CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Thermally Driven Cooling

Measure Number: 2016-NR-HVAC2-F

Nonresidential HVAC

2016 CALIFORNIA BUILDING ENERGY EFFICIENCY STANDARDS

California Utilities Statewide Codes and Standards Team October 2014

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

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Document Information

Category: Codes and Standards

Keywords: Statewide CASE, Statewide Codes and Standards Team, Statewide CASE Team, Codes and Standards Enhancements, Title 24, 2016, efficiency, thermal cooling, absorption, adsorption, desiccant.

EXECUTIVE SUMMARY

Introduction

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support California Energy Commission's (CEC) efforts to update California's Building Energy Efficiency Standards (Title 24) 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 Southern California Gas Company – and Los Angeles Department of Water and Power (LADWP) sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to energy efficiency in buildings. This report and the code change proposal presented herein is a part of the effort to develop technical information for proposed regulations on building energy efficient design practices and technologies.

The overall goal of this CASE Report is to propose a code change proposal for measure name. The report contains pertinent information that justifies the code change including:

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

Scope of Code Change Proposal

Thermally driven cooling will affect the following code documents listed Table 1.

Table 1: Scope of Code Change Proposal

Standards Requirements (see note below)	Compliance Option	Appendix	Modeling Algorithms	Simulation Engine	Forms
N/A	Yes	N/A	Yes	Yes	N/A

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

List of other areas affected including changes to trade-offs: None.

Measure Description

This code change proposal would add a new compliance option for applicants that wish to comply with Title 24 through the performance approach (whole building simulation energy trade-off). Specifically, the proposed code change recommends revisions to the ruleset for the compliance software. This will allow applicants to take credit for the energy benefits of cooling spaces with a thermally driven cooling system to demonstrate compliance with Title 24. This proposed code change affects new construction or major retrofits in nonresidential buildings or high-rise residential buildings that use thermally driven cooling in which the cooling effect is driven by heat rather than mechanical compressors. The heat source could be a boiler, solar thermal, waste heat, or a combination. The waste heat could be process heat, cogeneration, or other sources.

The proposed code change would enable applicants to model the impacts of a thermally driven cooling system that uses either an absorption chiller, adsorption chiller, or desiccant system. Absorption chillers are the most common form of thermally driven cooling systems and have been available for over 50 years. A number of manufacturers currently offer a variety of absorption chillers. Adsorption chillers are also available but they are less common. Another form of cooling that makes use of waste heat is desiccant cooling. Desiccants are used to remove water vapor out of an air stream and waste heat is used to regenerate the desiccant so it is ready to absorb more water vapor.

When on-site renewable energy or site recovered thermal energy is used to provide space cooling, the energy consumption of the proposed cooling system includes all energy consumption required to extract the heat and to convert this into cooling energy and all energy required to deliver the cooling to spaces within the building. If thermal storage is used any heat losses and equipment energy usage is also accounted for. The solar energy or thermal energy recovered from a process is treated as free and thus is not included in the energy budget. There is no credit for cooling energy created that is not used for space conditioning on site. The proposed code change is neither a prescriptive requirement nor a mandatory requirement and does not affect the base case, or standard budget, used to verify compliance with the performance approach.

Section 2 of this report provides detailed information about the code change proposal including: ***Section 2.2 Summary of Changes to Code Documents (page 5)*** provides a section-by-section description of the proposed changes to the standards, appendices, ACM, and/or other documents that will be modified as needed by the proposed code change. See the following tables for an inventory of sections of each document that will be modified:

- Table 6: Scope of Code Change Proposal (page 5)
- Table 7: Sections of ACM Impacted by Proposed Code Change (page 5)

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

Market Analysis and Regulatory Impact Assessment

The products affected by this proposal include absorption and adsorption chillers and desiccant cooling systems. Absorption chillers are the most common form of thermally driven cooling system and have been available for over 50 years. The most well-known absorption chiller manufacturers, Carrier, Trane, York, Broad, McQuay and Yazaki, offer a variety of absorption chillers. Adsorption chillers are less common in the United States, although they are gaining popularity in Europe. Adsorption chillers have the advantage of using a lower temperature hot water loop, as low as 122 degrees Fahrenheit (°F), which could be useful in many cases especially involving waste heat. Adsorption chiller manufacturers include ECO-MAX, Kawasaki, SorTech, and Weatherite.

Desiccant cooling systems include both solid and liquid desiccant designs. The solid version requires more maintenance and very few systems are available. The liquid version has better efficiency but again very few systems are commercially available. Some of the desiccant cooling manufacturers include Munters, Kathabar and Advantix.

The market structure is similar to that of electric chillers and other typical heating, ventilation and air conditioning (HVAC) equipment, with manufacturers selling to customers through a distribution network and a trained technical workforce available to support installation, repair and maintenance.

The Statewide CASE Team did not perform a cost effectiveness analysis for this proposal because it is an optional compliance credit and not a prescriptive requirement or a mandatory requirement.

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

- **Impact on builders:** The proposal is not expected to have a significant impact on builders other than additional compliance options available. However, considerable specialized experience will be required to install and start-up the system.
- **Impact on building designers:** The proposal is not expected to have a significant impact on building designers other than additional compliance options available. This particular revision to Title 24 will not require a departure from standard or common design practices for building designers, unless they choose to install a thermally driven cooling system. However, considerable specialized experience will be required to design and model the system if a designer chooses to take advantage of the new thermally driven cooling compliance option
- **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 California Division of Occupational Safety and Health. All existing health and safety rules will remain in place. Complying with the proposed code changes is not anticipated to have any impact on the safety or health occupants or those involved with the construction, commissioning, and ongoing maintenance of the building.

- **Impact on building owners and occupants:** The proposal is not expected to have a significant impact on building owners or occupants. However, considerable specialized experience will be required to operate and maintain the system.
- **Impact on equipment retailers (including manufacturers and distributors):** This group will see increased sales of thermally driven cooling systems.
- **Impact on energy consultants:** The proposal is not expected to have a significant impact on energy consultants. However, considerable specialized experience will be required to model the system.
- **Impact on building inspectors:** As compared to the overall code enforcement effort, this measure has negligible impact on the effort required to enforce the building codes.
- **Statewide employment impacts:** As a whole, the proposed changes to Title 24 are expected to result in positive job growth as noted below in Section 3.5. This measure will create jobs by expanding the small industry associated with thermally driven cooling systems.
- **Impacts on the creation or elimination of businesses in California:** This measure will create new and expand existing California businesses by expanding the small industry associated with thermally driven cooling systems. It is not anticipated that this measure will have a measureable impact on businesses that manufacturer, distribute, or install traditional HVAC systems.
- **Impacts on the potential advantages or disadvantages to California businesses:** This measure will provide additional compliance options, thus California businesses have an advantage due to a greater number of options.
- **Impacts on the potential increase or decrease of investments in California:** As described in Section 3.5 of this report, the California Air Resources Board (CARB) economic analysis of greenhouse gas reduction strategies for the State of California indicates that higher levels of energy efficiency and 33 percent Renewable Portfolio Standard (RPS) will increase investment in California by about 3 percent in 2020 compared to 20% RPS and lower levels of energy efficiency. After reviewing the CARB analysis, the Statewide CASE Team concluded that the majority of the increased investment of the more aggressive strategy is attributed to the benefits of efficiency (CARB 2010b Figures 7a and 10a). The specific code change proposal presented in this report is not expected to have an appreciable impact on investments in California.
- **Impacts on incentives for innovations in products, materials or processes:** Manufacturers of thermally driven cooling systems will have an incentive to develop new products and improve existing products. Utility efficiency programs could offer new incentive programs to encourage increased adoption of thermally driven cooling systems.
- **Impacts on the State General Fund, Special Funds and local government:** The proposed measure is not expected to have an appreciable impact on the State General Fund, Special Funds, or local government funds.
- **Cost of enforcement to State government and local governments:** All revisions to Title 24 will result in changes to Title 24 compliance determinations. State and local code

officials will be required to learn how buildings can comply with the new provisions included in the 2016 Standards, however the Statewide CASE Team anticipates that the cost of training is part of the regular training activates that occur every time the code is updated.

The proposed code change adds a compliance option to the performance approach. The energy impacts will be modeled through the compliance software. The measure does not add additional acceptance tests or field verification requirements that enforcing agencies would be responsible for conducting. For this reason, it is not expected that the proposed revision will have a significant impact on code enforcement. While additional training is not necessary for code compliance, the Statewide CASE Team believes that an education and training campaign will result in more designers taking advantage of the thermally driven cooling compliance option.

- **Impacts on migrant workers; persons by age group, race, or religion:** This proposal and all measures adopted by the CEC into Title 24, Part 6 do not advantage or discriminate in regards to race, religion or age group.
- **Impact on Homeowners (including potential first time homeowners):** The proposal does not impact residential buildings, thus there is no expected impact on homeowners.
- **Impact on Renters:** The proposal is not expected to have a significant impact on renters.
- **Impact on Commuters:** This proposal and all measures adopted by the CEC into Title 24, part 6 are not expected to have an impact on commuters.

Statewide Energy Impacts

Table 2 shows the estimated energy impacts over the first twelve months of implementation of the thermally driven cooling measure. These estimates are based on a series of building energy simulations as described in Section 4 of this report.

Table 2: Estimated First Year Energy Savings

	First Year Statewide Savings			First Year TDV Savings	
	Electricity Savings (GWh)	Power Demand Reduction (MW)	Natural Gas Impact (MMtherms)	TDV Electricity Savings (Million kBTU)	TDV Natural Gas Impact (Million kBTU)
Thermally driven cooling	1.2	0.6	-2.2 (increase)	42	-18 (increase)

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

Cost-effectiveness

The Statewide CASE Team did not perform a cost effectiveness analysis for this proposal because it is an optional compliance credit and not a prescriptive requirement or a mandatory requirement.

The Statewide CASE Team performed a TDV energy costs savings analysis and the results are presented in Table 3. The TDV energy costs savings are the present valued energy cost savings over the 15-year period of analysis. For a detailed description of the Cost-effectiveness Methodology see Section 4.7 of this report.

Table 3: TDV 15-Year Energy Cost Savings – Per Unit

Climate Zone	TDV Energy Cost Savings (2017 PV$/ton)
Climate Zone 1	$311
Climate Zone 2	$311
Climate Zone 3	$311
Climate Zone 4	$311
Climate Zone 5	$420
Climate Zone 6	$420
Climate Zone 7	$420
Climate Zone 8	$440
Climate Zone 9	$440
Climate Zone 10	$440
Climate Zone 11	$380
Climate Zone 12	$380
Climate Zone 13	$380
Climate Zone 14	$475
Climate Zone 15	$475
Climate Zone 16	$380

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

Greenhouse Gas and Water Related Impacts

For more a detailed and extensive analysis of the possible environmental impacts from the implementation of the proposed measure, please refer to Section 5.3 of this report.

Greenhouse Gas Impacts

Table 4 presents the estimated impact to greenhouse gas (GHG) emissions of the proposed code change for the first year the standards are in effect. Assumptions used in developing the GHG impacts are provided in Section 4.8.1 of this report.

Table 4: Estimated First Year Statewide Greenhouse Gas Emissions Impacts

	Increased GHG Emissions ($MTCO_2e/yr$)
Thermally driven cooling	11,200

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

Water Use and Water Quality Impacts

Impacts on water use and water quality are presented in Table 5. The water impacts presented below do not include impacts that occur at power plants. The methodology used to derive water use and water quality impacts is presented in Section 4.8.2.

Table 5: Impacts on Water Use and Water Quality (2017)

	On-Site Water Impact[1] (gallons/yr)	Embedded Energy Impact[2] (kWh/yr)	Impact on Water Quality Material Increase (I), Decrease (D), or No Change (NC) compared to existing conditions			
			Mineralization (calcium, boron, and salts)	Algae or Bacterial Buildup	Corrosives as a Result of PH Change	Others
Impact (I, D, or NC)	I	I	NC	NC	NC	NC
Per Unit Impacts[3]	2,800	28	-	-	-	-
Statewide Impacts (first year)	15,600,000	156,000	-	-	-	-

1. Does not include water savings at power plant
2. Assumes embedded energy factor of 10,045 kWh per million gallons of water.
3. The unit is tons of cooling capacity. For description of prototype buildings refer to Methodology section below.

Section 4.8.2 if this report discusses the methodology and Section 5.3.2 shows the results of the water use and water quality analysis.

Acceptance Testing

The existing Title 24 acceptance tests that apply to conventional electric chillers also apply to absorption and adsorption chillers. Depending on the design details for a particular project, this could include some or all of the following tests:

- Hydronic valve leakage
- Hydronic system variable flow controls
- Chiller isolation controls.

1. INTRODUCTION

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support California Energy Commission's (CEC) efforts to update California's Building Energy Efficiency Standards (Title 24) 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 Southern California Gas Company – and Los Angeles Department of Water and Power (LADWP) sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to energy efficiency in buildings. This report and the code change proposal presented herein is a part of the effort to develop technical and cost-effectiveness information for proposed regulations on building energy efficient design practices and technologies.

The overall goal of this CASE Report is to propose a code change for thermally driven cooling. The report contains pertinent information that justifies the code change.

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

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

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

Results from the energy, demand, costs, and environmental impacts analysis are presented in Section 5. The Statewide CASE Team calculated energy, demand, and environmental impacts using two metrics: (1) per unit, and (2) statewide impacts during the first year buildings complying with the 2016 Title 24 Standards are in operation. Time Dependent Valuation (TDV) energy impacts, which accounts for the higher value of peak savings, are presented for the first year both per unit and statewide. The incremental costs, relative to existing conditions are presented as are present value of year TDV energy cost savings and the overall cost impacts over the 30-year period of analysis.

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

2. MEASURE DESCRIPTION

2.1 Measure Overview

2.1.1 Measure Description

This code change proposal would add a new compliance option for applicants that wish to comply with Title 24 through the performance approach (whole building simulation energy trade-off). Specifically, the proposed code change recommends revisions to the ruleset for the compliance software. This will allow applicants to take credit for the energy benefits of cooling spaces with a thermally driven cooling system to demonstrate compliance with Title 24. This proposed code change affects new construction or major retrofits in nonresidential buildings or high-rise residential buildings that use thermally driven cooling in which the cooling effect is driven by heat rather than mechanical compressors. The heat source could be a boiler, solar thermal, waste heat, or a combination. The waste heat could be process heat, cogeneration, or other sources.

The proposed code change would enable applicants to model the impacts of a thermally driven cooling system that uses either an absorption chiller, adsorption chiller, or desiccant system. Absorption chillers are the most common form of thermally driven cooling systems and have been available for over 50 years. A number of manufacturers currently offer a variety of absorption chillers. Adsorption chillers are also available but they are less common. Another form of cooling that makes use of waste heat is desiccant cooling. Desiccants are used to remove water vapor out of an air stream and waste heat is used to regenerate the desiccant so it is ready to absorb more water vapor. The desiccant system operates mostly on heat energy rather than mechanical energy. Its electric demand is around 25% of a vapor-compression air conditioner. This system is especially effective at dehumidifying air and most of the cooling is latent heat transfer.

Figure 1 presents a psychrometric chart that illustrates the desiccant cooling process for a typical system. This unit includes a direct expansion (DX) pre-cooling coil, a desiccant wheel, and an integrated condensing package that reactivates the desiccant. At 6000 cfm airflow, for example, entering at 95°F db and 75°F wb, this unit uses 30 tons of compressor cooling. A conventional vapor compression DX unit uses 50 tons of compressor cooling to deliver the same conditions.

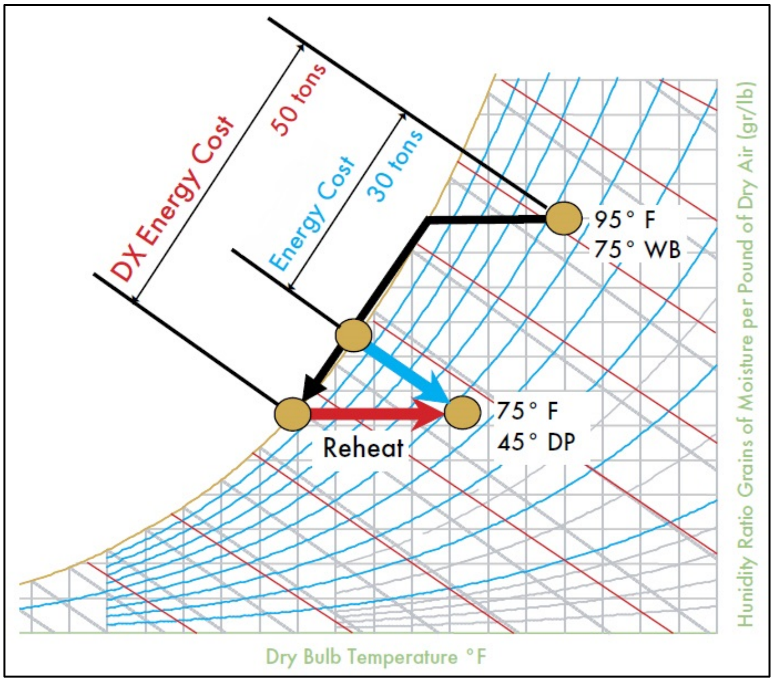

Figure 1: Psychrometric Chart for Desiccant Cooling Process

This change allows an applicant to model the energy impacts of cooling spaces with a thermally driven cooling system to demonstrate compliance with Title 24 through the performance (whole building simulation energy trade-off) approach. When on-site renewable energy or site recovered thermal energy is used to provide space cooling, the energy consumption of the proposed cooling system includes all energy consumption required to extract the heat and to convert this into cooling energy and all energy required to deliver the cooling to spaces within the building. If thermal storage is used any heat losses and equipment energy usage is also accounted for. The solar energy or thermal energy recovered from a process is treated as free and thus is not included in the energy budget. There is no credit for cooling energy created that is not used for space conditioning on site.

The proposed code change is neither a prescriptive requirement nor a mandatory requirement and does not affect the base case budget used to verify compliance with the performance approach.

2.1.2 Measure History

The 2001 Title 24 Standards included nonresidential gas absorption cooling. Performance was calculated using default DOE-2 curves that describe the chiller efficiency versus leaving chilled water temperature and condenser temperature. The 2001 Title 24 Standards did not address gas engine chillers and heat pumps.

For the 2005 Title 24 Standards, the Statewide CASE Team developed a code change proposal that recommended:

- Modifying the ACM Reference Manual so the model for absorption cooling used a more conservative performance curve than the default DOE-2 curves. This new curve is based on manufacturer data.

- Adding minimum performance values to the Standards' tables for gas engine chillers and heat pumps. Changes to the default DOE-2 performance curves were not recommended for gas engine chillers or heat pumps.
- Modifying *Section 141 Performance Approach: Energy Budgets*. Modify as follows: All energy from depletable sources <u>and recovered from space conditioning equipment</u> used for space conditioning, lighting, and service water heating shall be included .

As of the 2013 Title 24 Standards, there is no provision to account for the use of waste heat or solar thermal when calculating energy budgets. In addition, adsorption chillers are not yet included in Title 24.

2.1.3 Existing Standards

The 2013 Title 24 Standards include minimum efficiency requirements for absorption chillers, minimum unloading ratios, and cooling efficiency adjustment curves.

ASHRAE 90.1-2013 includes minimum efficiency requirements for absorption chillers. It specifies that onsite renewable energy and site-recovered energy shall not be considered as purchased energy and shall not be included in the design energy cost for the proposed design. It thus allows a credit for the energy that would otherwise have been purchased. It also restricts the credit to a maximum of 5% of the calculated energy cost budget for the budget building design (standard design building). The renewable energy must be generated onsite by systems included on the building permit and used directly by the building. This prohibits taking credit for a renewable energy system that is rented to or from another facility.

2.1.4 Alignment with Zero Net Energy Goals

The Statewide CASE Team and the CEC are committed to achieving California's zero-net-energy (ZNE) goal. This measure will help achieve ZNE goals by greatly reducing the electricity use and peak electric demand of chillers. This proposed modeling will set the foundation for future code changes that will help ensure ZNE goals are achieved. In particular, this measure could lead directly to the following code changes in the 2019 and 2022 code change cycles:

- Prescriptive requirement for thermally driven cooling systems for certain building types; and
- Potential mandatory requirements for thermally driven cooling systems.

If thermally driven cooling is an important aspect of the CEC's strategy for achieving ZNE goals for multi-family buildings, the Statewide CASE Team recommends that adding this compliance option be coupled with an education and training campaign that aims to encourage building designers to take advantage of the new compliance option.

2.1.5 Relationship to Other Title 24 Measures

There are no overlaps with other Title 24 code change proposals for the 2016 cycle.

2.2 Summary of Changes to Code Documents

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

2.2.1 Catalogue of Proposed Changes

Scope

Table 6 identifies the scope of the code change proposal. This measure will impact the following areas.

Table 6: Scope of Code Change Proposal

Mandatory	Prescriptive	Performance	Compliance Option	Trade-Off	Modeling Algorithms	Forms
No	No	Yes	Yes	No	Yes	No

Standards

No changes are needed to the Standards.

Nonresidential Alternative Calculation Method (ACM) Reference Manual

The proposed code change will modify the sections of the Nonresidential Alternative Calculation Method References identified in Table 7.

Table 7: Sections of ACM Impacted by Proposed Code Change

Nonresidential Alternative Calculation Method Reference		
Section Number	**Section Title**	**Modify Existing (E) New Section (N)**
5.7.7.2	Desiccant Heat Source	E: Add new heat sources for waste hot water, solar hot water, and condenser heat
5.8.2	Chiller Type	E: Add adsorption chiller
5.8.2	Chiller Fuel Source	E: Add adsorption chiller
5.8.2	Chiller Minimum Unloading Ratio	E: Add adsorption chiller
5.8.2	Fuel and Steam Chiller Cooling Efficiency Adjustment Curves	E: Add adsorption chiller
5.10	On-Site Power Generation	E: Describes ruleset for on-site renewable energy or site recovered thermal energy

Simulation Engine Adaptations

The proposed code changes cannot be entirely modeled using EnergyPlus, which is the current simulation engine. Changes to the simulation engine are thus necessary. EnergyPlus already includes a well-developed model for absorption chillers and desiccant systems but it's missing the capability for adsorption chillers. Section 8: Proposed Changes to EnergyPlus describes the necessary changes in detail.

2.2.2 Standards Change Summary

This proposal would modify the following sections of the Building Energy Efficiency Standards.

Changes in Scope

No changes are needed to the Standards.

Changes in Mandatory Requirements

No changes are needed in the mandatory requirements.

Changes in Prescriptive Requirements

No changes are needed in the prescriptive requirements.

Changes in Performance Requirements

No changes are needed in the performance requirements.

2.2.3 Standards Reference Appendices Change Summary

No changes are needed to the Standards Reference Appendices.

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

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

Section 5.7 HVAC Secondary Systems and Section 5.8 HVAC Primary Systems

In summary, this proposal will add new heat sources for waste hot water, solar hot water, and condenser heat. It also adds adsorption chillers, which are currently missing.

Section 5.7.7.2 Desiccant Heat Source: Add new heat sources for waste hot water, solar hot water, and condenser heat to ACM Reference Manual.

Section 5.8.2 Chiller Type: Add adsorption chiller to ACM Reference Manual

Section 5.8.2 Chiller Fuel Source: Add adsorption chiller to ACM Reference Manual.

Section 5.8.2 Chiller Minimum Unloading Ratio: Add adsorption chiller to ACM Reference Manual.

Section 5.8.2 Fuel and Steam Chiller Cooling Efficiency Adjustment Curves: Add adsorption chiller to ACM Reference Manual.

Section 5.10 On-Site Power Generation: Describes ruleset for on-site renewable energy or site recovered thermal energy.

2.2.5 Compliance Forms Change Summary

The proposed code change will not modify the Compliance Forms.

2.2.6 Simulation Engine Adaptations

The proposed code changes cannot be entirely modeled using EnergyPlus, which is the current simulation engine. Changes to the simulation engine are thus necessary. EnergyPlus already includes well-developed models for desiccant systems and absorption chillers but it’s missing the capability for adsorption chillers. Section 8: Proposed Changes to EnergyPlus describes the necessary changes in detail.

2.2.7 Other Areas Affected

The California Building Energy Code Compliance (for Commercial/Nonresidential buildings) software (CBECC-Com) is a nonresidential compliance software approved by the CEC for Title 24 compliance. The proposed code changes cannot be modeled using CBECC-Com, thus a number of software changes are needed. Section 7: Proposed Changes to CBECC-COM describes these changes in detail.

2.3 Code Implementation

2.3.1 Verifying Code Compliance

Code enforcement entities will determine if a building complies with the proposed code change similar to the current process for electric chillers. With regard to the new heat sources for waste hot water, solar hot water, and condenser heat, the code enforcement entities will need to review the design and construction documents, especially the plumbing drawings, and compare them with the actual installation.

Field verifications and acceptance tests for the absorption and adsorption changes are identical to those for electric chillers. No additional compliance forms are needed. With regard to the new heat sources for waste hot water, solar hot water, and condenser heat, no field verifications and acceptance tests are needed.

2.3.2 Code Implementation

This proposal will add compliance options for new heat sources including solar hot water, refrigeration condenser heat, heat from fuel cells, engine cooling jacket and exhaust, and turbine exhaust, across various heat transfer fluids including air, water, refrigerant, glycol, and steam. It also adds adsorption chillers, which are currently not included in the compliance software. These changes allow for more design options, which is a benefit to designers and builders. Absorption chillers and desiccant systems are already included in the compliance software and can be used to verify compliance with Title 24 through the performance approach. Adsorption chillers will be added but they are very similar to absorption chillers from a code implementation perspective. The affected industry is the HVAC industry, which is already very familiar with Title 24. Thermally driven cooling systems – particularly systems that use waste heat and heat generated from solar – are not already a common industry practice, which is why this is not a prescriptive or mandatory requirement.

Correct implementation of these changes should not present any undue burden or complexity to designers. It should be relatively easy for building inspectors to verify compliance during the inspection by comparing the design and construction documents, especially the plumbing drawings, with the actual installation. This is a similar process to electric chillers. The Statewide CASE Team does not anticipate that building officials or the building industry will have opposition to this measure.

2.3.3 Acceptance Testing

The existing Title 24 acceptance tests that apply to conventional electric chillers also apply to absorption and adsorption chillers. Depending on the design details for a particular project, this could include some or all of the following tests:

- Hydronic valve leakage
- Hydronic system variable flow controls
- Chiller isolation controls

There are no existing Title 24 acceptance tests that apply to desiccant systems and none are proposed at this time.

2.4 Issues Addressed During CASE Development Process

The Statewide CASE Team solicited feedback from a variety of stakeholders when developing the code change proposal presented in this report. In addition to personal outreach to key stakeholders, the Statewide CASE Team conducted a public stakeholder meeting to discuss the proposals. The team spoke with a number of researchers, product engineers and CEOs, project designers and engineers, and program managers. A few questions from stakeholders arose during development of the code change proposal as described here.

It was initially proposed that the energy budget of the proposed design will be reduced by the amount of on-site renewable energy generation or recovered energy that is used for space-conditioning and that the total reduction in the energy budget shall be no more than 15% of the calculated energy budget for the standard design building. It was pointed out that this approach would limit renewables, which was not our intent. The resolution was to include the following language in the ACM Reference Manual:

When on-site renewable energy or site recovered thermal energy is used to provide space cooling, the energy consumption of the proposed cooling system includes all energy consumption required to extract the heat and to convert this into cooling energy and all energy required to deliver the cooling to spaces within the building. If thermal storage is used any heat losses and equipment energy usage is also accounted for. The solar energy or thermal energy recovered from a process is treated as free and thus is not included in the energy budget. There is no credit for cooling energy created that is not used for space conditioning on site.

Another question arose regarding the temperature of the heat sources used for thermally driven cooling: should these temperatures be limited to certain ranges? The Statewide CASE Team decided to not establish limits on the fluid temperatures. This is because EnergyPlus directly uses the input temperatures, flow rates, and type of fluid (air, water, glycol, etc.) to calculate the available heat capacity on a sub-hourly basis. If this heat capacity is insufficient to entirely meet the needs of the thermally driven cooling system, then the backup heat source will be used and accounted for by EnergyPlus.

3. MARKET ANALYSIS

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

3.1 Market Structure

The products affected by this proposal include absorption and adsorption chillers and desiccant cooling systems. Absorption chillers are the most common form of thermally driven cooling system and have been available for over 50 years. Carrier, Trane, York, Broad, McQuay, Yazaki, Thermax and others offer a variety of absorption chillers. Adsorption chillers are less common in the United States, although they are gaining popularity in Europe. Adsorption chillers have the advantage of using a lower temperature hot water loop, as low as 122 degrees Fahrenheit (°F), which could be useful in many cases especially involving waste heat. Adsorption chiller manufacturers include ECO-MAX, Kawasaki, SorTech, and Weatherite.

Desiccant cooling systems include both solid and liquid desiccant designs. The solid version requires more maintenance and very few systems are available. The liquid version has better efficiency, but very few systems are commercially available. Some of the manufacturers include Munters, Kathabar and Advantix.

The market structure is similar to that of electric chillers, with manufacturers selling to customers through a distribution network and a trained workforce available to support installation, repair and maintenance.

3.2 Market Availability and Current Practices

The current market for absorption and adsorption chillers and desiccant cooling systems is relatively small. As of September 1, 2014, there are approximately seven different manufacturers of absorption chillers, four different manufacturers of adsorption chillers, and at least four different manufacturers of desiccant cooling systems.

Good applications for thermally driven cooling systems are sites that have a source of recovered energy that is coincident with the need for air conditioning and locations where the peak electric demand charge is high. Thermally driven cooling can help reduce or flatten the electric peaks in a building’s electric load profile.

Current or historical sales data was difficult to obtain for these products. Figure 2displays data from one of the major absorption chiller manufacturers. It shows the cumulative number of district cooling projects installed in Japan, with 152 total projects across 90 operators (district plants) as of 2002. Of these 152 installations, 57% use absorption chillers, or 87 absorption chillers in total. The apparent sales rate for absorption chillers in this example is around two units per year on average in recent history (1992-2002), or three units per year on average over the past 30 years (1972-2002). Again, this example is for one manufacturer in Japan for district cooling.

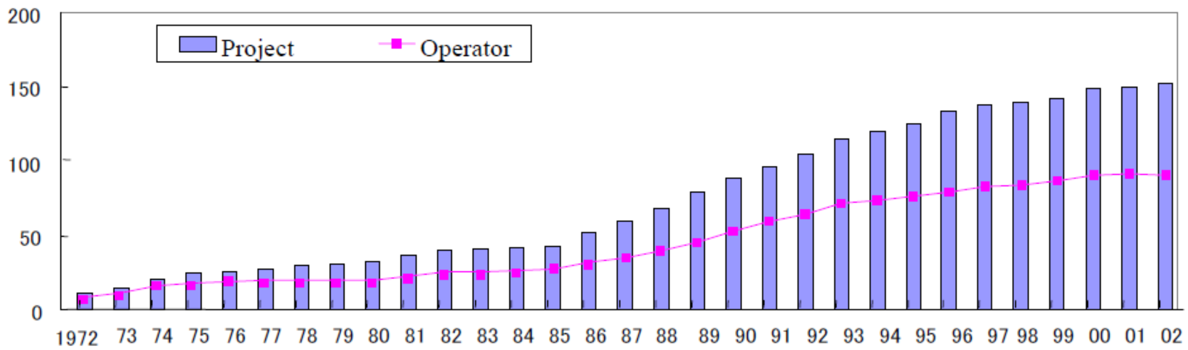

Figure 2: District Cooling Projects Installed in Japan

Figure 3 displays data from the same major absorption chiller manufacturer. It shows the cumulative number of absorption chillers installed in Egypt, with 48 units installed as of 2007. The apparent sales rate for absorption chillers in this example is around five to eighteen units per year, depending on the reference years.

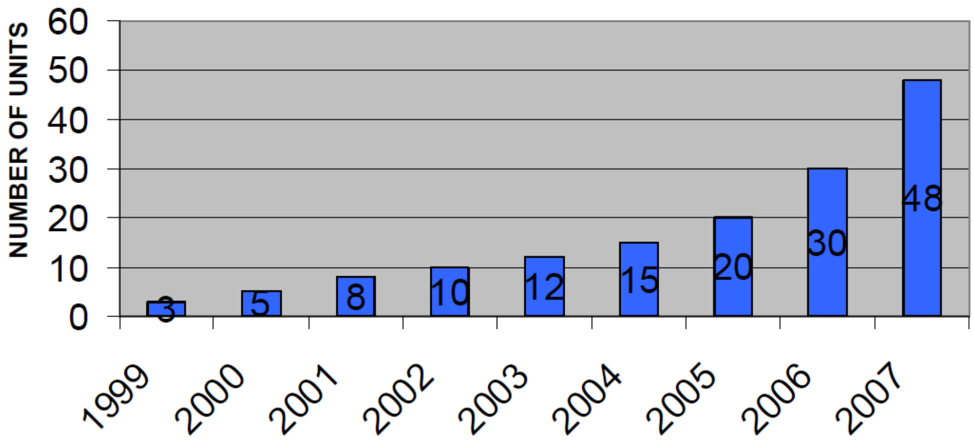

Figure 3: Absorption Chillers Installed in Egypt

New Jersey offers the only apparent incentive program in the country for thermally driven cooling systems using waste heat, called NJ SmartStart Buildings. This program is specifically targeted to direct-fired and indirect-fired absorption chillers and regenerative desiccant units. The incentive for absorption chillers ranges from $185/ton for large units (>400 tons) to $450/ton for smaller units (<100 tons). The incentive for desiccant units is $1/CFM based on process airflow. The Statewide CASE Team spoke with the program manager and learned this program has been available since before 2005. They have very few projects that enroll in the program, typically only around five units each year.

The proposed Standards change is projected to slowly increase awareness and sales of these technologies. There is no reason why the market cannot ramp up production to meet this slowly increasing demand. The system designs are mature and no additional product development or refinements are needed in response to this proposed Standards change.

These code change proposals are estimated to increase the current market share of thermally driven cooling systems by less than 5% per year. A value of five chillers per year is used in the statewide impact calculations.

3.3 Useful Life, Persistence, and Maintenance

The effective useful life of absorption and adsorption chillers is estimated at approximately 20 to 25 years per stakeholder input. Desiccant systems have an estimated useful life of 15 years. Maintenance procedures are not unlike those for electric chillers and include the typical items such as keeping the heat transfer surfaces free of scale and sludge and maintaining the pumps and other mechanical components. However, specially trained and experienced personnel are required to perform maintenance and repairs. The persistence of the energy savings is related to proper maintenance.

3.4 Market Impacts and Economic Assessments

3.4.1 Impact on Builders

There is no anticipated impact on builders other than additional compliance options available. However, considerable specialized experience will be required to install and start-up the system.

3.4.2 Impact on Building Designers

There is no anticipated impact on designers other than additional compliance options available. Title 24 is updated on a three-year revision cycle, so acclimating to changes in Title 24 Standards is routine practice for building designers; adjusting design practices to comply with changing code practices is within the normal practices of building designers.

This particular revision to Title 24 will not require a departure from standard or common design practices for building designers, unless they choose to install a thermally driven cooling system. That is, building designers do need to take advantage of this additional compliance option. For designers that choose not to comply using thermally driven cooling, this measure does not result in any changes to standard design practices. However, considerable specialized experience will be required to design and model thermally driven cooling systems. If a designer chooses to use a thermally driven cooling system, the proposed change will allow designers to count the energy benefits of the systems toward compliance with Title 24.

3.4.3 Impact on Occupational Safety and Health

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

3.4.4 Impact on Building Owners and Occupants

There is no anticipated impact on owners other than additional compliance options available. There is no impact on the occupants. However, considerable specialized experience will be required to operate and maintain the system.

3.4.5 Impact on Retailers (including manufacturers and distributors)

This group will see increased sales of thermally driven cooling systems.

3.4.6 Impact on Energy Consultants

There is no anticipated impact on energy consultants other than additional compliance options available. However, considerable specialized experience will be required to model the system.

3.4.7 Impact on Building Inspectors

As compared to the overall code enforcement effort, this measure has negligible impact on the effort required to enforce the building codes. Inspectors will not be required to complete any tasks that they are not already conducting to verify compliance with the 2013 Standards.

3.4.8 Impact on Statewide Employment

This measure will create jobs by expanding the small industry associated with thermally driven cooling systems.

3.5 Economic Impacts

The proposed Title 24 code changes, including this measure, are expected to increase job creation, income, and investment in California. As a result of the proposed code changes, it is anticipated that less money will be sent out of state to fund energy imports, and local spending is expected to increase due to higher disposable incomes due to reduced energy costs.

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

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

3.5.1 Creation or Elimination of Jobs

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

3.5.2 Creation or Elimination of Businesses within California

This measure will create new and expand existing California businesses by expanding the small industry associated with thermally driven cooling systems. It is not anticipated that this measure will have a measureable impact on businesses that manufacturer, distribute, or install traditional HVAC systems.

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

Table 8 below shows California industries that are expected to receive the economic benefit of the proposed Title 24 code changes. It is anticipated that these industries will expand due to an increase in funding as a result of energy efficiency improvements. The list of industries is based on the industries that the University of California, Berkeley identified as being impacted by energy efficiency programs (UC Berkeley 2011 Table 3.8).[1] This list provided below is not specific to one individual code change proposal, rather it is an approximation of the industries that may receive benefit from the 2016 Title 24 code changes. A table listing total expected job creation by industry that is expected in 2015 and 2020 from all investments in California energy efficiency and renewable energy is presented in the Appendix B of this CASE Report.

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

Table 8: Industries Receiving Energy Efficiency Related Investment, by North American Industry Classification System (NAICS) Code

Industry	NAICS Code
Nonresidential Building Construction	2362
Electrical Contractors	23821
Plumbing, Heating, and Air-Conditioning Contractors	23822
Boiler and Pipe Insulation Installation	23829
Insulation Contractors	23831
Manufacturing	32412
Industrial Machinery Manufacturing	3332
Ventilation, Heating, Air-Conditioning, & Commercial Refrigeration Equipment Manufacturing	3334
Computer and Peripheral Equipment Manufacturing	3341
Engineering Services	541330
Building Inspection Services	541350
Environmental Consulting Services	541620
Other Scientific and Technical Consulting Services	541690
Advertising and Related Services	5418
Corporate, Subsidiary, and Regional Managing Offices	551114
Commercial & Industrial Machinery & Equip. (exc. Auto. & Electronic) Repair & Maintenance	811310

3.5.3 Competitive Advantages or Disadvantages for Businesses within California

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

3.5.4 Increase or Decrease of Investments in the State of California

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

3.5.5 Incentives for Innovation in Products, Materials, or Processes

Manufacturers of thermally driven cooling systems will have an incentive to develop new products and improve existing products. Utility efficiency programs could offer new incentive programs to encourage increased adoption of thermally driven cooling systems.

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

There is no significant additional burden expected on state agencies, other than the documentation required for the compliance manuals for this measure, and subsequent training and support efforts.

3.5.6.1 Cost of Enforcement

The proposed code change adds a compliance option to the performance approach. The energy impacts will be modeled through the compliance software. The measure does not add additional acceptance tests or field verification requirements that enforcing agencies would be responsible for conducting. For this reason, it is not expected that the proposed revision will have a significant impact on code enforcement. While additional training is not necessary for code compliance, the Statewide CASE Team believes that an education and training campaign will result in more designers taking advantage of the thermally driven cooling compliance option.

Cost to the State

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

Cost to Local Governments

All revisions to Title 24 will result in changes to Title 24 compliance determinations. Local governments will need to train permitting staff on the revised Title 24 Standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2016 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining. As noted earlier, although retraining is a cost of the revised Standards, Title 24 Standards are expected to increase economic growth and income with positive impacts on local revenue. The cost to local governments should be minimal because the compliance verification and enforcement requirements are not changing.

3.5.6.2 Impacts on Specific Groups of Persons

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

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

4. METHODOLOGY

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

4.1 Existing Conditions

These measures affect new thermally driven cooling systems utilizing waste heat and heat from renewable energy sources that serve commercial buildings including high-rise residential buildings. The analysis for the absorption and adsorption chillers relies on a large office building simulation. The existing conditions are based on the 2013 ACM Reference Manual that specifies the HVAC system in the standard design. It specifies that buildings larger than 150,000 square feet (SF) and taller than one story must use a built-up variable air volume (VAV) system in the standard design. This is the only building type that uses a built-up system in the standard design. Thus, the existing conditions assume a building larger than 150,000 SF, taller than one story, and with a built-up variable volume system with chilled water and hot water coils, water-cooled electric chiller, tower and central boiler.

The 2013 Standards allow applicants to model absorption chillers to verify compliance with Title 24, but does not allow applicant to model adsorption chillers. However, the current version of CBECC-Com does not allow for selection of either absorption or adsorption chillers. In any case, electric chillers are much more commonly installed than absorption and adsorption chillers, which are mature technologies but rarely installed. The base case is thus an electric chiller as that is the common design specification. The 2013 ACM Reference Manual also specifies an electric chiller for the standard design.

The analysis for the desiccant cooling system relies on a small 1-story office building simulation. The existing conditions are based on the 2013 ACM Reference Manual that specifies the HVAC system in the standard design. It specifies that 1-story buildings smaller than 10,000 SF use a packaged single zone (PSZ) unit in the standard design. Thus, the existing conditions assume a 1-story building smaller than 10,000 SF with PSZ units with constant volume DX and gas heating. Each of the five thermal zones in the simulation is modeled with its own PSZ system, per the 2013 ACM Reference Manual standard design.

The 2013 standards allow for desiccant cooling. However, the current version of CBECC-Com does not allow input of any desiccant system. In any case, desiccant cooling systems are a mature technology but not commonly installed. The base case is thus a PSZ unit without desiccant cooling.

4.2 Proposed Conditions

The proposed conditions are defined as the design conditions that will comply with the proposed code change. They are summarized here for the three measures:

- Absorption chiller using solar heat for the generator heat source
- Adsorption chiller using solar heat for the generator heat source
- Desiccant cooling system using condenser heat for the regeneration heat load

Alternately, hot water, hot air, or steam, derived from waste heat could be used for the chiller or cooling system heat source.

The solar thermal system for the absorption and adsorption chiller models is sized to generate approximately 25% of the chiller heat demand on the peak day. The remaining 75% of the chiller heat demand on the peak day is satisfied by central gas boilers. The solar fraction on non-peak days is higher than 25%. Figure 4 illustrates a typical peak day, in this case for climate zone 12 in mid-July. The sum of the areas under the curves Thermal Energy from Solar and Thermal Energy from Boiler is equivalent to the area under the curve Chiller Heat Input Demand.

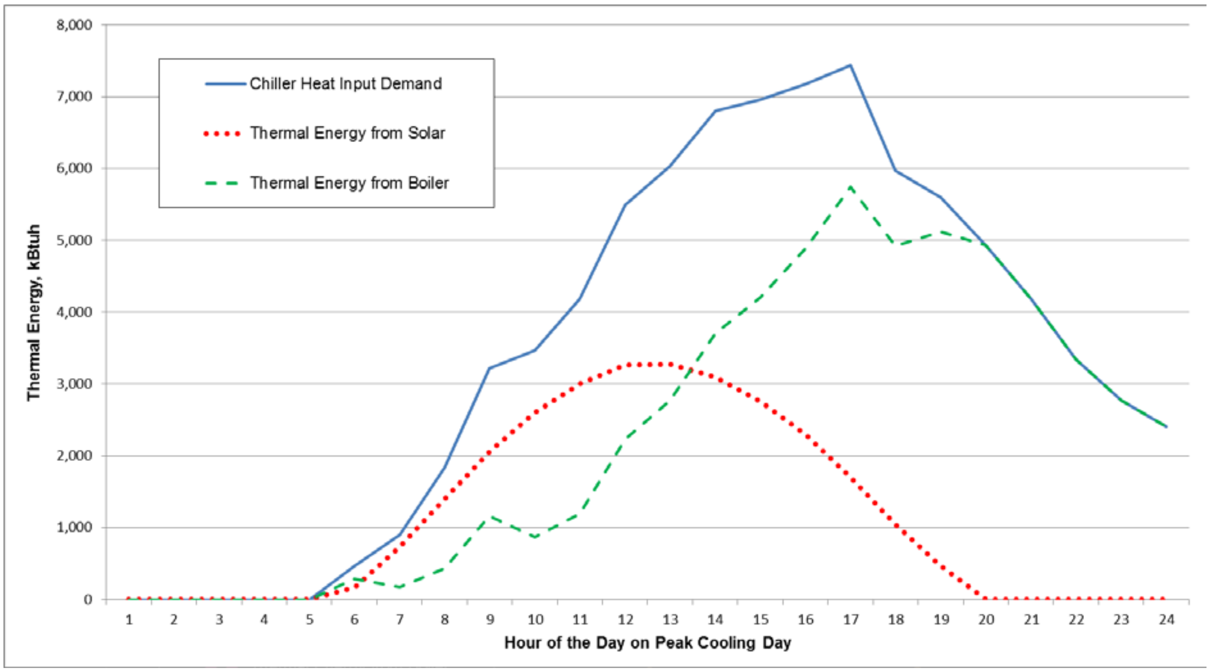

Figure 4: Typical Thermal Energy Demand from Solar Thermal System and Boiler, Mid-July in Climate Zone 12

4.3 Prototype Buildings

To assess the energy, demand, and environmental impacts for nonresidential prototype buildings, the Statewide CASE Team used a new construction small office and large office for the prototype buildings.

The prototype building simulation files originated from the CBECC-Com software installation package, which includes a number of example input files. These models include various building types and HVAC systems. The files with “-CECStd” in the name are intended to represent minimally compliant buildings with respect to the 2013 Title 24 Standards. That is, these files were developed to pass compliance with as small a compliance margin as possible, ideally zero. The models used in this analysis are: 020012-OffSml-CECStd (desiccant cooling model) and 040012-OffLrg-CECStd (absorption and adsorption chiller model).

CBECC-Com does not yet allow for modeling absorption and adsorption chillers or desiccant cooling systems. A workaround was thus used to model the measure cases. The -CECStd files were first run in CBECC-Com. One of the CBECC-Com output files is an EnergyPlus input file. CBECC-Com automatically created this file by mapping the CBECC input file to an EnergyPlus input file. The Statewide CASE Team modified this EnergyPlus input file as needed to include an absorption chiller, adsorption chiller, or a desiccant system for the measure cases. These revised files were then run in EnergyPlus to yield the measure case simulation results.

Table 9 summarizes some of the details of these prototype buildings. Note that the base case system is electric for all prototype buildings. The thermally driven cooling systems modeled for the measure case are not all-electric systems, and the proposed compliance option will use different fuels and/or heat sources than are assumed in the prescriptive baseline.

Table 9: Prototype Buildings used for Energy, Demand, and Environmental Impacts Analysis

Measure	Occupancy type	Floor area (SF)	Number of floors	Base case	Measure case	Heat source
Absorption chillers	Large office	498,589	12 + basement	Built up VAV with electric chiller	Indirect fired absorption chiller	Solar hot water
Adsorption chillers	Large office	498,589	12 + basement	Built up VAV with electric chiller	Indirect fired adsorption chiller	Solar hot water
Desiccant cooling	Small office	5,502	1	PSZ DX units	PSZ DX + desiccant cooling	Condenser heat

4.3.1 Large Office Prototype

The large office prototype is a typical large office building with 12 floors and a basement. The conditioned floor area is 498,589 SF. The HVAC system is a central plant with a variable air volume system, chilled water plant, central gas boiler, variable speed cooling towers, and hot water reheat at the terminal units. The HVAC systems for the measure cases are identical to the base case except for an absorption and adsorption chiller instead of electric chiller.

The internal load values are consistent with typical large office buildings in California:

- Lighting power density: 0.75 W/SF
- Equipment power density: 1.0 W/SF
- Occupancy density: 200 SF/person

As shown in Figure 5, the model includes the top floor, an upper floor with multiplier of 5, a mid-floor with multiplier of 5, the ground floor and the basement. Glazing is distributed around all four sides on all floors.

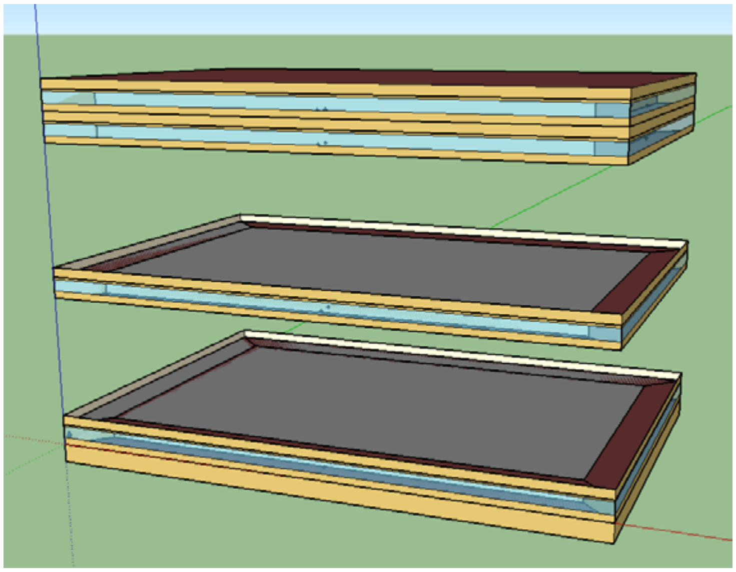

Figure 5. Large Office Prototype Model

4.3.2 Small Office Prototype

The small office prototype is a typical small office building with a single floor. The conditioned floor area is 5,502 SF. The HVAC system consists of five PSZ units with DX cooling coils and gas heat. The units are rated at 13.0 SEER, 10.8 EER, and 0.78 AFUE.

The HVAC systems for the measure case are identical to the base case but adds the EnergyPlus input object Dehumidifer:Desiccant:System. This system is located in the main air loop immediately downstream of the DX cooling coils. The dehumidifier operation is coordinated with the operation of the companion DX coil. The DX system's condenser waste heat is used to help regenerate the desiccant heat exchanger. This is described in more detail in the EnergyPlus Engineering Reference Manual.

The internal load values are consistent with typical small office buildings in California:

- Lighting power density: 0.75 W/SF
- Equipment power density: 1.0 W/SF
- Occupancy density: 200 SF/person

The model is illustrated in Figure 6.

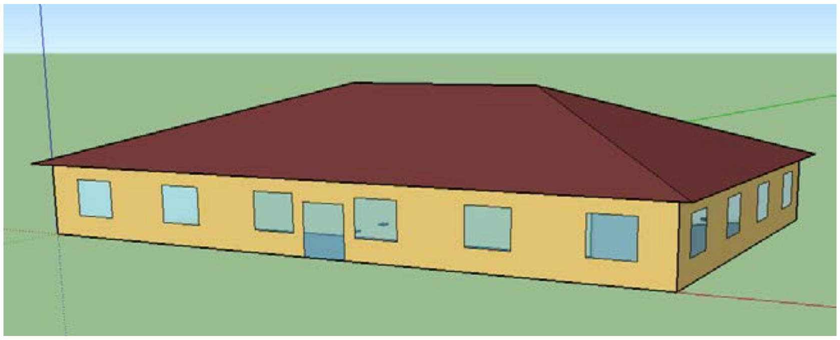

Figure 6. Small Office Prototype Model

4.4 Climate Dependent

The impacts of the proposed measure are climate specific, thus the impacts were modeled in a variety of climate zones to illustrate the full range of impacts that are expected statewide.

4.5 Time Dependent Valuation

The TDV (Time Dependent Valuation) of savings is a normalized format for comparing electricity and natural gas savings that takes into account the cost of electricity and natural gas consumed during different times of the day and year. The TDV values are based on long term discounted costs (30 years for all residential measures and nonresidential envelope measures and 15 years for all other nonresidential measures). In this case, the period of analysis used is 15 years. The TDV cost impacts are presented in 2017 present value dollars. The TDV energy estimates are based on present-valued cost savings but are normalized in terms of “TDV kBTUs” so that the savings are evaluated in terms of energy units and measures with different periods of analysis can be combined into a single value.

The CEC derived the 2016 TDV values that were used in the analyses for this report (CEC 2014). The TDV energy impacts are presented in Section 5.1 of this report, and the statewide TDV cost impacts are presented in Section 5.2.

4.6 Energy Impacts Methodology

This measure adds a compliance option that designers can use if they opt to comply with the Standards using the performance approach, but the measure does not change the baseline energy budget. It is assumed that designers that elect to use this compliance option will combine a thermally driven cooling system with other design features that will allow the building to be minimally compliant with Title 24. Using this new compliance option will not necessarily result in buildings that perform better than code minimum. Despite there being no intrinsic savings associated with this measure, the Statewide CASE Team did calculate the per unit impacts and statewide energy impact of the proposed compliance option relative to the prescriptive baseline. The statewide savings account for energy impacts associated with all new construction, alterations, and additions during the first year buildings complying with the 2016 Title 24 Standards are in operation.

4.6.1 Per Unit Energy Impacts Methodology

The Statewide CASE Team estimated the electricity and natural gas impacts associated with the proposed code change. The energy impacts were calculated per ton of cooling capacity. A series of building energy simulations and corresponding TDV analysis were conducted to estimate the potential energy impacts resulting from these code change proposals. A representative sample of California climate zones were modeled, including: 3, 6, 9, 12, 14, and 16. The other California climate zones were not included in these energy simulations as they are sufficiently represented by the selected zones for the purposes of this research. Figure 7 indicates which climate zones the selected zones represent and Figure 8 shows a map of the climate zones.

Simulated climate zone	Maps to climate zones:
3	1, 2, 3, 4
6	5, 6, 7
9	8, 9, 10
12	11, 12, 13
14	14, 15
16	16

Figure 7: Climate Zone Mapping for Energy Simulations

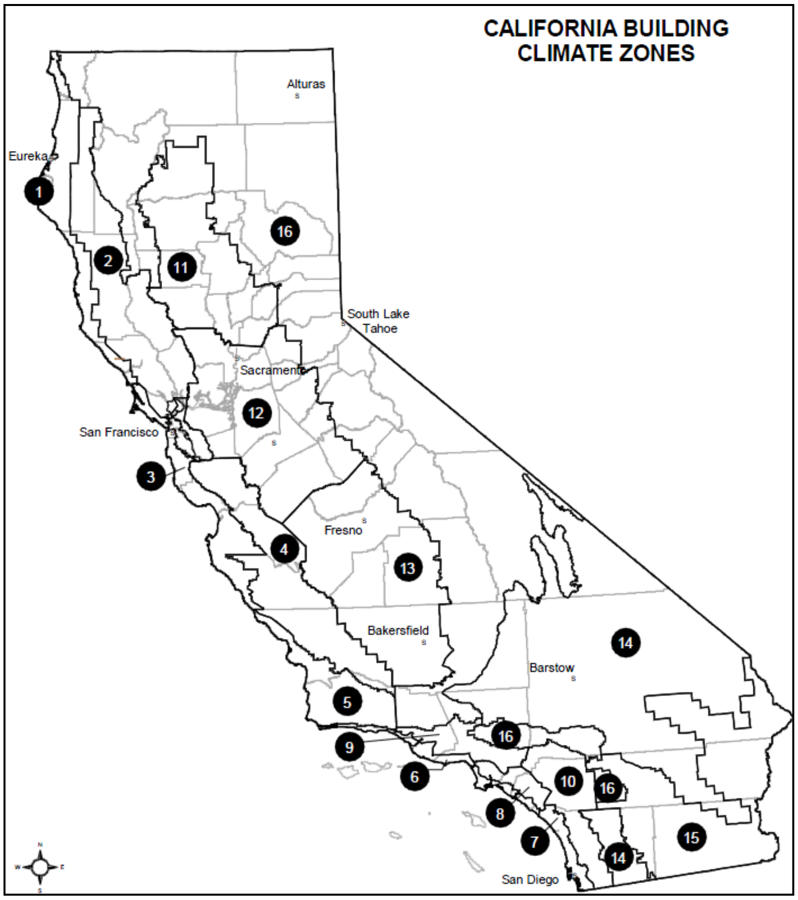

Figure 8. California Climate Zone Map

Analysis Tools

The Statewide CASE Team used CBECC-Com 2013 v2b (Build 609), EnergyPlus v8.1, and spreadsheet analysis to quantify energy impacts and peak electricity demand reductions resulting from the proposed measure.

Key Assumptions

As mentioned, the CEC provided a number of key assumptions to be used in the energy impacts analysis (CEC 2011). Some of the assumptions included in the CEC's Lifecycle Cost Methodology Guidelines (LCC Methodology) include hours of operation, weather data, and prototype building design. The key assumptions used in the per unit energy impacts analysis that are not already included in the assumptions provided in the LCC Methodology, or vary from the assumptions the CEC provided, are presented in Table 10.

Table 10: Key Assumptions for Per Unit Energy Impacts Analysis

Parameter	Assumption	Source
Large office floor area	498,589 SF	CBECC-Com CEC-Std prototype model
Small office floor area	5,502 SF	CBECC-Com CEC-Std prototype model
Lighting power density	0.75 W/SF	PNNL ASHRAE 90.1 Prototype Building Modeling Specifications
Equipment power density	1.0 W/SF	PNNL ASHRAE 90.1 Prototype Building Modeling Specifications
Occupancy density	200 SF/person	PNNL ASHRAE 90.1 Prototype Building Modeling Specifications
Zone Supply Air Temp	55°F (cooling)	CBECC-Com CEC-Std prototype model
Zone Supply Air Temp	95°F (heating)	CBECC-Com CEC-Std prototype model

4.6.2 Statewide Energy Impacts Methodology

First Year Statewide Impacts

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

The proposed code change applies to only a fraction of new construction, additions and alterations. This is because these changes are optional and not mandatory or prescriptive. The Statewide CASE Team assumed that the proposed code change would apply to only five new chillers in the first year.

The CEC Demand Analysis Office provided the Statewide CASE Team with the residential and nonresidential new construction forecast for 2017, broken out by building type and forecast climate zones (FCZ). The Statewide CASE Team translated this data to building climate zones (BCZ) using the same weighting of FCZ to BCZ as the previous code update cycle (2013), as presented in Table 12.

The projected nonresidential new construction forecast is presented in Table 13. Table 11 provides a more complete definition of the various space types used in the forecast.

Table 11: Description of Space Types used in the Nonresidential New Construction Forecast

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

Table 12:Translation from FCZ to BCZ

Source: CEC Demand Analysis Office

		Building Standards Climate Zones (BCZ)																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Grand Total
Forecast Climate Zones (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%	21.0%	22.8%	54.5%	0.0%	0.0%	1.8%	100%
	4	0.2%	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%	40.4%	0.0%	51.1%	8.1%	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%	7.0%	0.0%	24.5%	57.9%	0.0%	0.0%	0.0%	0.0%	6.7%	0.0%	4.0%	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%	33.0%	0.0%	24.8%	42.2%	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%	0.9%	0.0%	20.2%	75.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.7%	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	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%
	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%
	17	3.0%	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%	0.0%	97.1%	100%

Table 13: Estimated New Nonresidential Construction in 2017 by Climate Zone and Building Type (Million Square Feet)

Source: CEC Demand Analysis Office

Climate Zone	New Construction in 2017 (Million Square Feet)												
	OFF-SMALL	REST	RETAIL	FOOD	NWHSE	RWHSE	SCHOOL	COLLEGE	HOSP	HOTEL	MISC	OFF-LRG	TOTAL
1	0.058	0.016	0.041	0.014	0.040	0.002	0.046	0.018	0.028	0.031	0.094	0.069	0.457
2	0.227	0.088	0.630	0.163	0.327	0.031	0.244	0.163	0.200	0.350	0.742	1.140	4.306
3	0.728	0.408	2.913	0.677	2.518	0.183	1.000	0.625	0.729	1.400	3.894	4.952	20.026
4	0.484	0.190	1.586	0.413	0.595	0.071	0.541	0.408	0.490	0.890	1.641	2.935	10.245
5	0.094	0.037	0.308	0.080	0.116	0.014	0.105	0.079	0.095	0.173	0.319	0.570	1.990
6	0.811	0.825	3.072	0.756	2.649	0.122	0.659	0.649	0.508	0.571	4.144	2.264	17.030
7	0.959	0.300	1.635	0.502	1.004	0.013	0.772	0.448	0.325	1.059	3.077	1.253	11.347
8	1.078	1.106	4.241	1.034	3.588	0.162	0.856	0.931	0.773	0.872	5.860	3.186	23.686
9	0.971	0.916	3.975	0.937	3.287	0.119	0.600	1.095	1.127	1.329	5.376	5.675	25.408
10	1.372	0.707	2.995	0.839	2.630	0.074	0.883	0.580	0.528	1.056	8.010	1.496	21.170
11	0.333	0.088	0.770	0.268	0.875	0.089	0.504	0.156	0.239	0.197	0.737	0.629	4.885
12	1.710	0.502	3.656	1.014	3.157	0.202	1.687	0.678	1.048	1.480	3.637	4.721	23.493
13	0.668	0.205	1.606	0.544	1.706	0.286	1.401	0.390	0.520	0.359	1.884	0.817	10.387
14	0.224	0.138	0.609	0.162	0.527	0.025	0.156	0.128	0.115	0.185	1.472	0.431	4.171
15	0.349	0.096	0.675	0.238	0.761	0.022	0.192	0.098	0.133	0.204	1.123	0.289	4.180
16	0.199	0.106	0.506	0.142	0.449	0.042	0.205	0.122	0.125	0.144	0.931	0.394	3.367
TOTAL	10.264	5.729	29.218	7.784	24.228	1.457	9.852	6.570	6.983	10.301	42.941	30.821	186.148

4.7 Cost-effectiveness Methodology

This measure does not propose mandatory or prescriptive requirements. A lifecycle cost analysis is not necessary because the measure is not proposed to be part of the baseline level of stringency. The energy cost savings were calculated to better understand the energy trade-off benefits for these measures.

4.7.1 Cost Savings Methodology

Energy Cost Savings Methodology

The present value (PV) of the energy impacts were calculated using the method described in the LCC Methodology. In short, the hourly energy impacts estimates for the first year of building operation were multiplied by the 2016 TDV cost values to arrive at the PV of the cost savings over the period of analysis. This analysis used the 15-year nonresidential TDV cost values. This measure is climate sensitive, so the energy cost savings were calculated in each climate zone using TDV values for each unique climate zone. The nonresidential 15-year conversion factor is $0.089/TDVkBTU expressed in 2017 dollars, which is used to convert between kBTU and PV$.

Other Cost Savings Methodology

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

4.8 Environmental Impacts Methodology

4.8.1 Greenhouse Gas Emissions Impacts Methodology

Greenhouse Gas Emissions Impacts Methodology

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

This measure does not recommend changes to the baseline energy budget. It is anticipated that designers that elect to use this new compliance option will combine a thermally driven cooling system with other measures that will allow the building to achieve the required energy budget. We do not anticipate that designers that elect to use this measure will necessarily design buildings that perform more efficiently than is required by the Standards. As such, there are no inherent savings associated with this compliance option. The Statewide CASE Team did evaluate the impacts of complying using this compliance option relative to the prescriptive baseline. As mentioned previously, the prescriptive baseline assumes all-electric systems but thermally driven cooling systems are oftentimes not all-electric. As such the analysis presented in this report assumes some fuel switching. Further, as described in more detail in Section 4.8.3, the Statewide CASE Team does anticipate an incremental increase of onsite emissions from the combustion of fossil fuel and, potentially, renewable fuel such as landfill gas. The GHG emissions impacts presented in this report account for the increase in natural gas use.

4.8.2 Water Use and Water Quality Impacts Methodology

The embedded energy value used in the analysis is 10,045 kWh/million gallons of water (MG). This value was derived from a California Energy Commission PIER study (CEC 2006), which states the embedded energy values presented in the report "are sufficient for informing policy and prioritization of research and development investments." See Appendix A: Environmental Impacts Methodology for a more detailed description of the methodology used to calculate embedded energy savings.

Per ton of cooling, water cooled absorption chillers require larger heat rejection equipment (cooling towers) and therefore will use more water on-site as compared to a water cooled electric chiller. If evaporative cooling is used (with desiccants) more water will also be used. However, less water is needed at the power plants due to the electricity savings and demand reduction. The water impacts presented in Section 5.3.2 present the increased water use from larger heat rejection equipment, but it does not account for the reduction in water use at the power plant.

4.8.3 Other Impacts Methodology

The Statewide CASE Team does anticipate an incremental increase of onsite emissions from the combustion of fossil fuel and, potentially, renewable fuel such as landfill gas. Not all projects will have increased combustion. This combustion will be a result of systems that are generating onsite electricity (turbine and engine generators), supplemental/back-up boilers (used when waste heat and/or renewable heat is not available but cooling is required), and other combustion equipment that is used for supplemental/back-up heating. In some cases, the cooling system may be direct-fired (e.g. direct-fired absorption chiller and utilizes waste heat to preheat combustion air) that would also increase onsite combustion. The onsite emissions increase is frequently offset by the decrease in power plant emissions. The Statewide CASE Team assumed that the proposed code change would apply to only five new chillers in the first year. Perhaps one or two of these units will be direct-fired. The other units will indirectly result in increased combustion from the back-up heating sources. Based on this small number of units there is not a significant environmental impact in the state air districts resulting from approval of this proposal.

5. ANALYSIS AND RESULTS

Results from the energy, demand, and environmental impacts analyses are presented in this section. This measure does not propose mandatory or prescriptive requirements. A lifecycle cost analysis is not necessary because the measure is not proposed to be part of the baseline level of stringency. The energy cost savings were calculated to better understand the energy trade-off benefits for these measures.

5.1 Energy Impacts Results

5.1.1 Per Unit Energy Impacts Results

Per unit energy and demand impacts of the proposed measure are presented in Table 14. Per unit savings for the first year are expected to be 216 kilowatt-hours per year per ton of cooling (kWh/yr/ton) and -406 therms/yr/ton (increased consumption). Demand savings are expected to be 0.12 kilowatts per ton of cooling (kW/ton).

It is estimated that the first year TDV electricity and natural gas savings will be 7,800 kBTU/ton and -3,300 kBTU/ton (increased consumption), respectively. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. Thermally driven cooling can help reduce or flatten the electric peaks in a building's load profile for peak electricity savings.

Table 14: Energy Impacts per Unit[1]

Climate Zone	Per Unit First Year Savings[2]			Per Unit First Year TDV Savings[3]	
	Electricity Savings[4] (kWh/yr/ton)	Demand Savings (kW/ton)	Natural Gas Impact (Therms/yr/ton)	TDV Electricity Savings[5] (kBTU/ton)	TDV Natural Gas Impact[5] (kBTU/ton)
Climate Zone 1	137	0.09	-212	5,917	-2,426
Climate Zone 2	137	0.09	-212	5,917	-2,426
Climate Zone 3	137	0.09	-212	5,917	-2,426
Climate Zone 4	137	0.09	-212	5,917	-2,426
Climate Zone 5	251	0.10	-444	8,140	-3,419
Climate Zone 6	251	0.10	-444	8,140	-3,419
Climate Zone 7	251	0.10	-444	8,140	-3,419
Climate Zone 8	258	0.13	-366	8,990	-4,046
Climate Zone 9	258	0.13	-366	8,990	-4,046
Climate Zone 10	258	0.13	-366	8,990	-4,046
Climate Zone 11	207	0.12	-383	7,367	-3,094
Climate Zone 12	207	0.12	-383	7,367	-3,094
Climate Zone 13	207	0.12	-383	7,367	-3,094
Climate Zone 14	278	0.14	-651	9,194	-3,861
Climate Zone 15	278	0.14	-651	9,194	-3,861
Climate Zone 16	163	0.13	-378	7,119	-2,848

1. The unit is ton of cooling capacity.
2. Savings from one ton of cooling capacity for the first year the building is in operation.
3. TDV energy impacts for one ton of cooling capacity for the first year the building is in operation.
4. Site electricity savings. Does not include TDV of electricity savings.
5. Calculated using CEC's 2016 TDV factors and methodology. Includes savings from electricity and natural gas. The negative values for natural gas indicate increased consumption rather than savings.

5.1.2 Statewide Energy Impacts Results

First Year Statewide Energy Impacts

The statewide energy impacts of the proposed measure are presented in Table 15. During the first year buildings complying with the 2016 Title 24 Standards are in operation, the proposed measure is expected to reduce annual statewide electricity use by 1.2 GWh with an associated demand reduction of 0.6 MW. Natural gas use is expected to increase by 2.2 MMtherms.

Table 15: Statewide Energy Impacts

	First Year Statewide Savings[1]			First Year TDV Savings[2]	
	Electricity Savings[3] (GWh)	Power Demand Reduction (MW)	Natural Gas Savings (MMtherms)	TDV Electricity Savings[4] (Million kBTU)	TDV Natural Gas Savings[4] (Million kBTU)
Thermally driven cooling	1.2	0.6	-2.2 (increase)	42	-18 (increase)

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

5.2 Cost-effectiveness Results

This measure does not propose mandatory or prescriptive requirements. A lifecycle cost analysis is not necessary because the measure is not proposed to be part of the baseline level of stringency. The energy cost savings were calculated to better understand the energy trade-off benefits for these measures.

5.2.1 Cost Savings Results

Energy Cost Savings Results

The per unit TDV energy cost savings over the 15 year period of analysis are presented in Table 16. Refer to Section 4.7.1 Cost Savings Methodology for the calculation details. The proposed measure results in cost savings in every climate zone.

Table 16: TDV Energy Cost Savings Over 15 Year Period of Analysis - Per Unit

Climate Zone	TDV Electricity Cost Savings (2017 PV$/ton)	TDV Natural Gas Cost Savings (2017PV$/ton)	Total TDV Energy Cost Savings (2017 PV$/ton)
Climate Zone 1	$527	($216)	$311
Climate Zone 2	$527	($216)	$311
Climate Zone 3	$527	($216)	$311
Climate Zone 4	$527	($216)	$311
Climate Zone 5	$724	($304)	$420
Climate Zone 6	$724	($304)	$420
Climate Zone 7	$724	($304)	$420
Climate Zone 8	$800	($360)	$440
Climate Zone 9	$800	($360)	$440
Climate Zone 10	$800	($360)	$440
Climate Zone 11	$656	($275)	$380
Climate Zone 12	$656	($275)	$380
Climate Zone 13	$656	($275)	$380
Climate Zone 14	$818	($344)	$475
Climate Zone 15	$818	($344)	$475
Climate Zone 16	$634	($253)	$380

The Statewide CASE Team estimates that TDV energy cost savings for 15 years of all thermally driven cooling measures installed during the first year the 2016 Standards are in effect will be $1.97 million.

Other Cost Savings Results

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

5.3 Environmental Impacts Results

5.3.1 Greenhouse Gas Emissions Results

Table 17 presents the estimated first year GHG emissions impacts of the proposed code change. During the first year the 2016 Standards are in effect the proposed measure will result in an increase in GHG emissions of 11,200 $MTCO_2e$. As discussed in Section 4.8.1, this increase is attributed, in part, to the switch from all-electric cooling . The monetary value of GHG emissions is included in TDV cost factors (TDV $) for each hour of the year and thus included in the Cost-effectiveness Analysis presented in this report.

Table 17: Statewide First Year Greenhouse Gas Emissions Impacts

	Increased GHG Emissions[1] ($MTCO_2e$/yr)
Thermally driven cooling	11,200

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

5.3.2 Water Use and Water Quality Impacts

Per ton of cooling, water cooled absorption chillers require larger heat rejection equipment (cooling towers) and therefore will use more water on-site as compared to a water cooled electric chiller. If evaporative cooling is used (with desiccants) more water will also be used. However, less water is needed at the power plants due to the electricity savings and demand reduction. Impacts on the onsite water use and water quality are presented in Table 18. The values presented in the table below do not account for water savings at the power plant.

Table 18: Impacts of Water Use and Water Quality

	On-Site Water Savings[1] (gallons/yr)	Embedded Energy Savings[2] (kWh/yr)	Impact on Water Quality Material Increase (I), Decrease (D), or No Change (NC) compared to existing conditions			
			Mineralization (calcium, boron, and salts)	Algae or Bacterial Buildup	Corrosives as a Result of PH Change	Others
Impact (I, D, or NC)	I	I	NC	NC	NC	NC
Per Unit Impacts[3]	2,800	28	-	-	-	-
Statewide Impacts (first year)	15,600,000	156,000	-	-	-	-

2. Does not include water savings at power plant
3. Assumes embedded energy factor of 10,045 kWh per million gallons of water.
4. The unit is tons of cooling capacity. For description of prototype buildings refer to Methodology section below.

5.3.3 Other Impacts Results

The Statewide CASE Team does anticipate that a subset of the thermally driven cooling systems will use on-site fuel combustion to provide a source of heat when other heat sources are not available. The Statewide CASE Team did not conduct a quantitative analysis of the impacts of on-site combustion. However, we anticipate that only one or two systems that use on-site combustion will be installed during the first year the Standards are in effect. Based on this small number of systems that will use on-site combustion, the Statewide CASE Team anticipates that this measure will not result in significant environmental impact in the state air districts resulting from approval of this proposal.

6. PROPOSED LANGUAGE

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

6.1 Standards

No revisions are needed.

6.2 Reference Appendices

No revisions are needed.

6.3 ACM Reference Manual

5.7.7.2 Desiccant

Desiccant Heat Source: Definition

- Gas – Hydronic – the regeneration heat load is met with a gas-fired heater
- Hot water – the heat load is met with hot water from the plant
- <u>Waste hot water – the regeneration heat load is met with waste hot water</u>
- <u>Solar hot water – the regeneration heat load is met with hot water from solar thermal</u>
- <u>Condenser heat – the regeneration heat load is met with hot air from a condenser</u>

5.8.2 Chillers

Definition: The type of chiller, either a vapor-compression chiller, ~~or~~ an absorption chiller<u>, or an adsorption chiller</u>.

Chiller Fuel Source

- Electricity (for all vapor-compression chillers)
- Gas (Absorption units only, designated as direct-fired units)
- Hot Water (Absorption <u>and adsorption</u> units only, designated as indirect-fired units)
- Steam (Absorption units only, designated as indirect-fired units)

Chiller Rated Efficiency: add adsorption chiller

Fuel and Steam Chiller Cooling Efficiency Adjustment Curves

Default Curves for Steam-Driven Single and Double Effect Absorption Chillers

Default Curves for Direct-Fired Double Effect Absorption Chillers

Default Curves for Hot Water-Driven Absorption and Adsorption Chillers. The default curves are the same format as those for the Steam-Driven Single and Double Effect Absorption Chillers.

5.10 On-Site Power and Heat Generation

Building projects may incorporate other on-site electricity generation equipment, such as cogeneration plants or fuel cells that make electricity and produce heat. Projects may also include wind turbines. These systems may be modeled in various ways and the building descriptors described below should be considered an example of one set. In all cases, the baseline building will be modeled without on-site generation equipment. If there is no thermal link between the power generation equipment and building equipment (such as heat recovery from CHP), on-site power generation can be modeled in a separate process; otherwise, it needs to be linked to the building simulation.

When on-site renewable energy or site recovered thermal energy is used to provide space cooling, the energy consumption of the proposed cooling system includes all energy consumption required to extract the heat and to convert this into cooling energy and all energy required to deliver the cooling to spaces within the building. If thermal storage is used any heat losses and equipment energy usage is also accounted for. The solar energy or thermal energy recovered from a process is treated as free and thus is not included in the energy budget. There is no credit for cooling energy created that is not used for space conditioning on site.

RESERVED FOR FUTURE USE – onsite power generation systems are not currently modeled for Title 24 compliance or reach. Qualifying solar water heating systems are specified by a solar fraction, and referenced in Section 5.9.

6.4 Compliance Manuals

No revisions to the compliance manual are needed.

6.5 Compliance Forms

No revisions to the compliance forms are needed.

7. Proposed Changes to CBECC-Com

CBECC-Com is a nonresidential compliance software approved by the CEC for Title 24 compliance. As of early September 2014, CBECC-Com 2013 v2b (Build 609) is the current approved version. Another version is publicly available, CBECC-Com 2013 v3-beta (Build 645), but has not yet been approved by the CEC for Title 24 compliance. A number of changes to CBECC-Com v2b and v3beta are needed for the software to correctly handle thermally driven cooling systems. These changes are described here. In addition, the CBECC-Com User Manual will need updated based on these revisions.

7.1 Absorption and Adsorption Chillers

The CBECC-Com Chiller Data input screen does not yet allow for absorption or adsorption chillers. The Type field includes centrifugal, reciprocating, scroll, and screw chiller types. This needs to be expanded to include the following selection options. Note that adsorption chillers are only available in single-stage and not two-stage.

- Single-stage absorption, air-cooled
- Single-stage absorption, water-cooled
- Two-stage absorption, indirect-fired
- Two-stage absorption, direct-fired
- Single-stage adsorption

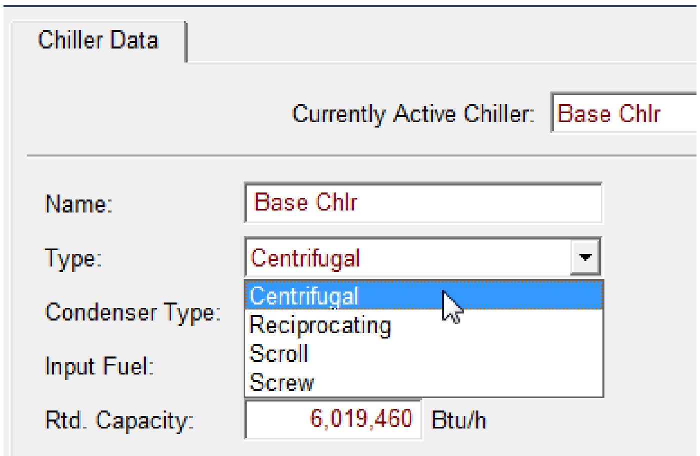

Figure 9: CBECC Chiller Type Selection

The chiller Input Fuel field as currently available in CBECC is shown below.

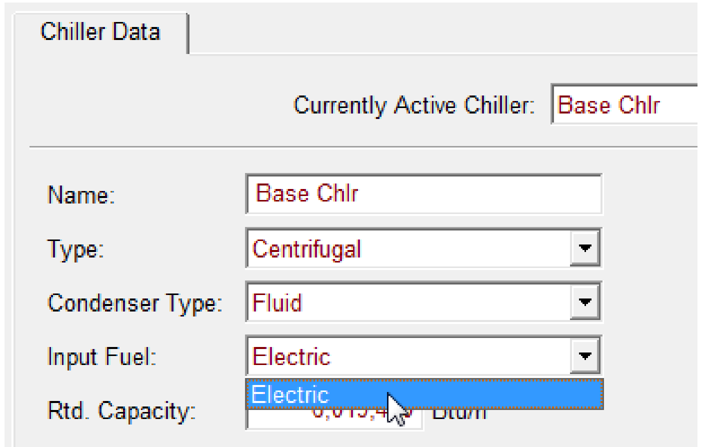

Figure 10: CBECC Chiller Input Fuel Selection

The chiller Input Fuel field should be modified to allow for the following fuel options for absorption chillers:

- Direct-fired from natural gas
- Exhaust-fired from onsite recovered heat source (waste heat)
- Hot water from a natural gas boiler
- Hot water from solar thermal
- Hot water from district heating plant
- Hot water from onsite recovered heat source (waste heat)
- Hot water from electric chiller condenser heat
- Steam from natural gas boiler
- Steam from district heating plant
- Steam from onsite recovered heat source (waste heat)
- Other onsite recovered heat source (waste heat)

The chiller Input Fuel field should be modified to allow for the following fuel options for adsorption chillers. Note that steam, direct-fired, or exhaust-fired are not input fuel options for adsorption chillers due to the batch cooling/heating nature of the process.

- Hot water from a natural gas boiler
- Hot water from solar thermal
- Hot water from district heating plant
- Hot water from onsite recovered heat source (waste heat)
- Hot water from electric chiller condenser heat
- Other onsite recovered heat source (waste heat)

The chiller Input Fuel field shall allow the user to select multiple fuel sources of a common fuel type. That is, choose multiple sources of hot water or choose multiple sources of steam, with one designated as the primary source and the other as a backup source. For example, a user could select the primary fuel source as hot water from solar thermal and the backup as hot water from a natural gas boiler. In this case, the user shall input a fuel schedule by fuel type and hour of the day and day of the week. The schedule type should be On-Off or Fractional. When solar thermal is selected as the primary fuel source, the simulation engine should determine when the solar thermal hot water supply is sufficient to meet the demand and thus when to rely on the backup fuel source.

On-site renewable energy sources or recovered energy shall not be considered to be purchased energy and shall not be included in the energy budget for the proposed design building. Where on-site renewable or recovered sources are used, the energy budget for the standard design building shall be based on the energy source used as the backup energy source or electricity if no backup energy source has been specified. The following table shows which fuel options shall be included in the energy budget for the proposed design building.

Table 19: Fuel Sources Included in Energy Budget for the Proposed Design Building

Fuel Source	Include in Energy Budget for Proposed Design?
Direct-fired from natural gas	Yes
Exhaust-fired from onsite recovered heat source (waste heat)	No
Hot water from a natural gas boiler	Yes
Hot water from solar thermal	No
Hot water from district heating plant	Yes
Hot water from onsite recovered heat source (waste heat)	No
Hot water from electric chiller condenser heat	No
Steam from natural gas boiler	Yes
Steam from district heating plant	Yes
Steam from onsite recovered heat source (waste heat)	No
Other onsite recovered heat source (waste heat)	No

In all cases, the software shall allow hot water and steam loops to connect with the absorption chillers and hot water loops with the adsorption chillers. For example, a solar hot water loop will need to connect with the HVAC plant loop when the user specifies such a configuration.

The Chiller Data input screen needs to allow for the numerous parameters and performance curves used as inputs to EnergyPlus. Changes to the software should be coordinated with changes to EnergyPlus as described in the section Proposed Changes to EnergyPlus. For example, the default values and range of allowed values for the various parameters should be coordinated in particular. These parameters and performance curves are extensive and are described in more detail in the section Proposed Changes to EnergyPlus.

Finally, the software shall follow these procedures:

When on-site renewable energy or site recovered thermal energy is used to provide space cooling, the energy consumption of the proposed cooling system includes all energy consumption required to extract the heat and to convert this into cooling energy and all energy required to deliver the cooling to spaces within the building. If thermal storage is used any heat losses and equipment energy usage is also accounted for. The solar energy or thermal energy recovered from a process is treated as free and thus is not included in the energy budget. There is no credit for cooling energy created that is not used for space conditioning on site.

7.2 Desiccant Cooling

CBECC-Com does not yet allow for desiccant cooling as a modeling option. The software needs to allow for the numerous parameters and performance curves used as inputs to EnergyPlus. Changes to the software should be coordinated with changes to EnergyPlus as described in the section Proposed Changes to EnergyPlus. For example, the default values and range of allowed values for the various parameters should be coordinated in particular. These parameters and performance curves are described in more detail in the section Proposed Changes to EnergyPlus. In addition, the CBECC-Com User Manual will need updated based on these revisions.

The software shall follow these procedures:

When on-site renewable energy or site recovered thermal energy is used to provide space cooling, the energy consumption of the proposed cooling system includes all energy consumption required to extract the heat and to convert this into cooling energy and all energy required to deliver the cooling to spaces within the building. If thermal storage is used any heat losses and equipment energy usage is also accounted for. The solar energy or thermal energy recovered from a process is treated as free and thus is not included in the energy budget. There is no credit for cooling energy created that is not used for space conditioning on site.

8. PROPOSED CHANGES TO ENERGYPLUS

CBECC-Com relies on EnergyPlus version 8.1 as its simulation engine, which comes bundled with the CBECC-Com installation package. A number of changes to EnergyPlus are needed for the software to correctly handle thermally driven cooling systems. These changes are described here.

8.1 Absorption and Adsorption Chillers

The EnergyPlus object Chiller:Absorption:Indirect is an absorption chiller model that relies on performance curves and various parameters to describe the chiller operation and performance. The following table shows the complete list of parameters available as inputs for this object. A similar EnergyPlus object must be developed for adsorption chillers as EnergyPlus does not specifically support adsorption chillers. As a workaround, a user could use Chiller:Absorption:Indirect with adsorption chiller performance data. The list of input parameters for adsorption chillers will be identical to that for absorption chillers.

Field	Units
Name	
Nominal Capacity	W
Nominal Pumping Power	W
Chilled Water Inlet Node Name	
Chilled Water Outlet Node Name	
Condenser Inlet Node Name	
Condenser Outlet Node Name	
Minimum Part Load Ratio	
Maximum Part Load Ratio	
Optimum Part Load Ratio	
Design Condenser Inlet Temperature	C
Condenser Inlet Temperature Lower Limit	C
Chilled Water Outlet Temperature Lower Limit	C
Design Chilled Water Flow Rate	m3/s
Design Condenser Water Flow Rate	m3/s
Chiller Flow Mode	
Generator Heat Input Function of Part Load Ratio Curve Name	
Pump Electric Input Function of Part Load Ratio Curve Name	
Generator Inlet Node Name	
Generator Outlet Node Name	
Capacity Correction Function of Condenser Temperature Curve Name	
Capacity Correction Function of Chilled Water Temperature Curve Name	
Capacity Correction Function of Generator Temperature Curve Name	
Generator Heat Input Correction Function of Condenser Temperature Curve Name	
Generator Heat Input Correction Function of Chilled Water Temperature Curve Name	
Generator Heat Source Type	
Design Generator Fluid Flow Rate	m3/s
Temperature Lower Limit Generator Inlet	C
Degree of Subcooling in Steam Generator	C
Degree of Subcooling in Steam Condensate Loop	C
Sizing Factor	

Figure 11: EnergyPlus Chiller:Absorption:Indirect Input Screen

The first half of the Chiller:Absorption:Indirect object input screen includes a few inputs to describe how the chiller connects with the rest of the simulation model (e.g. chilled water inlet and outlet node names). The first half of this screen also includes input fields related to basic characteristics for the modeled chiller (e.g. nominal capacity and minimum part load ratio), which should be readily available from product catalogs and communication with sales engineers. The second half of the Chiller:Absorption:Indirect object input screen includes inputs for the chiller performance curves (e.g. how the capacity varies with chilled water temperature). These curves should be readily available from product catalogs, communication with sales engineers, or monitored data from prior projects.

The input fields for the first half of the input screen are described here:

The *Nominal Capacity* is a user defined input for the cooling capacity in units of Watts.

The *Nominal Pumping Power* is a user defined input that contains the nominal pumping power of the absorber in Watts. From stakeholder input, the pumping power for adsorption chillers varies linearly with cooling capacity as described by the following equation. If the user does not input a value to this field, then the equation should be used to estimate the value.

$$\text{Nominal Pumping Power} = 0.0012 * \text{Nominal Capacity} + 125$$

The field *Minimum Part Load Ratio* contains the chiller's minimum part-load ratio. The expected range is between 0 and 1, while the typical value is between 0.05 and 0.12 per stakeholder input. The default value should be 0.12. The minimum part load is not the load where the machine shuts off, but where the amount of power remains constant to produce smaller loads than this fraction.

The field *Maximum Part Load Ratio* contains the chiller's maximum part-load ratio. This value may exceed 1, but the normal range is between 0 and 1.15. The typical value is between 1.0 and 1.15, while 1.0 should be set as the default value.

The field *Optimum Part Load Ratio* contains the chiller's optimum part-load ratio. This is the part-load ratio at which the chiller performs at its maximum COP. The normal range is between 1.0 and 1.1. The typical value is 1.0, which should be set as the default value.

The field *Design Condenser Inlet Temperature* contains the chiller's condenser inlet design temperature in Celsius. The default value for this field is 30º C (also confirmed with stakeholder input) and is only used when the Design Chilled Water Flow Rate is auto-sized.

The field *Condenser Inlet Temperature Lower Limit* contains the chiller's lower limit for the condenser entering water temperature in Celsius. The default value for this field is 15ºC. Per stakeholder input, this value can be as low as 4°C. If this limit is exceeded, a warning message will report the incident. No correction to chiller capacity is made for low condenser entering water temperatures.

The field *Chilled Water Outlet Temperature Lower Limit* contains the chiller's lower limit for the evaporator leaving water temperature in Celsius. The default value for this field is 5ºC. Per stakeholder input, this value can be as low as 3°C. If this limit is exceeded, a warning message will report the incident. No correction to chiller capacity is made for low evaporator leaving water temperatures.

The field *Design Chilled Water Flow Rate* specifies the design evaporator volumetric flow rate in cubic meters per second. The value specified must be greater than 0 or this field is auto-sizable. For variable volume chiller this is the maximum flow and for constant flow chiller this is the design flow rate. For adjustable flowrates, the flow is typically between 50% and 120% of design flow.

The field *Design Condenser Water Flow Rate* specifies the chiller's design condenser water flow rate in cubic meters per second. The value specified must be greater than 0 or this field is auto-sizable.

The following tables summarize the basic performance data of typical absorption and adsorption chillers based on stakeholder input.

Table 20: Performance Data for Typical Single-Stage Absorption Chillers

	Typical Small Chiller	Typical Medium Chiller	Typical Large Chiller	Units
Nominal Cooling Capacity	205	2,046	10,230	kW
Rated COP	0.76	0.76	0.76	
Power Demand	2.5	8.6	27.3	kW
Minimum Part Load Ratio	0.05	0.05	0.05	
Maximum Part Load Ratio	1.15	1.15	1.15	
Design Condenser Water Flow Rate	61.7	616	3082	m3/h
Design Condenser Inlet Temperature	30	30	30	C
Min Condenser Water Temp	10	10	10	C
Design CHW Flow Rate	25.1	251	1253	m3/h
Adjustable CHW Flow Rate	50% - 120%	50% - 120%	50% - 120%	%
Design Leaving CHW Temp	7	7	7	C
Min Leaving CHW Temp	5	5	5	C
Design Hot Water Flow Rate	23.2	232	1158	m3/h
Design Hot Water Inlet Temperature	98	98	98	C

Source: Broad and SOLID

Table 21: Performance Data for Typical Two-Stage Absorption Chillers

	Typical Small Chiller	Typical Medium Chiller	Typical Large Chiller	Units
Nominal Cooling Capacity	233	2,326	11,630	kW
Rated COP	1.41	1.41	1.41	
Power Demand	1.7	10.2	34.9	kW
Minimum Part Load Ratio	0.05	0.05	0.05	
Maximum Part Load Ratio	1.15	1.15	1.15	
Design Condenser Water Flow Rate	48.8	488	2442	m3/h
Design Condenser Inlet Temperature	30	30	30	C
Min Condenser Water Temp	10	10	10	C
Design CHW Flow Rate	28.5	285	1429	m3/h
Adjustable CHW Flow Rate	50% - 120%	50% - 120%	50% - 120%	%
Design Leaving CHW Temp	7	7	7	C
Min Leaving CHW Temp	5	5	5	C
Design Hot Water Flow Rate	10.3	103	514	m3/h
Design Hot Water Inlet Temperature	180	180	180	C

Source: Broad and SOLID

Table 22: Performance Data for Typical Adsorption Chillers

	Typical Small Chiller	Typical Medium Chiller	Typical Large Chiller	Units
Nominal Cooling Capacity	106	528	1,161	kW
Nominal Pumping Power	0.25	0.25	1.5	kW
Minimum Part Load Ratio	0.12	0.12	0.12	
Maximum Part Load Ratio	1	1	1	
Optimum Part Load Ratio	1	1	1	
Design Condenser Water Flow Rate	48	238	524	m3/h
Design Condenser Inlet Temperature	29	29	29	C
Min Condenser Water Temp	4.4	4.4	4.4	C
Max Condenser Water Temp	35	35	35	C
Design CHW Flow Rate	16	82	180	m3/h
Design Leaving CHW Temp	7.2	7.2	7.2	C
Min Leaving CHW Temp	3.3	3.3	3.3	C
Max Leaving CHW Temp	21	21	21	C
Design Hot Water Flow Rate	27	136	300	m3/h
Design Hot Water Inlet Temperature	91	91	91	C
Min Hot Water Inlet Temperature	54	54	54	C
Max Hot Water Inlet Temperature	93	93	93	C

Source: ECO-MAX and Power Partners

The input fields for the second half of the input screen, namely the various performance curves, are described here:

The field *Generator Heat Input Function of Part Load Ratio Curve* specifies the name of the curve used to determine the heat input to the chiller. The curve is a quadratic or cubic curve that characterizes the heat input as a function of chiller part-load ratio. The curve output is multiplied by the chiller's nominal capacity and operating part-load ratio or minimum part-load ratio, whichever is greater, to determine the amount of heat input required for the given operating conditions. This field is related to chiller COP as a function of part-load ratio. The following series of figures show how the COP varies by part-load ratio for a variety of typical absorption and adsorption chillers. This is based on performance data provided by various stakeholders. The curve shapes primarily depend on the type of chiller, number of stages, and fuel source.

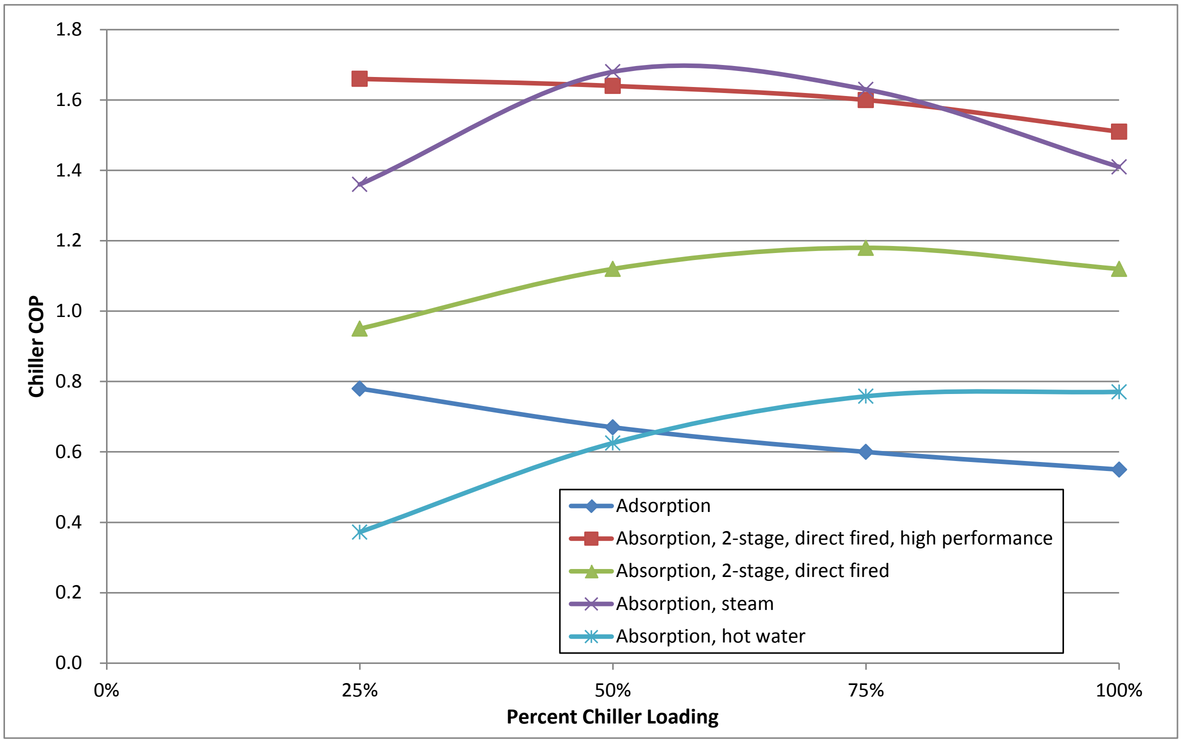

Figure 12: Chiller COP by Percent Loading

Source: ECO-MAX, Power Partners, Broad, SOLID

Similarly, the next figure shows how the COP varies by part-load ratio but normalized so the COP is 1.0 at full load.

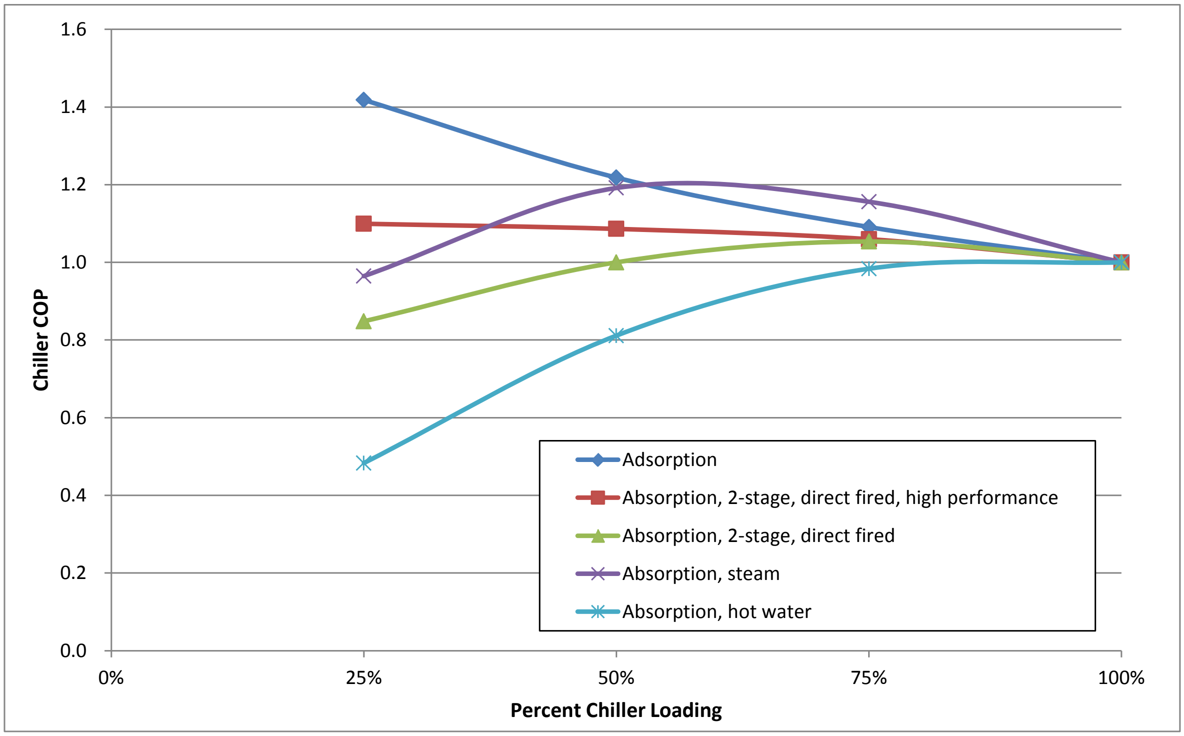

Figure 13: Chiller COP by Percent Loading Normalized to Full Load

Source: ECO-MAX, Power Partners, Broad, SOLID

Finally, the next figure shows how the COP varies by part-load ratio but including the performance curve data for one additional chiller. This new chiller curve is provided as an example file in EnergyPlus called ExhaustFired.idf. This particular curve significantly deviates from the other five chiller performance curves. We recommend the EnergyPlus developers review this ExhaustFired.idf performance curve for potential errors and revise the ExhaustFired.idf example file if needed.

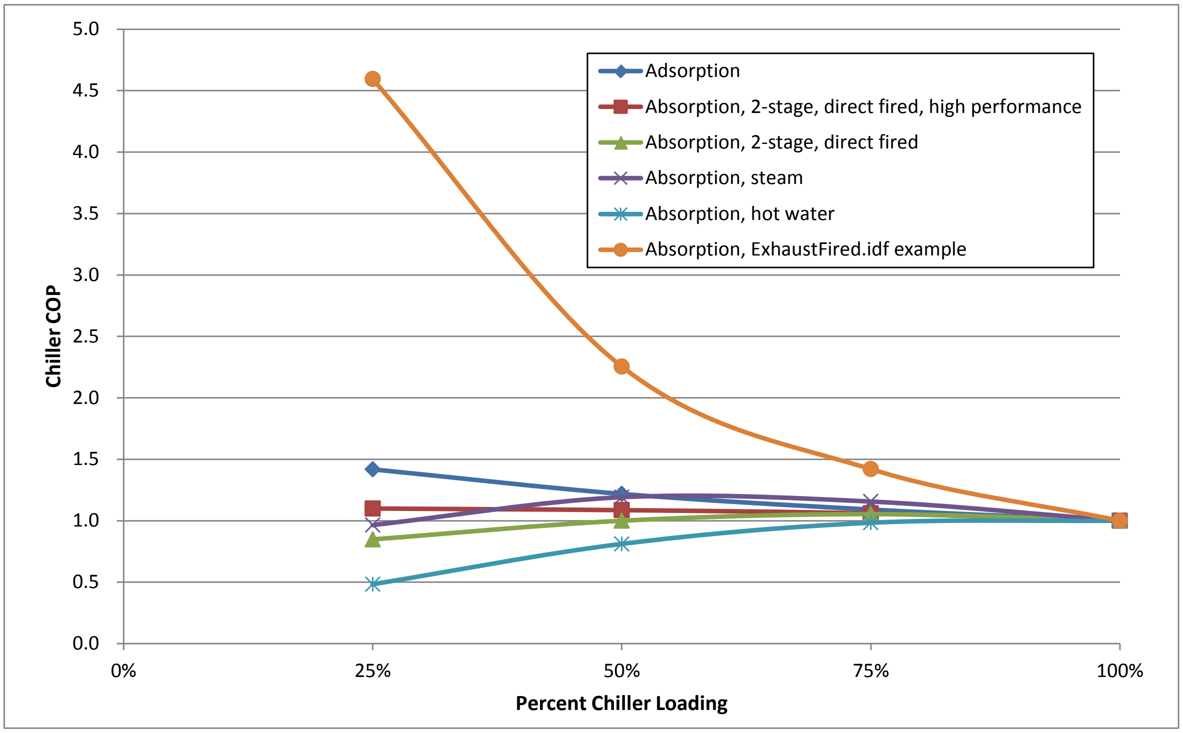

Figure 14: Chiller COP by Percent Loading Normalized to Full Load with ExhaustFired.idf Example Curve

Source: ECO-MAX, Power Partners, Broad, SOLID

The field *Pump Electric Input Function of Part Load Ratio Curve* specifies the name of the curve used to determine the pump electrical input to the chiller. The curve is a quadratic or cubic curve that characterizes the pump electrical power as a function of chiller part-load ratio. The curve output is multiplied by the chiller's nominal pumping power and operating part-load ratio or minimum part-load ratio, whichever is greater, to determine the amount of pumping power required for the given operating conditions.

The field *Capacity Correction Function of Condenser Temperature Curve* specifies the name of a quadratic or cubic curve that correlates the chiller's evaporator capacity as a function of condenser entering water temperature. This curve is used to correct nominal capacity at off-design condensing temperatures.

The field *Capacity Correction Function of Chilled Water Temperature Curve* specifies the name of a quadratic or cubic curve that correlates the chiller's evaporator capacity as a function of evaporator leaving water temperature. This curve is used to correct nominal capacity at off-design evaporator temperatures.

The field *Capacity Correction Function of Generator Temperature Curve* specifies the name of a quadratic or cubic curve that correlates the chiller's evaporator capacity as a function of generator entering water temperature. This curve is used to correct nominal capacity at off-design evaporator temperatures and is only used when the Generator Fluid Type is specified as Hot Water.

The following equations describe the capacity correction as a function of condenser, chilled water, and generator temperatures, as mentioned in the previous three paragraphs.

$$CAPFT_{evaporator} = a + b\left(T_{evaporator}\right) + c\left(T_{evaporator}\right)^2 + d\left(T_{evaporator}\right)^3$$

$$CAPFT_{condenser} = e + f\left(T_{condenser}\right) + g\left(T_{condenser}\right)^2 + h\left(T_{condenser}\right)^3$$

$$CAPFT_{generator} = i + j\left(T_{generator}\right) + k\left(T_{generator}\right)^2 + l\left(T_{generator}\right)^3 \quad \text{(Hot Water only)}$$

Where:

$CAPFT_{evaporator}$ = Capacity correction (function of evaporator temperature) factor

$CAPFT_{condenser}$ = Capacity correction (function of condenser temperature) factor

$CAPFT_{generator}$ = Capacity correction (function of generator temperature) factor

$T_{evaporator}$ = evaporator outlet water temperature [°C]

$T_{condenser}$ = condenser inlet water temperature [°C]

$T_{generator}$ = generator inlet water temperature [°C]

These equation coefficients are a user defined input that will vary with each chiller. The following table shows some example data for an adsorption chiller as provided by stakeholder input. These values could be used as default values in EnergyPlus.

Table 23: Coefficients for Typical Adsorption Chiller Capacity Correction Function of Generator Temperature

Equation coefficients	Default values for adsorption chiller
a	0.7758
b	0.0305
c	0.0001
d	0
e	2.0711
f	-0.0646
g	0.0017
h	0
i	-1.0966
j	-0.01
k	0.0009
l	0

The associated performance curves are included in the following three figures. These curves could be used as default performance curves in EnergyPlus. They are based on performance data provided by stakeholders.

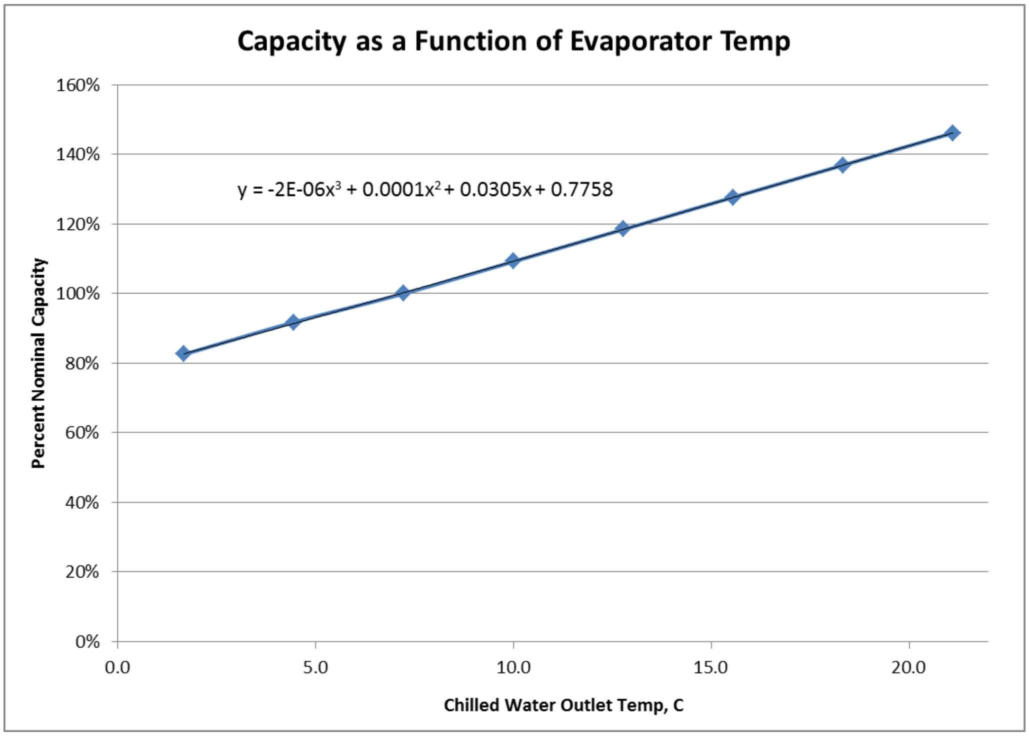

Figure 15: Typical Adsorption Chiller Capacity as a Function of Evaporator Temperature

Source: ECO-MAX and Power Partners

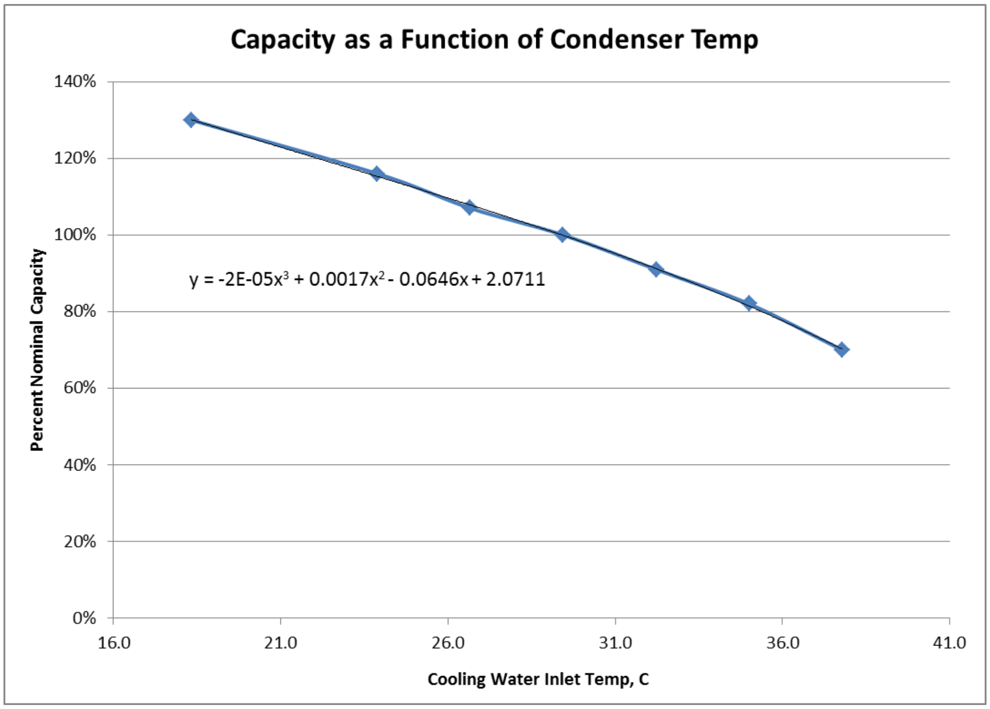

Figure 16: Typical Adsorption Chiller Capacity as a Function of Condenser Temperature

Source: ECO-MAX and Power Partners

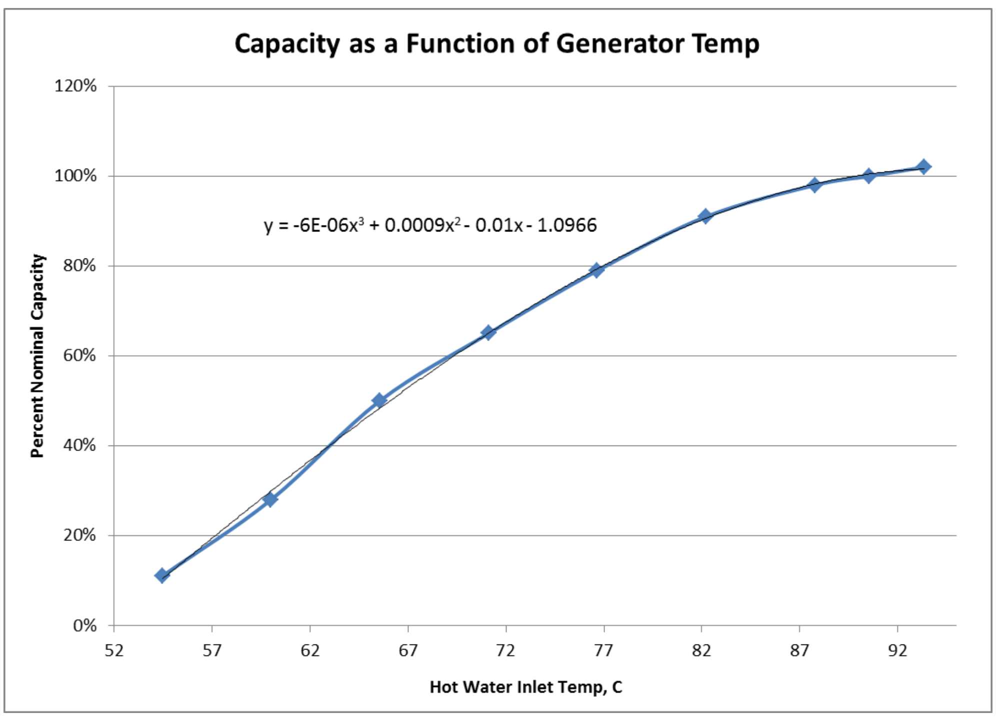

Figure 17: Typical Adsorption Chiller Capacity as a Function of Generator Temperature

Source: ECO-MAX and Power Partners

The field *Generator Heat Input Correction Function of Condenser Temperature Curve* specifies the name of a quadratic or cubic curve that correlates the chiller's heat input as a function of condenser entering water temperature. This curve is used to correct generator heat input at off-design condensing temperatures.

The field *Generator Heat Input Correction Function of Chilled Water Temperature Curve* specifies the name of a quadratic or cubic curve that correlates the chiller's heat input as a function of evaporator leaving water temperature. This curve is used to correct generator heat input at off-design evaporator temperatures.

8.2 Desiccant Cooling

EnergyPlus already allows for desiccant cooling as a modeling option. It provides two options as described here. No apparent changes are needed to the software to support thermally driven cooling.

The EnergyPlus object Dehumidifier:Desiccant:NoFans models a solid desiccant dehumidifier (excluding associated fans). It is described here as reported in the EnergyPlus Input-Output Reference Manual:

> The process air stream is the air which is dehumidified. The regen air stream is the air which is heated to regenerate the desiccant. This object determines the process air outlet conditions, the load on the regeneration heating coil, the electric power consumption for the wheel rotor motor, and the regeneration air fan mass flow rate. All other heat exchangers are modeled as separate objects connected to the inlet and outlet nodes of the dehumidifier. The solid desiccant dehumidifier is typically used in an AirLoopHVAC:OutdoorAirSystem object, but can also be specified in any AirLoopHVAC. The regeneration heating coil can be Gas, Electric, Steam, or Hot Water coil. When hot water coil is selected as regeneration heating coil user-defined curves designed for lower temperature operation must be specified in the input field Performance Model Type along with the Nominal Regeneration Temperature input field. The default performance model type is valid for higher nominal regeneration temperature (e.g. 121C).

The EnergyPlus object Dehumidifier:Desiccant:System also models a solid desiccant dehumidifier. It is described here as reported in the EnergyPlus Input-Output Reference Manual:

> The Dehumidifier:Desiccant:System object models the dehumidification of an air stream, normally called the process air stream. A second heated air stream, called the regeneration air stream, is used to remove the collected moisture from the desiccant heat exchanger and this moisture-laden air is then usually exhausted from the building. This Dehumidifier:Desiccant:System object is similar to the Dehumidifier:Desiccant:NoFans object but has some additional modeling capabilities.
>
> The Dehumidifier:Desiccant:System object in EnergyPlus is a compound object that can be placed anywhere in an air loop (AirLoopHVAC). Common locations for this object are in an AirLoopHVAC:OutdoorAirSystem or in the main air loop (AirLoopHVAC)

downstream of a cooling coil (postcooling desiccant dehumidifier). This compound object coordinates the operation of several ‘children’ objects: a desiccant heat exchanger, a regeneration air fan, and an optional regeneration air heater. Gas, Electric, Steam, or Hot Water heating coils can be used for regenerator air heaters. If this dehumidifier is placed in the main air loop immediately downstream of a direct expansion (DX) cooling coil, then the dehumidifier’s operation can be coordinated with the operation of the companion DX coil and it is also possible to specify that the DX system’s condenser waste heat can be used to help regenerate the desiccant heat exchanger. For the case of condenser waste heat regeneration, an optional exhaust fan can also be modeled by this desiccant dehumidifier compound object to help maintain a set point temperature for air entering the regeneration side of the desiccant heat exchanger.

9. References and Other Research

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APPENDIX A: ENVIRONMENTAL IMPACTS METHODOLOGY

Greenhouse Gas Emissions Impacts Methodology

Greenhouse Gas Emissions Impacts Methodology

The GHG emissions impacts were calculated assuming an emission factor of 353 metric tons of carbon dioxide equivalents ($MTCO_2e$) per GWh of electricity. The Statewide CASE Team calculated air quality impacts associated with the electricity impacts from the proposed measure using emission factors that indicate emissions per GWh of electricity generated.[2] When evaluating the impact of increasing the Renewable Portfolio Standard (RPS) from 20 percent renewables by 2020 to 33 percent renewables by 2020, California Air Resources Board (CARB) published data on expected air pollution emissions for various future electricity generation scenarios (CARB 2010). The Statewide CASE Team used data from CARB's analysis to inform the air quality analysis presented in this report.

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

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

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

Water Use and Water Quality Impacts Methodology

Per ton of cooling, water cooled absorption chillers require larger heat rejection equipment (cooling towers) and therefore will use more water on-site as compared to a water cooled electric chiller. If evaporative cooling is used (with desiccants) more water will also be used.

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

However, less water is needed at the power plants due to the electricity savings and demand reduction. The change in water use is calculated by the EnergyPlus simulations.

Embedded Energy in Water

The embedded energy value used in the analysis is 10,045 kWh/million gallons of water (MG). This value was derived from a California Energy Commission PIER study (CEC 2006), which states the embedded energy values shown in the table below "are sufficient for informing policy and prioritization of research and development investments."

Table A- 1: Recommended Embedded Energy Estimates

Source: CEC 2006. Table 7.

	Indoor Uses		Outdoor Uses	
	Northern California kWh/MG	Southern California kWh/MG	Northern California kWh/MG	Southern California kWh/MG
Water Supply and Conveyance	2,117	9,727	2,117	9,727
Water Treatment	111	111	111	111
Water Distribution	1,272	1,272	1,272	1,272
Wastewater Treatment	1,911	1,911	0	0
Regional Total	5,411	13,022	3,500	11,111

The total regional values shown in Table A- 1 were weighted based on the population in Northern and Southern California in 2011 (U.S. Census Bureau). All water used in toilets and urinals is used indoors, so only the indoor embedded energy values apply.

The California Public Utilities Commission (CPUC) has conducted additional research on embedded energy since the CEC's 2006 report was released. However, the values presented in the CEC's 2006 report are still the most up-to-date values recommended for use to inform policies the Statewide CASE Team has used the CEC's 2006 embedded energy values for this analysis.

The CPUC has made notable progress in improving understanding of the relationship between water and energy in California. CPUC's Decision 07-12-050, issued December 20, 2007, authorized the largest electricity utilities to partner with water utilities and administer pilot programs that aimed to save water and energy (CPUC 2011c). The Decision also authorized three studies to validate claims that saving water can save energy and explore whether embedded energy savings associated with water use efficiency are measurable and verifiable. The pilot programs succeed at demonstrating that water conservation measures also result in energy savings.

The CPUC studies were effective at obtaining a more granular understanding of how energy use varies based on a number of factors including supply, (i.e. surface, ground, brackish, or ocean desalination), geography, and treatment technology. The authors found "that the value of energy embedded in water is higher than initially estimated in the CEC’s 2005 and 2006 studies.” Although the data collected for the studies is the most comprehensive set of data on energy used to meet water demand, the data is still just a small sampling of all the potential data points in California. Since the authors did not find strong patterns within the sample data and there was no strong evidence that the sample data was representative for a particular region, process, or technology type, the authors did not have a strong basis to estimate the embedded energy values for specific geographic regions. Further, the CPUC studies did not recommend changes to the embedded energy values presented in the CEC’s 2006 report.

While the CASE Report analysis uses the embedded energy values associated with water supply and conveyance, there is no evidence that reducing water use at the building level will impact water supply and conveyance activities. Thus water efficiency standards may result in reductions to energy used to supply and convey water.