Controlled Environment Horticulture

2022-NR-COV-PROC4-D | Covered Processes | June 2020 DRAFT CASE REPORT

Prepared by Energy Solutions and Cultivate Energy and Optimization

Please submit comments to info@title24stakeholders.com by July 24, 2020.

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Executive Summary

This is a draft report. The Statewide CASE Team encourages readers to provide comments on the proposed code changes and the analyses presented in this draft report. When possible, provide supporting data and justifications in addition to comments. Suggested revisions will be considered when refining proposals and analyses. The Final CASE Report will be submitted to the California Energy Commission in September 2020. For this report, the Statewide CASE Team is requesting input on the following:

- *Lighting efficacy photosynthetic photon efficacy levels*
- *Triggers for lighting alterations*
- *Dehumidification system requirements, and*
- *Greenhouse envelope definitions and requirements*

*Email comments and suggestions to info@title24stakeholders.com by **July 24, 2020**. Comments will not be released for public review or will be anonymized if shared.*

Introduction

The Codes and Standards Enhancement (CASE) Initiative presents recommendations to support the California Energy Commission's (Energy Commission) efforts to update the California Energy Efficiency Building Standards (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies. Three California Investor Owned Utilities (IOUs) – Pacific Gas and Electric Company, San Diego Gas & Electric, and Southern California Edison – and two Publicly Owned Utilities – Los Angeles Department of Water and Power and Sacramento Municipal Utility District (herein referred to as the Statewide CASE Team when including the CASE Author) – sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to improve energy efficiency and energy performance in California buildings. This report and the code change proposals presented herein are a part of the effort to develop technical and cost-effectiveness information for proposed requirements on building energy-efficient design practices and technologies.

The Statewide CASE Team submits code change proposals to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. See the Energy Commission's 2022 Title 24 website for information about the rulemaking schedule and how to participate in the process: https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency.

The overall goal of this Draft CASE Report is to present a code change proposal for controlled environment horticulture. The report contains pertinent information supporting the code change.

This is the first code cycle for which standards are being proposed for the CEH industry in California. Other states and local jurisdictions have already gained experience with their own standards, including Massachusetts, Illinois, and Seattle, which have been invaluable examples. In particular, the proposed standards for dehumidification equipment are identical to those recently adopted by the City of Denver.

Measure Description

Background Information

Controlled environmental horticulture (CEH) is an agricultural method that utilizes technology to maintain optimal growing conditions under electric light in indoor warehouse and greenhouse crop production facilities. CEH is most commonly practiced in the production of herbs, vegetables, microgreens, flowers, and cannabis. Because CEH facilities must artificially replicate the environmental inputs needed to produce crops (light, water, air, nutrients, the right temperature, and space and time to grow), CEH facilities are energy-intensive operations. Many CEH facilities have separate rooms for each stage of plant development so that inputs and controls can be set to meet the plants' needs at each stage: seedling, propagation, vegetative, flowering, and ripening. In response to California legalizing adult-use cannabis under the Medicinal and Adult-Use Cannabis Regulation and Safety Act (MAUCRSA, effective January 1, 2018), California has experienced a marked increase in the number of CEH facilities, particularly indoor CEH facilities in urban areas. This surge is forecast to significantly increase the energy demand from the CEH sector (New Frontier Data 2018).

The Statewide CASE Team proposes to categorize CEH operations as a covered process. The proposed submeasures apply to new construction, additions to facilities with CEH operations, alterations that change the occupancy classification of a building (for example, a warehouse converted to a CEH facility), and alterations that involve installing new dehumidification systems in CEH facilities.

Proposed Code Changes

To address this marked increase in energy demand by the CEH sector, the Statewide CASE Team proposes three submeasures related to CEH facilities:

- Horticultural lighting minimum efficacy,
- Efficient dehumidification and reuse of transpired water, and
- Greenhouse envelope standards.

Horticultural Lighting Minimum Efficacy

The horticultural lighting minimum efficacy submeasure proposes a mandatory requirement for minimum photosynthetic photon efficacy (PPE) of 2.1 micromoles per joule (μMol/J) for luminaires used for plant growth and maintenance in indoor growing facilities with more than 1,000 ft^2 of canopy and a minimum PPE of 1.7 μMol/J in greenhouses with more than 1,000 ft^2 of canopy. The submeasure requires time-switch controls and multilevel lighting controls in both types of CEH facilities.

The submeasure applies to new construction, additions to CEH facilities, alterations that change the occupancy classification of a building (for example, a warehouse converted to a CEH facility), and alterations that involve replacing 10 percent or more of the luminaires serving an enclosed space.

Efficient Dehumidification and Reuse of Transpired Water

The efficient dehumidification and reuse of transpired water submeasure mandates the use of one of the following dehumidification systems in indoor growing facilities:

- Integrated HVAC system with on-site heat recovery for reheating dehumidified air; or
- Chilled water system with on-site heat recovery for reheating dehumidified air; or
- Solid or liquid desiccant dehumidification system.

Facilities with less than 2,000 ft^2 of canopy in combined CEH spaces are permitted to use stand-alone dehumidification units with a minimum energy factor of 1.9 liters per kWh (L/kWh).

The submeasure requires the on-site heat recovery system to be designed to fulfill at least 60 percent of the facility's dehumidification needs during peak dehumidification periods.

Furthermore, under this submeasure, dehumidification equipment must have the capability to reuse transpired water for irrigation in indoor growing facilities.

This submeasure exempts CEH facilities from the prescriptive requirement to install an air-side economizer when carbon dioxide (CO_2) enrichment is used as a strategy to promote plant growth.

The proposed submeasure applies to newly constructed facilities and newly installed HVAC and dehumidification systems in existing facilities.

Greenhouse Envelope Standards

The greenhouse envelope standards submeasure is a code cleanup measure that proposes the following envelope requirements specific to conditioned greenhouses:

- Opaque wall and roof assemblies must meet the existing insulation and building envelope requirements in Section 120.7 and 140.3(a).

- Non-opaque walls assemblies must have a weighted average U-factor of 0.7 or less; and
- Non-opaque roof assemblies must have a weighted average U-factor of 0.5 or less.

The submeasure also exempts greenhouses from existing prescriptive building envelope requirements for window wall ratio, skylight roof ratio, and daylighting requirements for large enclosed spaces.

The proposed submeasure applies to newly constructed greenhouses and to greenhouses being converted from unconditioned to conditioned.

Since this submeasure is a code cleanup effort, there are no associated savings or incremental costs.

Scope of Code Change Proposal

Table 1: Scope of Code Change Proposal summarizes the scope of the proposed changes and which sections of standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manual, and compliance documents would be modified as a result of the proposed changes.

Table 1: Scope of Code Change Proposal

Submeasure Name	Type of Requirement	Modified Section(s) of Title 24, Part 6	Modified Title 24, Part 6 Appendices	Would Compliance Software Be Modified	Modified Compliance Document(s)
Horticultural Lighting Minimum Efficacy	Mandatory	100.1, 120.6, 141.1	No	No	NRCC-PRC-E
Horticultural Lighting Minimum Efficacy	Prescriptive	140.6	No	No	N/A
Efficient Dehumidification and Reuse of Transpired Water	Mandatory	100.1, 120.6, 141.1	No	No	NRCC-PRC-E
Efficient Dehumidification and Reuse of	Prescriptive	140.4	No	No	N/A

Transpired Water					
Greenhouse Envelope	Mandatory	100.1, 120.6, 141.1	No	No	NRCC-PRC-E
Greenhouse Envelope	Prescriptive	140.3	No	No	N/A

Market Analysis and Regulatory Assessment

California's CEH market has historically been driven by greenhouse vegetable and flower production, with approximately $1.6 billion in sales in 2017 (USDA 2019). The market has experienced significant growth from the cannabis industry since California legalized adult-use cannabis in 2018, with approximately $3.1 billion in sales in 2019 (Dorbian 2019). There are more than 1,300 indoor cannabis facilities based on 2019 CalCannabis licensing information. Energy intensity for a California indoor cannabis facility averages 252 kWh per square foot of canopy (New Frontier Data 2018).

The key market actors affected by this proposal are operators and designers of CEH facilities, equipment manufacturers, building inspectors, and electric utilities. The technologies to achieve compliance are well understood and widely available. At the time this report was finalized, 70 out of the 86 luminaires listed on the DesignLights Consortium's Qualified Products List for indoor growing facilities meet the proposed efficacy requirement. The proposed dehumidification requirements are similar to dehumidification requirements in the City of Denver energy code, and major dehumidification equipment manufacturers reviewed the proposed code language. The proposed greenhouse envelop code cleanup aligns with requirements recently adopted in the IECC 2021 Energy Code.

Cost Effectiveness

The proposed code change was found to be cost effective for all climate zones. The benefit-to-cost (B/C) ratio compares the benefits or cost savings to the costs over the 15-year period of analysis. Proposed code changes that have a B/C ratio of 1.0 or greater are cost effective. The larger the B/C ratio, the faster the measure pays for itself from energy cost savings. The greenhouse envelope submeasure does not deliver energy savings and is not included in the cost-effectiveness summary. The B/C ratios for the submeasures are as follows:

Table 2: Cost Effectiveness of CEH Proposals

Submeasure Name	B/C Range
Horticultural Lighting Minimum Efficacy – Indoor	6.0-7.3

Horticultural Lighting Minimum Efficacy – Greenhouse	2.0-3.6
Efficient Dehumidification and Reuse of Transpired Water	3.3-3.4

See Section 5 for the methodology, assumptions, and results of the cost-effectiveness analysis.

Statewide Energy Impacts: Energy, Water, and Greenhouse Gas (GHG) Emissions Impacts

Table 3 presents the estimated energy and demand impacts of the proposed code change that would be realized statewide during the first 12 months that the 2022 Title 24, Part 6 requirements are in effect. First-year statewide energy impacts are represented by the following metrics: electricity savings in gigawatt-hours per year (GWh/yr), peak electrical demand reduction in megawatts (MW), natural gas savings in million therms per year (million therms/yr), and time dependent valuation (TDV) energy savings in kilo British thermal units per year (TDV kBtu/yr). See Section 6 for more details on the first-year statewide impacts calculated by the Statewide CASE Team. Section 4 contains details on the per-unit energy savings calculated by the Statewide CASE Team.

Table 3: First-Year Statewide Energy and Impacts

Submeasure	Electricity Savings (GWh/yr)	Peak Electrical Demand Reduction (MW)	Natural Gas Savings (million therms/yr)	TDV Energy Savings (TDV kBtu/yr)
Horticultural Lighting Minimum Efficacy (Total)	**325.0**	**22.9**	**N/A**	**8,344.6**
New Construction	238.5	16.2	N/A	6,123.7
Additions and Alterations	86.5	6.6	N/A	2,220.9
Efficient Dehumidification and Reuse of Transpired Water (Total)	**(2.3)**	**(0.3)**	**4.7**	**1,119.9**
New Construction	(1.8)	(0.2)	3.6	862.8
Additions and Alterations	(0.5)	(0.1)	1.1	257.0

Horticultural lighting represents the largest submeasure savings opportunity for the 2022 Title 24, Part 6 code cycle. The proposed code change applies more stringent requirements to indoor CEH facilities to maximize cost effective savings potential for the state and business owners. The lower efficacy requirement of 1.7 μMol/J for greenhouses provides more flexibility in lighting technologies for greenhouse growers. Greenhouses often use lighting to increase daylight hours or supplement natural light.

Operating hours are typically lower than those of indoor facilities, so it may not be as cost effective to require a more expensive lighting type in greenhouses.

Table 4 presents the estimated avoided GHG emissions associated with the proposed code change for the first year the standards are in effect. Avoided GHG emissions are measured in million metric tons of carbon dioxide equivalent (metric tons CO2e). Assumptions used in developing the GHG savings are provided in Section 6.2 and Appendix C of this report. The monetary value of avoided GHG emissions is included in TDV cost factors and is thus included in the cost-effectiveness analysis.

Table 4: First-Year Statewide GHG Emissions Impacts

Submeasure	Avoided GHG Emissions (Metric Tons CO2e/yr)	Monetary Value of Avoided GHG Emissions ($2023)
Horticultural Lighting Minimum Efficacy	45,750	$1,372,488
Efficient Dehumidification and Reuse of Transpired Water	35,044	$1,051,329
Total	**80,794**	**$2,423,817**

Water and Water Quality Impacts

Water savings that the proposed code changes would have during the first year they are in effect are presented in Table 5 along with the associated embedded electricity savings. See Table 58 in Section 6.3 of this report to see water quality impacts and the methodology used to derive water savings and water quality impacts. The methodology used to calculate embedded electricity in water is presented in Appendix B.

Table 5: First-Year Water and Embedded Electricity Impacts

	On-Site Indoor Water Savings (gallons/yr)	On-Site Outdoor Water Savings (gallons/yr)	Embedded Electricity Savings (kWh/yr)
Per Square Foot Impacts	14.1	0	1.09
First-Year Statewide Impacts	313,958,155	0	1,522,069

Compliance and Enforcement

Overview of Compliance Process

The Statewide CASE Team worked with stakeholders to develop a recommended compliance and enforcement process and to identify the impacts this process would have on various market actors. The compliance process is described in Section 2, Measure Description, below. Impacts that the proposed measure would have on market actors are described in Appendix E. The key issues related to compliance and enforcement are summarized below:

- Greenhouse and indoor CEH facility designers having to follow energy standards for the first time
- Updating compliance documents in a way that allows for easy understanding of the code proposal. This would involve documenting equipment on compliance forms and ensuring the information is presented in a way that allows for clear understanding of efficiency levels.
- Ensuring building inspectors are knowledgeable about new requirements and metrics specific to CEH equipment.

Field Verification and Acceptance Testing

The horticultural lighting and dehumidification submeasures require acceptance testing for the lighting and thermostatic controls requirements. Compliance would be shown through verification of permit documents.

1. Introduction

This is a draft report. The Statewide CASE Team encourages readers to provide comments on the proposed code changes and the analyses presented in this draft report. When possible, provide supporting data and justifications in addition to comments. Suggested revisions will be considered when refining proposals and analyses. The Final CASE Report will be submitted to the California Energy Commission in September 2020. For this report, the Statewide CASE Team is requesting input on the following:

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The Codes and Standards Enhancement (CASE) initiative presents recommendations to support the California Energy Commission's (Energy Commission) efforts to update California's Energy Efficiency Building Standards (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies. Three California Investor Owned Utilities (IOUs) – Pacific Gas and Electric Company, San Diego Gas and Electric, and Southern California Edison – and two Publicly Owned Utilities – Los Angeles Department of Water and Power and Sacramento Municipal Utility District (herein referred to as the Statewide CASE Team when including the CASE Author) – sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to improve energy efficiency and energy performance in California buildings. This report and the code change proposal presented herein are a part of the effort to develop technical and cost-effectiveness information for proposed requirements on building energy-efficient design practices and technologies.

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The overall goal of this Draft CASE Report is to present a code change proposal for controlled environment horticulture (CEH). The report contains pertinent information supporting the code change.

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with a number of industry stakeholders including growers, manufacturers, builders, utility incentive program managers, Title 24 energy analysts, horticultural facility designers, horticultural researchers, and compliance subject matter experts. The proposal incorporates feedback received during public stakeholder workshops that the Statewide CASE Team held on September 19, 2019, and April 16, 2020.

The following is a brief summary of the contents of this report:

- Section 2 – Measure Description of this Draft CASE Report provides a description of the measure and its background. This section also presents a detailed description of how this code change is accomplished in the various sections and documents that make up the Title 24, Part 6 Standards.
- Section 3 – In addition to the Market Analysis section, this section includes a review of the current market structure. This section describes the feasibility issues associated with the code change, including whether the proposed measure overlaps or conflicts with other portions of the building standards, such as fire, seismic, and other safety standards, and whether technical, compliance, or enforceability challenges exist.
- Section 4 – Energy Savings presents the per-unit energy, demand reduction, and energy cost savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate per-unit energy, demand reduction, and energy cost savings.
- Section 5 – This section includes a discussion and presents analysis of the materials and labor required to implement the measure and a quantification of the incremental cost. It also includes estimates of incremental maintenance costs, i.e., equipment lifetime and various periodic costs associated with replacement and maintenance during the period of analysis.
- Section 6 – First-Year Statewide Impacts presents the statewide energy savings and environmental impacts of the proposed code change for the first year after the 2022 code takes effect. This includes the amount of energy that would be saved by California building owners and tenants and impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic by the state of California. Statewide water consumption impacts are also reported in this section.
- Section 7 – Proposed Revisions to Code Language concludes the report with specific recommendations with ~~strikeout~~ (deletions) and underlined (additions) language for the Standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manual, Compliance Manual, and compliance

documents.

- Section 8 – Bibliography presents the resources that the Statewide CASE Team used when developing this report.
- Appendix A: Statewide Savings Methodology presents the methodology and assumptions used to calculate statewide energy impacts.
- Appendix B: Embedded Electricity in Water Methodology presents the methodology and assumptions used to calculate the electricity embedded in water use (e.g., electricity used to draw, move, or treat water) and the energy savings resulting from reduced water use.
- Appendix C: Environmental Impacts Methodology presents the methodologies and assumptions used to calculate impacts on GHG emissions and water use and quality.
- Appendix D: California Building Energy Code Compliance (CBECC) Software Specification presents relevant proposed changes to the compliance software (if any).
- Appendix E: Impacts of Compliance Process on Market Actors presents how the recommended compliance process could impact identified market actors.
- Appendix F: Summary of Stakeholder Engagement documents the efforts made to engage and collaborate with market actors and experts.
- Appendix G: Existing Codes and Standards provides actual language of codes and standards related to energy and water efficiency of CEH facilities.
- Appendix H: Sources of Cost Data provides sources from which the Statewide CASE Team developed baseline and proposed costs and the actual prices.

2. Measure Description

Controlled environmental horticulture (CEH) refers to agricultural methods used for greenhouses and indoor growing facilities. It is most commonly used for herbs, vegetables, microgreens, flowers, and cannabis. CEH facilities are energy-intensive, sophisticated operations since they must artificially replicate the environmental inputs needed to produce crops: light, water, air, nutrients, temperature, and humidity. They typically have separate rooms for each stage of plant development so that inputs and controls can be set to meet the plants' needs at each stage: seedling, propagation, vegetative, budding, flowering, and ripening. The inputs are interconnected; for example, the choice of lighting technology can greatly affect heating load, which would impact the heating, ventilation, and air conditioning (HVAC) and dehumidification systems.

California's CEH market is currently valued at over $4.7 billion. It has historically been driven by greenhouse production (USDA 2019) but new growth has largely come from cannabis since California legalized adult-use cannabis in 2018. There are more than 1,900 CEH facilities in the state, with over 75 million ft^2 of production space (USDA 2019; CA Department of Food & Agriculture 2020). More than 1,300 (roughly 70 percent) of these facilities grow cannabis, which includes about 900 greenhouses and 400 indoor facilities. The largest growth segment has been indoor CEH facilities in urban areas, which use the most energy since they rely 100 percent on electric lighting. Energy demand for cannabis grown in CEH facilities is projected to exceed 380 gigawatt-hours (GWh) of total energy use by 2022 (New Frontier Data 2018).

To address this increase in energy demand by the CEH sector, the Statewide CASE Team proposes three mandatory submeasures related to CEH facilities:

- Horticulture lighting minimum efficacy, with separate standards for greenhouses and indoor growing facilities, as well as standards for lighting controls in both facility types (see Section 2.1).
- Efficient dehumidification and reuse of transpired water, as well as an exemption from an economizer prescriptive requirements when carbon dioxide enrichment is used (see Section 2.2).
- Greenhouse envelope standards, with envelope requirements that provide a feasible compliance path for greenhouse construction (see Section 2.3). This cleanup effort does not result in savings claims.

The Statewide CASE Team proposes to categorize CEH as a covered process. The proposed submeasures apply to new construction, additions to CEH facilities, alterations that change the occupancy classification of a building (for example, a warehouse converted to a CEH facility), and alterations that involve lighting systems, installing new HVAC, or new dehumidification systems in CEH facilities.

Historically, CEH facilities have not been directly addressed as a building type in Title 24, Part 6. However, Title 24, Part 6 regulates envelopes and mechanical HVAC systems of conditioned greenhouses as well as warehouses that may be used for indoor horticulture. While 2019 Title 24, Part 6 does not have specific requirements for CEH facilities, the requirements can be added since the Energy Commission's scope of covered buildings includes buildings with Occupancy Group U. In accordance with 2016 Title 24, Part 2, Occupancy Group U covers agricultural buildings and greenhouses.

Compliance and Enforcement

When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how negative impacts on market actors who are involved in the process could be mitigated or reduced. This section describes how to comply with the proposed code change. It also describes the compliance verification process. Appendix E presents how the proposed changes could impact various market actors.

The proposed code changes would have significant impact on all phases of the project since Title 24, Part 6 does not currently regulate CEH facilities as a covered process. The activities that occur during each phase of the project are described below:

- **Design Phase:** An owner, developer, architect, and other team members involved in the design of a CEH facility familiarize themselves with new code requirements and design the facility to meet the requirements.
- **Permit Application Phase:** The permit applicant completes a certificate of compliance document and ensures building plans are consistent with the information in the certificate of compliance. A horticulture facility designer or general contractor usually fulfills the role of permit applicant. Plans examiners at an enforcement agency familiarize themselves with new code requirements to determine compliance.
- **Construction Phase:** Field changes resulting in noncompliance require an approval of the revised certificate of compliance document. As needed, the permit applicant coordinates approval of field changes with the plans examiner at the enforcement agency.
- **Inspection Phase:** An appropriate responsible party completes the certificate of installation document and submits the document to the enforcement agency. A general contractor normally submits the certificate of installation document. Enforcement agency field inspector reviews the certificate of installation and certificate of acceptance documents. The enforcement agency field inspector may conduct a visual inspection of the project upon project completion.

2.1 Horticultural Lighting Minimum Efficacy

2.1.1 Measure Overview

The horticultural lighting minimum efficacy submeasure proposes a mandatory requirement for minimum photosynthetic photon efficacy (PPE) of 2.1 micromoles per joule (µMol/J) for luminaires used for plant growth and maintenance in indoor growing facilities with more than 1,000 ft^2 of canopy and a minimum PPE of 1.7 µMol/J in greenhouses with more than 1,000 ft^2 of canopy. The submeasure requires time-switch controls and multilevel lighting controls in both types of CEH facilities.

The Statewide CASE Team proposes a less stringent horticultural lighting efficacy standard for greenhouses as compared with indoor growing facilities for several reasons. First, greenhouses do not need as much lighting since they use daylight. Also, greenhouses are used to grow a wider range of crop types, such as flowers and vegetables, that have lower lighting needs than cannabis (a predominant crop in the indoor growing facilities). Second, less stringent requirements for greenhouses would put less burden on vegetable and flower growers, who have lower profit margins than cannabis growers. Third, a lower PPE for greenhouses provides an option for growers to switch from indoor to greenhouse growing if they want to use legacy lighting technologies. Lastly, light-emitting diode (LED) lighting can have a larger form factor and cause shading in greenhouses, with one research study finding that LED lighting caused a daylight reduction 2.5 to 11 times greater than that of HPS (Radetsky 2018). While this issue may be addressed in coming years by luminaire redesign and technological improvement, in today's market providing options other than LED lighting for greenhouses is important.

The submeasure applies to new construction, additions to CEH facilities, alterations that change the occupancy classification of a building (for example, a warehouse converted to a CEH facility), and alterations that involve replacing 10 percent or more of the luminaires serving an enclosed space. The 10 percent threshold is consistent with the threshold triggering code for lighting retrofit projects in nonresidential buildings (Section 141.0(b)2I).

2.1.2 Measure History

The introduction of photosynthetic photon efficacy, which is specific to horticultural lighting, is a new proposal for the 2022 Title 24, Part 6 rulemaking. The industry-accepted metric for horticultural lighting efficacy is PPE. PPE characterizes the amount of light from a light source that is useful for the photosynthesis process per unit of energy usage. Lighting power density (LPD) is another metric that has been used to specify energy efficiency requirements for horticultural lighting. LPD is simply based on the lighting power per square footage, indiscriminatory of whether the light is useful for the photosynthesis process. For details on horticulture lighting current practices, and why PPE was chosen over lighting power density (LPD) see Section 3.2.1.3, Current Practices.

The American Society of Agricultural and Biological Engineers (ASABE) and the DesignLights Consortium (DLC) laid the foundation for this submeasure by establishing definitions and a testing procedure for horticultural lighting. A similar proposal on horticultural lighting minimum efficacy was considered and approved as part of International Energy Conservation Code (IECC) 2021 standards setting cycle (IECC 2019).

2.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals, and compliance documents would be modified by the proposed change. See Section 7 of this report for detailed proposed revisions to code language.

2.1.3.1 Summary of Changes to the Standards

This proposal would modify the following sections of the California Energy Code as shown below. See Section 7 of this report for marked-up code language.

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

Section 100.1(b) – Definitions: Recommends new or revised definitions as follows.

New Definitions:

- “ANSI/ASABE S640 JUL2017” – necessary as a reference standard for definitions related to horticultural lighting.
- “canopy in buildings with CEH spaces” – necessary to define how canopy is calculated for buildings with CEH operations.
- “controlled environment horticulture (CEH) space” – necessary to define a new process type that would be covered by the proposed measure.
- “greenhouse” – necessary to define a building type that would be covered by the proposed measure.
- “horticultural lighting” – necessary to define a new term used in the proposed measure.
- “indoor growing” – necessary to define a CEH space type that would be covered by the proposed measure.
- “photosynthetic photon efficacy (PPE)” – necessary to define a new term used in the proposed measure.

Revised Definition:

- "process, covered" – adds CEH spaces to the list of covered processes.

SECTION 120.6 – MANDATORY REQUIREMENTS FOR COVERED PROCESSES

- **Section 120.6(h) – Mandatory Requirements for Controlled Environment Horticulture Spaces:** Creates a new section (Section 120.6(h)) so that all requirements for CEH spaces are in one section. Includes standards related to horticultural lighting efficacy and lighting controls in indoor growing facilities and greenhouses.

SECTION 140.6 – PRESCRIPTIVE REQUIREMENTS FOR INDOOR LIGHTING

- **Section 140.6(a)3G – Prescriptive Requirements for Indoor Lighting, Lighting Wattage Excluded:** Adds a clarifying statement that CEH spaces must comply with Section 120.6(h).
- **Section 140.6(a)3O – Prescriptive Requirements for Indoor Lighting, Lighting Wattage Excluded:** Adds a clarifying statement that CEH spaces must comply with Section 120.6(h).
- **Section 140.6(a)3P – Prescriptive Requirements for Indoor Lighting, Lighting Wattage Excluded:** Adds a clarifying statement that CEH spaces must comply with Section 120.6(h).

SECTION 141.1 – REQUIREMENTS FOR COVERED PROCESSES IN ADDITIONS, ALTERATIONS TO EXISTING NONRESIDENTIAL, HIGH-RISE RESIDENTIAL, AND HOTEL/MOTEL BUILDINGS

- **Section 141.1(a)3 – Controlled Environment Horticulture Spaces:** Adds a new requirement for horticultural lighting alterations that increase lighting wattage or replace 10 percent or more of the luminaires serving an enclosed space to comply with the proposed Section 120.6(h).
- **Section 141.1(a)3 EXCEPTION:** Exempts horticultural lighting alterations that only involve replacement of only lamps, or only ballasts, or only drivers. Also, exempts any alterations limited to adding lighting controls.

2.1.3.2 Summary of Changes to the Reference Appendices

The proposed code change would not modify the Reference Appendices.

2.1.3.3 Summary of Changes to the Nonresidential ACM Reference Manual

The proposed code change would not modify the Nonresidential ACM Reference Manual.

2.1.3.4 Summary of Changes to the Nonresidential Compliance Manual

The proposed code change would modify Chapter 10 Covered Processes of the Nonresidential Compliance Manual. Chapter 10 on covered processes of the Nonresidential Compliance Manual would need to be revised to include a new section on CEH facilities as a covered process.

2.1.3.5 Summary of Changes to Compliance Documents

The proposed code change would modify the (NRCC-PRC-E Process Systems compliance document listed below. Compliance information for a CEH production as a covered process would need to be added to the certificate of compliance document.

2.1.4 Regulatory Context

2.1.4.1 Existing Requirements in the California Energy Code

Lighting for plant growth is exempt from 2019 Title 24, Part 6 prescriptive indoor lighting requirements when the lighting is controlled by a multilevel astronomical time-switch control (Section 140.6(a)3G). Non-horticultural lighting in CEH facilities (e.g., lighting in restrooms, office space) would be subject to Section 140.6 Prescriptive Requirements for Indoor Lighting in Title 24, Part 6 under a prescriptive compliance approach.

Existing requirements for mandatory indoor lighting controls do not exempt CEH facilities or tailor requirements to CEH facilities (Section 130.1).

2.1.4.2 Relationship to Requirements in Other Parts of the California Building Code

There are no relevant requirements to the proposed measure on horticultural lighting in other parts of the California Building Code.

2.1.4.3 Relationship to Local, State, or Federal Laws

Several local and state jurisdictions have adopted or in the process of adopting regulations related to horticultural lighting. See Appendix G for more details.

In the 2015 code cycle of Seattle Energy Code, the City of Seattle adopted a minimum PPE requirement of 1.2 μMol/J for horticultural lighting (City of Seattle 2015).

In December 2019, the Denver City Council adopted a standard for horticultural lighting that requires PPE of 1.6 μMol/J for luminaires and 1.9 μMol/J for lamps (City of Denver 2019). The proposed code applies to new construction and additions.

The Massachusetts Cannabis Control Commission was established in 2017 to regulate the cannabis industry in the state of Massachusetts and adopted regulations on cannabis cultivation in 2019 (935 CMR 500 Adult Use of Marijuana). Per revised regulations adopted in December 2019, there are three compliance options related to horticultural lighting (State of Massachusetts n.d.). The first compliance option sets maximum lighting power density (LPD) to 36 watts per square foot of canopy for operations 5,000 ft^2 or more and to 50 watts per square foot of canopy for operations under 5,000 ft^2. The second compliance option requires all horticultural lighting used in a facility to be listed on the current DLC Qualified Products List (QPL), with PPE of at least 15 percent above the minimum DLC QPL threshold. The minimum DLC QPL PPE is 1.9 μMol/J as of this report writing. The third compliance option allows a facility seeking to use horticultural lighting not included on the DLC QPL or other similar list approved by the Massachusetts Cannabis Control Commission to apply for a waiver and provide documentation of third-party certification of the energy efficiency features of the proposed lighting.

In June 2019, the Illinois state government passed HB 1438, the Cannabis Regulation and Tax Act, which legalized cannabis for adults aged 21 and over and set energy efficiency facilities for cultivation spaces (Marijuana Policy Project n.d.). The licenses and energy efficiency specifics for a grow facility are made available by the state's Department of Agriculture. HB 1438 contains a provision that indoor growing facilities commit to minimum technology standards for resource efficiency (Illinois General Assembly 2019). Among these requirements are two options for meeting lighting efficiency standards. One option involves having a maximum LPD of 36 watt per square foot of canopy, and the other option is having a PPE of at least ≥ 2.2 μMol/J with products from the DLC Qualified Products List (QPL). These energy efficiency standards took effect on January 1, 2020 (Illinois General Assembly 2019).

Table 6 summarizes mandatory standards on horticultural lighting efficacy.

Table 6: Existing Mandatory Standards on Horticultural Lighting Efficacy

Jurisdiction	Year	Standard Type	Requirements
City of Seattle	2015	PPE	PPE ≥ 1.2 μMol/J
City and County of Denver	2019	PPE	1.6 and 1.9 μMol/J for luminaires and lamps, respectively
State of Massachusetts	2017; Updated in 2019	LPD or PPE for cannabis crop	• LPD of 36 W/ft^2 of canopy for operations equal to or over 5,000 ft^2 of canopy; LPD of 50 W/ft^2 of canopy operations under 5,000 ft^2 of canopy or • PPE ≥ 15% above the minimum DLC QPL threshold with products from DLC QPL, which means PPE ≥ 2.2 μMol/J as of this report writing.
State of Illinois	2019	LPD or PPE for	• Either LPD of 36 W/ft^2 of canopy, or • PPE ≥ 2.2 μMol/J with products from DLC QPL

		cannabis crop	

As of 2018, the City of Santa Rosa requires all cannabis grow lights to be controlled by a multilevel astronomical time switch (City of Santa Rosa n.d.). The Statewide CASE Team is not aware of other relevant local or state laws and regulations pertaining to lighting controls in CEH facilities.

2.1.4.4 Relationship to Industry Standards

There are two relevant voluntary industry standards for horticultural lighting efficacy.

DLC published version 1.2 of its technical requirements for horticultural lighting in October 2019. The manual specifies performance requirements, warranty, thermal properties, and output maintenance properties required for listing horticultural lighting products with the DLC. DLC also maintains a QPL for high-efficiency LED horticultural lighting products. Lighting devices must have a PPE at or above 1.9 µMol/J in order to qualify for QPL (Design Light Consortium n.d.). However, since the QPL is new, many manufacturers are still in the process of listing their products.

Additionally, proposal for 2021 IECC to require at least 95 percent of permanently installed luminaires for plant growth and maintenance to have a PPE of at least 1.6 µMol/J (IECC 2019) was approved in the final vote in late 2019. Table 7 summarizes existing voluntary standards on horticultural lighting efficacy.

Related to lighting controls, 2018 IECC has a provision requiring horticultural lighting to be controlled by a time switch.

Table 7: Existing Voluntary Standards on Horticultural Lighting Efficacy

Organization	Voluntary Requirements
Design Lights Consortium (DLC) Horticultural Lighting Qualified Products List (QPL)	• PPE ≥ 1.9 micromoles per joule • 86 luminaire models in DLC QPL Products List from over 20 manufacturers with PPE range of 1.87 to 3 µMol/J (as of this report writing)
International Energy Conservation Code (IECC)	PPE ≥ 1.6 µMol/J (proposed for 2021 IECC)

2.1.5 Compliance and Enforcement

Since it is a standard practice for CEH facilities to install time-switch controls, horticultural lighting would normally be exempt from 2019 Title 24, Part 6. To enforce the proposed submeasure, a new compliance process would need to be established.

For non-cannabis crop types, permit applicants would need to perform canopy size calculations to determine whether their project triggers proposed submeasure on horticultural lighting. In cases when submeasure applies to the project, the permit applicants would need to gather PPE ratings of the proposed luminaires to demonstrate compliance.

For cannabis crop type, compliance with California Department of Food & Agriculture (CDFA) CalCannabis regulations will support the compliance process with the proposed submeasure. Specifically, as part of CDFA CalCannabis licensing requirements, license applicants must submit canopy size calculations and a lighting diagram for indoor and mixed-light license types. The lighting diagram must include locations of all lights in the canopy areas and maximum wattage for each light (California Code of Regulations (CCR) n.d.). In other words, for cannabis crop type, permit applicants would have canopy size calculations available since they are required by another agency. Based on canopy size calculations, prospective permit applicants can determine whether their project triggers the proposed submeasure on horticultural lighting. If the project is subject to the proposed horticultural lighting code, the permit applicants would have to still gather PPE rating(s) of the proposed luminaires since CDFA CalCannabis licensing requirements only call for luminaire count and wattage not PPE ratings.

For all crop types in facilities with canopy size exceeding 1,000 ft^2, the permit applicants would also need to install multi-level and time-switch lighting controls as well as coordinate an acceptance testing for the time-switch controls to comply with the proposed submeasure.

To streamline the compliance process, it will be critical to develop resources such as compliance guidance for CEH facilities in the Nonresidential Compliance Manual and training for building department officials. For a complete list of specific recommendations for simplifying the compliance and enforcement process, refer to Table 64 in Appendix E.

2.2 Efficient Dehumidification and Reuse of Transpired Water

2.2.1 Measure Overview

This submeasure mandates the use of one of the following dehumidification systems in indoor growing facilities:

- Integrated HVAC system with on-site heat recovery for reheating dehumidified air; or
- Chilled water system with on-site heat recovery for reheating dehumidified air; or
- Solid or liquid desiccant dehumidification system.

Facilities with less than 2,000 ft^2 of canopy in combined CEH spaces are permitted to use stand-alone dehumidification units with a minimum energy factor of 1.9 liters per kWh (L/kWh).

The submeasure requires the on-site heat recovery system to be designed to fulfill at least 60 percent of the facility's dehumidification needs during peak dehumidification periods.

Furthermore, under this submeasure, dehumidification equipment must have the capability to reuse transpired water for irrigation in indoor growing facilities.

This submeasure exempts CEH facilities from the prescriptive requirement to install an air-side economizer when carbon dioxide (CO_2) enrichment is used as a strategy to promote plant growth.

The proposed submeasure applies to newly constructed facilities and newly installed HVAC and dehumidification systems in existing facilities.

2.2.2 Measure History

Standards for horticultural dehumidification have not been a focus for a measure proposal prior to this rulemaking cycle. The Statewide CASE Team's proposal is an adaptation of standards recently developed and adopted by the City and County of Denver. Industry organizations such as ASHRAE and ASABE have started to develop a guidance document specific to horticultural HVAC and dehumidification systems, but the effort is likely to take several years.

In the absence of a standardized testing procedure specific to CEH facilities, the Statewide CASE Team proposes to use an existing test procedure for portable dehumidifiers only. The existing testing procedure is codified in the Code of Federal Regulation (CFR) Title 10, Part 430.

The proposed submeasure would reduce energy use by requiring the use of more efficient dehumidification systems in indoor growing facilities. These systems utilize site-recovered energy to reheat dehumidified air instead of relying solely on natural gas heating or electric heating to reheat the air. The use of site-recovered energy for reheat saves a significant amount of natural gas, as natural gas makes up approximately 90 percent of the air reheat fuel type. Electricity increases associated with this measure are due to an electric penalty for the proposed heat recovery systems.

The reuse of transpired water for irrigation would lower water consumption of indoor growing facilities, resulting in water savings and the embedded energy savings associated with extracting, treating, transporting, and collecting water.

2.2.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, ACM Reference Manuals, and compliance documents would be modified by the proposed changes. See Section 7 of this report for detailed proposed revisions to code language.

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

Section 100.1(b) – Definitions: Recommends new or revised definitions as follows.

New Definitions:

- "canopy in buildings with CEH spaces" – necessary to define how canopy is calculated for buildings with CEH operations.
- "carbon dioxide enrichment" – necessary to define this operational practice for the proposed exemption on installation of air-size economizer.
- "controlled environment horticulture (CEH) spaces" – necessary to define a new process type that would be covered by the proposed measure.
- "desiccant dehumidification systems" – necessary to define a type of dehumidification system permitted in the proposed code.
- "greenhouse" – necessary to define a building type that would be covered by the proposed measure.
- "indoor growing" – necessary to define a new process type that would be covered by the proposed measure.

Revised Definitions:

- "process, covered" – adds CEH spaces to the list of covered processes.
- "USDOE 10 CFR 430" – adds reference to the testing method for measuring energy consumption of dehumidifiers.

SECTION 120.6 – MANDATORY REQUIREMENTS FOR COVERED PROCESSES

Section 120.6(h) – Mandatory Requirements for Controlled Environment Horticulture Spaces: Consolidates all requirements for CEH spaces in one new section. Includes standards related to HVAC, dehumidification, and reuse of transpired water for irrigation.

SECTION 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

Section 140.4(e) EXCEPTION 7 – Economizers: Adds an exemption from the prescriptive requirement for an economizer in buildings with CEH spaces that use carbon dioxide enrichment strategy to promote plant growth.

SECTION 141.1 – REQUIREMENTS FOR COVERED PROCESSES IN ADDITIONS, ALTERATIONS TO EXISTING NONRESIDENTIAL, HIGH-RISE RESIDENTIAL, AND HOTEL/MOTEL BUILDINGS

Section 141.1(a)1 – Controlled Environment Horticulture Spaces: Mandates newly installed HVAC and dehumidification systems in existing indoor growing facilities to comply with the proposed mandatory requirements for CEH spaces.

2.2.3.1 Summary of Changes to the Reference Appendices

The proposed code change would not modify the Reference Appendices.

2.2.3.2 Summary of Changes to the Nonresidential ACM Reference Manual

The proposed code change would not modify the Nonresidential ACM Reference Manual.

2.2.3.3 Summary of Changes to the Nonresidential Compliance Manual

The proposed code change would modify Chapter 10 Covered Processes of the Nonresidential Compliance Manual. See Section 7.5 for the detailed proposed revisions to the text of the Nonresidential Compliance Manual.

2.2.3.4 Summary of Changes to Compliance Documents

The proposed code change would modify a certificate of compliance (NRCC-PRC-E Process Systems). Compliance information for a CEH production as a covered process would need to be added. Examples of the revised documents are presented in Section 7.6.

2.2.4 Regulatory Context

2.2.4.1 Existing Requirements in the California Energy Code

There are currently no requirements specific to HVAC and dehumidification in CEH facilities in the California Energy Code.

2.2.4.2 Relationship to Requirements in Other Parts of the California Building Code

There are no relevant requirements in other parts of the California Building Code.

2.2.4.3 Relationship to Local, State, or Federal Laws

Several local and state jurisdictions adopted regulations related to dehumidification and HVAC in CEH facilities. See Appendix G for more details.

The City and County of Denver requires CEH facilities to use one of the three options for dehumidification:

- Freestanding dehumidification units with a minimum energy factor of 1.9 L/kWh,
- Chilled water system with heat recovery from the condenser coil to achieve dehumidification reheat, or
- Integrated HVAC system with heat recovery to achieve dehumidification reheat.

The City and County of Denver code also allows the use of supplementary heat for dehumidification provided that the primary dehumidification system can fulfill at least 60 percent of the facility's peak dehumidification needs. Additionally, the code sets a minimum energy efficiency ratio for space-cooling equipment used in indoor growing facilities (City of Denver 2019). The Statewide CASE Team used the City and County of Denver code as a model for the proposed submeasure.

The City of Santa Rosa requires a ventilation rate of 15 cubic feet per minute (cfm) per person in the cultivation area for the number of occupants (City of Santa Rosa n.d.).

The Washington State Energy Code exempts indoor growing facilities from air-side economizer requirements if cooling equipment meets specified energy efficiency values (Washington State 2015).

Illinois state law requires cannabis grow facilities with less than 6,000 ft^2 of canopy to have high-efficiency ductless split HVAC units. For facilities with 6,000 or more ft^2 of canopy, the law mandates the use of variable refrigeration flow HVAC units, or more efficient units. The law also mandates filtering and using HVAC condensate, dehumidification water, and excess runoff (Illinois n.d.).

The Massachusetts Cannabis Control Commission requires HVAC and dehumidification systems in grow facilities to meet the state's building energy efficiency code and relevant ASHRAE and IECC metrics (State of Massachusetts n.d.).

CFR Title 10, Part 430 has minimum performance standards for consumer dehumidifiers, including portable and whole-home dehumidifiers. CFR Title 10, Part 430, Subpart B - Appendix X specifies a testing procedure to measure the energy performance of dehumidifiers.

2.2.4.4 Relationship to Industry Standards

There are no industry performance standards or testing procedures specific to CEH facilities for dehumidification equipment.

In 2019, ASABE and ASHRAE started to develop a guidance document (ASABE/ASHRAE Standard X653) on recommended practices for HVAC and dehumidification in indoor growing facilities (ASHRAE, ASHRAE Plant and Animal Environment, Technical Committee 2.2 2019).

There are several existing industry standards for performance testing of dehumidification equipment non-specific to CEH facilities. The Statewide CASE Team assessed whether existing performance testing procedures for dehumidification equipment non-specific to CEH facilities could be adapted to CEH facilities and concluded that these standards would need to be updated to reflect equipment performance for CEH application.

The Association of Home Appliance Manufacturers (AHAM) developed AHAM DH-1-2017, titled Dehumidifiers. The standard establishes a test procedure for measuring the rated capacity in pints per hours and liters per kWh performance for portable dehumidifiers under specified test conditions of 82oF and 60 percent relative humidity. The test conditions for this standard reflect environmental conditions within CEH facilities; however, the test is designed only for portable equipment with low daily capacity. The testing procedure for dehumidifiers codified in 10 CFR, Part 430, Subpart B - Appendix X incorporates by reference and leverages an earlier version of the standard, ANSI/AHAM DH-1-2008.

The Air-Conditioning, Heating, and Refrigeration Institute (AHRI) developed ANSI/AHRI Standard 910, titled Performance Rating of Indoor Pool Dehumidifiers. The testing procedure could be adapted to single package and spit-system direct-expansion commercial dehumidification systems used in the CEH facilities. However, more research needs to be done to establish minimum performance metrics specific to CEH facilities.

AHRI also developed ANSI/AHRI Standard 920, titled Performance Rating of DX Dedicated Outdoor Air System (DOAS) Units. The standard is used to rate the performance of DX equipment that is used to dehumidify air coming from outdoors. While CEH facilities utilize DX dehumidification equipment similar to DOAS units, it is standard practice to not introduce outside air in order to maintain desired CO_2 levels and mitigate biosecurity concerns.

ENERGY STAR® established efficiency criteria for portable dehumidifiers. Version 5.0 of ENERGY STAR Program Requirements for Dehumidifiers set the following criteria that went into effect in October 2019:

- Minimum 1.57 L/kWh energy factor for dehumidifiers with 25 pints/day capacity,

- Minimum 1.80 L/kWh energy factor for dehumidifiers with capacity between 25 and 50 pints/day, and
- Minimum 3.30 L/kWh energy factor for dehumidifiers with capacity of 50 pints/day or more (ENERGY STAR 2019).

2.2.5 Compliance and Enforcement

The development of compliance resources, such as compliance guidance for CEH facilities in the Nonresidential Compliance Manual and training for building department officials, is critical to successful implementation. For a list of specific recommendations for simplifying the compliance and enforcement process, refer to Appendix E.

2.3 Greenhouse Envelope Standards

2.3.1 Measure Overview

The greenhouse envelope standards submeasure is a code cleanup measure that proposes the following envelope requirements specific to conditioned greenhouses:

- Opaque wall and roof assemblies must meet the existing insulation and building envelope requirements in Section 120.7 and 140.3(a);
- Non-opaque walls assemblies must have a weighted average U-factor of 0.7 or less; and
- Non-opaque roof assemblies must have a weighted average U-factor of 0.5 or less.

The submeasure also exempts greenhouses from existing prescriptive building envelope requirements for window wall ratio, skylight roof ratio, and daylighting requirements for large enclosed spaces.

The proposed submeasure applies to newly constructed greenhouses and to greenhouses being converted from unconditioned to conditioned.

Since this submeasure is a code language cleanup effort, there are no associated savings or incremental costs.

2.3.2 Measure History

Greenhouses with heating capacity greater than 10 British thermal units (Btu)/hr-ft^2 or mechanical cooling with capacity greater than 5 Btu/hr-ft^2 fall under the 2019 Title 24, Part 6 definition of a directly conditioned space. Consequently, these greenhouses must meet nonresidential building envelope requirements, specifically prescriptive envelope requirements (i.e., Section 140.3(a)5 Exterior Windows, and Section 140.3(a)6 Skylights), or use a performance compliance approach. Both compliance pathways were never intended for greenhouses that need large non-opaque envelope surfaces to grow plants. To get around this issue, greenhouse designers have had to ask for exemptions on specific projects or use subsoil hydronic heating rather than unit heaters.

The proposed submeasure addresses this issue by creating a reasonable compliance path tailored to conditioned greenhouses.

2.3.3 Summary of Proposed Changes to Code Documents

2.3.3.1 Summary of Changes to the Standards

The sections below summarize how the standards, Reference Appendices, ACM Reference Manuals, and compliance documents would be modified by the proposed change. See Section 7 of this report for detailed proposed revisions to code language.

This proposal would modify the following sections of the California Energy Code as shown below. See Section 7.2 of this report for marked-up code language.

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

Section 100.1(b) – Definitions: Recommends new or revised definitions as follows.

New Definitions:

- "greenhouses" – necessary to define a building type that would be covered by the proposed measure.

Revised Definitions:

- "process, covered" – adds CEH spaces to the list of covered processes.

SECTION 120.6 – MANDATORY REQUIREMENTS FOR COVERED PROCESSES

Section 120.6(h) – Mandatory Requirements for Controlled Environment Horticulture Spaces: Creates a new section so that all requirements for CEH facilities are in one section. Adds standards related to greenhouse envelopes to create a feasible compliance path for conditioned greenhouses.

SECTION 140.3 – PRESCRIPTIVE REQUIREMENTS FOR BUILDING ENVELOPES

Section 140.3(a)5 EXCEPTION 1: Adds an exemption for greenhouses from the existing prescriptive building envelope requirement for window wall ratio.

Section 140.3(a)6 EXCEPTION 1: Adds an exemption for greenhouses from the existing prescriptive building envelope requirement for skylight roof ratio.

Section 140.3(c) EXCEPTION 1: Adds CEH spaces to the list of spaces exempt from minimum daylighting requirements.

SECTION 141.1 – REQUIREMENTS FOR COVERED PROCESSES IN ADDITIONS, ALTERATIONS TO EXISTING NONRESIDENTIAL, HIGH-RISE RESIDENTIAL, AND HOTEL/MOTEL BUILDINGS

Section 141.1(a)2 – Controlled Environment Horticulture Spaces: Mandates greenhouses being converted to conditioned greenhouses to comply with the greenhouse specific proposed requirements on building envelope and space-conditioning systems.

2.3.3.2 Summary of Changes to the Reference Appendices

The proposed code change would not modify the Reference Appendices.

2.3.3.3 Summary of Changes to the Nonresidential ACM Reference Manual

The proposed code change would not modify the Nonresidential ACM Reference Manual.

2.3.3.4 Summary of Changes to the Nonresidential Compliance Manual

The proposed code change would modify Chapter 10 Covered Processes of the Nonresidential Compliance Manual. See Section 7.5 of this report for the detailed proposed revisions to the text of the Nonresidential Compliance Manual.

2.3.3.5 Summary of Changes to Compliance Documents

The proposed code change would modify the certificate of compliance (NRCC-PRC-E Process Systems). Compliance information for a CEH production as a covered process would need to be added. Examples of the revised documents are presented in Section 7.6.

2.3.4 Regulatory Context

2.3.4.1 Existing Requirements in the California Energy Code

2019 Title 24, Part 6 does not have envelope requirements tailored to conditioned greenhouses.

2.3.4.2 Relationship to Requirements in Other Parts of the California Building Code

There are no relevant requirements in other parts of the California Building Code.

2.3.4.3 Relationship to Local, State, or Federal Laws

The 2018 Washington State Energy Code has envelope requirements for non-opaque roof and walls of conditioned greenhouses. Specifically, the code sets a maximum U-factor of 0.5 for non-opaque roof, 0.71 for non-opaque south-, east-, and west-facing walls, and 0.6 for non-opaque north-facing wall.

2.3.4.4 Relationship to Industry Standards

2018 IECC exempts greenhouses from building thermal envelope provisions. A proposal (code change number CE56-19) for 2021 IECC to add envelope requirements specific to conditioned greenhouses was approved in the final vote in late 2019 (ICC 2020). The proposal mandates U-factor of 0.5 Btu/(hr-ft²-ºF) for skylights and a U-factor of 0.7 for vertical fenestration. The Statewide CASE Team used 2021 IECC proposal related to greenhouses as a model for the proposed submeasure.

2.3.5 Compliance and Enforcement

The development of compliance resources, such as compliance guidance for CEH facilities in the Nonresidential Compliance Manual, and training for building department officials, is critical to successful implementation. For a list of specific recommendations for simplifying the compliance and enforcement process, refer to Appendix E.

As part of compliance verification for this submeasure, a building department official would verify the U-values of greenhouse envelope materials based on specification sheets.

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. It then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during the public stakeholder meetings that the Statewide CASE Team held on September 19, 2019, and April 16, 2020.

3.1 Market Structure

Table 8 below summarizes the impacts of this proposal on key market actors.

Table 8: Market Actors and Impacts

Market actor	How market actor could be affected by proposal
Indoor facility operators with > 1,000ft^2 of canopy	When building a new facility or making qualifying additions or alterations to an existing facility, would have to: • Use lighting luminaires with a minimum lighting efficacy of 2.1 μMol/J. • Install time-switch and dimming lighting controls. • Install one of the following dehumidification systems: freestanding with a minimum energy factor of 1.9 kWh; chilled water system with heat recovery; or integrated HVAC systems with heat recovery for dehumidification air reheat (wrap around heat exchanger or hot gas bypass). • Install thermostatic and humidity controls. • If stand-alone dehumidification systems are present, must reuse transpired water for irrigation.
Greenhouse facility operators with > 1,000ft^2 of canopy	When building a new facility or making qualifying additions or alterations to an existing facility, would have to: • Use electric luminaires with a minimum lighting efficacy of 1.7 μMol/J. • Install time-switch lighting controls and dimming lighting controls. For greenhouses with qualifying heating or cooling systems, install a shade curtain system if the non-opaque envelope has U-value over 0.71.

Market actor	How market actor could be affected by proposal
CEH facility designers	Become familiar with new standards and modify standard design practices to incorporate minimum code efficiencies.
Lighting manufacturers	Ensure the specification sheet for every model clearly reports efficacy in micromoles per joule and provide PPE for legacy lighting luminaires such as double-ended high-pressure sodium (HPS) and ceramic metal halide luminaires.
Dehumidification unit manufacturers	Ensure the specification clearly delineates specifications relating to heat recovery such as hot gas bypass.
Building departments	Review plans for lighting, HVAC, dehumidification, and water reuse for compliance.
Utilities	• Review horticultural lighting incentives. Although the baseline efficiency may be increasing, there should still be room for incentives in greenhouses and possibly for higher efficiency LED luminaires. • Savings from demand side management (DSM) programs may be reduced because of a more efficient baseline.
Equipment dealers	• Understand code minimum baselines and technologies that are allowable for indoor lighting, greenhouse lighting, and indoor dehumidification.

The table below summarizes potential barriers that could reduce proposal effectiveness, and the proposed solutions.

Table 8: Barriers and Solutions

Barrier	Solution
Cost	The benefit/cost analyses in this proposal demonstrate the measure would have positive returns.
Environmental and energy use requirements differ by crop type and by stage of the crop type	The Statewide CASE Team considered six crop types in the analysis to evaluate the cost effectiveness of the proposed submeasures. Three distinct crop types were used in calculations due to similarities between other crop type requirements.

Barrier	Solution
Lack of data on standard baseline practices and sharing of best management practices among growers	The Statewide CASE Team conducted a survey to gather information on baseline standard practices. Benchmarking efforts include development of tools by the industry for assessing energy use: • Indoor Cannabis Cultivator Energy Use Estimator developed by Oregon Department of Energy: • https://energy.odoe.state.or.us/cannabis • Resource Innovation Institute PowerScore benchmarking tool • Cornell's Greenhouse Lighting and Systems Engineering (GLASE) benchmarking tool (in development)
Widely accepted performance metrics for CEH operations not fully developed	Currently there are no widely used or accepted horticultural performance metrics in the CEH industry. Resource Innovation Institute has developed the PowerScore benchmarking tool and is working to increase adoption of the tool by the industry. Cornell's GLASE group is also developing a benchmarking tool specific to greenhouses. ASHRAE is evaluating how to approach measures related to CEH and has recently created a CEH Multidisciplinary Task Group to provide technical guidance. Continued coordination with these organizations would support data gathering and CEH facility performance data availability.
Lack of CEH HVAC standards	ASHRAE is starting to develop a standard specific to CEH facilities that will provide test conditions to measure the efficiency of CEH HVAC systems. Until that is developed, measures such as heat recovery can be utilized to increase CEH HVAC efficiency.
Reluctance of producers to switch to LED lighting	The proposed code change offers less stringent requirements for greenhouses, which offers a viable option to producers hesitant to use LED luminaires for plant growth.

3.2 Technical Feasibility, Market Availability, Current Practices, and Potential Barriers

3.2.1 Horticultural Lighting Minimum Efficacy

3.2.1.1 Technical Feasibility

In CEH facilities, electric lighting provides plants with the amount and intensity of illumination needed for photosynthesis at each stage of plant development. It is the primary source of energy that plants need for growth. Technologies that meet the proposed greenhouse efficacy levels are widely available and include double-ended

HPS, ceramic metal halide, and LED luminaires. The required minimum efficacy for indoor facilities is more stringent than greenhouses and encourages the use of LED lighting technology by setting efficacy levels that are challenging to meet with other less efficacious light sources. There may be plasma lighting and double-ended HPS options that can meet minimum requirements, but no test data was found for these technology types at the proposed minimum indoor lighting efficacy.

In the next decade, PPE of 3.5 μmol/J is possible for LEDs (Runkle and Bugbee 2017). At the time of this report, the highest efficiency LED luminaire was rated at 3.0 μmol/J.

The most accepted metric for horticultural lighting efficacy is PPE. PPE is photosynthetic photon flux divided by input electric power, measured in micromoles per joule (see Section 3.2.1.3 on Current Practices for more detail.) Table 9 provides typical efficacy ranges for the common horticultural lighting technology types.

Table 9: Efficacy of Horticultural Lighting Technologies

Technology	PPE (micromoles per joule)	Meets proposed minimum PPE greenhouse	Meets proposed minimum PPE indoor
Single-ended 400-W HPS lamp with magnetic ballast	0.9	No	No
Double-ended 1,000-W HPS lamp with electronic ballast	1.7–2.1	Yes	No (maybe highest efficacy luminaires)
Single-ended HPS[a]	1.0	No	No
Metal halide luminaire[b]	0.8	No	No
Ceramic metal halide luminaire[a]	1.5	Yes	No
Fluorescent lighting luminaire[a]	0.84–0.95	No	No
LED lighting luminaire[c]	1.1–3.0	Yes	Yes

Sources:

a. (Navigant 2017);

b. (Radetsky 2018);

c. (Radetsky 2018) and (DesignLights Consortium 2019)

In the next decade, PPE of 3.5 μmol/J is possible for LEDs (Runkle and Bugbee 2017). At the time of this report, the highest efficiency LED luminaire was rated at 3.0 μmol/J.

3.2.1.2 Market Availability

Energy-efficient horticultural lighting products are readily available on the market. The greenhouse requirement of 1.7 PPE could be met by ceramic metal halide, double-ended HPS, and LED luminaires. For indoor growing facilities, as of May 2020, 70 of 86 luminaires listed on DLC's QPL, which met the 2.1 PPE requirement.

3.2.1.3 Current Practices

As stated in 3.2.1.1, PPE is photosynthetic photon flux divided by input electric power. Photosynthetic photon flux (PPF) is the rate of flow of photons between 400 to 700 nanometers in wavelength, which are those needed for photosynthesis, measured in micromoles per second. The unit of measure for a plant's lighting needs is the daily light integral (DLI), expressed as the number of photosynthetically active photons accumulated per square meter per day ($mol/m^2/d$). Table 10 below illustrates the range of parameters typically found in various indoor growing facilities.

Table 10: Range of Lighting Parameters in Indoor Facilities

Crop type	Photosynthetic Photon Flux Density (PPFD) ($\mu mol/m^2/s$)	Hours per day of Lighting	Daily Light Integral (DLI) ($mol/m^2/d$)	Source
Leafy greens and herbs	140–200	16–24	12–17	https://www.horti-growlight.com/leafy-greens; and PPFD calculation for DLI of 17
Flowering crops (e.g., peppers and tomatoes)	170–600	16–24	15-40	https://www.horti-growlight.com/leafy-greens; Fluence High-PPFD Cultivation Guide; and PPFD calculation for DLI of 40
Cannabis, seedling and vegetative stages	300–600	18–24	19-43	DLI calculation for PPFD of 300-500 at 18–24 hrs/day
Cannabis, flowering stage	600–1,000	12	26-43	DLI calculation for PPFD of 600-1,000 at 12 hrs/day

Sources: MechaTronix n.d.

Many factors determine the effectiveness of electric light in horticulture. A 2018 study by the Lighting Research Center Rensselaer Polytechnic Institute proposed a technology-neutral framework to evaluate overall performance, which includes 16 different luminaire-specific and application-specific metrics. However, PPE was chosen because it is simple for manufacturers to publish and is the metric most commonly adopted by other existing standards (Radetsky 2018).

Another metric is LPD, expressed in watts per square foot of canopy, which has been used by other jurisdictions such as Massachusetts and Illinois. One reason it was not chosen is that it does not take into account the wavelengths needed for photosynthesis. Also, growers can bypass LPD requirements by spacing out their plants farther, thus actually decreasing overall productivity per square foot while continuing the use of lower-efficiency luminaires. In addition, stacked operations can make the LPD calculation complicated and prone to noncompliance.

Greenhouses and indoor growing facilities are different applications, and thus require different baselines. The lighting efficiency standard for greenhouses is lower than for indoor growing facilities. First, greenhouses do not need as much electric lighting, as they also use natural sunlight. Further, they are used for flowers and vegetables rather than just for cannabis, which has much higher lighting needs. Second, lower requirements for greenhouses would put less burden on vegetable and flower growers, who have lower profit margins than cannabis growers. Third, a lower PPE for greenhouses provides an option for growers to switch from indoor to greenhouse growing if they want to use legacy technologies. In addition, LED lighting can have a larger form factor and cause shading in greenhouses, so providing options other than LED lighting for greenhouses is important.

The baselines used for energy savings calculations are presented below. The baselines were determined through stakeholder outreach such as the online and phone surveys described in Section 4.1.2 and Appendix F.

Table 11: Baselines for Lighting Energy Savings Analysis

Crop	Weight	Baseline PPE	Proposed PPE
Greenhouse			
Cannabis - Flower	24.9%	1.02	1.7
Cannabis - Vegetative	4.5%	1.02	1.7
Cannabis - Clone	0.6%	0.55	1.7
Leafy Greens	30%	1.02	1.7
Tomatoes	40%	1.02	1.7
Indoor			
Cannabis - Flower	76.4%	1.7	2.1
Cannabis - Vegetative	13.8%	1.02	2.1
Cannabis - Clone	1.8%	0.55	2.1
Leafy Greens	5%	1.02	2.1
Tomatoes	3%	1.02	2.1

Indoor facilities often grow plants on stacks of shelves to optimize space. The luminaires are mounted on each shelf. Since they are close to the plants, they cannot produce excessive heat and so must be either linear fluorescent lamps or LED. Linear fluorescent luminaires are often used due to their familiarity and low first cost. An advantage of LED lighting is better control of light intensity through dimming and optical distribution engineering. This allows LED luminaires to be placed very close to the plants, thus reducing shelf height and increasing yield potential per square foot. According to a 2017 Navigant study commissioned by the U.S. Department of Energy (U.S. DOE) (DOE 2017), average lighting time is 15 hours a day for non-stacked configuration and 17.2 hours a day for stacked configuration. The data sources for the study included 19 grower interviews, interviews with lighting manufacturers, retailers, utilities, and industry experts, and review of product specification databases and the U.S. Agriculture and Horticulture Censuses. It found lighting for indoor facilities to be distributed as shown in the following table:

Table 12: Percentage of Stacked Growing by Lighting Type

Lighting Type	Unstacked	Stacked
LED	4%	66%
HPS and Metal Halide	89%	<1%
Fluorescent	7%	34%

According to a November 2019 survey conducted by the Cannabis Business Times, 21 percent of cannabis cultivators currently use LEDs. Of those who responded they did not, 48 percent said it was still unproven technology and 42 percent said it was too expensive. However, 72 percent of the same research participants noted that energy efficiency and light intensity were the most important factors when making lighting purchases (Cannabis Business Times 2019).

Two popular high-intensity discharge (HID) luminaires—HPS and metal halide—produce distinct wavelengths of light across the PAR spectrum (400-700nm): metal halide luminaires produce a high concentration of blue light (400-500 nm), while HPS luminaires produce a high percentage of red light (600-700 nm). Historically, for non-stacked configuration, growers chose between these two different types of HID lighting depending on the crop type, plant cycle, PPF requirement, and cost (DOE 2017).

Illumination intensity and daily schedules are controlled based on each crop's individual needs throughout a 24 hour period, which has a direct effect on both crop quality and yield. PPE or the efficacy of horticultural lighting is a measurement of how efficiently the system provides light to the crop per unit of energy during the specified photoperiod. Lighting system intensity can be controlled locally by a dimmer switch on each luminaire or by a centralized programmable device. Daily on/off schedules are set and controlled locally within each individual production space by a programmable device.

There are many specialty manufacturers that market directly to the CEH industry. Since the legalization of recreational cannabis, major lighting manufacturers (Signify, Current, Osram, etc.) have also entered the market. The most sophisticated manufacturers and service providers in this sector focus on automation through integrated controls. For example, Wadsworth Controls advertises its product and service offering as a "complete climate solution" while GrowLink offers "data driven farm automation and networking systems for greenhouse and indoor vertical farming."

3.2.1.4 Potential Barriers and Solutions

Specific to the horticultural lighting minimum efficacy submeasure is a concern by some producers that LED technology is unproven for cannabis (New Frontier 2018). However, as shown by the examples below, some growers have reported successful adoption.

- A grower in Oregon reported no impact on yields in vegetative rooms after replacing 1,270 T5 fluorescent lamps with tubular LED lamps while keeping the same luminaires and ballasts (Southwest Energy n.d.).
- Another grower in Oregon reported higher crop quality with LED lighting compared to HPS or metal halide lighting (Energy Trust of Oregon 2017b).
- A third grower in Sacramento, California, reported a decrease in yields but increased crop quality in a study comparing LED and HPS lighting in flowering rooms (SMUD 2018b). The study states that the LED lighting intensity was set too high initially, which may have been a contributing factor for yield decrease (35–40 percent lower than expected).
- Another grower in Sacramento, California, reported expected ranges for yield for six out of seven strains and expected crop quality for all seven strains in a study comparing LED and HPS lighting in flowering rooms (SMUD 2018a). The study states that the room with the LED lighting and three of the seven cultivated strains, including the strain with lower than expected yield, experienced an HVAC outage and lighting timer issues at first. These technical issues may have been a contributing factor for yield decrease for one of the seven strains (40 percent lower than expected).

Mixed results in the above studies are expected given that, even under the same conditions, the same crop may have yield variation of 10 to 20 percent (Caulkins, Cohen and Zamarra 2014). Based on self-reported data collected via Resource Innovation Institute's PowerScore Tool from 34 indoor growers, New Frontier Data (2018) reported an average electricity productivity of 0.6 grams/kWh for facilities with HPS flowering lighting and 1.4 grams/kWh for facilities with LED flowering lighting. Most of the data are from growers in Oregon (18 out of 34). While there may be other factors at play, this limited dataset suggests that LED lighting leads to significantly higher yields per kilowatt-hour compared to HPS lighting.

3.2.2 Efficient Dehumidification and Reuse of Transpired Water

3.2.2.1 Technical Feasibility

Indoor growing facilities shall utilize one of the following types of dehumidification equipment: freestanding unit with minimum energy factor of 1.9 L/kWh; chilled water system with heat recovery; or integrated HVAC system with heat recovery from condenser coil. As shown in Section 2.2.4, this proposal largely aligns with current requirements in the City of Denver. All three solutions are technically feasible. The intent of the proposed submeasure is to set an industry-accepted code baseline that encourages heat recovery systems. The Statewide CASE Team held a stakeholder discussion at the Indoor Agriculture Energy Solutions Conference in February 2020 in San Diego, and the proposed submeasure received broad support from various stakeholders. The proposed submeasure is similar to Denver, Colorado, dehumidification code language creating regional consistency.

3.2.2.2 Market Availability

The table below lists some current approaches for dehumidification.

Table 13: Available Dehumidification Technologies

Equipment Type	Description	Market Availability
Stand-alone units	Simple and flexible.	This is a common product carried by CEH equipment dealers.
Not dedicated – reheat (conventional)	Unitary AC, unitary heat pumps, and air-cooled and water-cooled chiller systems typically used in commercial building applications.	The market is mature, with wide availability. Equipment is not specifically designed for horticulture.
Not dedicated – reheat (reclaimed waste heat)	Unitary AC, unitary heat pumps, and air-cooled and water-cooled chiller systems with hot gas bypass or other heat recovery systems.	Hot gas bypass options and other heat recovery systems are available from most commercial HVAC manufacturers.
Dedicated dehumidification units	Direct expansion HVAC units designed specifically for dehumidification.	Several manufacturers offer this technology, but it is more specialized and has fewer options than sensible cooling products such as unitary AC.
Fully integrated cooling plus dehumidification	Direct expansion HVAC systems designed to handle both the sensible and latent load needs of a facility.	Several manufacturers offer this technology, but it is more specialized and has fewer options than sensible cooling products such as unitary AC.

Humidity and thermostatic controls are available from both major manufacturers such as Honeywell or from specialty manufacturers. Products are typically provided with equipment purchases.

Dehumidification equipment is typically manufactured and sold by large HVAC manufacturers, but some manufacturers specialize in indoor agriculture products. Indoor agriculture specialists include Surna, Anden, Therma-Stor LLC, KCC Manufacturing, and InSpire Transpiration (headquartered in San Francisco, CA). Additional manufacturers that service this sector are DesertAire, Dri-Eaz Products, Inc., Munters, Active Air Inc., Aprilaire (a division of Research Products Corporation), and IdealAir Heating and Cooling, Inc., which offers a full suite of HVAC products, including controls equipment.

Some manufacturers that service the dehumidification market provide more comprehensive solutions. For example, San Francisco-based InSpire Transpiration offers “full turnkey solutions” for indoor and greenhouse horticulture, including HVAC equipment manufacturing, construction and project management, system design and engineering, horticultural consulting, and even capital financing options.

Ideal environmental growing conditions are highly dependent on crop type and reproductive stage. Based on stakeholder outreach, the Statewide CASE Team has determined that CEH facilities maintain 70–80°F and 40–65 percent relative humidity in plant production space. To manage these unique environmental conditions, CEH operators use integrated (programmable logic control type) or stand-alone devices from a wide array of manufacturers. These devices can either be operated by a centralized network or managed individually.

Honeywell is one of the largest and most widely known agricultural thermostat manufacturer. Additional agriculture specialists, some of which specialize in cannabis, include Agronomic IQ, Wadsworth Controls, Argus Controls, Titan Controls, Dosatron, and GrowLink. Active Air Inc., which also manufactures HVAC and dehumidification equipment, services residential and commercial clients beyond agriculture.

The most sophisticated manufacturers and service providers in this sector focus on integrated controller software that allows system automation across the entire indoor or greenhouse ecosystem. For example, Wadsworth Controls advertises its product and service offering as a “complete climate solution” while GrowLink offers “data driven farm automation and networking systems for greenhouse and indoor vertical farming.”

3.2.2.3 Current Practices

Humidity control is essential to plant health, and the equipment used to control humidity in CEH facilities is an integral part of CEH facility design. The most common dehumidification equipment currently used to control latent loads within indoor plant production space are stand-alone dehumidifiers due to their low equipment costs, installation costs, and configurability. Stand-alone dehumidification units are widely available through equipment dealers and installed during the primary construction phase. These dehumidification units are typically mentioned in electrical plans due to high electric loads. However, they can be added or removed by facility operators if moisture removal requirements change from the initial design specifications.

The dehumidification requirements of a CEH facility change when the lights turn off because of the reduction in heat load due to the lighting system and transpiration of the plants. This changes the sensible heat ratio of the facility, causing less sensible load and more latent load. A facility's HVAC and dehumidification systems must be designed to handle both the peak sensible and latent loads.

Some dehumidification equipment, such as stand-alone dehumidifiers, utilize moisture removal efficiency (MRE) as a metric of how efficiently the system can remove water from the air, measured in pounds of moisture removed per kilowatt-hour. This metric is not applied or measured for integrated HVAC units, which cool and dehumidify simultaneously. There is no testing procedure which measures equipment efficiency under CEH conditions. However, there is movement in the HVAC industry to develop such a standard, and ASHRAE has started a working group to begin developing a standard. There is currently no set timeline for the completion of a horticultural HVAC test procedure or standard.

When designing a dehumidification system, the interactive effects of lighting and HVAC are important considerations. Lighting intensity, duration, and heat output alter a CEH facility's air temperature, humidity, water use, and evaporation rates. When lights in a CEH facility are on, the space requires significant cooling from the HVAC system to remove heat generated by the lighting system. When lights turn off, the air begins to rapidly cool reducing the amount of moisture it can hold and increasing humidity. Dehumidification and HVAC systems that are improperly sized to handle varying loads in a CEH facility can lead to excessive energy consumption, shortened equipment life, and poor humidity control. Oversized equipment may cycle more frequently which can increase energy consumption and be detrimental to plant health. Undersized equipment may not be able to meet specified environmental conditions causing cultivators to purchase additional standalone units that increase cooling loads and energy use by rejecting heat back into the plant production space. While it is common for growers to specify a wide range of target temperatures and relative humidity (such as +/- 5 °F and +/- 7 percent humidity), systems not optimized for CEH applications can lead to poor energy performance, and environmental control (New Frontier 2018).

Humidity and thermostatic controls are typically operated locally without communication to other system or equipment in the facility. More sophisticated products have integrated solutions and software with the ability to deploy automation across the entire CEH facility, though this is not a mainstream technique.

Transpired water is typically re-captured by collecting condensate within dehumidification and HVAC systems and piping into reservoirs for re-use. Techniques range from complex systems comprised of pumps and transportation pipes to simple gravity-based methods that collect water in barrels to be removed and transported by hand.

3.2.2.4 Potential Barrier and Solutions

Since the legalization of recreational cannabis, more HVAC manufacturers have started to offer dehumidification products engineered for CEH application. These are generally sold directly from manufacturer to consumer and through specialty horticultural retail shops. If the proposed submeasure is adopted, manufacturers would have to start selling integrated HVAC units that are specified and sized to provide at least 60 percent of the facility's primary dehumidification through reheat. There is currently equipment available that would satisfy this requirement, but customer visibility of these features could be improved. Designers and engineers are more familiar with these options and can help facilitate correct equipment choice for end-users. For indoor CEH facilities to utilize the second or third option of the proposed submeasure, engineers and architects would have to properly calculate expected latent loads for integrated HVAC equipment in each room with plant production and report the reheat percentage during plan check. Additionally, all manufacturers of stand-alone dehumidification units would need to report MRE for each model on their equipment specification sheet. Some currently provide this, but not all manufacturers have it listed in a publicly accessible document.

For this code proposal, the Statewide CASE Team analyzed stand-alone packaged and integrated HVAC units. Based on research and interviews with stakeholders, the Statewide CASE Team found that many of the available products are not specifically manufactured to mitigate high moisture loads and manage the complex environmental interactions that exist in a CEH facility.

Table 14: Barriers and Solutions to Dehumidification Submeasure

Barrier	Solution
Efficient dehumidification units are typically specified for larger CEH facilities	The Statewide CASE Team worked with manufacturers to identify technologies for small to medium CEH facilities. Efficient technologies for small and medium operations include high efficiency stand-alone dehumidifiers, wrap-around heat exchangers, and integrated HVAC/dehumidification units with hot gas bypass.
Commercial economizers can lead to air contamination and	Based on stakeholder feedback, the Statewide CASE Team proposes to exempt CEH facilities from air-side economizer requirements when CO2 enrichment is used.

Barrier	Solution
mold issues and negatively affect targeted CO_2 concentration	
No unified standard or test procedure for horticultural HVAC equipment	Code language would be created based on available metrics such as MRE for stand-alone dehumidifiers and technology features for equipment that currently has no applicable metric.
Not all stand-alone dehumidification manufacturers list MRE	Manufacturers would be notified of requirements for minimum MRE requirements so they can start listing the metric for units that do not currently list MRE on cut sheets.

3.2.3 Greenhouse Standards

3.2.3.1 Technical Feasibility

The envelope options eliminated by the proposed U-value requirement of 0.71 or less are single-pane glass, single-layer polyethylene sheeting, and corrugated single-wall polycarbonate. A U-value of 0.71 was chosen in order to align with the Double Pane U-Factor requirements for a metal frame mandated in Title 24, Part 6, Section 110.6. This U-value is also nearly aligned with the 2021 IECC proposal described in Section 2.3.4. These materials can still be used if the facility chooses the other compliance option of installing a shade curtain system. Materials that meet the proposed requirement are widely available and used currently in the greenhouse industry, and include double- and triple-wall polycarbonate, double polyethylene sheeting, and double-pane glass.

There is a trade-off between light transmittance and insulation value. Generally, light transmittance decreases as insulation value increases. This concern was raised during stakeholder outreach. The option to install a shade curtain as an alternate path to compliance was added to allow producers who require or prefer high light transmittance materials (e.g., single-pane glass or corrugated single-wall polycarbonate) to continue use of these materials.

Shade curtains are a commonly used technology in the greenhouse industry. They are less suitable to greenhouse construction types such as hoop houses, but these types of greenhouses utilize polyethylene sheet material for their envelope and typically do not fall into the conditioned space requirements.

3.2.3.2 Market Availability

Table 15 provides a listing of the common greenhouse envelope materials currently utilized for greenhouse construction. The data presented below are estimates provided by multiple manufacturers.

Table 15: Common Greenhouse Envelope Materials Used

Greenhouse Covering	R-Value	U-Value	Light Transmittance	Cost / Ft^2	Useful Life (Years)
16mm Triple-Wall Polycarbonate	2	0.5	78%	$4.00	15
Double-Pane Storm Windows	2	0.5	78%	$6.00	25
10mm Double-Wall Polycarbonate	1.89	0.53	80%	$2.50	15
8mm Double-Wall Polycarbonate	1.6	0.63	80%	$1.66	15
6mm Double-Wall Polycarbonate	1.54	0.65	82%	$1.54	15
4mm Double-Wall Polycarbonate	1.43	0.7	83%	$1.50	15
Single-Pane Glass, 3mm	0.95	1.05	88%	$3.00	25
Single-Sheet Polyethylene Film	0.83	1.2	77%	$0.09	4
Double-Sheet Polyethylene Film	0.70	1.43	85%	$0.18	4
Corrugated Single-Wall Polycarbonate	0.83	1.2	91%	$1.33	15

3.2.3.3 Current Practices

The current California conditioned greenhouse stock utilizes a variety of envelope materials, with double-wall polycarbonate being a common choice. Polycarbonate comes in various thicknesses, each with slightly different cost and material properties. Glass is also used for conditioned greenhouses due to its high light transmittance. Polyethylene is not as commonly used for conditioned greenhouses, but it is more common for unconditioned greenhouses or heated hoop houses in colder climates outside of California.

Shade curtains are commonly used to reduce heat gain during warm, sunny weather. They can also be utilized to reduce heat loss at night. Shade curtains usually hang several feet below the ceiling of the greenhouse, effectively reducing the volume of air to maintain a desired temperature.

3.2.3.4 Potential Barrier and Solutions

The conditioned greenhouse envelope requirement issue was brought to the attention of the Statewide CASE Team from designers and engineers that are currently working through compliance with new construction greenhouses that meet the definition of a conditioned space. In some cases, designers have had to request exemptions for projects due to an inability to meet envelope code requirements. According to greenhouse designers in California, many jurisdictions are not strictly enforcing these code requirements on greenhouses; when jurisdictions do strictly enforce the requirements, projects can be delayed or discontinued.

To resolve these issues, the Statewide CASE Team proposes code language that defines greenhouses as a distinct building type and includes U-value requirements that align with widely available greenhouse building materials. This would allow designers to easily determine a design that complies with the envelope requirements for conditioned greenhouses. Unconditioned greenhouses are not subject to envelope requirements, and the proposed code language only applies to conditioned greenhouses.

Table 16 provides an overview of the major barriers for greenhouse envelope requirements and the solutions associated with them.

Table 16: Barriers and Solutions to Greenhouse Envelope Submeasure

Barrier	Solution
Existing code requirements for conditioned spaces do not include greenhouse-specific options and are not feasible to comply with when using typical greenhouse construction and materials	Proposed code language cleanup would create greenhouse-specific requirements that utilize common industry technologies.
Some growers require or prefer greenhouse materials with high light transmittance	Two options for compliance are offered, either U-value of materials or installing a shade curtain system.
Compliance with existing envelope requirements is not widely enforced across the state	Proposed code language would allow for wider compliance enforcement.

3.3 Market Impacts and Economic Assessments

3.3.1 Impact on Builders

Builders of CEH structures are directly impacted by many of the measures proposed by the Statewide CASE Team for the 2022 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

California’s construction industry comprises about 80,000 business establishments and 860,000 employees (see Table 17).[1] In 2018, total payroll was $80 billion. Nearly 17,000 establishments and 344,000 employees focus on the commercial sector. Numerous establishments and employees support industrial, utilities, infrastructure, and other heavy construction (industrial sector).

Table 17: California Construction Industry, Establishments, Employment, and Payroll

Construction Sectors	Establish ments	Employ ment	Annual payroll (billions $)
Commercial	**17,273**	**343,513**	**$27.8**
Foundation, Structure, & Building Exterior	2,153	53,531	$3.7
Building Equipment Contractors	6,015	128,812	$10.9
Building Finishing Contractors	4,597	85,612	$6.2
Industrial, Utilities, Infrastructure, & Other	**4,103**	**96,550**	**$9.2**
Industrial Building Construction	299	5,864	$0.5

Source: (State of California, Employment Development Department n.d.)

The proposed standards for CEH would likely affect commercial builders and firms that focus on construction and retrofit of industrial buildings. The effects on the commercial building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. While CEH facilities typically employ the same types of market actors as commercial construction projects, such as HVAC contractors, equipment distributors, and architects, the individuals involved in constructing CEH facilities typically specialize in this industry. Additionally, indoor grow facilities and greenhouses are considered industrial facilities since a manufacturing process is occurring. The Statewide CASE Team’s estimates of the magnitude of these impacts are shown in Section 3.4.

[1] Average total monthly employment in California in 2018 was 18.6 million; the construction industry represented 4.5 percent of 2018 employment.

Table 18: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard

Construction Subsector	Establishments	Employment	Annual Payroll (billions $)
Commercial building construction	4,508	75,558	$6.95
Nonresidential poured foundation contractors	504	14,917	$1.08
Nonresidential structural steel contractors	318	12,044	$0.87
Nonresidential glass and glazing contractors	280	5,244	$0.43
Nonresidential roofing contractors	347	8,939	$0.62
Nonresidential siding contractors	25	396	$0.02
Nonresidential electrical contractors	3,115	66,951	$5.61
Nonresidential plumbing and HVAC contractors	2,394	52,977	$4.47
Nonresidential site preparation contractors	1,157	17,059	$1.27
All other nonresidential trade contractors	988	17,960	$1.40

Source: (State of California, Employment Development Department n.d.)

3.3.2 Impact on Building Designers and Energy Consultants

Although this code proposal would be the first regulations specifically impacting horticultural equipment, adjusting design practices to comply with changing building codes practices is within the normal practices of CEH building designers who have had to comply Title 24, Part 6 for other parts of the building such as building envelope or lights in an office. Building codes (including the California Energy Code) are typically updated on a three-year revision cycle and building designers and energy consultants engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (North American Industry Classification System [NAICS] 541310). Table 19 shows the number of establishments, employment, and total annual payroll for Architectural Services. The code change proposals the Statewide CASE Team is proposing for the 2022 code cycle would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for this CEH proposal to affect firms that focus on nonresidential and industrial construction.

There is no NAICS[2] code specific to energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which includes firms primarily engaged in the physical inspection of residential and nonresidential buildings.[3] It is not possible to determine which business establishments in the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 19 provides an upper bound indication of the size of this sector in California.

Table 19: California Building Designer and Energy Consultant Sectors

Sector	Establishments	Employment	Annual Payroll (billions $)
Architectural Services [a]	3,704	29,611	$2.91
Building Inspection Services [b]	824	3,145	$0.22

Source: (State of California, Employment Development Department n.d.)

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures.
b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential and nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services.

3.3.3 Impact on Occupational Safety and Health

The proposed code change does not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by the California Division of Occupational Safety and Health. All existing health and safety rules would remain in place. Complying with the proposed code change is not anticipated to have

[2] NAICS is the standard used by federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was developed jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia to allow for a high level of comparability in business statistics among the North American countries. NAICS replaced the Standard Industrial Classification (SIC) system in 1997.

[3] Establishments in this sector include businesses primarily engaged in evaluating a building’s structure and component systems and includes energy-efficiency inspection services and home inspection services. This sector does not include establishments primarily engaged in providing inspections for pests, hazardous wastes or other environmental contaminants, nor does it include state and local government entities that focus on building or energy code compliance/enforcement of building codes and regulations.

adverse impacts on the safety or health of occupants or those involved with the construction, commissioning, and maintenance of the building.

3.3.4 Impact on Building Owners and Occupants

Controlled Environment Horticulture Buildings

The CEH sector includes a wide variety of grow facilities. There are numerous demarcations and descriptions to classify facilities. For instance, CalCannabis breaks grow facilities down into six categories: nursery, specialty cottage, specialty, small, medium, and large (CalCannabis 2017). These facilities range in size from a few hundred ft^2 of canopy to tens of thousands of ft^2 of canopy. Just as these facilities differ in size, they also can differ in growing processes. Smaller grow facilities may not utilize specialized dehumidification equipment, whereas larger facilities may dedicate many resources for integrated HVAC equipment. Section 6.1 shows estimates for the total canopy square footage impacted by these proposals.

Estimates for the energy intensity of grow facilities varies greatly depending on type of facility. One study shows that energy intensity can range from 128 kilowatt-hours per canopy square foot for indoor facilities but only 1 kilowatt-hour for outdoor operations in 2017. Earlier estimates for indoor facilities determined this value to be closer to 450 kilowatt-hours (Northwest Power and Conservation Council 2018).

Building owners would benefit from lower energy bills. As discussed in Section 3.4.1 when building owners save on energy bills, they tend to spend it elsewhere in the economy, thereby creating jobs and economic growth for the California economy. The Statewide CASE Team does not expect the proposed code change for the 2022 code cycle to impact building owners adversely.

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

Refer to Section 3.4.2 for the economic impacts on building component retailers, including HVAC and lighting manufacturer and distributors.

3.3.6 Impact on Building Inspectors

Table 21 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings and industrial facilities are employed. Building inspectors participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

Table 20: Employment in California State and Government Agencies with Building Inspectors, 2018

Sector	Govt.	Establishments	Employment	Annual Payroll (millions $)
Administration of Housing Programs[a]	State	17	283	$29.0
	Local	36	2,882	$205.7
Urban and Rural Development Admin[b]	State	35	552	$48.2
	Local	52	2,446	$186.6

Source: (State of California, Employment Development Department n.d.)

a. Administration of Housing Programs (NAICS 925110) comprises government establishments primarily engaged in the administration and planning of housing programs, including building codes and standards, housing authorities, and housing programs, planning, and development.

b. Urban and Rural Development Administration (NAICS 925120) comprises government establishments primarily engaged in the administration and planning of the development of urban and rural areas. Included in this industry are government zoning boards and commissions.

3.3.7 Impact on Statewide Employment

The Statewide CASE Team does not anticipate significant employment or financial impacts to any particular sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 3.4, the Statewide CASE Team estimates how CEH standards would affect statewide employment and economic output directly and indirectly through its impact on builders, designers and energy consultants, and building inspectors. In addition, the Statewide CASE Team estimates how energy savings associated with these proposed changes would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

3.4 Economic Impacts

For the 2022 code cycle, the Statewide CASE Team used the IMPLAN model software, along with economic information from published sources, and professional judgement to develop estimates of the economic impacts associated with each proposed code change.[4] While this is the first code cycle in which the Statewide CASE Team develops estimates of economic impacts using IMPLAN, it is important to note that the economic impacts developed for this report are only estimates and are based on limited and to

[4] IMPLAN (Impact Analysis for Planning) software is an input-output model used to estimate the economic effects of proposed policies and projects. IMPLAN is the most commonly used economic impact model due to its ease of use and extensive detailed information on output, employment, and wage information.

some extent speculative information. In addition, the IMPLAN model provides a relatively simple representation of the California economy; though there is confidence that direction and approximate magnitude of the estimated economic impacts are reasonable, it is important to recognize that the IMPLAN model is a simplification of extremely complex actions and interactions of individual, businesses, and other organizations as they respond to changes in energy efficiency codes. In all aspects of this economic analysis, the CASE Authors rely on conservative assumptions regarding the likely economic benefits associated with the proposed code change. By following this approach, the Statewide CASE Team believes the economic impacts presented below represent lower bound estimates of the actual impacts associated with this proposed code change.

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by industrial contractors, architects, energy consultants, and building inspectors. The Statewide CASE Team does not anticipate that money saved by businesses or other organizations affected by the proposed 2022 code cycle regulations would result in additional spending by those businesses.

Table 21: Estimated Impact that Adoption of the Proposed Submeasure Would Have on the California Commercial Construction Sector

Type of Economic Impact	Employment (jobs)	Labor Income (millions $)	Total Value Added (millions $)	Output (millions $)
Direct effects (additional spending by commercial builders)	1,029	$68.08	$90.21	$149.22
Indirect effect (additional spending by firms supporting commercial builders)	224	$16.29	$25.95	$50.07
Induced effect (spending by employees of firms experiencing direct or indirect effects)	448	$25.22	$45.12	$73.67
Total Economic Impacts	**1,703**	**$109.51**	**$161.29**	**$272.96**

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

Table 22: Estimated Impact that Adoption of the Proposed Submeasure Would Have on the California Building Designers and Energy Consultants Sectors

Type of Economic Impact	Employment (jobs)	Labor Income (millions $)	Total Value Added (millions $)	Output (millions $)
Direct effects (additional spending by building designers & energy consultants)	3	$0.27	$0.27	$0.48
Indirect effect (additional spending by firms supporting bldg. designers & energy consult.)	2	$0.11	$0.15	$0.24
Induced effect (spending by employees of firms experiencing direct or indirect effects)	2	$0.12	$0.21	$0.34
Total Economic Impacts	**7**	**$0.50**	**$0.63**	**$1.06**

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

Table 23: Estimated Impact that Adoption of the Proposed Submeasure Would Have on California Building Inspectors

Type of Economic Impact	Employment (jobs)	Labor Income (millions $)	Total Value Added (millions $)	Output (millions $)
Direct effects (additional spending by building inspectors)	3	$0.32	$0.37	$0.45
Indirect effect (additional spending by firms supporting building inspectors)	0	$0.03	$0.04	$0.07
Induced effect (spending by employees of building inspection bureaus and departments)	2	$0.10	$0.18	$0.30
Total Economic Impacts	**5**	**$0.44**	**$0.60**	**$0.82**

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

3.4.1 Creation or Elimination of Jobs

No measures that the Statewide CASE Team is proposing for the 2022 code cycle regulation would lead to the creation of new *types* of jobs or the elimination of *existing* types of jobs. In other words, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. Rather, the estimates of economic impacts discussed in this section would lead to modest changes in employment of existing jobs.

3.4.2 Creation or Elimination of Businesses in California

The Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. The proposed standards represent changes to CEH which would not excessively burden or competitively disadvantage California businesses—nor would it necessarily lead to a competitive advantage for California businesses. The Statewide CASE Team has received feedback that high start-up costs for lighting products may lead to difficulties for small grows to enter the market. The proposed code language includes a minimum canopy square footage that would allow small grows to be exempted. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor that any existing businesses would be eliminated due to the proposed code changes to the California Energy Code.

3.4.3 Competitive Advantages or Disadvantages for Businesses in California

The code changes the Statewide CASE Team is proposing for the 2022 code cycle would apply to all businesses incorporated in California, regardless of whether the business is located inside or outside of the state.[5] Therefore, the Statewide CASE Team does not anticipate that these measures proposed for the 2022 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, businesses located outside of California would be not be particularly advantaged or disadvantaged.

3.4.4 Increase or Decrease of Investments in the State of California

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[6] As Table 24 shows, between 2015 and 2019, NPDI as a percentage of corporate profits ranged from 26 to 35 percent, and the average was 31 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE Team believes it provides a reasonable

[5] Government Code Sections 11346.3(c)(1)(C), 11346.3(a)(2); 1 CCR Section 2003(a)(3) Competitive advantages or disadvantages for California businesses currently doing business in the state.

[6] NPDI is the total amount of investment in capital by the business sector that is used to expand the capital stock, rather than maintain or replace due to depreciation. Corporate profit is the money left after a corporation pays its expenses.

estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

Table 24: Net Domestic Private Investment and Corporate Profits, U.S.

Year	Net Domestic Private Investment by Businesses, Billions of Dollars	Corporate Profits After Taxes, Billions of Dollars	Ratio of Net Private Investment to Corporate Profits
2015	609.3	1,740.4	35%
2016	456.0	1,739.8	26%
2017	509.3	1,813.6	28%
2018	618.3	1,843.7	34%
2019	580.9	1,827.0	32%
		5-Year Average	31%

Source: (Federal Reserve Economic Data n.d.)

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in investment in any directly or indirectly affected sectors of California's economy. Nevertheless, a reasonable estimate of the change in investment by California businesses is derived by multiplying the sum of business income estimated in Table 21 through Table 23 above by 31 percent.

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

The Statewide CASE Team does not expect the proposed code changes to have a measurable impact on the California's General Fund, any state special funds, or local government funds.

3.4.5.1 Cost of Enforcement

Cost to the State

State government already has a budget for code development, education, and compliance enforcement. While state government would be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals. Since this proposal only impacts indoor growing facilities and greenhouses, there are no expected impacts on state facilities.

Cost to Local Governments

All revisions to Title 24, Part 6 result in changes to compliance determinations. Local governments train building department staff on the revised Title 24, Part 6 Standards. While this retraining is an expense to local governments, it is not a new cost associated with the 2022 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. Numerous resources are available to local governments to support compliance training that can help mitigate the cost of retraining, including tools, training and resources provided by the Energy Commission's Compliance and Enforcement support team and the IOU Codes and Standards Compliance Improvement Program (Energy Code Ace). As noted in the executive summary and Appendix E, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

3.4.6 Impacts on Specific Persons

While the objective of this proposal is to promote energy efficiency, the Statewide CASE Team recognizes the potential that a proposed update to the 2022 code cycle may result in unintended consequences. The Statewide CASE Team does not believe that this code change would negatively impact a specific group of persons more so than any others.

4. Energy Savings

4.1 Horticultural Lighting Minimum Efficacy

4.1.1 Key Assumptions for Energy Savings Analysis

The California Building Energy Code Compliance (CBECC) Software does not support space functions and conditioning equipment associated with CEH facilities and would not be an appropriate tool to model energy consumption in CEH facilities. Energy savings calculations performed in support of this proposal were estimated using spreadsheet calculations developed by a management consulting firm under contract with the Statewide CASE Team. The consulting firm developed hourly simulation spreadsheets to estimate the impacts of energy efficiency measures implemented in CEH facilities, including lighting retrofits and dehumidification improvements. Market research conducted by the Statewide CASE Team informed the establishment of industry-standard practices and equipment. The industry-standard practices and equipment serve as the baseline condition to which the proposed measures are compared for estimating the energy savings associated with each submeasure.

The key assumptions used in the energy savings analysis are summarized in Table 25 and Table 26.

Table 25: Assumptions Used in Indoor Lighting Energy Savings Analysis

Parameter	Cannabis - Flower	Cannabis - Vegetative	Cannabis - Clone	Leafy Greens	Tomatoes
Canopy Area per Luminaire (ft^2)	20	24	10	58	56
Photoperiod (hours per day)	12	18	24	18	12
PPFD (µMol/m^2/s)	1,000	600	200	200	350
Baseline PPE (µMol/J)	1.02	1.02	1.02	1.02	1.02
Proposed PPE (µMol/J)	2.1	2.1	2.1	2.1	2.1

Table 26: Assumptions Used in Greenhouse Lighting Energy Savings Analysis

Parameter	Cannabis - Flower	Cannabis - Vegetative	Cannabis - Clone	Leafy Greens	Tomatoes
Canopy Area per Luminaire (ft^2)	20	24	10	58	56
Photoperiod (hours per day)	12	18	24	18	12
PPFD (µMol/m^2/s)	600	400	200	200	350

Baseline PPE (μMol/J)	1.02	1.02	1.02	1.02	1.02
Proposed PPE (μMol/J)	1.7	1.7	1.7	1.7	1.7

Baseline photometric photon efficacy (PPE) is considered the average PPE for single-ended high-pressure sodium (HPS) luminaires (Navigant 2017). Baseline lighting technology was determined to be single-ended metal halide and HPS luminaires based on the 2017 U.S. DOE Report on Horticultural Lighting (DOE 2017). Due to uncertainty on breakdown of metal halide to HPS luminaires, the higher PPE of HPS luminaires was utilized. Typical power input for these luminaires are 600 to 1,000 watts. Photoperiod and required photosynthetic photon flux density (PPFD) for each crop is based on typical operational parameters and survey data (LEDTonic 2019).

Canopy area per luminaire was calculated using the required PPFD for each crop and the performance of baseline lighting luminaires. Photoperiod shows the time per day that plants require light. For indoor facilities, the entire photoperiod is supplied by luminaires. For greenhouses, the photoperiod does not necessarily correlate to luminaire run hours.

The proposed indoor CEH facility minimum PPE of 2.1 was determined by surveying existing lighting technologies available, talking with DesignLights Consortium (DLC) about future updates to their qualified products list (QPL), and vetting the requirement with lighting technology experts. The primary technology type that qualifies is LED lighting technology, although plasma lighting technology may also qualify. Efficacy data for lighting technologies other than LED technology is sparse, and additional test data may prove additional technologies to be eligible. The DLC currently utilizes a minimum PPE of 1.9 for its QPL, but they plan on increasing the minimum efficacy to 2.1 by 2021.

The proposed greenhouse minimum PPE of 1.7 represents the typical efficacy of double-ended high-pressure sodium (HPS) luminaires. The minimum requirement allows double-ended HPS and LED luminaires to qualify.

4.1.2 Energy Savings Methodology

4.1.2.1 Energy Savings Methodology per Prototypical Building

The Energy Commission directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent typical building geometries for different types of buildings. The prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 27.

Assumptions for prototypical building models that represent industry-standard indoor and greenhouse horticultural facilities were developed by the Statewide CASE Team to estimate energy savings for each submeasure. Each building model (i.e., indoor grow and greenhouse) simulated the energy impacts of growing cannabis, tomatoes, and leafy greens in separate facilities. Microgreens and herbs are represented by leafy greens, and vine crops and flowering crops are represented by tomatoes due to similar crop growth requirements. The energy impacts were evaluated on a per square foot basis, and results were weighted to represent the proportion of statewide horticultural facilities dedicated to growing each crop.

Table 27: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Crop Type
Indoor (Warehouse)	Cannabis: 83% flowering growth stage, 15% vegetative growth stage, 2% clone growth stage
Indoor (Warehouse)	Leafy greens
Indoor (Warehouse)	Tomatoes
Greenhouse	Cannabis: 83% flowering growth stage, 15% vegetative growth stage, 2% clone growth stage
Greenhouse	Leafy greens
Greenhouse	Tomatoes

The Statewide CASE Team estimated energy and demand impacts by simulating the proposed code change using a spreadsheet-based calculation tool specific to CEH facilities. The tool calculates hourly lighting energy based on the parameter assumptions summarized in Table 28 and Table 29. For indoor CEH facilities, interactive effects on air conditioning equipment caused by reduced cooling loads were estimated assuming minimal compliance with 2019 Title 24, Part 6 efficiency requirements for air conditioners and condensing units (Table 110.2-A). Cooling energy savings are calculated using a generic DX cooling coil performance curve and hourly outside air temperatures sourced from weather files in the 2022 CBECC-Com software. Interactive cooling effects were not accounted for in the greenhouse lighting simulation since greenhouses typically vent for the first stage of cooling. Hourly energy savings are multiplied by the 2022 TDV values to evaluate energy cost savings.[7]

There are no existing requirements in Title 24, Part 6 that cover the lighting systems in CEH facilities. The Statewide CASE Team created a baseline model that represents the most common current design practice, or industry standard practice. Through stakeholder feedback and research, the Statewide CASE Team determined baseline HVAC, lighting, and dehumidification equipment as well as temperature, humidity, and irrigation assumptions.

[7] The Statewide CASE Team used the final 2022 TDV factors in the analysis for this report. The final TDV factors are available on the Energy Commission's website here: https://www.energy.ca.gov/event/workshop/2020-03/staff-workshop-2022-energy-code-compliance-metrics.

The proposed model was identical to the baseline model in all ways except for the revisions that represent the proposed changes to the code. These baseline assumptions were updated to reflect the proposed code change. The baseline model assumptions are used for both new construction and alterations and are listed in Section 4.1.1. Table 28 and Table 29 present the parameters that were modified and the values that were used in the baseline and proposed models for indoor lighting and greenhouse lighting, respectively.

Comparing the energy impacts of the baseline model to the proposed model reveals the impacts of the proposed code change relative to a building that follows industry typical practices.

Table 28: Modifications Made to Indoor Lighting Baseline Model in Each Prototype to Simulate Proposed Code Change

Prototype ID	Climate Zone	Parameter Name	Baseline Parameter Value	Proposed Parameter Value
Cannabis - Flower	All	PPE	1.02	2.1
Cannabis - Vegetative	All	PPE	1.02	2.1
Cannabis - Clone	All	PPE	1.02	2.1
Leafy Greens	All	PPE	1.02	2.1
Tomatoes	All	PPE	1.02	2.1

Table 29: Modifications Made to Greenhouse Lighting Baseline Model in Each Prototype to Simulate Proposed Code Change

Prototype ID	Climate Zone	Parameter Name	Baseline Parameter Value	Proposed Parameter Value
Cannabis - Flower	All	PPE	1.02	1.7
Cannabis - Vegetative	All	PPE	1.02	1.7
Cannabis - Clone	All	PPE	1.02	1.7
Leafy Greens	All	PPE	1.02	1.7
Tomatoes	All	PPE	1.02	1.7

The Statewide CASE Team's spreadsheet tool calculates lighting energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/yr) and therms per year (therms/yr). It then applies the 2022 time dependent valuation (TDV) factors to calculate annual energy use in kilo British thermal units per year (TDV kBtu/yr) and annual peak electricity demand reductions measured in kilowatts (kW). TDV energy cost savings values measured in 2023 present value dollars (2023 PV$) and nominal dollars were generated.

The energy impacts of the proposed code change vary by climate zone. The Statewide CASE Team simulated the energy impacts in every climate zone and applied the climate-zone specific TDV factors when calculating energy and energy cost impacts.

4.1.3 Per-Unit Energy Impacts Results

Per-unit energy impacts for nonresidential buildings are presented in savings per square foot of canopy. Annual energy and peak demand impacts for each prototype building were calculated on a per-square-foot basis. This step allows for an easier comparison of savings across different building types and enables calculation of statewide savings by multiplying the per-unit energy impacts by the affected statewide building areas.

Energy savings and peak demand reductions per unit are presented in Table 30 and Table 31 and include both new construction and alterations savings. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. Per-unit savings for the first year are expected to range from 13.5 to 199.0 kWh/yr depending upon climate zone and facility type. Demand reductions are expected to range between 0.002 to 0.012 kW depending on climate zone.

As expected, there are significant energy savings as a result of this proposal. Savings per square foot of canopy of indoor facilities are much higher than that of greenhouses. This is due to the higher PPE standard for lighting in indoor growing facilities, sunlight contributing to the PPFD requirements of the plants in greenhouses, and the additional HVAC requirements that apply to indoor growing facilities.

Table 30: First-Year Energy Impacts Per Square Foot of Canopy – Indoor

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	189.5	0.012	0.0	4,318.4
2	192.4	0.012	0.0	4,886.1
3	191.2	0.012	0.0	4,636.7
4	193.1	0.012	0.0	5,011.9
5	191.8	0.012	0.0	4,501.0
6	193.2	0.012	0.0	4,842.6
7	192.8	0.012	0.0	4,611.1
8	194.4	0.012	0.0	5,213.4
9	194.3	0.012	0.0	5,210.2
10	195.0	0.012	0.0	5,020.3
11	194.8	0.012	0.0	4,956.6
12	193.7	0.012	0.0	4,881.8
13	195.1	0.012	0.0	4,948.7

14	195.1	0.012	0.0	5,146.7
15	199.0	0.012	0.0	5,100.7
16	191.2	0.012	0.0	4,394.2

Table 31: First-Year Energy Impacts Per Square Foot of Canopy – Greenhouse

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	23.2	0.003	0.0	597.3
2	18.5	0.002	0.0	473.2
3	18.7	0.002	0.0	478.7
4	17.6	0.002	0.0	447.7
5	16.0	0.002	0.0	417.8
6	16.4	0.002	0.0	429.0
7	15.5	0.002	0.0	390.3
8	16.3	0.002	0.0	443.0
9	15.9	0.002	0.0	414.9
10	15.6	0.002	0.0	398.2
11	18.7	0.002	0.0	468.8
12	18.6	0.002	0.0	464.9
13	18.2	0.002	0.0	457.5
14	13.5	0.002	0.0	331.4
15	14.1	0.002	0.0	343.8
16	17.5	0.002	0.0	452.2

4.2 Efficient Dehumidification and Reuse of Transpired Water

4.2.1 Key Assumptions for Energy Savings Analysis

Energy savings calculations performed in support of this proposal were estimated using spreadsheet calculations developed by a management consulting firm under contract with the Statewide CASE Team. The consulting firm developed specialized tools to estimate the impacts of dehumidification improvements. Market research conducted by the Statewide CASE Team informed the establishment of industry-standard practices and equipment. The industry-standard practices and equipment serve as the baseline condition to which the proposed measures are compared for estimating the energy savings associated with each submeasure. Key assumptions include baseline HVAC, lighting, baseline dehumidification equipment, lighting schedule, temperature, humidity, and irrigation rates.

The energy savings calculations on based on three primary baseline configurations. The breakdown of baseline equipment type was determined from Resource Innovation Institute PowerScore data, grower survey data, and information on standard design from engineers.

Table 32: Baseline HVAC Assumptions

Configuration	% of Statewide forecast baseline
Code-compliant 11–20-ton DX HVAC (11 EER, 12.4 IEER) with stand-alone dehumidifiers (Table 110.2-A)	95%
Code-compliant < 150-ton air-cooled chiller (10.1 EER, 13.7 IPLV) with no heat recovery for dehumidification air reheat (Table 110.2-D)	2.5%
Code-compliant < 300-ton water-cooled centrifugal chiller (≤0.61 kW/ton full load and ≤0.55 kW/ton IPLV) with no heat recovery for dehumidification air reheat (Table 110.2-D)	2.5%

An estimated 60 percent of existing facilities currently reuse dehumidification water based on grower and designer input. The proposed heat recovery system has an estimated 35 percent efficient heat exchanger based on industry standards for heat exchangers. For leafy greens and tomatoes, a single set of environmental conditions throughout the crop's growth. Cannabis facilities require different environmental conditions for cloning, vegetative growth, and flowering, and each growth stage was modeled separately.

Table 33, Table 34, and Table 35 provide environmental condition assumptions utilized in both the baseline and proposed designs. Lighting power densities used in the dehumidification energy consumption analysis are based on the baseline lighting technologies, light spacing, and PPE values identified in Section 4.1.1.

Table 33: Common Assumptions Used for Cannabis Dehumidification Energy Savings Calculations

	Flower Room Lights On	Flower Room Lights Off	Veg Room Lights On	Veg Room Lights Off	Clone Room Lights On	Clone Room Lights Off
Temperature (°F)	80	70	75	65	75	65
RH (%)	50%	50%	55%	55%	55%	55%
Wet bulb temperature (°F)	66.6	58.4	63.9	55.5	63.9	55.5

Lighting Power density (W/ft^2)	46.6	0.0	26.5	0.0	8.9	0.0
Lights on (Hour)	7	N/A	7	N/A	0	N/A
Lights off (Hour)	19	N/A	25	N/A	24	N/A
Schedule (hr/day)	12	12	18	6	24	0
Watering rate (gal/ft^2/day)	0.1138	0.1138	0.0719	0.0719	0.0359	0.0359

Table 34: Common Assumptions Used for Leafy Green Dehumidification Energy Savings Calculations

	Lights On	Lights Off
Temperature (°F)	75	65
RH (%)	60%	60%
Wet bulb temperature (°F)	65.3	56.6
Lighting Power density (W/ft^2)	17.82	0.0
Lights on (Hour)	7	N/A
Lights off (Hour)	25	N/A
Schedule (hr/day)	18	6
Watering rate (gal/sq.ft./day)	0.0719	0.0719

Table 35: Common Assumptions Used for Tomato Dehumidification Energy Savings Calculations

	Lights On	Lights Off
Temperature (°F)	75	65
RH (%)	60	60
Wet bulb temperature (°F)	65.3	56.6
Lighting Power density (W/ft^2)	31.19	0
Lights on (Hour)	7	N/A
Lights off (Hour)	25	N/A
Schedule (hr/day)	18	6
Watering rate (gal/ft^2/day)	0.0839	0.0839

Water savings were estimated by calculating the amount of water transpired throughout a year of crop production for each crop using the watering rates listed in Table 33, Table 34, and Table 35. It is assumed that all water provided to the plants is transpired and removed by the dehumidification system. Survey data and discussions with designers provided insight that approximately 60 percent of existing growers reuse water from their dehumidification equipment. This existing reuse rate was applied across the statewide facility stock to estimate statewide impacts. The water savings calculation assumes 100 percent of the transpired water is recovered for reuse.

4.2.2 Energy Savings Methodology

4.2.2.1 Energy Savings Methodology per Prototypical Building

The Energy Commission directed the Statewide CASE Team to model the energy impacts of all Title 24, Part 6 proposals. The Energy Commission's prototypes do not include indoor growing facilities. The Statewide CASE Team developed prototype indoor growing facilities in order to conduct energy and cost savings modeling. An 8,760-hour heat load calculation was performed on the prototype facilities to model both sensible and latent heat loads for baseline and proposed equipment. The assumptions outlined in this section were applied to baseline and proposed cases to determine savings for the proposed measure.

The prototype building used to calculate facility HVAC use assumed 10,000 ft^2 of plant canopy. The prototype buildings were modeled, and then the energy use per prototype building was divided by the canopy square footage to calculate the energy use per square foot of canopy. The following breakdown of cannabis canopy area per growth stage is based on grower and designer experience:

- 83 percent flower room
- 15 percent vegetative area
- 2 percent clone area

Table 36: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Canopy Area (ft^2)	Crop Type
Indoor (Warehouse)	10,000	Cannabis: 83% flowering growth stage, 15% vegetative growth stage, 2% clone growth stage
Indoor (Warehouse)	10,000	Leafy greens
Indoor (Warehouse)	10,000	Tomatoes

4.2.3 Per-Unit Energy Impacts Results

Annual energy and peak demand impacts for each prototype building were calculated on a per-canopy-square-foot basis. This step allows for an easier comparison of savings across different building types and enables estimation of statewide savings by multiplying the per-unit energy impacts by the affected statewide building areas.

The Statewide CASE Team's spreadsheet simulation calculates whole-building energy consumption measured in kilowatt-hours per year (kWh/yr) and therms per year (therms/yr) and then divides by ft^2 of canopy of the prototype building. The 2022 TDV factors[8] are applied to calculate annual energy use in kilo British thermal units per year (TDV kBtu/yr) and annual peak electricity demand reductions measured in kilowatts (kW). TDV energy cost savings values measured in 2023 PV$ and nominal dollars are also generated.

The energy impacts of the proposed code change vary by climate zone. The Statewide CASE Team simulated the energy impacts in every climate zone and applied the climate-zone specific TDV factors when calculating energy and energy cost impacts. Savings vary minimally per climate zone due to the predominant heating and cooling loads of indoor CEH facilities being internal process loads.

Energy savings and peak demand reductions per unit are presented in Table 37 and apply to both new construction and alterations. Electricity increases associated with this measure are due to an electric penalty for the proposed heat recovery systems. The natural gas savings results in a net positive energy savings in all climate zones. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. Per-unit savings for the first year are expected to range from -2.4 to -1.3 kWh/yr and 3.3 to 3.4 therms/yr depending on climate zone.

[8] The Statewide CASE Team used the final 2022 TDV factors in the analysis for this report. The final TDV factors are available on the Energy Commission's website here: https://www.energy.ca.gov/event/workshop/2020-03/staff-workshop-2022-energy-code-compliance-metrics.

Table 37: First-Year Energy Impacts Per Square Foot of Canopy – Dehumidification

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(2.2)	(0.00026)	3.3	785
2	(1.4)	(0.00017)	3.4	809
3	(1.3)	(0.00016)	3.4	811
4	(1.4)	(0.00018)	3.4	807
5	(1.3)	(0.00015)	3.4	812
6	(1.3)	(0.00015)	3.4	820
7	(1.3)	(0.00015)	3.4	823
8	(1.5)	(0.00017)	3.4	815
9	(1.6)	(0.00019)	3.4	811
10	(1.6)	(0.00019)	3.4	808
11	(1.9)	(0.00022)	3.4	788
12	(1.5)	(0.00018)	3.4	800
13	(1.8)	(0.00021)	3.4	796
14	(1.9)	(0.00021)	3.4	798
15	(2.4)	(0.00026)	3.4	789
16	(1.4)	(0.00019)	3.4	811

5. Cost and Cost Effectiveness

5.1 Horticultural Lighting Minimum Efficacy

5.1.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the TDV energy cost factors to the energy savings estimates that were derived using the methodology described in Section 4.1.2. TDV is a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the period of analysis (30 years for 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 nominal dollars and in 2023 present value dollars and represent the energy cost savings realized over 15 years.

Since there is no current horticultural lighting efficacy standard, the Statewide CASE Team conducted stakeholder outreach in order to determine baseline technologies. A survey was developed, and the Statewide CASE Team conducted this survey with growers across the state with the assistance of various grower associations.

This code change proposal applies to newly constructed CEH facilities and greenhouses. Additionally, the horticulture lighting standard is triggered if alterations to a system increase horticulture lighting wattage by 10 percent or add, replace, or alter 10 percent of the horticulture luminaires in an enclosed space.

LEDs have become the majority of vertical farming, and HPS and metal halide lamps comprise over 80 percent of non-stacked indoor farms and greenhouses. To gather the costs of these baseline technologies, many online searches were completed, as single- and double-ended HPS and metal halide luminaires are both readily available and commonly purchased online.

5.1.2 Energy Cost Savings Results

Per-unit energy cost savings for newly constructed buildings and alterations that are realized over the 15-year period of analysis are presented in nominal dollars and 2023 dollars in Table 38 through Table 41.

The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. Horticultural lighting often starts at 6 a.m. or 7 a.m. Pacific Standard Time (PST) to align with day shift employee hours. Vegetable crops, flower crops, and vegetative cannabis crops typically operate on 18–24 hour/day schedules. Cannabis flowering rooms operate on 12 hour/day lighting schedules. Light schedule information was provided by California growers that were surveyed. All crop types operate during at least part of the 4-9 p.m. PST peak electricity period. Approximately, 20–25 percent of proposed savings occur during peak periods, depending on crop type.

Table 38: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot of Canopy – New Construction and Alterations Indoor

Climate Zone	15-Year TDV Electricity Cost Savings (Nominal $)	15-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year TDV Energy Cost Savings (Nominal $)
1	$542	$0	$542
2	$613	$0	$613
3	$582	$0	$582
4	$629	$0	$629
5	$565	$0	$565
6	$608	$0	$608
7	$579	$0	$579
8	$654	$0	$654
9	$654	$0	$654
10	$630	$0	$630
11	$622	$0	$622
12	$613	$0	$613
13	$621	$0	$621
14	$646	$0	$646
15	$640	$0	$640
16	$551	$0	$551

Table 39: 2023 PV TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot of Canopy – New Construction and Alterations Indoor

Climate Zone	15-Year TDV Electricity Cost Savings (2023 PV$)	15-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 15-Year TDV Energy Cost Savings (2023 PV$)
1	$384	$0	$384
2	$435	$0	$435
3	$413	$0	$413
4	$446	$0	$446
5	$401	$0	$401
6	$431	$0	$431
7	$410	$0	$410
8	$464	$0	$464
9	$464	$0	$464
10	$447	$0	$447

11	$441	$0	$441
12	$434	$0	$434
13	$440	$0	$440
14	$458	$0	$458
15	$454	$0	$454
16	$391	$0	$391

Table 40: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot of Canopy – New Construction and Alterations Greenhouse

Climate Zone	15-Year TDV Electricity Cost Savings (Nominal $)	15-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year TDV Energy Cost Savings (Nominal $)
1	$75	$0	$75
2	$59	$0	$59
3	$60	$0	$60
4	$56	$0	$56
5	$52	$0	$52
6	$54	$0	$54
7	$49	$0	$49
8	$56	$0	$56
9	$52	$0	$52
10	$50	$0	$50
11	$59	$0	$59
12	$58	$0	$58
13	$57	$0	$57
14	$42	$0	$42
15	$43	$0	$43
16	$57	$0	$57

Table 41: 2023 PV TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot of Canopy – New Construction and Alterations Greenhouse

Climate Zone	15-Year TDV Electricity Cost Savings (2023 PV$)	15-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 15-Year TDV Energy Cost Savings (2023 PV$)
1	$53	$0	$53
2	$42	$0	$42
3	$43	$0	$43
4	$40	$0	$40
5	$37	$0	$37
6	$38	$0	$38
7	$35	$0	$35
8	$39	$0	$39
9	$37	$0	$37

10	$35	$0	$35
11	$42	$0	$42
12	$41	$0	$41
13	$41	$0	$41
14	$29	$0	$29
15	$31	$0	$31
16	$40	$0	$40

5.1.3 Incremental First Cost

Baseline technology for the horticulture lighting efficacy submeasure was determined through both stakeholder outreach and online research. The grower survey included detailed questions to determine what type of lighting luminaires were commonly used in CEH facilities growing cannabis, leafy greens, and tomatoes throughout California. Respondents were able to list information about single- and double-ended HPS luminaires, metal halide luminaires, T8/T5 luminaires, plasma luminaires, incandescent/CFL luminaires, and LED luminaires.

Retailers such as Amazon, Hydrobuilder, and Growershouse and manufacturer websites such as Maxlite, Eye Hortilux, and VivoSun listed the prices for many products. Additionally, the Statewide CASE Team directly reached out to Fluence, Lumigrow, Thrive LED, Signify, and Illumitex to obtain price estimates.

The costs of luminaires that meet the proposed PPE levels were determined through online searches of the sources listed in the previous paragraph. All luminaires found to meet the proposed standards are LEDs. There may be other technology types that meet the required minimum efficacy, but there was no test data available to verify they can achieve 2.1μMol/J. The Statewide CASE Team analyzed price points for LED luminaires manufactured by many of the sources listed above, among others. In total, prices for over 30 fixtures and lamps were used to conduct this cost-effectiveness analysis. The specific fixtures and lamps used in the cost analysis were added to Appendix H. An average cost for single-ended HPS fixtures and lamps was the baseline cost for greenhouse lighting, and the average cost for double-ended HPS fixtures and lamps was the baseline for indoor lighting and also the proposed cost for greenhouse lighting. The average costs for the LED fixtures with PPE at or above 2.1 was the proposed cost for indoor lighting.

There was no assumed increase in labor costs with this submeasure, as the proposed submeasure can replace the baseline technology on a one-for-one basis. Incremental costs would not vary between alterations and new construction since the incremental cost is solely dependent on product cost differences in both cases. Table 42 shows the total incremental costs per luminaire for the horticulture lighting submeasure in both greenhouses and indoor facilities.

Table 42: 15-Year Lighting Incremental Cost Per Square Foot of Canopy

Building Type	Incremental Equipment Cost	Incremental Maintenance Cost	Total Incremental Cost
Indoor	$110.58	($37.35)	$73.23
Greenhouse	$4.62	$13.49	$18.11

For indoor lighting, LED luminaires with enough light output to replace a 1,000-watt double-ended HPS luminaire were chosen for determining average proposed equipment cost. The average proposed indoor lighting equipment cost per luminaire was $1,274. For greenhouse lighting, double-ended HPS luminaires with enough light output to replace a 1,000-watt single-ended HPS luminaire were chosen for determining average proposed equipment cost. The average proposed greenhouse lighting equipment cost per luminaire was $261.

Baseline lighting costs for both indoor and greenhouse lighting used single-ended HPS and metal halide luminaire equipment cost. The average baseline lighting equipment cost per luminaire was $261.

5.1.4 Incremental Maintenance and Replacement Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the 15-year period of analysis. The present value of equipment maintenance costs (savings) was calculated using a 3 percent discount rate (d), which is consistent with the discount rate used when developing the 2022 TDV. The present value of maintenance costs that occurs in the n^{th} year is calculated as follows:

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

Increasing the minimum PPE for horticulture lighting will often lead to the use of lighting products that last longer in addition to working more efficiently. This will lead to a decrease in maintenance costs with fewer replacements being necessary.

The baseline technology for indoor growing facilities assumed a lamp replacement every year and a luminaire replacement every 10 years for all crop types. The proposed standard did not have any maintenance costs assumed as there is no lamp replacement associated with horticultural LED luminaires.

The baseline and proposed levels for greenhouse facilities assumed a lamp replacement every year and a luminaire replacement every 10 years. The incremental maintenance costs from the proposal is the added costs for lamps at the proposed PPE level.

5.1.5 Cost Effectiveness

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

The Energy Commission establishes the procedures for calculating cost effectiveness. The Statewide CASE Team collaborated with Energy Commission staff to confirm that the methodology in this report is consistent with their guidelines, including which costs were included in the analysis. The incremental first cost and incremental maintenance costs over the 15-year period of analysis were included. The TDV energy cost savings from electricity and natural gas savings were also included in the evaluation. Design costs were not included nor were the incremental costs of code compliance verification.

According to the Energy Commission's definitions, a measure is cost effective if the benefit-to-cost (B/C) ratio is greater than 1.0. The B/C ratio is calculated by dividing the cost benefits realized over 15 years by the total incremental costs, which includes maintenance costs for 15 years. The B/C ratio was calculated using 2023 PV costs and cost savings.

Results of the per-unit cost-effectiveness analyses are presented in Table 43 and Table 44 for indoor grow and greenhouse facilities. Cost effectiveness is identical for new construction and alterations. Indoor facility cost effectiveness is higher due to increased light intensity requirements for indoor facilities and decreased maintenance costs going from high intensity discharge luminaires to LED luminaires.

The proposed submeasure saves money over the 15-year period of analysis relative to the existing conditions. The proposed code change is cost effective in every climate zone.

Table 43: 15-Year Cost-Effectiveness Summary Per Square Foot of Canopy – Indoor Lighting

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$384.34	$63.99	6.0
2	$434.87	$63.99	6.8
3	$412.66	$63.99	6.4
4	$446.06	$63.99	7.0
5	$400.59	$63.99	6.3
6	$430.99	$63.99	6.7
7	$410.39	$63.99	6.4
8	$463.99	$63.99	7.3
9	$463.71	$63.99	7.2
10	$446.80	$63.99	7.0
11	$441.14	$63.99	6.9
12	$434.48	$63.99	6.8
13	$440.43	$63.99	6.9
14	$458.05	$63.99	7.2
15	$453.96	$63.99	7.1
16	$391.09	$63.99	6.1

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) three percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

Table 44: 15-Year Cost-Effectiveness Summary Per Square Foot of Canopy – Greenhouse Lighting

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$53.16	$14.76	3.6
2	$42.12	$14.76	2.9
3	$42.60	$14.76	2.9
4	$39.85	$14.76	2.7
5	$37.18	$14.76	2.5
6	$38.18	$14.76	2.6
7	$34.74	$14.76	2.4
8	$39.43	$14.76	2.7
9	$36.93	$14.76	2.5
10	$35.44	$14.76	2.4
11	$41.72	$14.76	2.8
12	$41.37	$14.76	2.8
13	$40.72	$14.76	2.8
14	$29.49	$14.76	2.0
15	$30.60	$14.76	2.1
16	$40.25	$14.76	2.7

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) three percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

5.2 Efficient Dehumidification and Reuse of Transpired Water

5.2.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the TDV energy cost factors to the energy savings estimates that were derived using the methodology described in Section 4.1.2. TDV is a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the period of analysis (30 years for 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 nominal dollars and in 2023 present value dollars and represent the energy cost savings realized over 15 years.

This submeasure applies to newly installed dehumidification systems and so would have both new construction and alterations impacts. The energy cost savings for new construction and alterations are the same since the equipment and labor costs are assumed to be the same. Surveys were used to estimate the baseline dehumidification technologies installed in grow facilities.

5.2.2 Energy Cost Savings Results

Per-unit energy cost savings for newly constructed buildings and alterations that are realized over the 15-year period of analysis are presented in nominal dollars and 2023 dollars in Table 45 and Table 46.

The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. Peak demand savings are calculated as the energy consumed during peak hours (i.e. high TDV hours), multiplied by scalars that sum to one over the course of the year.

Table 45: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot of Canopy – New Construction and Alterations

Climate Zone	15-Year TDV Electricity Cost Savings (Nominal $)	15-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year TDV Energy Cost Savings (Nominal $)
1	($7.71)	$106.98	$99.26
2	($5.24)	$107.51	$102.27
3	($4.73)	$107.32	$102.59
4	($5.67)	$107.72	$102.05
5	($4.68)	$107.36	$102.68
6	($4.74)	$108.41	$103.68
7	($4.64)	$108.70	$104.06
8	($5.60)	$108.65	$103.05
9	($6.07)	$108.63	$102.56
10	($6.08)	$108.19	$102.11
11	($7.61)	$107.29	$99.68
12	($6.14)	$107.31	$101.17
13	($7.09)	$107.76	$100.67
14	($7.34)	$108.22	$100.88
15	($9.56)	$109.28	$99.72
16	($5.40)	$107.95	$102.55

Table 46: 2023 PV TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot of Canopy – New Construction and Alterations

Climate Zone	15-Year TDV Electricity Cost Savings (2023 PV$)	15-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 15-Year TDV Energy Cost Savings (2023 PV$)
1	($5.47)	$75.34	$69.87
2	($3.72)	$75.71	$71.99
3	($3.35)	$75.57	$72.22
4	($4.02)	$75.86	$71.84
5	($3.32)	$75.61	$72.29
6	($3.36)	$76.35	$72.99
7	($3.29)	$76.55	$73.26
8	($3.97)	$76.52	$72.54
9	($4.31)	$76.50	$72.19
10	($4.31)	$76.19	$71.88
11	($5.40)	$75.56	$70.16
12	($4.35)	$75.57	$71.22
13	($5.03)	$75.89	$70.86
14	($5.21)	$76.21	$71.01
15	($6.78)	$76.96	$70.18
16	($3.83)	$76.02	$72.19

5.2.3 Incremental First Cost

The baseline technology for the indoor dehumidification submeasure was assumed to be a Title 24, Part 6-compliant HVAC system without heat recovery for dehumidification air reheat and stand-alone dehumidification units. Proposed equipment adds heat recovery such as hot gas bypass or wrap-around heat exchangers to reheat dehumidified air to the baseline equipment. Cost information for the baseline and proposed conditions came from estimates from manufacturers and online equipment dealers. Information on cost sources for baseline dehumidification equipment is presented in Appendix H. All cost sources used for the code minimum scenario were from confidential sources.

A 5,000 ft^2 canopy was used to calculate equipment and installation costs. That cost was then divided by the square footage to obtain a cost per square foot of canopy. Equipment was specified for cannabis, the crop with the highest dehumidification load. Other crop types would not require as much dehumidification, potentially reducing their incremental cost. Utilizing the incremental cost for a cannabis facility design provides a conservative incremental cost estimate.

Baseline HVAC equipment cost assumed 120 tons of 2019 Title 24, Part 6 code minimum unitary AC and twelve stand alone dehumidification units rated at 50 gallons per day of water removal. These equipment specifications are for 5,000 ft^2 of canopy. Baseline lighting equipment described in Section 5.1.3 was used to determine internal heat load for HVAC equipment sizing. For proposed equipment cost, manufacturer equipment cost was provided for the specified operating conditions and canopy size. All incremental costs were then broken down to a cost per square foot of canopy.

Table 47 depicts total incremental costs for the efficient dehumidification submeasure.

Table 47: Incremental Costs for Efficient Dehumidification

Building Type	Incremental Equipment Cost	Incremental Maintenance Cost	Total Incremental Cost
Indoor – per Square Foot of Canopy	$24.34	($3.73)	$20.61

5.2.4 Incremental Maintenance and Replacement Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the 15-year period of analysis. The present value of equipment maintenance costs (savings) was calculated using a 3 percent discount rate (d), which is consistent with the discount rate used when developing the 2022 TDV. The present value of maintenance costs that occurs in the n^{th} year is calculated as follows:

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

Maintenance costs include stand-alone dehumidifier filter replacement twice a year. A reduction in maintenance costs was included in the incremental cost analysis due to the decrease in use of stand-alone dehumidifiers. The proposed exception for facilities under 2,000 ft^2 of canopy to utilize stand-alone dehumidifiers applies to approximately 25 percent of the building stock based on CalCannabis licensing information

5.2.5 Cost Effectiveness

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

The Energy Commission establishes the procedures for calculating cost effectiveness. The Statewide CASE Team collaborated with Energy Commission staff to confirm that the methodology in this report is consistent with their guidelines, including which costs were included in the analysis. The incremental first cost and incremental maintenance costs over the 15-year period of analysis were included. The TDV energy cost savings from electricity and natural gas savings were also included in the evaluation.

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

According to the Energy Commission's definitions, a measure is cost effective if the benefit-to-cost (B/C) ratio is greater than 1.0. The B/C ratio is calculated by dividing the cost benefits realized over 15 years by the total incremental costs, which includes maintenance costs for 15 years. The B/C ratio was calculated using 2023 PV costs and cost savings.

Results of the per-unit cost-effectiveness analyses are presented in Table 48.

The proposed submeasure saves money over the 15-year period of analysis relative to the existing conditions. The proposed code change is cost effective in every climate zone. Cost effectiveness is identical between new construction and alterations.

Table 48: 15-Year Cost-Effectiveness Summary Per Square Foot of Canopy – Indoor Dehumidification

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$69.87	$21.37	3.27
2	$71.99	$21.37	3.37
3	$72.22	$21.37	3.38
4	$71.84	$21.37	3.36
5	$72.29	$21.37	3.38
6	$72.99	$21.37	3.42
7	$73.26	$21.37	3.43
8	$72.54	$21.37	3.39
9	$72.19	$21.37	3.38
10	$71.88	$21.37	3.36
11	$70.16	$21.37	3.28
12	$71.22	$21.37	3.33
13	$70.86	$21.37	3.32
14	$71.01	$21.37	3.32
15	$70.18	$21.37	3.28
16	$72.19	$21.37	3.38

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) three percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

6. First-Year Statewide Impacts

6.1 Statewide Energy and Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings for new construction by multiplying the per-unit savings, which are presented in Section 4.1.3, by assumptions about the percentage of newly constructed buildings that would be impacted by the proposed code. The statewide new construction forecast for 2023 is presented in Appendix A as are the Statewide CASE Team's assumptions about the percentage of new construction that would be impacted by the proposal (by climate zone and building type).

CalCannabis licensing data from January 2020 was used to estimate the 2019 existing indoor and greenhouse cannabis building stock. A 29 percent growth rate for the cannabis industry was used to estimate the building stock forecast for 2023 (BDS Analytics 2019). Sites can purchase multiple licenses per location, and there is an average of two licenses per location. Zip codes from the licensing data were correlated to climate zones to determine the square footage of building stock per climate zone. The licensing data also provides a range of canopy square footage for each license type, and it was assumed that producers utilize 75 percent of the maximum canopy of the license type. The license type size ranges are provided in Table 49:

Table 49: CalCannabis License Types

License Type	Indoor Size (ft^2)	Greenhouse (ft^2)
Specialty Cottage	500	2,500
Specialty	5,000	5,000
Small	10,000	10,000
Medium	22,000	22,000

For non-cannabis facility stock, the USDA 2017 Ag Census data provided square footage for crops grown under cover (greenhouse) (USDA 2017). The Ag Census data also provided an average growth rate of 2.3 percent for non-cannabis crops based on growth from 2012 to 2017. The Statewide CASE Team assumed that 20 percent of the greenhouse space utilized supplemental lighting based on an estimate from the 2017 U.S. DOE Report on Horticultural Lighting (DOE 2017).

For alterations, it is assumed that 8 percent of the building stock requires alterations annually based on equipment useful life for horticultural lighting and HVAC equipment. Table 50 shows estimated crop breakdown for both indoor and greenhouse facility stock:

Table 50: Facility Stock Crop Type Breakdown

Building Type	Crop Type	% of Facility Stock
Indoor	Cannabis	92%
Indoor	Leafy Greens/Microgreens/Herbs	5%
Indoor	Tomatoes/Flowers/Vine Plants	3%
Greenhouse	Cannabis	30%
Greenhouse	Leafy Greens/Microgreens/Herbs	30%
Greenhouse	Tomatoes/Flowers/Vine Plants	40%

The first-year energy impacts represent the first-year annual savings from all buildings that estimated to be completed in 2023. The 15-year energy cost savings represent the energy cost savings over the entire 15-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

Table 51 and Table 52 present the first-year statewide energy and energy cost savings for lighting by climate zone from new constructions and alterations, respectively. Table 53 and Table 54 present the first-year statewide energy and energy cost savings for dehumidification by climate zone from new constructions and alterations, respectively.

Table 51: Statewide Energy and Energy Cost Impacts – New Construction – Lighting

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (ft² of canopy)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (million therms)	15-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	337,875	11.84	1.09	N/A	$25.95
2	502,266	17.38	1.61	N/A	$39.37
3	462,964	39.02	2.69	N/A	$84.85
4	60,974	6.85	0.45	N/A	$15.80
5	88,338	1.84	0.19	N/A	$4.18
6	288,303	8.13	0.73	N/A	$18.55
7	16,780	1.09	0.08	N/A	$2.34
8	100,695	18.36	1.12	N/A	$43.84
9	239,564	45.57	2.78	N/A	$108.75
10	16,245	2.86	0.17	N/A	$6.55
11	35,278	4.33	0.28	N/A	$9.80
12	168,313	26.92	1.68	N/A	$60.36
13	36,583	7.13	0.43	N/A	$16.09
14	92,694	16.82	1.02	N/A	$39.47
15	149,275	28.26	1.70	N/A	$64.45
16	82,311	2.11	0.21	N/A	$4.67
TOTAL	**2,678,458**	**238.50**	**16.22**	**N/A**	**$545.01**

a. First-year savings from all buildings completed statewide in 2023.

Table 52: Statewide Energy and Energy Cost Impacts – Alterations – Lighting

Climate Zone	Statewide Alterations Impacted by Proposed Change in 2023 (ft^2 of canopy)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (million therms)	15-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	260,785	7.23	0.74	N/A	$16.24
2	382,302	9.49	1.02	N/A	$21.53
3	284,376	14.36	1.12	N/A	$31.52
4	32,490	2.29	0.16	N/A	$5.28
5	70,147	1.25	0.13	N/A	$2.87
6	223,227	4.68	0.48	N/A	$10.77
7	11,172	0.42	0.03	N/A	$0.91
8	33,458	5.53	0.34	N/A	$13.20
9	74,163	13.62	0.83	N/A	$32.50
10	5,720	0.87	0.05	N/A	$1.98
11	17,876	1.43	0.10	N/A	$3.23
12	66,716	8.33	0.54	N/A	$18.67
13	10,923	2.12	0.13	N/A	$4.79
14	31,174	5.06	0.31	N/A	$11.86
15	48,459	8.47	0.51	N/A	$19.32
16	64,558	1.33	0.15	N/A	$3.00
TOTAL	**1,617,544**	**86.47**	**6.65**	**N/A**	**$197.66**

a. First-year savings from all alterations completed statewide in 2023.

Table 53: Statewide Energy and Energy Cost Impacts – New Construction – Dehumidification

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (ft^2 of canopy)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (million therms)	15-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	24,122	(0.05)	(0.01)	0.08	$1.69
2	46,370	(0.06)	(0.01)	0.16	$3.34
3	175,995	(0.22)	(0.03)	0.59	$12.71
4	32,904	(0.05)	(0.01)	0.11	$2.36
5	2,459	(0.00)	(0.00)	0.01	$0.18
6	19,204	(0.03)	(0.00)	0.06	$1.40
7	4,684	(0.01)	(0.00)	0.02	$0.34
8	93,911	(0.14)	(0.02)	0.32	$6.81
9	234,074	(0.37)	(0.05)	0.79	$16.90
10	14,520	(0.02)	(0.00)	0.05	$1.04
11	20,843	(0.04)	(0.00)	0.07	$1.46
12	135,831	(0.21)	(0.02)	0.46	$9.67
13	36,534	(0.06)	(0.01)	0.12	$2.59
14	85,714	(0.16)	(0.02)	0.29	$6.09
15	141,451	(0.33)	(0.04)	0.48	$9.93
16	3,864	(0.01)	(0.00)	0.01	$0.28
TOTAL	**1,072,478**	**(1.76)**	**(0.21)**	**3.62**	**$76.79**

a. First-year savings from all buildings completed statewide in 2023.

Table 54: Statewide Energy and Energy Cost Impacts – Alterations – Dehumidification

Climate Zone	Statewide Alterations Impacted by Proposed Change in 2023 (ft^2 of canopy)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (million therms)	15-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	7,185	(0.02)	(0.00)	0.02	$0.50
2	13,813	(0.02)	(0.00)	0.05	$0.99
3	52,425	(0.07)	(0.01)	0.18	$3.79
4	9,801	(0.01)	(0.00)	0.03	$0.70
5	732	(0.00)	(0.00)	0.00	$0.05
6	5,720	(0.01)	(0.00)	0.02	$0.42
7	1,395	(0.00)	(0.00)	0.00	$0.10
8	27,974	(0.04)	(0.00)	0.09	$2.03
9	69,726	(0.11)	(0.01)	0.24	$5.03
10	4,325	(0.01)	(0.00)	0.01	$0.31
11	6,209	(0.01)	(0.00)	0.02	$0.44
12	40,461	(0.06)	(0.01)	0.14	$2.88
13	10,883	(0.02)	(0.00)	0.04	$0.77
14	25,532	(0.05)	(0.01)	0.09	$1.81
15	42,135	(0.10)	(0.01)	0.14	$2.96
16	1,151	(0.00)	(0.00)	0.00	$0.08
TOTAL	**319,468**	**(0.52)**	**(0.06)**	**1.08**	**$22.87**

a. First-year savings from all alterations completed statewide in 2023.

Table 55 and Table 56 present first-year statewide savings from new construction, additions, and alterations for lighting and dehumidification, respectively.

Table 55: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions – Lighting

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (million therms)	15-Year Present Valued Energy Cost Savings (PV$ million)
New Construction	238.5	16.2	N/A	$545.01
Additions and Alterations	86.5	6.6	N/A	$197.66
TOTAL	**325.0**	**22.9**	N/A	**$742.67**

Table 56: Statewide Energy and Energy Cost Impacts – Dehumidification – New Construction, Alterations, and Additions

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (million therms)	15-Year Present Valued Energy Cost Savings (PV$ million)
New Construction	(1.8)	(0.2)	3.6	$76.79
Additions and Alterations	(0.5)	(0.1)	1.1	$22.87
TOTAL	**(2.3)**	**(0.3)**	**4.7**	**$99.66**

6.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions assuming the emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion. Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42). See Appendix C for additional details on the methodology used to calculate GHG emissions. In short, this analysis assumes an average electricity emission factor of 240.4 metric tons CO2e per GWh based on the average emission factors for the CACX EGRID subregion.

Table 57 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 80,794 metric tons of carbon dioxide equivalents (metric tonsCO2e) would be avoided.

Table 57: First-Year Statewide GHG Emissions Impacts

Submeasure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings[a] (Metric Tons CO2e)	Natural Gas Savings[a] (million therms/yr)	Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tons CO2e)	Total Reduced CO_2e Emissions[a,b] (Metric Tons CO2e)
Horticultural Lighting Minimum Efficacy	324.97	0.08	0.00	0	0.08
Efficient Dehumidification and Reuse of Transpired Water	(2.29)	0.00	4.69	0.03	0.03
Total	322.68	0.08	4.69	0.03	0.11

a. First-year savings from all buildings completed statewide in 2023.

b. Assumes the following emission factors: 240.4 MTCO2e/GWh and 5,454.4 MTCO2e/million therms.

6.3 Statewide Water Use Impacts

The horticultural lighting minimum efficacy submeasure does not include water savings.

The efficient dehumidification and reuse of transpired water submeasure provides water savings in addition to energy savings.

Impacts on water use are presented in Table 58. It was assumed that all water savings occurred indoors, and the embedded electricity value was 4,848 kWh/million gallons of water. The embedded electricity estimate was derived from a 2015 CPUC study that quantified the embedded electricity savings from IOU programs that save both water and energy (CPUC 2015b). See Appendix B for additional information on the embedded electricity savings estimates.

Table 58: Impacts on Water Use and Embedded Electricity in Water - Dehumidification

Impact	On-Site Indoor Water Savings (gallons/yr)	On-site Outdoor Water Savings (gallons/yr)	Embedded Electricity Savings[a] (kWh/yr)
Per Square Foot of Canopy Impacts	13.7	0	0.066
First-Year Statewide Impacts[b]	19,064,607	0	92,425.216

a. Assumes embedded energy factor of 4,848 kWh per million gallons of water for indoor use (CPUC 2015).

b. First-year savings from all buildings completed statewide in 2023.

6.4 Statewide Material Impacts

The primary impacts on statewide materials would come from the transition of HID lights to LEDs. Notably, the Statewide CASE Team expects to see a decrease of mercury since CFLs contain mercury while LEDs do not. While both HIDs and LEDs contain copper, the decrease in replacements that accompany a transition to LEDs would lead to less copper usage. The Statewide CASE Team does not expect a change in the use of lead, steel, or plastic. While LEDs may contain more lead than some HIDs, the reduced lamp replacement may cancel this out. There would be a slight increase in arsenic due to trace amounts that are contained in some types of LEDs.

Table 59: First-Year Statewide Impacts on Material Use

Material	Impact (I, D, or NC)[a]	Impact on Material Use (pounds/year)	
		Per-Unit Impacts	First-Year[b] Statewide Impacts
Mercury	TBD		
Lead	TBD		
Copper	TBD		
Steel	TBD		
Plastic	TBD		
Arsenic	TBD		

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

b. First-year savings from all buildings completed statewide in 2023.

The Statewide CASE Team is still in the process of determining the materials impacts associated with this code proposal.

6.5 Other Non-Energy Impacts

The proposed indoor horticultural lighting minimum efficacy requirement would require the use of LED lighting. Some anecdotal evidence from a couple cannabis growers that were interviewed mentioned that transitioning from legacy lighting technologies such as double-ended HPS luminaires or metal halide luminaires can take two to three grow cycles of getting used to the technology to produce similar yields to the legacy technologies. Yield concerns were addressed in Section 3.2.1 as part of the market barriers and solutions. The studies listed in Section 3.2.1 provide some evidence that LED lighting may increase cannabis quality, such as delta-9-tetrahydrocannabinol (THC), cannabidiol (CBD), and terpene levels. These quality attributes can increase the crop value. Yield and quality effects can be strain specific. No studies were found showing positive or negative effects on crop yield of other crop types.

The industry is developing materials to support growers transitioning to LED horticultural lighting. Resource Innovation Institute has developed the LED Lighting for Cannabis Cultivation and Controlled Environment Agriculture Best Practices Guide. They have also been hosting Efficient Yields workshops to provide growers with lessons learned directly from their peers on growing with LED lighting.

7. Proposed Revisions to Code Language

7.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2019 documents are marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

7.2 Standards

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

ANSI/ASABE S640 is the American National Standards Institute/American Society of Agricultural and Biological Engineers document titled "Quantities and Units of Electromagnetic Radiation for Plants (Photosynthetic Organisms)" (ANSI/ASABE S640 JUL2017).

PROCESS, COVERED is a process that is regulated under Part 6, Section 120.6 and 140.9, which includes computer rooms, data centers, elevators, escalators and moving walkways, laboratories, enclosed parking garages, commercial kitchens, refrigerated warehouses, commercial refrigeration, compressed air systems, ~~and~~ process boilers, and controlled environment horticulture spaces.

USDOE 10 CFR 430 is the regulation issued by Department of Energy and available in the Code of Federal Regulation - Title 10, Chapter II, Sub-chapter D, Part 430 – Energy Conservation Program for Consumer Products. Relevant testing methodologies are specified in "Appendix N to sub-part B of Part 430 – Uniform test method for measuring the energy consumption of furnaces and boilers~~.~~" and in "Appendix X to sub-part B of Part 430 – Uniform test method for measuring the energy consumption of dehumidifiers."

CONTROLLED ENVIRONMENT HORTICULTURE definitions:

Canopy in buildings with CEH spaces may be noncontiguous, but each unique area included in the total canopy calculation shall be separated by an identifiable boundary that includes, but is not limited to, interior walls, shelves, and fencing. If plants are being cultivated using a shelving system, the surface area of each level is included in the total canopy calculation. Canopy is calculated by summing the surface area of spaces that will be used for growing and maintaining plants.

Carbon dioxide enrichment is injection of additional carbon dioxide into the CEH spaces for the purpose of stimulating plant growth.

Controlled environment horticulture (CEH) space is a building space dedicated to plant production by manipulating indoor environmental conditions, such as through electric lighting, irrigation, and HVAC. CEH space does not include building space where plants are grown solely to decorate that same space. Greenhouse and indoor growing are types of CEH spaces (see "greenhouse" and "indoor growing").

Desiccant dehumidification systems are mechanical dehumidification technologies that use a solid or liquid material to remove moisture from the air.

Greenhouse is a type of CEH space that maintains a sunlit environment for the purpose of plant growth, production, or maintenance, with Skylight Roof Ratio of 50% or more above the growing area.

Greenhouse, conditioned is a greenhouse with heating that has a capacity exceeding 10 Btu/hr-ft^2 or mechanical cooling that has a capacity exceeding 5 Btu/hr-ft^2.

Horticultural lighting consists of luminaires used for plant growth and maintenance. Horticultural luminaires may have either plug-in or hard-wired connections for electric power.

Indoor growing is a type of CEH space in a building with a Skylight Roof Ratio less than 50%. Growing plants in a warehouse with or without skylights is an example of an indoor growing.

Photosynthetic photon efficacy (PPE) is photosynthetic photon flux divided by input electric power in units of micromoles per second per watt, or micromoles per joule as defined by ANSI/ASABE S640.

Photosynthetic photon flux (PPF) is the rate of flow of photons between 400 to 700 nanometers in wavelength from a radiation source as defined by ANSI/ASABE S640.

SECTION 120.6 – MANDATORY REQUIREMENTS FOR COVERED PROCESSES

(h) **Mandatory Requirements for Controlled Environment Horticulture (CEH) Spaces**

1. **Indoor Growing, Space-Conditioning Systems and Insulation.**
   A. Space-conditioning systems and insulation used for plant production shall comply with all applicable requirements of Part 6.
2. **Indoor Growing, Dehumidification.** Dehumidification systems used in indoor growing shall conform to the following requirements:
   A. **Dehumidification Equipment.** Dehumidification equipment shall be one of the following:
      i. Integrated HVAC system with on-site heat recovery to achieve dehumidification reheat, or
      ii. Chilled water system with on-site heat recovery to achieve dehumidification reheat, or
      iii. Solid or liquid desiccant dehumidification system.

EXCEPTION to 120.6(h)2: In buildings with less than 2,000 square feet of canopy in combined CEH spaces, stand-alone dehumidification units with a minimum energy factor of 1.9 L/kWh are permitted.

B. **Reheat.** The on-site heat recovery system in Section 120.6(h)3A shall be designed to fulfill at least 60% of the facility's dehumidification air reheat needs during peak dehumidification periods.

C. **Transpired Water Reuse.** Dehumidification equipment shall have the capability to reuse transpired water for irrigation.

4. **Indoor Growing, Horticultural Lighting.** In buildings with more than 1,000 square feet of canopy in combined CEH spaces, the electric lighting systems used for plant growth and plant maintenance shall meet the following requirements:

   A. Luminaires shall have a photosynthetic photon efficacy of not less than 2.1 micromoles per joule rated in accordance with ANSI / ASABE S640 for wavelengths from 400 to 700 nanometers.

   B. Time-switch lighting controls shall be installed and comply with Section 110.9(b)1, Section 130.4(a)4, and applicable sections of NA7.6.2.

   C. Multilevel lighting controls shall be installed and comply with Section 130.1(b).

5. **Greenhouses, Horticultural Lighting.** In greenhouses with more than 1,000 square feet of canopy, the electric lighting system used for plant growth and plant maintenance shall meet the following requirements:

   A. Luminaires shall have photosynthetic photon efficacy of not less than 1.7 micromoles per joule rated in accordance with ANSI / ASABE S640 for wavelengths from 400 to 700 nanometers.

   B. Astronomical time-switch lighting controls shall be installed and comply with Section 110.9(b)1, Section 130.4(a)4, applicable sections of NA7.6.2, and capable of dimming lighting according to a schedule.

   C. Multilevel lighting controls shall be installed and comply with Section 130.1(b).

6. **Conditioned Greenhouses, Building Envelope.** Conditioned greenhouses shall meet the following requirements:

   A. Opaque wall and roof assemblies shall meet the requirements of Sections 120.7 and 140.3(a).

   B. Non-opaque wall assemblies shall have a weighted average U-factor of 0.7 or less.

   C. Non-opaque roof assemblies shall have a weighted average U-factor of 0.5 or less.

7. **Conditioned Greenhouses, Space-Conditioning Systems.**

   B. Space-conditioning systems used for plant production shall comply with all applicable requirements of Part 6.

SECTION 140.3 – PRESCRIPTIVE REQUIREMENTS FOR BUILDING ENVELOPES

(a) 5. Exterior Windows.

EXCEPTION 1 to Section 140.3(a)5: Conditioned Greenhouses. The requirements of Section 120.6(h)6 apply.

(a) 6. Skylights.

EXCEPTION 1 to Section 140.3(a)6: Conditioned Greenhouses. The requirements of Section 120.6(h)6 apply.

(c) Minimum Daylighting Requirement for Large Enclosed Spaces.

EXCEPTION 1 to Section 140.3(c): Auditoriums, churches, movie theaters, museums, ~~and~~ refrigerated warehouses, and controlled environment horticulture spaces.

SECTION 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

(e) Economizers.

EXCEPTION 7 to Section 140.4(e)1: Systems installed in buildings with controlled environment horticulture spaces that use carbon dioxide enrichment as a strategy to promote plant growth.

SECTION 140.6 – PRESCRIPTIVE REQUIREMENTS FOR INDOOR LIGHTING

(a) […]

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

[…]

G. Lighting for plant growth or maintenance, if it is controlled by a multi-level astronomical time-switch control that complies with the applicable provisions of Section 110.9. For controlled environment horticulture spaces, the requirements of Section 120.6(h) also apply.

[…]

O. Lighting in occupancy group U buildings less than 1,000 square feet. For controlled environment horticulture spaces, the requirements of Section 120.6(h) apply.

P. Lighting in unconditioned agricultural buildings less than 2,500 square feet. For controlled environment horticulture spaces, the requirements of Section 120.6(h) apply.

SECTION 141.1 – REQUIREMENTS FOR COVERED PROCESSES IN ADDITIONS, ALTERATIONS TO EXISTING NONRESIDENTIAL, HIGHRISE RESIDENTIAL, AND HOTEL/MOTEL BUILDINGS

Covered processes in additions or alterations to existing buildings that will be nonresidential, high-rise residential, and hotel/motel occupancies shall comply with the applicable subsections of section 120.6 and 140.9.

(a) **Controlled Environment Horticulture Spaces.**

1. **Indoor Growing, Space-Conditioning Systems and Dehumidification**. All newly installed heating, ventilation, air conditioning systems or dehumidification systems in buildings with indoor growing shall meet the applicable requirements of Section 120.6(h)2 and 120.6(h)3.
2. **Greenhouses, Building Envelope and Space-Conditioning Systems**. A greenhouse being converted to the conditioned greenhouse shall meet the requirements of Sections 120.6(h)6 and 120.6(h)7.
3. **Indoor Growing and Greenhouses, Horticultural Lighting**. Alterations to horticultural lighting systems that increase lighting wattage or include adding, replacing, or altering 10 percent or more of the luminaires serving an enclosed space shall meet the requirements of Section 120.6(h)4 for indoor growing or Section 120.6(h)5 for greenhouses.

   EXCEPTION to Section 141.1(a)3: Any alteration limited to adding lighting controls or replacing lamps, ballasts, or drivers.

NOTE: For alterations that change the occupancy classification of the building, the requirements of Section 141.1 apply to the occupancy that will exist after the alterations.

7.3 Reference Appendices

There are no proposed changes to the Reference Appendices.

7.4 ACM Reference Manual

There are no proposed changes to the Nonresidential ACM Reference Manual.

7.5 Compliance Manuals

Chapter 10 on covered processes of the Nonresidential Compliance Manual would need to be revised to include a new section on CEH production as a covered process, including an example of canopy calculation. The Compliance Manual should specify what sections in Title 24, Part 6 outside of the proposed Section 120.6(h) apply to:

- Space conditioning systems and insulation requirements in indoor growing operations (i.e., Sections 110.2(a), 120.2(a), 120.2(b), 120.2 (d) through 120.2(g), 120.3, 120.4, 120.7, 140.3(a), 140.4(c), 140.4(d), and 140.4(g) through 140.4(o)) and
- Space conditioning systems in conditioned greenhouses (i.e., Sections 110.2(a), 120.2(a), 120.2(b), 120.2 (d) through 120.2(g), 120.3, 120.4, 140.4(c), 140.4(d), and 140.4(g) through 140.4(o)).

7.6 Compliance Documents

Certificate of compliance document (NRCC-PRC-E Process Systems) would need to be revised to add compliance information for a CEH production as a covered process.

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Appendix A: Statewide Savings Methodology

To calculate first-year statewide savings, the Statewide CASE Team multiplied the per-unit savings by statewide construction estimates for the first year the standards would be in effect (2023). This section describes how the Statewide CASE Team developed these estimates.

The Statewide CASE Team developed per canopy square footage savings for both the greenhouse and indoor growing facility proposals. Greenhouse savings consist of reduction in energy usage from the updated lighting PPE. Indoor savings consists of reductions in energy and water usage from the updated lighting PPE and dehumidification proposals. As noted in Section 5, the Statewide CASE Team used a spreadsheet analysis to calculate savings at the proposed efficiency levels relative to the assumed baseline. Detailed depictions of the presumed baseline technologies are described in Section 5. After developing these per canopy square foot savings, the Statewide CASE Team extrapolated into statewide results.

Using data from CalCannabis licensing, a New Frontier 2018 report, and US Department of Agriculture, the Statewide CASE Team estimated new construction canopy square footage by 2023 as shown in Table 60. It was assumed that 8 percent of existing canopy square footage would be impacted by the alterations requirements.

The below table estimates the square footage of canopy of new construction and alterations that are impacted by this code proposal for both indoor growing facilities and greenhouses.

Table 60: First-year Canopy Square Footage Impacted by Proposal

Building Type	New Construction Impacted by Proposal in 2023 (ft^2 of canopy)	Alterations Impacted by Proposal In 2023 (ft^2 of canopy)
Indoor Horticulture	1,072,478	319,468
Greenhouse	1,605,980	1,298,076

Table 61: Percent of Floorspace Impacted by Proposed Measure, by Climate Zone

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

a. Percent of existing floorspace that would be altered during the first year the 2022 standards are in effect.

Appendix B: Embedded Electricity in Water Methodology

The Statewide CASE Team assumed the following embedded electricity in water values: 4,848 kWh/million gallons of water for indoor water use and 3,565 kWh/million gallons for outdoor water use. Embedded electricity use for indoor water use includes electricity used for water extraction, conveyance, treatment to potable quality, water distribution, wastewater collection, and wastewater treatment. Embedded electricity for outdoor water use includes all energy uses upstream of the customer; it does not include wastewater collection or wastewater treatment. The embedded electricity values do not include on-site energy uses for water, such as water heating and on-site pumping. On-site energy impacts are accounted for in the energy savings estimates presented in Section 4 of this report.

These embedded electricity values were derived from research conducted for CPUC Rulemaking 13-12-011. The CPUC study aimed to quantify the embedded electricity savings associated with IOU incentive programs that result in water savings, and the findings represent the most up-to-date research by the CPUC on embedded energy in water throughout California (CPUC 2015a, 2015b). The CPUC analysis was limited to evaluating the embedded electricity in water and does not include embedded natural gas in water. For this reason, this Draft CASE Report does not include estimates of embedded natural gas savings associated with water reductions, though the embedded electricity values can be assumed to have the same associated emissions factors as grid-demanded electricity in general.

The specific CPUC embedded electricity values used in the CASE analysis are shown in Table 62. These values represent the average energy intensity by hydrologic region, which are based on the historical supply mix for each region regardless of who supplied the electricity (IOU-supplied and non-IOU- supplied electricity). The CPUC calculated the energy intensity of marginal supply but recommended using the average IOU and non-IOU energy intensity to estimate total statewide average embedded electricity of water use in California.

Table 62: Embedded Electricity in Water by California Department of Water Resources Hydrologic Region (kWh Per Acre Foot (AF))

Region	Extraction, Conveyance, and Treatment	Distribution	Wastewater Collection + Treatment	Outdoor (Upstream of Customer)	Indoor (All Components)
NC	235	163	418	398	816
SF	375	318	418	693	1,111
CC	513	163	418	677	1,095
SC	1,774	163	418	1,937	2,355
SR	238	18	418	255	674
SJ	279	18	418	297	715
TL	381	18	418	399	817
NL	285	18	418	303	721
SL	837	163	418	1,000	1,418
CR	278	18	418	296	714

Hydrologic Region Abbreviations:
NC = North Coast, SF = San Francisco Bay, CC = Central Coast, SC = South Coast, SR = Sacramento River, SJ = San Joaquin River, TL = Tulare Lake, NL = North Lahontan, SL = South Lahontan, CR = Colorado River
Source: Navigant team analysis

Source: CPUC 2015b.

The Statewide CASE Team used CPUC's indoor and outdoor embedded electricity estimates by hydrologic region (presented in Table 62) and population data by hydrologic region from the U.S. Census Bureau (U.S. Census Bureau, Population Division 2014) to calculate the statewide population-weighted average indoor and outdoor embedded electricity values that were used in the CASE analysis (see Table 63). The energy intensity values presented in Table 62 were converted from kWh per acre foot to kWh per million gallons to harmonize with the units used in the CASE analysis. There are 3.07 acre-feet per million gallons.

Table 63: Statewide Population-Weighted Average Embedded Electricity in Water

Hydrologic Region	Indoor Water Use (kWh/million gallons)	Outdoor Water Use (kWh/million gallons)	Percent of California Population
North Coast	2,504	1,221	2.1%
San Francisco	3,410	2,127	18.2%
Central Coast	3,360	2,078	3.8%
South Coast	7,227	5,944	44.8%
Sacramento River	2,068	783	8.1%
San Joaquin River	2,194	911	4.7%
Tulare Lake	2,507	1,224	6.3%
North Lahontan	2,213	930	0.1%
South Lahontan	4,352	3,069	5.5%
Colorado River	2,191	908	6.5%
Statewide Population-Weighted Average	4,848	3,565	

Sources: U.S. Census Bureau, Population Division 2014; California Department of Water Resources 2016.

Appendix C: Environmental Impacts Methodology

Greenhouse Gas (GHG) Emissions Factors

As directed by Energy Commission staff, GHG emissions were calculated making use of the average emissions factors specified in the United States Environmental Protection Agency (U.S. EPA Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion (United States Environmental Protection Agency 2018). This ensures consistency between state and federal estimations of potential environmental impacts. The electricity emissions factor calculated from the eGRID data is 240.4 metric tonsCO2e per GWh. The Summary Table from eGrid 2016 reports an average emission rate of 529.9 pounds CO2e/MWh for the WECC CAMX subregion. This value was converted to metric tons CO2e/GWh.

Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in Chapter 1.4 of the U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42) (United States Environmental Protection Agency 1995). The U.S. EPA's estimates of GHG pollutants that are emitted during combustion of one million standard cubic feet of natural gas are: 120,000 pounds of CO_2 (Carbon Dioxide), 0.64 pounds of N_2O (Nitrous Oxide) and 2.3 pounds of CH_4 (Methane). The emission value for N_2O assumed that low NOx burners are used in accordance with California air pollution control requirements. The carbon equivalent values of N_2O and CH_4 were calculated by multiplying by the global warming potentials (GWP) that the California Air Resources Board used for the 2000-2016 GHG emission inventory, which are consistent with the 100-year GWPs that the Intergovernmental Panel on Climate Change used in the fourth assessment report (AR4). The GWP for N_2O and CH_4 are 298 and 25, respectively. Using a nominal value of 1,000 Btu per standard cubic foot of natural gas, the carbon equivalent emission factor for natural gas consumption is 5,454.4 metric tons CO2e per therms.

GHG Emissions Monetization Methodology

The 2022 TDV energy cost factors used in the lifecycle cost-effectiveness analysis include the monetary value of avoided GHG emissions based on a proxy for permit costs (not social costs). As of the Draft CASE Report's date of publication, the Energy Commission has not released the final TDV factors. The Final CASE Report will show the monetary value of avoided GHG emissions using assumptions that align with those used for the 2022 TDV factors.

Water Use and Water Quality Impacts Methodology

To calculate water savings, the Statewide CASE Team assumed that a baseline of 60 percent of dehumidification condensate water is reclaimed in the facility, and in the proposed case, 100 percent of water is reclaimed. These water savings do not vary by climate zone. Roughly 14 gallons per year per square foot of canopy is saved in indoor facilities. See Table 5 for the total water savings and embedded electricity savings.

Appendix D: California Building Energy Code Compliance (CBECC) Software Specification

There are no recommended revisions to the compliance software as a result of this code change proposal.

Appendix E: Impacts of Compliance Process on Market Actors

This appendix discusses how the recommended compliance process, which is described in the compliance section of the Executive Summary, could impact various market actors. Table 64 identifies the market actors who would play a role in complying with the proposed change, the tasks for which they would be responsible, their objectives in completing the tasks, how the proposed code change could impact their existing work flow, and ways negative impacts could be mitigated. The information contained in Table 64 is a summary of key feedback the Statewide CASE Team received when speaking to market actors about the compliance implications of the proposed code changes. Appendix F summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the code change proposal, including gathering information on the compliance process.

This code change proposal would create significant changes in the compliance process for many market actors since controlled environment horticulture was not previously regulated under Title 24, Part 6. Completion of compliance documents is an essential step to ensure compliance, and horticulture facility owners, contractors, and designers may need guidance on how to do so. Compliance documents would need to identify relevant lighting and HVAC equipment in order to document specific technologies used.

To facilitate an efficient compliance process under the proposed code change, collaboration among a variety of individuals is important. General, lighting, and HVAC contractors would need to closely collaborate with the design team and ensure the relevant documents are shared with one another. Field inspectors would need to now work with indoor horticulture permit applicants to ensure the proper parts of the facility are inspected and that the proposed building plans meet Title 24, Part 6 regulations.

On smaller projects, the same person would likely perform multiple functions. For example, a general contractor may design and build lighting, irrigation, and HVAC/dehumidification systems. Large projects would more likely involve specialized vendors for lighting, controls, and HVAC/dehumidification systems.

Table 64: Roles of Market Actors in the Proposed Compliance Process

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Energy Commission	Did not previous regulate grow light and dehumidification efficiency standards in horticulture facilities.	Make the process of demonstrating compliance as simple as possible.	• Update the Nonresidential Compliance Manual and certificate of compliance document (NRCC-PRC-E Process Systems). • Develop a new certificate of acceptance document.	The Statewide CASE Team recommends including the following data fields in the certificate of compliance document: • Canopy size. • PPE ratings of lighting luminaires in micromoles per joule. • Type of dehumidification system and its moisture removal efficiency in pounds of moisture per kilowatt-hour. • Type of HVAC system • Yes/no on the use of carbon dioxide.
Indoor Horticulture Facility Designer	• Design facility to the needs and plans of the facility owner. • Comply with relevant non-energy efficiency related building codes.	Produce building plans for a facility that is compliant with Title 24, Part 6.	• Design a facility that meets applicable Title 24, Part 6 requirements and other building standards. • Complete or assist in completing a certificate of compliance document for permit application. • Ensure building plans are consistent with the information in the certificate of compliance. • Would have to document compliance with the proposed requirements.	The Statewide CASE Team recommends including the following in the Nonresidential Compliance Manual: • Examples showing facilities that are compliant with Title 24, Part 6. • Examples showing facilities that are not compliant with Title 24, Part 6 with explanations as to why.

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Greenhouse Designer	• Design facility to the needs of the owner. • Comply with non-energy standards in Title 24, Part 6. • If a conditioned greenhouse, comply with required nonresidential envelope requirements.	Design a greenhouse that meets the updated Title 24, Part 6 envelope and lighting efficacy requirements.	• Would now have more practical envelope requirements to meet for both conditioned and unconditioned greenhouses • Would have to design lighting systems that meet the proposed requirements.	The Statewide CASE Team recommends including the following in the Nonresidential Compliance Manual: • Examples showing facilities that are compliant with Title 24, Part 6. • Examples showing facilities that are not compliant with Title 24, Part 6 with explanations as to why.
Lighting Designer	• Identify lighting luminaires and lighting controls that suit the needs of the facility. • Coordinate design with HVAC designers to account for interaction between lighting and HVAC/dehumidification systems. • Serve as an expert in lighting technology.	Design lighting system design that meets the needs of the occupant and is compliant with Title 24, Part 6.	• Would have to design lighting systems that meet the proposed requirements. • May need to document compliance with the proposed requirements. • Identify lighting luminaires and lighting controls that meet the proposed standards. • Assist in completing or complete a certificate of compliance for permit application.	The Statewide CASE Team recommends setting a standard that uses metrics with which lighting designers would be familiar.

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Mechanical HVAC Designer	• Serve as an expert for specifying HVAC/dehumidification system.	Produce specification for a dehumidification system that is compliant with Title 24, Part 6.	• Design a dehumidification system that meets the proposed standards. • Assist in completing or complete a certificate of compliance for permit application.	Support horticulture industry efforts to develop a testing protocol for dehumidification systems.
Enforcement Agency Plans Examiner	• No relevant tasks under current code.	Validate quickly and easily that the horticulture facility meets Title 24, Part 6 requirements based on submitted plans.	• Would need to verify canopy calculations and equipment specifications are compliant with the proposed requirements. • Become aware of relevant code requirements and updated compliance documents. • Review submitted building plans and compliance documents to verify compliance.	• Develop training for building department officials to handle new code requirements. • Develop compliance document that auto-verifies compliance status of entered data.
General Contractor	• Build the horticulture facility in accordance with the building plans.	Build a horticulture facility that is compliant with Title 24, Part 6.	• Would have to build a horticulture facility that meets the proposed requirements. • When field changes result in noncompliance, obtain an approval from the enforcement agency of the revised certificate of compliance document. • Complete a certificate of installation document.	Provide an option to contractors for getting answers related to compliance over the phone.

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Lighting Contractor or Electrician	• Build lighting system in accordance with the building plans.	Build lighting system that is compliant with Title 24, Part 6.	Would have to build lighting system that meets the proposed requirements.	Provide an option to contractors for getting answers related to compliance over the phone.
Building Automation Controls Contractor	• Serve as an expert for selecting, installing, and commissioning environmental and irrigation controls.	Install controls in accordance with the building plans.	Would have to install controls that meet the proposed requirements.	Provide an option to contractors for getting answers related to compliance over the phone.
Enforcement Agency Field Inspector	• Coordinate final inspection with the permit applicant. • Verify that the horticulture facility is constructed in accordance with the building plans.	Validate quickly and easily that the CEH facility meets Title 24, Part 6 requirements based on field inspection.	Would have to verify compliance with Title 24, Part 6 for horticulture facilities.	Develop training for building department officials to handle new code requirements.

Appendix F: Summary of Stakeholder Engagement

Collaborating with stakeholders that might be impacted by proposed changes is a critical aspect of the Statewide CASE Team's efforts. The Statewide CASE Team aims to work with interested parties to identify and address issues associated with the proposed code changes so that the proposals presented to the Energy Commission in this Draft CASE Report are generally supported. Public stakeholders provide valuable feedback on draft analyses and help identify and address challenges to adoption including: cost effectiveness; market barriers; technical barriers; compliance and enforcement challenges; or potential impacts on human health or the environment. Some stakeholders also provide data that the Statewide CASE Team uses to support analyses.

This appendix summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the recommendations presented in this report.

Utility-Sponsored Stakeholder Meetings

Utility-sponsored stakeholder meetings provide an opportunity to learn about the Statewide CASE Team's role in the advocacy effort and to hear about specific code change proposals that the Statewide CASE Team is pursuing for the 2022 code cycle. The goal of stakeholder meetings is to solicit input on proposals from stakeholders early enough to ensure the proposals and the supporting analyses are vetted and have as few outstanding issues as possible. To provide transparency in what the Statewide CASE Team is considering for code change proposals, during these meetings the Statewide CASE Team asks for feedback on:

- Proposed code changes
- Draft code language
- Draft assumptions and results for analyses
- Data to support assumptions
- Compliance and enforcement, and
- Technical and market feasibility

The Statewide CASE Team hosted two stakeholder meetings for controlled environment horticulture via webinar. Please see below for dates and links to event pages on Title24Stakeholders.com. Materials from each meeting, such as slide presentations, proposal summaries with code language, and meeting notes, are included in the bibliography section of this report.

Table 65: Stakeholder Meeting Date and Information

Meeting Name	Meeting Date	Event Page from Title24stakeholders.com
First Round of Controlled Environment Horticulture Utility-Sponsored Stakeholder Meeting	Thursday, September 19, 2019	https://title24stakeholders.com/event/covered-processes-utility-sponsored-stakeholder-meeting/
Second Round of Controlled Environment Horticulture Utility-Sponsored Stakeholder Meeting	Thursday, April 16, 2020	https://title24stakeholders.com/event/covered-processes-part-2-controlled-environment-horticulture-utility-sponsored-stakeholder-meeting/

The first round of utility-sponsored stakeholder meetings occurred from September to November 2019 and were important for providing transparency and an early forum for stakeholders to offer feedback on measures being pursued by the Statewide CASE Team. The objectives of the first round of stakeholder meetings were to solicit input on the scope of the 2022 code cycle proposals; request data and feedback on the specific approaches, assumptions, and methodologies for the energy impacts and cost-effectiveness analyses; and understand potential technical and market barriers. The Statewide CASE Team also presented initial draft code language for stakeholders to review.

The second round of utility-sponsored stakeholder meetings occurred from March to May 2020 and provided updated details on proposed code changes. The second round of meetings introduced early results of energy, cost effectiveness, and incremental cost analyses, and solicited feedback on refined draft code language.

Utility-sponsored stakeholder meetings were open to the public. For each stakeholder meeting, two promotional emails were distributed from info@title24stakeholders.com One email was sent to the entire Title 24 Stakeholders listserv, totaling over 1,900 individuals, and a second email was sent to a targeted list of individuals on the listserv depending on their subscription preferences. The Title 24 Stakeholders' website listserv is an opt-in service and includes individuals from a wide variety of industries and trades, including manufacturers, advocacy groups, local government, and building and energy professionals. Each meeting was posted on the Title 24 Stakeholders' LinkedIn page[9] (and cross-promoted on the Energy Commission LinkedIn page) two weeks before each meeting to reach out to individuals and larger organizations and channels outside of the listserv. The Statewide CASE Team conducted extensive personal outreach to stakeholders identified in initial work plans who had not yet opted into the listserv. Exported webinar meeting data captured attendance numbers and individual comments,

[9] Title 24 Stakeholders' LinkedIn page can be found here: https://www.linkedin.com/showcase/title-24-stakeholders/

and recorded outcomes of live attendee polls to evaluate stakeholder participation and support.

Statewide CASE Team Communications

The Statewide CASE Team held personal communications over email and phone with numerous stakeholders when developing this report.

To gain a nuanced understanding of the controlled environment horticulture industry, the Statewide CASE Team reached out a wide array of stakeholders. These stakeholders included policy makers, research groups, growers, consultants, engineers, and others are found in Table 66 lists the names of individuals and groups that played key collaborative roles in assisting the Statewide CASE Team in writing this Draft CASE Report.

Table 66: Stakeholders involved in the CASE process

Name of person/group	Role
Andrew Alfred	Chief Scientist LivWell
Jennifer Amann	Director of Building Programs, ACEEE
Ned Bent	AHRI
Ian Burnside	Energy efficiency engineer with PG&E
Gary Corlett	Southern California Edison
Keith Coursin	President at Desert Aire
Nicole Hathaway	Development Engineer at California Lighting Technology Center (CLTC)
Armin Hauer	Regulatory affairs at EBM Papst
Jill Hootman	Trane
Harold Jepsen	Vice President of Standards at Legrand
Neil Kolwey	Industrial Program Director of SWEEP
Nick Maderas	Chief Visionary Officer of Agnetix
Erico Mattos	Executive Director at Greenhouse Lighting and Systems Engineering (GLASE)
Matthew McGregor	Strategic account advisor - SMUD
Jesse Monn	Project Manager at Cascade Energy
Lauren Morlino	Efficiency Vermont
Kevin Muldoon	HVAC Engineering lead at KCC International
National Cannabis Industry Association	National cannabis trade association
Nick O'Neil	Director at Energy 350
Morgan Pattinson	President of Solid State Lighting Services

Name of person/group	Role
Leora Radetsky	Senior Lighting Scientist at the DesignLights Consortium
Tim Rasinski	Program Manager at NIST
Nadia Sabeh	Specialist in indoor agriculture HVAC / co-chair of ASHRAE indoor agriculture HVAC committee
Derek Smith	Executive Director of Resource Innovation Institute
Andy Souza	Mechanical Engineer at TEP Engineering
Walter Stark	Expert in indoor agriculture HVAC equipment
Chris Uhlig	Ceres Greenhouse Solutions

Summary of Outreach

Horticulture Lighting Minimum Efficacy

Significant outreach was conducted both to determine the proposed PPE level for the horticulture lighting minimum efficacy standard and to analyze important technical considerations related to this standard. The DesignLight Consortium's Qualified Products List (DLC QPL) provides essential information on PPE levels for a variety of lighting types.

Representatives of Cascade Energy noted that proposed regulations for lighting efficacy needed to use a metric that product specification sheets often noted.

CLTC noted that plant scientists now favor full spectrum lighting to best mimic sunlight. It was recommended to choose an efficacy point that allowed for flexibility and for LED incentive programs to continue.

Individuals with the Resource Innovation Institute noted that creating an LPD requirement would be difficult because it would be based on room area and not canopy area, which is the main focus.

Staff members of PG&E noted that PPFD changes per crop so studying the efficacy of the luminaires themselves would likely be most effective. Additionally, it was noted that greenhouses are naturally much more lighting efficient due to natural light. Southern California Edison staff mentioned that a PPE level of 2.1 may lead to more individuals growing illicitly. It was also indicated that the Statewide CASE Team should look into prescribing different PPE levels for different stages of growth. The costs for existing growers to get into the legal market should also be analyzed.

Individuals with Solid State Lighting Service also noted that PPE is most likely the best approach for lighting regulation. Additionally, it was noted that the LED market is primed to handle high rates of PPE and that light spectrum is important to many industry members.

SMUD staff provided estimates of grows that are currently operating with LEDs and what percentage of planned facilities will be. Additionally, it was noted that full spectrum LEDs are able to combat yield concerns.

Individuals from the DLC noted that growers care more about performance than about efficiency, and this should inform the standard setting. Along similar lines, stakeholders provided feedback that dimming is not common right now in the market. Additionally, the inclusion of a dimming requirement would lead to changes in ventilation and shade needs.

Efficient Dehumidification and Reuse of Transpired Water

ACEEE staff noted that requiring separate dehumidification units would limit technology and not allow integrated HVAC systems.

Individuals from KCC International noted that growers often have their own specific mix of temperature, humidity set points, and schedule that they prefer. Additionally, it was noted that 80°F and 60 percent relative humidity are the most common ratings used by the most common test procedures.

SMUD staff noted that the most common dehumidification setups are DX technology. Unitary in-room dehumidification units would be considered the baseline. He also noted that most control systems are basic, but some facilities are installing advanced controls from groups such as Argus. Additionally, it was noted that a lot of grows reuse their water.

Individuals from Trane provided comments as to the efficiency standards for the dehumidification submeasure.

Greenhouse Envelope

Communication with representatives from Energy 350 notified the Statewide CASE Team of potential inclusion of greenhouse envelope code language in ICC 2021 code language.

Dr. Greenhouse also provided key insight regarding the options for the envelope proposal in addition to the lighting and dehumidification submeasure.

Staff from GLASE noted that the Statewide CASE should consider differentiating requirements options for shade and energy curtains.

TEP Engineering indicated that it would be essential to make specific code language as to the percent shading and mounting of any curtain.

Grower Surveys

The Statewide CASE Team prepared a grower survey that was conducted over the phone with indoor agriculture growers from around the state. The National Cannabis Industry Association assisted the Statewide CASE Team in reaching out to growers, and growers who expressed interest in the survey were contacted by the Statewide CASE Team. During the phone interview, growers were asked to specify the type of HVAC, controls, dehumidification, and lighting systems used. The data gathered in these surveys were essential pieces of information used to determine the industry baseline efficiency levels for lighting and dehumidification.

Additionally, the Statewide CASE Team sent a short email survey to the designated responsible parties listed in CalCannabis Cultivation licensing information. This data contains the contact information for parties in the state who have received or are in the process of receiving a license to legally grow cannabis. This survey was run through SurveyMonkey and included questions that asked about lighting type, dehumidification equipment, and controls.

In both the phone and email surveys, double-ended HPS was the most common lighting type used by growers. LEDs were the next most prevalent followed by metal halides and fluorescents. Free-standing dehumidification units was the most popular dehumidification technology used in indoor facilities. Nearly all respondents had thermostatic controls and most had humidistat and time-switch lighting controls as well.

Indoor Agriculture Energy Solutions Conference Roundtable and Focus Groups

The Statewide CASE Team sent representatives to Indoor Agriculture Energy Solutions Conference that was held in San Diego from February 24–26, 2020. During this conference, the Statewide CASE Team interacted with growers, energy consultants, and policy officials who were involved in the indoor agriculture market. Additionally, the Statewide CASE Team hosted a roundtable with a variety of market actors to specifically discuss this proposal. The primary topics covered in this roundtable were the lighting efficacy and efficient dehumidification submeasures.

Additionally, at the end of February, the Statewide CASE Team led a focus group, organized by SMUD officials, in Sacramento that focused on these CEH proposals. Attendees included growers, energy consultants, and equipment manufacturers.

Appendix G: Existing Codes and Standards

Table 67 provides actual language of codes and standards related to energy and water efficiency of CEH facilities listed in alphabetical order by regulating authority.

Table 67: Existing Codes and Standards

Regulating Authority	Language
Various	• **Definitions of Occupancy Group F1 and U** Source: 2019 California Building Code (CBC), Title 24, Part 2, Volume 1, Chapter 3 Occupancy Classification and Use; https://codes.iccsafe.org/content/chapter/15437/ "306.2 Moderate-hazard factory industrial, Group F-1. Factory industrial uses that are not classified as Factory Industrial F-2 Low Hazard shall be classified as F-1 Moderate Hazard." "312 Utility and Miscellaneous Group U. Buildings and structures of an accessory character and miscellaneous structures not classified in any specific occupancy shall be constructed, equipped and maintained to conform to the requirements of this code commensurate with the fire and life hazard incidental to their occupancy. Group U shall include, but not be limited to, the following: agricultural buildings …" • **Definition of Controlled Plant Growth Environment** Source: 2015 Washington State Energy Code; http://www.energy.wsu.edu/Documents/2015WSEC_C_final.pdf "Controlled Plant Growth Environment. Group F and U buildings or spaces that are specifically controlled to facilitate and enhance plant growth and production by manipulating various indoor environmental conditions. Technologies include indoor agriculture, cannabis growing, hydroponics, aquaculture and aquaponics. Controlled indoor environment variables include, but are not limited to, temperature, air quality, humidity and carbon dioxide." • **Definition of Indoor Cultivation** Source: CCR, Title 3, Division 8 Cannabis Cultivation, Chapter 1, Article 1 https://static.cdfa.ca.gov/MCCP/document/CDFA%20Final%20Regulation%20Text_01162019_Clean.pdf "(n) "Indoor cultivation" means the cultivation of cannabis within a permanent structure using exclusively artificial light or within any type of structure using artificial light at a rate above twenty-five watts per square foot."

- **Definition of Canopy**

  Source: CCR, Title 3, Division 8 Cannabis Cultivation https://static.cdfa.ca.gov/MCCP/document/CDFA%20Final%20Regulation%20Text_01162019_Clean.pdf

  "(f) "Canopy" means the designated area(s) at a licensed premises, except nurseries and processors, that will contain mature plants at any point in time, as follows: (1) Canopy shall be calculated in square feet and measured using clearly identifiable boundaries of all area(s) that will contain mature plants at any point in time, including all of the space(s) within the boundaries; (2) Canopy may be noncontiguous but each unique area included in the total canopy calculation shall be separated by an identifiable boundary that includes, but is not limited to, interior walls, shelves, greenhouse walls, hoop house walls, garden benches, hedgerows, fencing, garden beds, or garden plots; and (3) If mature plants are being cultivated using a shelving system, the surface area of each level shall be included in the total canopy calculation."

- **Definitions of Photosynthetically Active Radiation (PAR)**, **Photosynthetic Photon Flux (PPF), Photosynthetic Photon Efficacy (PPE)**

  Source: ANSI/ASABE S640

  "Photosynthetically active radiation (PAR) designates the spectral range (waveband) of radiation, from 400 to 700 nm, which by definition photosynthetic organisms are able to use in the process of photosynthesis. The measured result of PAR can be reported as PPF or PPFD."

  "Photosynthetic photon flux is the rate of flow of photons within the PAR waveband from a radiation source."

  "The photosynthetic photon efficacy (K_p) is the photosynthetic photon flux divided by input electric power. The unit is micromoles per second per electric watt (μmol x s^{-1} x W_e^{-1}), or micromoles per joule (μmol x J^{-1})."

DesignLights Consortium (DLC) (voluntary)

Source: https://www.designlights.org/horticultural-lighting/technical-requirements/

Parameter/ Attribute/ Metric	Requirement	Requirement Type	Method of measurement/ evaluation
Photosynthetic Photon Efficacy (PPE) (μmol/J)	≥1.9 μmol/J, with -5% tolerance	Required/Threshold	(ANSI/IES LM-79) 400-700nm range

International Energy Conservation Code (IECC) 2021 (voluntary)	Source: https://newbuildings.org/wp-content/uploads/2019/02/Indoor_Horticultural_Lighting-NBI-5155.pdf "C405.4 Lighting for plant growth and maintenance. Not less than 95 percent of the permanently installed luminaires used for plant growth and maintenance shall have a photon efficiency of not less than 1.6 μmol/J rated in accordance with ANSI/ASABE S640." Source: www.cdpaccess.com "402.1.1.1 Greenhouses Greenhouse structures or areas that are mechanically heated or cooled and that comply with all of the following shall be exempt from the building envelope requirements of this code: 1. Exterior opaque envelope assemblies comply with Sections C402.2 and C402.4.5. Exception: Low energy greenhouses that comply with Section C402.1.1. 2. Interior partition building thermal envelope assemblies that separate the greenhouse from conditioned space comply with Sections C402.2, C402.4.3 and C402.4.5. 3. Fenestration assemblies that comply with the thermal envelope requirements in Table C402.1.1.1. The U-factor for a roof shall be for the roof assembly or a roof that includes the assembly and an internal curtain system. Exception: Unconditioned greenhouses. TABLE C402.1.1.1 FENESTRATION THERMAL ENVELOPE MAXIMUM REQUIREMENTS **Component** — **U-factor (BT U/h-ft 2-°F)** Skylight — 0.5 Vertical fenestration — 0.7
City and County of Denver	Source: https://www.denvergov.org/content/dam/denvergov/Portals/696/documents/Denver_Building_Code/2019-code-update/2019_final_amendments.pdf "**C403.13 Dehumidification and cooling efficiency for plant growth and maintenance (Mandatory).** Indoor agricultural operations must follow the requirements for dehumidification and cooling from sections C403.13.1 and C403.13.2. Space cooling equipment for indoor plant grow operations shall meet the minimum energy efficiency ratio (EER) or seasonal energy efficiency ratio (SEER) specified in C403.3.2.

	C403.13.1 Dehumidification. All indoor plant grow operations that require dehumidification shall utilize one of the following dehumidification options: 1. Free-standing dehumidification units with a minimum energy factor of 1.9 l/kWh. The test method for minimum energy factor shall be as specified in 10 CFR Part 430, Subpart B - Appendix X. 2. Chilled water system with heat recovery from the condenser coil to achieve dehumidification reheat. 3. Integrated HVAC system with heat recovery from the condenser coil (hot gas reheat) to achieve dehumidification reheat. **C403.13.2 Dehumidification backup.** Electric or fossil fuel reheat systems may be employed as supplementary heat for dehumidification when the primary dehumidification system in C403.13.1 is designed to fulfill at least 60% of the facility's dehumidification needs during peak dehumidification periods. **C405.3.3 Lighting for plant growth and maintenance.** All non-LED lighting using replaceable lamps must be installed with electronic ballasts. All luminaires shall be listed by an OSHA Nationally Recognized Testing Labs (NRTL) or field certified by an OSHA NRTL to an appropriate standard. In addition, not less than 80 percent of the total Watts of lighting for canopy areas (areas used for plant growth and plant maintenance) must be provided by lighting having a photosynthetic photon efficacy of not less than 1.6 μmol/J (luminaires), or 1.9 μmol/J (lamps). Indoor agriculture facilities have three options to demonstrate that lighting meets these efficacy requirements: 1. LED luminaires listed in the Design Lights Consortium's Horticultural Qualified Products List (QPL), https://www.designlights.org/horticultural-lighting/search/, will be considered to comply with this section. 2. Double-ended high-pressure sodium (HPS) lamps with efficacies of 1.9 μmol/J or greater, used with any reflector and ballast combination, satisfy the requirements of this section. Compliance with this efficacy requirement must be demonstrated by a third-party test report providing the lamps' photosynthetic photon efficacy (measured in μmol/J), generated by a facility accredited to the ANSI/IES LM-51 standard. 3. For lamps or luminaires not included in 1) or 2) above, compliance with the efficacy requirements of this section must be demonstrated by a third-party test report providing the lamps' or luminaires' photosynthetic photon efficacy (measured in μmol/J), generated by a facility accredited to the ANSI/ASABE S642, ANSI/IES LM-79, or ANSI/IES LM-51 standards. **C502.2.6.4 Lighting Systems for Plant Growth Vegetation Areas.** New lighting installed in new canopy areas (areas used for plant growth and plant maintenance) within a new addition shall comply with Section C405.3.3. **C503.6.2 Lighting Systems for Plant Growth Vegetation Areas.** New lighting installed in new canopy areas (areas used for plant growth and plant maintenance) as part of an expansion of operations or change of use within

	an existing building shall comply with Section C405.3.3. **Exceptions:** 1. Replacement luminaires in existing plant growth and maintenance areas. 2. New lighting in new canopy areas where the building ceiling height is 9 feet or less.”
City of Santa Rosa (mandatory)	Source: https://www.srcity.org/DocumentCenter/View/22641/Cannabis-Related-Occupancies---Building-and-Fire-Code-Requirements?bidId= “2. Cannabis Cultivation facilities shall be consistent with CBC, Chapter 3 requirements based upon Use and Occupancy Classification for a Factory Industrial, F-1, Moderate-hazard Occupancy. CBC § 306.2. 3. Cannabis Cultivation facilities for the exclusive use of plant production may be classified as a U occupancy and shall be consistent with the requirements of CBC Appendix C. … 5. Grow lights must be installed per the manufacture instructions and wired per CEC article 410. A. Remote ballasts shall be installed as near to the lamp as practicable to keep the secondary conductors as short as possible. CEC article 410.144(B). B. Ballast secondary cord/conductors cannot pass through partitions and must be visible its entire length outside the luminaire. CEC article 410.62(C)(1). C. All grow lights shall be controlled by a multi-level astronomical time switch. … 8. Cultivation areas shall be supplied with ventilation at a minimum rate of 15 cfm/person for the number of occupants. The minimum occupant load for ventilation design shall be specified by the building designer, and shall not be less than one half of the maximum occupant load assumed for egress purposes as specified in the California Building Code, whichever is greater. (CMC table 402.1 footnote 4 & CEC subchapter 120.1(b).”
City of Seattle (mandatory)	Source: http://www.seattle.gov/documents/Departments/SDCI/Codes/SeattleEnergyCode/2015SECCommercialChapter4.pdf “Lighting for plant growth or maintenance where the lamp has a tested photosynthetic photon flux (PPF) per watt of not less than 1.20 micromoles per joule.”

State of Illinois (mandatory)	Source: http://www.ilga.gov/legislation/publicacts/101/101-0027.htm "(B) Lighting. The Lighting Power Densities (LPD) for cultivation space commits to not exceed an average of 36 watts per gross square foot of active and growing space canopy, or all installed lighting technology shall meet a photosynthetic photon efficacy (PPE) of no less than 2.2 micromoles per joule luminaire shall be featured on the DesignLights Consortium (DLC) Horticultural Specification Qualified Products List (QPL). In the event that DLC requirements for minimum efficacy exceeds 2.2 micromoles per joule luminaire, that PPE shall become the new standard. (C) HVAC. (i) For cannabis grow operations with less than 6,000 square feet of canopy, the licensee commits that all HVAC units will be high-efficiency ductless split HVAC units, or other more energy efficient equipment. (ii) For cannabis grow operations with 6,000 square feet of canopy or more, the licensee commits that all HVAC units will be variable refrigerant flow HVAC units, or other more energy efficient equipment. (D) Water application. (i) The cannabis cultivation facility commits to use automated watering systems, including, but not limited to, drip irrigation, and flood tables, to irrigate cannabis crop. (ii) The cannabis cultivation facility commits to measure runoff from watering events and report this volume in its water usage plan, and that on average, watering events shall have no more than 20% runoff of water. (E) Filtration. The cultivator commits that HVAC condensate, dehumidification water, excess runoff, and other wastewater produced by the cannabis cultivation facility shall be captured and filtered to the best of the facility's ability to achieve the quality needed to be reused in subsequent watering rounds."
Cannabis Control Commission, State of Massachusetts (mandatory)	Source: https://www.mass.gov/doc/935-cmr-500-adult-use-of-marijuana/download "(11) A Marijuana Cultivator shall satisfy minimum energy efficiency and equipment standards established by the Commission and meet all applicable environmental laws, regulations, permits and other applicable approvals including, but not limited to, those related to water quality and quantity, wastewater, solid and hazardous waste management, and air pollution control, including prevention of odor and noise pursuant to 310 CMR 7.00: Air Pollution Control as a condition of obtaining a final license under 935 CMR 500.103(2) and as a condition of renewal under 935 CMR 500.103(4). A Marijuana Cultivator shall adopt and use additional best management practices as determined by the Commission, in consultation with the working group established under St. 2017, c. 55, § 78(b) or applicable departments or divisions of the EOEEA, to reduce energy and water usage, engage in energy conservation and mitigate other environmental impacts, and shall provide energy and water usage reporting to the

	Commission in a form determined by the Commission. Each license renewal application under 935 CMR 500.103(4) must include a report of the Marijuana Cultivator's energy and water usage over the 12-month period preceding the date of application. Marijuana Cultivators shall be subject to the following minimum energy efficiency and equipment standards: (a) The building envelope for all facilities, except Greenhouses, must meet minimum Massachusetts Building Code requirements and all Massachusetts amendments (780 CMR: State Building Code), International Energy Conservation Code (IECC) Section C402 or The American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) Chapters 5.4 and 5.5 as applied or incorporated by reference in 780 CMR: State Building Code, except that facilities using existing buildings may demonstrate compliance by showing that the envelope insulation complies with code minimum standards for Type Factory Industrial F-1, as further defined in guidelines issued by the Commission. (b) Lighting used for Cannabis Cultivation must meet one of the following compliance requirements: 1. Horticulture Lighting Power Density must not exceed 36 watts per square foot, except for Tier 1 and Tier 2 which must not exceed 50 watts per square foot; or 2. All horticultural lighting used in a facility is listed on the current Design Lights Consortium Solid-state Horticultural Lighting Qualified Products List ("Horticultural QPL") or other similar list approved by the Commission as of the date of license application, and lighting Photosynthetic Photon Efficacy (PPE) is at least 15% above the minimum Horticultural QPL threshold rounded up to the nearest 0.1 mol/J (micromoles per joule). 3. A facility seeking to use horticultural lighting not included on the Horticultural QPL or other similar list approved by the Commission shall seek a waiver pursuant to 935 CMR 500.850 and provide documentation of third-party certification of the energy efficiency features of the proposed lighting. All facilities, regardless of compliance path, shall provide third-party safety certification by an OSHA NRTL or SCC-recognized body, which shall certify that products meet a set of safety requirements and standards deemed applicable to horticultural lighting products by that safety organization. (c) Heating Ventilation and Air Condition (HVAC) and dehumidification systems must meet Massachusetts Building Code requirements and all Massachusetts amendments (780 CMR State Building Code), IECC Section C403 or ASHRAE Chapter 6 as applied or incorporated by reference in (780 CMR: State Building Code).”
State of Washington (mandatory)	Source: http://www.energy.wsu.edu/Documents/2015WSEC_C_final.pdf https://www.sbcc.wa.gov/sites/default/files/2020-02/2018%20WSEC_C%20Final%20Package.pdf “**C402.1.1.3 Greenhouses**. Greenhouse structures or areas that comply with all of the following shall be exempt from the building envelope requirements of this code:

1. Exterior opaque envelope assemblies complying with Sections C402.2 and C402.4.4.

Exception: Low energy greenhouses that comply with Section C402.1.1.1.

2. Interior partition building thermal envelope assemblies that separate the greenhouse from conditioned space complying with Sections C402.2, C402.4.3 and C402.4.4.

3. Non-opaque envelope assemblies complying with the thermal envelope requirements in Table C402.1.1.3. The U-factor for the non-opaque roof shall be for the roof assembly or a roof that includes the assembly and an internal curtain system.

Exception: Unheated greenhouses.

4. No mechanical cooling is provided.

5. For heated greenhouses, heating is provided by a radiant heating system, a condensing natural gas-fired or condensing propane-fired heating system, or a heat pump with cooling capacity permanently disabled as pre-approved by the jurisdiction.

TABLE C402.1.1.3 NON-OPAQUE THERMAL ENVELOPE MAXIMUM REQUIREMENTS

Component U-Factor Btu/hr-ft2 -°F	**Climate Zone 5 and Marine 4**
Non-opaque roof	0.5
Non-opaque SEW wall	0.7
Non-opaque N wall	0.6

C403.3 Economizers (Prescriptive). Air economizers shall be provided on all new systems including those serving computer server rooms, electronic equipment, radio equipment, and telephone switchgear. Economizers shall comply with Sections C403.3.1 through C403.3. 4.

Exception: Economizers are not required for the systems listed below

8. Equipment used to cool Controlled Plant Growth Environments provided these are high-efficiency cooling equipment with SEER, EER and IEER values a minimum of 20 percent greater than the values listed in Tables C403.2.3(1), (3) and (7).”

Appendix H: Source of Cost Data

Table 68: Lighting products used in cost analysis

Name/Manufacturer	Type	Source	Cost ($)	HID equivalent wattage (watts)
iPower Grow Light	Single-ended HPS Fixture	Zenhydro	158	1000
iPower Grow Light	Single-ended HPS Fixture	Zenhydro	140	600
Yield Lab HPS	Single-ended HPS Fixture	Growace	175	600
Yield Lab HPS	Single-ended HPS Fixture	Growace	210	1000
UltraSun	Single-ended HPS Fixture	Growershouse	160	1000
SunStream	Double-ended HPS Fixture	Amazon	260	1000
Hydro Crunch	Double-ended HPS Fixture	Home Depot	275	1000
Yield Lab HPS	Double-ended HPS Fixture	Growace	270	1000
VivoSun	Double-ended HPS Fixture	Amazon	210	1000
Gavita	Double-ended HPS Fixture	Hydrobuilder	290	1000
Spectrum King Grow Light	LED Fixture	Hydrobuilder	1350	1000
MaxLite PhotonMax	LED Fixture	MaxLite	994	1000
Growers Choice Grow Light	LED Fixture	Hydrobuilder	1000	1000
Gavita Pro 1700e	LED Fixture	Hydrobuilder	1299	1000

Photobio M Flowering	LED Fixture	Hydrobuilder	1391	1000
Photobio M Full Spectrum	LED Fixture	Hydrobuilder	1416	1000
NextLight Mega Grow Light	LED Fixture	Hydrobuilder	1526	1000
Eye Hortilux	Single-ended HPS Lamp	Hydrobuilder	75	1000
ArgoSun	Single-ended HPS Lamp	Hydrobuilder	30	1000
Interlux	Single-ended HPS Lamp	Hydrobuilder	32	1000
Spectrolux	Single-ended HPS Lamp	Hydrobuilder	35	1000
UltraSun	Single-ended HPS Lamp	Hawthorne	72	1000
Gavita	Double-ended HPS Lamp	Hydrobuilder	105	1000
Eye Hortilux	Double-ended HPS Lamp	Hydrobuilder	84	1000
Philips	Double-ended HPS Lamp	Hydrobuilder	110	1000
Ushio	Double-ended HPS Lamp	Hydrobuilder	90	1000
Growlite	Single-ended HPS Lamp	Hydrobuilder	67	600
Delux	Single-ended HPS Lamp	Hydrobuilder	50	600
Interlux	Single-ended HPS Lamp	Hydrobuilder	39	600
Gavita	Single-ended HPS Lamp	Hydrobuilder	35	600
Ultra Sun	Single-ended HPS Lamp	Hawthorne	64	600

Grower's Choice	Double-ended HPS Lamp	Hydrobuilder	60	600
Solis Tek	Double-ended HPS Lamp	Hydrobuilder	65	600

Table 69: Products used for dehumidification baseline costs

Equipment Type[a]	**Cost ($)**	**Source**
Sensible HVAC Equipment Cost (30 ton)	20,580	CPUC Workpaper SWHC013
Latent HVAC Equipment Cost	3,900	Agronomic IQ A400
Standalone dehumidifier filter replacement	69	Sylvane

a. Please note that costs for code minimum dehumidification products are confidential