the larger, more efficient towers, but as the analysis in this CASE Report shows, the more efficient towers have a 15-year payback and lower energy bills. There are a few near cost-neutral cooling towers available for certain tower sizes that can meet proposed standards as well. Occupants will be generally unaffected by the more efficient towers, although the likely noise deduction due to lower fan speeds may provide benefits.

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, but 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 apply only to condenser water plants that are above 900 gpm, which is the typical sizing for a 300-ton chilled water plant. The code change team expects negligible impact to cooling tower sales since design jobs are prescriptively required to provide water-cooled systems at the system sizes that the proposed code changes impact. Since the towers sold could be larger and more expensive, there may be an increase in total sales revenue in California, though interviews with engineers as well as the previous cooling tower energy efficiency CASE Report from 2013 Title 24reveal that many projects are choosing to install towers that are more efficient than the minimum 42.1 gpm/hp efficiency to reduced operating cost.

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 (Title 24, Part 6, Section 140.4(j)), and the Statewide CASE Team is increasing the required size of the towers, 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 report titled *Energy Efficiency Services Sector: Workforce Size and Expectations for Growth* (2010) provides details 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 attributed to 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, Patadia, and Kammen (2010) estimate that energy efficiency creates 0.17 to 0.59 net job-years[2] per GWh saved. 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 proposed code change will result in a statewide first-year savings of 1.46 GWh, this measure will result in approximately 0.55 jobs created in the 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 in 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.

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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.

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 in 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 be otherwise 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 ACM 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 the 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	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

Since the size and runtime of cooling tower fans vary greatly with the climate, the impacts of this measure are climate-specific. 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 calculated using Time Dependent Valuation (TDV) methodology.

The per-unit energy savings estimates do not take naturally occurring market adoption or compliance rates into account.

4.3 Per-Unit Energy Impacts Results

There are no natural gas savings for this measure. The per-unit energy savings estimates do not take naturally occurring market adoption or compliance rates into account. Electricity savings and peak-demand reductions per-unit for new construction and alterations presented in 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 year (kWh/yr) per square foot to no savings, depending on the climate zone. Demand reductions are expected to range between 1.33 x 10^{-5} kilowatts per square foot (kW/ft^2) and 5.71 x 10^{-5} kW/ft^2 depending on climate zone. The large office prototype in Climate Zone 12 saves 0.5 percent of annual energy use, and 1.4 percent peak demand savings.

The peak demand reductions 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 in the other climate zones. This is because the climate is very mild all year, so the airside economizer is nearly always in operation. The airside economizer reduces or eliminates the need for heat rejection requirements, so cooling tower runtime is low compared to other climate zones. This suggests that Climate Zone 1 and 16 should 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	3.03×10^{-5}	0.03
2	0.032	4.06×10^{-5}	1.63
3	0.012	3.69×10^{-5}	0.59
4	0.036	4.35×10^{-5}	1.78
5	0.012	3.32×10^{-5}	0.45
6	0.053	4.40×10^{-5}	2.10
7	0.041	4.37×10^{-5}	1.80
8	0.054	4.26×10^{-5}	2.29
9	0.063	4.58×10^{-5}	2.78
10	0.061	5.40×10^{-5}	2.78
11	0.058	4.36×10^{-5}	2.55
12	0.048	4.27×10^{-5}	2.24
13	0.062	4.28×10^{-5}	2.63
14	0.046	3.95×10^{-5}	2.08
15	0.120	5.71×10^{-5}	4.53
16	0.010	3.00×10^{-5}	0.33
LARGE SCHOOL (new construction and alterations)			
1	0.000	1.33×10^{-5}	0.01
2	0.014	2.55×10^{-5}	0.79
3	0.004	2.00×10^{-5}	0.24
4	0.016	2.70×10^{-5}	0.81
5	0.004	2.01×10^{-5}	0.16
6	0.023	2.43×10^{-5}	0.96
7	0.017	2.33×10^{-5}	0.79
8	0.024	2.45×10^{-5}	1.11
9	0.031	2.85×10^{-5}	1.52
10	0.028	2.90×10^{-5}	1.37
11	0.029	2.76×10^{-5}	1.30
12	0.023	2.60×10^{-5}	1.14
13	0.031	2.66×10^{-5}	1.34
14	0.023	2.49×10^{-5}	1.08
15	0.068	3.94×10^{-5}	2.70
16	0.004	1.94×10^{-5}	0.13

Alterations for office buildings typically fall under the building-mounted cooling tower exception, so it is assumed that there are no savings from alterations in large office buildings. Alterations are included for the large schools prototype because these buildings typically have ground-mounted cooling towers, which are required to follow proposed requirements.

The proposed code change revises the prescriptive minimum efficiency requirements for cooling towers to 80 gpm/hp. The 80 gpm/hp cooling tower establishes the energy budget for the Standard Design. Builders who use the performance approach still have the option of using a less efficient cooling tower (as long as it meets the minimum efficiency requirement of 42.1 gpm/hp) in combination with other efficiency measures to comply with the standards. If the building's energy performance is equal to or better than the Standard Design, then the building complies. For example, a builder could install a 42.1 gpm/hp cooling tower in combination with a chiller with a coefficient of performance (COP) that exceeds the minimum required efficiency. For illustrative purposes, Table 10 presents the chiller efficiency that would be required in combination with a 42.1 gpm/hp cooling tower to achieve the Standard Design energy budget, which is defined using a 80 gpm/hp cooling tower. The table also presents the percent chiller efficiency increase relative to a minimally-compliant 6.01 COP chiller. This example is for the large office prototype.

Table 10: Example Compliance Approach Using 42.1 gpm/hp Cooling Tower and Higher Efficiency Chiller in Large Office Prototype

Climate Zone	Chiller Efficiency Required to Meet Standard Design [a] (COP)	Chiller Efficiency Increase from Minimally Compliant Chiller [b]
1	6.3	5%
2	6.6	10%
3	6.46	7.5%
4	6.6	10%
5	6.46	7.5%
6	6.76	12.5%
7	6.6	10%
8	6.6	10%
9	6.6	10%
10	6.6	10%
11	6.6	10%
12	6.6	10%
13	6.6	10%
14	6.46	7.5%
15	6.76	12.5%
16	6.3	5%

a. Chiller efficiency (COP) required in combination with 42.1 gpm/hp cooling tower to meet the Standard Design, which is defined using 80 gpm/hp cooling tower.

b. Minimally compliant chiller has a COP of 6.01.

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 of 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 value (PV) 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 analyses completed can be easily reproduced using the existing CBECC-Com software packages without need for enhancement. 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, Part 6. Two models were created in CBECC-Com, representing both the baseline minimum compliant Title 24, Part 6 model and the model based on proposed code changes. This analysis made use of OpenStudio[3] models that CBECC-Com generates. 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 for new construction and additions/alterations over the 15-year period of analysis are presented in Table 11. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. Savings are higher during peak periods as cooling tower fans run at their maximum capacity, though most savings occur throughout the year.

Table 11: TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot

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	N/A	$0.00
2	$0.15	N/A	$0.15
3	$0.05	N/A	$0.05
4	$0.16	N/A	$0.16
5	$0.04	N/A	$0.04
6	$0.19	N/A	$0.19
7	$0.16	N/A	$0.16
8	$0.20	N/A	$0.20
9	$0.25	N/A	$0.25
10	$0.25	N/A	$0.25
11	$0.23	N/A	$0.23
12	$0.20	N/A	$0.20
13	$0.23	N/A	$0.23
14	$0.19	N/A	$0.19
15	$0.40	N/A	$0.40
16	$0.03	N/A	$0.03
LARGE SCHOOL (new construction and alterations)			
1	$0.00	N/A	$0.00
2	$0.07	N/A	$0.07
3	$0.02	N/A	$0.02
4	$0.07	N/A	$0.07
5	$0.01	N/A	$0.01
6	$0.09	N/A	$0.09
7	$0.07	N/A	$0.07
8	$0.10	N/A	$0.10
9	$0.14	N/A	$0.14
10	$0.12	N/A	$0.12
11	$0.12	N/A	$0.12
12	$0.10	N/A	$0.10
13	$0.12	N/A	$0.12
14	$0.10	N/A	$0.10
15	$0.24	N/A	$0.24
16	$0.01	N/A	$0.01

[3] OpenStudio is a software platform and graphical user interface for running EnergyPlus simulations. https://www.openstudio.net/.

5.3 Incremental First Cost

The Statewide CASE Team estimated the current incremental construction costs, which represents the incremental cost of the measure if a building meeting the proposed standard were built today.

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. RSMeans 2017 was consulted to find the cost of a base cooling tower. 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 tower. The cost increase was identified to go from a 42.1 gpm/hp tower to an 80 gpm/hp tower for all three manufacturers for tower sizes used in all 16 climate zones. The different size cooling towers in the analysis are due to the auto-sizing done in the prototype models, which have vastly different design conditions in different 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 lowest cost tower that meets the simulation based capacity, 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 12: Cost Increase for High Efficiency Cooling Towers in Analysis

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

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

b. 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

Higher efficiency cooling towers can be made by both increasing the footprint and increasing the height. Because 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. To assess potential structural concerns, a major 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 weight increases due to rooftop HVAC equipment. Their response was that a weight increase on the order of 2,000 pounds (lbs) "would not have a significant cost impact by any stretch of the imagination," and for an increase on the order of 5,000 lbs "you could see some impact," perhaps on the order of $2,000 due to around a half ton of extra steel. Overall, the structural engineers commented that placement is a much more important metric than weight, and placement is usually out of the designer's hands. The weight increase for cooling towers will occur due to the larger size of the cooling towers and the additional volume of water in the system. While the flow rate (gpm) of water and the evaporation rate are not expected to alter due to more efficient cooling towers, a larger basin will collect more water, which further increases the weight. Manufacturers publish the operating weight, and through a survey of published values, the weight increase associated with increasing efficiency from 42.1 gpm/hp to 80 gpm/hp is shown in Table 13.

Table 13: Expected Weight Increase for Cooling Towers due to Efficiency Increase

Tower Size (gal/min)	**1000-1500**	**1501-2000**	**2001+**
Weight Increase (lbs)	7,500	9,000	9,000

The cost increases due to weight increase were estimated based on $2,000 of additional steel costs for roughly 5,000 lbs additional rooftop weight. Since this analysis assumes that offices typically have building mounted towers, and schools/colleges typically have ground mounted towers, this structural cost is only applied to the office buildings.

The study assumes the 80 gpm/hp cooling tower incremental cost is found from the survey results of Table 12. This incremental cost factor is used to estimate the incremental cost of the tower, via the following formula:

Incremental cost = percent cost increase × $120/ton × cooling tower tonnage × number of towers + structural cost

Per the ACM, there are two cooling towers present in each case with the exception of the Climate Zone 1 school which falls under the one tower category.

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 the 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:

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

Cooling towers require similar maintenance to other hydronic equipment, but 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. According to ASHRAE, cooling towers that are properly maintained can have an expected useful life of 20 years.

As cooling towers are by design open and exposed to outdoors, their service life can be reduced at coastal locations due to salt air corrosion. Projects in these locations often choose more expensive tower options like stainless steel in lieu of cheaper and more typical galvanized towers. The CASE team interviewed engineers about potential rules of thumb regarding when a stainless steel tower may be required, but none were uncovered. Engineers interviewed agreed that it’s unlikely a meaningful amount of projects are forced into using stainless steel cooling towers, or have shortened life due to corrosion, since projects must be very close to the coast to be affected. Based on the interviews, these items were left out of maintenance or replacement costs.

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 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 15-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 14 for new construction and alterations. The B/C ratios range from a low of 0.03 to a high of 9.72. The proposed measure was found to be cost-effective in 14 out of 16 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 that allows airside economizer operation nearly year-round, so the cooling tower has very low usage. This results in a very poor B/C ratio. Climate Zone 16 is the coldest climate zone, so the short cooling season reduces the effectiveness of efficient cooling towers.

Table 14: Lifecycle Cost-Effectiveness Summary Per Square Foot

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2020 PV $)	Costs Total Incremental Present Valued (PV) Costs[b] (2020 PV $)	Benefit-to-Cost Ratio
LARGE OFFICE (new construction)			
1	$0.00	$0.04	0.06
2	$0.15	$0.07	2.21
3	$0.05	$0.05	1.03
4	$0.16	$0.05	2.90
5	$0.04	$0.04	1.02
6	$0.19	$0.05	3.49
7	$0.16	$0.05	2.91
8	$0.20	$0.06	3.40
9	$0.25	$0.06	4.09
10	$0.25	$0.05	4.51
11	$0.23	$0.05	4.14
12	$0.20	$0.06	3.33
13	$0.23	$0.05	4.32
14	$0.19	$0.06	2.99
15	$0.40	$0.04	9.72
16	$0.03	$0.06	0.45
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
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	5.90
15	$0.24	$0.05	5.06
16	$0.01	$0.01	0.83

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 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.

b. **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 PV costs, the B/C 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 (Section 4.3) by the statewide new construction forecast for 2020 or expected alterations in 2020 (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. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account. Results from new construction by climate zone are presented in Table 15 and Table 16 presents first-year statewide savings from new

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 15: Statewide Energy and Energy Cost Impacts – New Construction

Climate Zone	Statewide Construction in 2020 (million square feet)	First-Year[a] Electricity Savings (GWh)	First-Year[a] Peak Electrical Demand Reduction (MW)	Lifecycle[b] 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**

a. First-year savings from all buildings completed statewide in 2020.

b. Energy cost savings from all buildings completed statewide in 2020 accrued during 15-year period of analysis.

Table 16: Statewide Energy and Energy Cost Impacts – New Construction Large School

Climate Zone	Statewide Construction in 2020 (million square feet)	First-Year[a] Electricity Savings (GWh)	First-Year[a] Peak Electrical Demand Reduction (MW)	Lifecycle[b] Present Valued Energy Cost Savings (PV $ million)
1	0	0	0	$0
2	0.18	0	0	$0.01
3	0.70	0	0.01	$0.01
4	0.41	0.01	0.01	$0.03
5	0.08	0	0	$0
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	0	$0.01
15	0.14	0.01	0.01	$0.03
16	0	0	0	$0
TOTAL	**6.35**	**0.15**	**0.16**	**$0.61**

a. First-year savings from all alterations completed statewide in 2020.

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

Table 17: Statewide Energy and Energy Cost Impacts – Alterations Large School

Climate Zone	Statewide Construction in 2020 (million square feet)	First-Year[a] Electricity Savings (GWh)	First-Year[a] Peak Electrical Demand Reduction (MW)	Lifecycle[b] Present Valued Energy Cost Savings (PV $ million)
1	0	0	0	$0
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	0	$0
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	0	0	$0
TOTAL	**15.95**	**0.36**	**0.41**	**$1.52**

a. First-year savings from all alterations completed statewide in 2020.

b. 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 18: Impacts of Material Use

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

a. Material Increase (I), Decrease (D), or No Change (NC) compared to base case (lbs/yr).

b. 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 systems with a combined rated capacity of 900 gpm at design conditions, 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 that are not connected to a water economizer system

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 will need to have this requirement added and identified as a prescriptive requirement. In addition, the NRCC-MCH-02-E will 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 19. 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 20.

To calculate first-year statewide savings, the Statewide CASE Team multiplied the per-unit savings by statewide new construction estimates for the first year the standards will be in effect (2020). The Energy Commission Demand Analysis Office provided the Statewide CASE Team with the nonresidential new construction forecast. The raw data presented annual total building stock and new construction estimates for twelve building types by forecast climate zones (FCZ). 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 standards climate zones (BSCZ). Since Title 24, Part 6 uses BSCZ, the Statewide CASE Team converted the construction forecast from FCZ to BSCZ using conversion factors supplied by the Energy Commission. The conversion factors, which are presented in Table 21 represent the percentage of building square footage in FCZ that is also in BSCZ. For example, looking at the first column of conversion factors in Table 21, 22.5 percent of the building square footage in FCZ 1 is also in BSCZ 1 and 0.1 percent of building square footage in FCZ 4 is in BSCZ 1. To convert from FCZ to BSCZ, the total forecasted construction for a specific building type in each FCZ was multiplied by the conversion factors for BSCZ 1, then all square footage from all FCZs that are found to be in BSCZ 1 are summed to arrive at the total construction for that building type in BSCZ 1. This process was repeated for every climate zone and every building type. See Table 23 for an example calculation to convert from FCZ to BSCZ. In this example, construction BSCZ 1 is made up of building floorspace from FCZs 1, 4, and 14.
2. Redistributed square footage allocated to the "Miscellaneous" building type. The building types included in the Energy Commissions' forecast are summarized in Table 22. 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 23 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 25 and Table 26 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 25 and Table 26 and are 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 19 and Table 20.

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 19: 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	0	0	0	0	0.0000	0.0000	0.0000	0	0	0.0000	0.**0000**
2	0	0	0	0	0	0.0000	0.1319	0.0492	0	0	0.5219	0.**7030**
3	0	0	0	0	0	0.0000	0.4841	0.2192	0	0	3.4641	**4.1675**
4	0	0	0	0	0	0.0000	0.2980	0.1106	0	0	1.1713	1.**5799**
5	0	0	0	0	0	0.0000	0.0579	0.0215	0	0	0.2274	0.**3068**
6	0	0	0	0	0	0.0000	0.3199	0.1373	0	0	2.1831	**2.6403**
7	0	0	0	0	0	0.0000	0.3442	0.1130	0	0	1.1002	1.**5574**
8	0	0	0	0	0	0.0000	0.4669	0.1926	0	0	3.1959	**3.8554**
9	0	0	0	0	0	0.0000	0.4735	0.2263	0	0	4.3115	**5.0114**
10	0	0	0	0	0	0.0000	0.6613	0.1654	0	0	1.0850	1.**9117**
11	0	0	0	0	0	0.0000	0.1723	0.0416	0	0	0.2060	0.**4199**
12	0	0	0	0	0	0.0000	0.7029	0.2027	0	0	2.2520	3.**1576**
13	0	0	0	0	0	0.0000	0.3812	0.0829	0	0	0.3949	0.**8590**
14	0	0	0	0	0	0.0000	0.1203	0.0292	0	0	0.2718	0.**4213**
15	0	0	0	0	0	0.0000	0.1215	0.0220	0	0	0.1361	0.**2796**
16	0	0	0	0	0	0.0000	0.0000	0.0000	0	0	0.0000	0.**0000**
TOTAL	**0**	**0**	**0**	**0**	**0**	**0.0000**	**4.7359**	**1.6137**	**0**	**0**	**20.5212**	**26.8708**

Table 20: 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	0	0	0	0	0	0.0000	0.0000	0	0	0	**0.0000**
2	0	0	0	0	0	0	0.3164	0.1293	0	0	0	**0.4457**
3	0	0	0	0	0	0	1.2286	0.5420	0	0	0	**1.7706**
4	0	0	0	0	0	0	0.7249	0.2975	0	0	0	**1.0224**
5	0	0	0	0	0	0	0.1408	0.0578	0	0	0	**0.1985**
6	0	0	0	0	0	0	1.0730	0.4510	0	0	0	**1.5240**
7	0	0	0	0	0	0	0.7045	0.2878	0	0	0	**0.9924**
8	0	0	0	0	0	0	1.5093	0.6208	0	0	0	**2.1301**
9	0	0	0	0	0	0	1.3389	0.6611	0	0	0	**2.0000**
10	0	0	0	0	0	0	1.3853	0.4278	0	0	0	**1.8131**
11	0	0	0	0	0	0	0.3476	0.1069	0	0	0	**0.4546**
12	0	0	0	0	0	0	1.4795	0.5056	0	0	0	**1.9851**
13	0	0	0	0	0	0	0.7853	0.2181	0	0	0	**1.0034**
14	0	0	0	0	0	0	0.2608	0.0765	0	0	0	**0.3373**
15	0	0	0	0	0	0	0.2212	0.0487	0	0	0	**0.2699**
16	0	0	0	0	0	0	0.0000	0.0000	0	0	0	**0.0000**
TOTAL	**0**	**0**	**0**	**0**	**0**	**0**	**11.5160**	**4.4311**	**0**	**0**	**0**	**15.9471**

Table 21: Translation from Forecast Climate Zone (FCZ) to Building Standards Climate Zone (BSCZ)

		Building Standards Climate Zone (BSCZ)																
		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 22: 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 23: Converting from Forecast Climate Zone (FCZ) to Building Standards Climate Zone (BSCZ) – Example Calculation

Climate Zone	**Total Statewide Small Office Square Footage in 2020 by FCZ** (Million Square Feet) **[A]**	**Conversion Factor FCZ to BSCZ 1 [B]**	**Small Office Square Footage in BSCZ 1** (Million Square Feet) **[C] = A x B**
1	0.204	22.5%	0.046
2	0.379	0.0%	0.000
3	0.857	0.0%	0.000
4	1.009	0.1%	0.001
5	0.682	0.0%	0.000
6	0.707	0.0%	0.000
7	0.179	0.0%	0.000
8	1.276	0.0%	0.000
9	0.421	0.0%	0.000
10	0.827	0.0%	0.000
11	0.437	0.0%	0.000
12	0.347	0.0%	0.000
13	1.264	0.0%	0.000
14	0.070	2.9%	0.002
15	0.151	0.0%	0.000
16	0.035	0.0%	0.000
Total	**8.844**		**0.049**

Table 24: 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 25: Percent of Floor Space Impacted by Proposed Measure by Building Type

Building Type *Building sub-type*	**Composition of Building Type by Sub-types**[a]	**Percent of Square Footage Impacted**[b]	
		New Construction	**Existing Building Stock (Alterations)**[c]
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%

a. 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.

b. 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.

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

Table 26: 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	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%

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 26, 2016 and March 15, 2017. The key results from feedback received during stakeholder meetings and other target outreach efforts are detailed below.

Market Actors. Table 27 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 documents to reflect the code change.

Table 27: 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, Part 6 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 documents • 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, Part 6 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