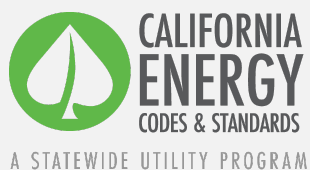


# Controlled Environment Horticulture – Results Report



Measure ID: 2022-NR-COV-PROC4-F  
Covered Processes

December 2022



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

Copyright 2022 Pacific Gas and Electric Company, Southern California Edison, San Diego Gas & Electric Company, Los Angeles Department of Water and Power, and Sacramento Municipal Utility District. All rights reserved, except that this document may be used, copied, and distributed without modification.

Neither Pacific Gas and Electric Company, Southern California Edison, San Diego Gas & Electric Company, Los Angeles Department of Water and Power, Sacramento Municipal Utility District or any of its employees makes any warranty, express or implied; or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any data, information, method, product, policy or process disclosed in this document; or represents that its use will not infringe any privately-owned rights including, but not limited to, patents, trademarks or copyrights.



## Document Information

<b>Category:</b>	Codes and Standards
<b>Keywords:</b>	Statewide Codes and Standards Enhancement (CASE) Initiative, Statewide Utility Codes and Standards Team, Codes and Standards Enhancements, 2022 Title 24, Part 6, efficiency, horticultural lighting; dehumidification; greenhouse envelope.
<b>Authors:</b>	Kyle Booth, Simon Silverberg (Energy Solutions)
<b>Prime Contractor</b>	Energy Solutions
<b>Project Management:</b>	California Utilities Statewide Codes and Standards Team: Pacific Gas and Electric Company, Southern California Edison, San Diego Gas & Electric Company, Los Angeles Department of Water and Power, and Sacramento Municipal Utility District

# Table of Contents

<b>1. Introduction</b>	<b>1</b>
<b>2. Measure Description</b>	<b>1</b>
2.1 Summary of Adopted Requirements	1
2.2 Summary of Proposed Requirements That Were Not Adopted	3
<b>3. Statewide Energy Impacts of Adopted Requirements</b>	<b>5</b>
<b>4. Compliance and Enforcement</b>	<b>5</b>
<b>5. Interactions with Existing Regulations</b>	<b>6</b>
<b>6. Evolution of Code Requirements</b>	<b>6</b>
6.1 Lowering PPE Requirement for Indoor CEH Facilities	6
6.2 Modifying the Stand-Alone Dehumidification Option	7
6.3 Modifying Requirements for Greenhouse Non-Opaque Envelopes	8
<b>7. Adopted Code Language</b>	<b>8</b>
7.1 California Energy Code, Title 24, Part 6	8
<b>8. Bibliography</b>	<b>13</b>
<b>Attachment 1: Public Comments Submitted by the Statewide CASE Team</b>	<b>14</b>
<b>Attachment 2: Final CASE Report</b>	<b>15</b>

## List of Tables

Table 1: Scope of Adopted Code Change	3
Table 2: Estimated Statewide First Year <sup>a</sup> Energy and Water Savings	5

# 1. Introduction

The Codes and Standards Enhancement (CASE) Initiative presents recommendations to support the California Energy Commission's (CEC) efforts to update the California Energy Code (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 to the CEC, the state agency that has authority to adopt revisions to Title 24, Part 6. The CEC evaluates proposals submitted by the Statewide CASE Team and other stakeholders and may revise or reject proposals.

In March 2021, the Statewide CASE Team submitted the updated Final CASE Report that is presented in Attachment 1 to recommend code changes related to controlled environment horticulture. This document explains the revisions that occurred to the proposed code changes between the submittal of the Final CASE Report to the CEC and the CEC's adoption of the 2022 Title 24, Part 6 Standards on August 11, 2021. The document begins with a concise description of the adopted code language, followed by the estimated energy savings of the adopted requirements, with the remainder of the document outlining the evolution of the code changes and the final adopted language.

## 2. Measure Description

### 2.1 Summary of Adopted Requirements

Newly constructed greenhouses and indoor controlled environment horticulture (CEH) facilities, as well as facilities undergoing major retrofits, are impacted by the new energy efficiency requirements. The Statewide CASE Team proposed a variety of changes to the CEC and most of the proposed changes were adopted. The code changes adopted as part of this CASE effort were under three system types:

1. New lighting efficacy requirements.
2. New dehumidification efficiency requirements.
3. Clarifications to greenhouse envelope requirements.

These changes take effect on January 1, 2023.

#### **Lighting Efficacy**

The adopted code language sets separate requirements for greenhouses defined as facilities with skylit areas greater than 50 percent of roof area and indoor grow facilities.

For newly constructed greenhouses, the adopted requirements mandate that CEH spaces with more than 40 kW of horticultural lighting load use luminaires or lamps with a rated photosynthetic photon efficacy (PPE) of 1.7 micromoles per joule ( $\mu\text{mol/J}$ ). For newly constructed indoor grow facilities, the adopted requirements mandate that CEH spaces with more than 40 kW of horticultural lighting load use luminaires or lamps with a rated PPE of 1.9  $\mu\text{mol/J}$ . Both facility types will require time-switch and multilevel lighting controls to be installed.

Additions to greenhouses or CEH facilities and indoor warehouses that are converted to indoor CEH facilities also trigger the lighting efficacy requirements for new construction.

Additionally, horticultural lighting wattage used in CEH spaces are exempted from Adjusted Indoor Lighting Power calculations that determine the total watts of all planned permanent lighting systems.

Alterations to horticultural lighting in greenhouses or CEH facilities that increase lighting wattage or alter 10 percent or more of the horticultural luminaires servicing a space must meet the new efficacy requirements.

Electric power distribution systems serving CEH spaces must be designed so that a measurement device can monitor the electrical energy usage of the aggregate horticultural load.

### **Efficient Dehumidification**

For newly constructed indoor CEH facilities, dehumidification equipment must be one of the following types:

1. A dehumidifier that complies with federal appliance standards;
2. An integrated HVAC system with on-site heat recovery designed to fulfill at least 75 percent of the annual energy for dehumidification reheat;
3. A chilled water system with on-site heat recovery designed to fulfill at least 75 percent of the annual energy for dehumidification reheat; or
4. If systems require dewpoint of 50°F or less, a desiccant system can be used.

Newly installed dehumidification systems trigger the requirements as well.

### **Greenhouse Envelope Standards**

The opaque wall and roof assembly of conditioned greenhouses must meet the insulation requirements of other nonresidential spaces. The non-opaque envelopes shall have two or more glazing layers separated by either air or gas fill. A greenhouse

being converted to a conditioned greenhouse or additions to conditioned greenhouses must also meet these requirements.

Conditioned greenhouses were exempted from certain exterior window and skylight envelope requirements for non-residential buildings as they must follow the newly adopted requirements for opaque and non-opaque envelopes.

Table 1 identifies sections of the standards and Reference Appendices that were modified as a result of advocacy activities. The table also indicates if the compliance software will be updated. There is no compliance software for CEH facilities.

**Table 1: Scope of Adopted Code Change**

<b>Measure Name</b>	<b>Type of Requirement</b>	<b>Modified Section(s) of Title 24, Part 6</b>	<b>Modified Title 24, Part 6 Appendices</b>	<b>Will Compliance Software Be Modified</b>
Horticultural Lighting Minimum Efficacy	Mandatory	100.1(b), 120.6(h)2, 141.1(c)	No	No
Horticultural Lighting Adjusted Indoor Lighting Power	Prescriptive	140.6(a)3	No	No
Efficient Dehumidification	Mandatory	100.1(b), 120.6(h)1, 141.1(c)	No	No
Economizer exception	Prescriptive	140.4(e)1	No	No
Greenhouse Envelope	Mandatory	100.1(b), 110.6, 120.6(h)4, 141.1(c)	No	No
Greenhouse Envelope	Prescriptive	140.3(a)5 and 6	No	No

## 2.2 Summary of Proposed Requirements That Were Not Adopted

### Lighting Efficacy

In the Final CASE Report published in October 2020, the Statewide CASE Team proposed a lighting efficacy standard for indoor facilities that would have required the use of LEDs. Specifically, the proposal mandated that CEH spaces with more than 40 kW of horticultural lighting load use luminaires with a PPE of at least 2.1  $\mu\text{mol/J}$ . However, after publication of the Final CASE Report, the Statewide CASE Team determined that changes to the minimum efficacy requirements were needed based on extensive stakeholder suggestions. In an addendum published in March 2021, the

Statewide CASE Team proposed to lower the required PPE level from 2.1 to 1.9  $\mu\text{mol}/\text{J}$  for luminaires and lamps that are a part of luminaires. This revision allowed highly efficient high pressure sodium double-ended lamps to qualify. Therefore, the original Statewide CASE Team proposal with a PPE level of 2.1  $\mu\text{mol}/\text{J}$  was not adopted.

Additionally, proposals to exempt CEH spaces from a requirement to have holiday shut-off lighting controls and to have a separate control system for horticultural lighting were not adopted.

### **Efficiency Dehumidification**

The Statewide CASE Team proposal in the Final CASE Report regarding use of stand-alone dehumidifiers was modified. The proposal permitted use of stand-alone dehumidifiers that were tested using the federal test procedure (Appendix X1 to Subpart B of CRF 10 Part 430). Stand-alone dehumidifiers with product volumes 8 cubic feet or less must have an integrated energy factor of at least 1.77 liters per kilowatt hour (L/kWh); if the product volume is greater than 8 cubic feet the unit must have an integrated energy factor of at least 2.41 (L/kWh).

The adopted language only states that dehumidifiers subject to federal appliance standards that meet the federal performance standards while being tested, in accordance with either Appendix X or X1 to Subpart B of 10 CFR Part 430 as applicable, are permitted. This change was due to concerns that any other language would be federally pre-empted since dehumidifiers are federally covered products.

### **Greenhouse Envelope**

In the Final CASE Report, the Statewide CASE Team proposed that non-opaque roof and wall assemblies for conditioned greenhouses have a maximum U-factor. A table was provided demonstrating the default U-factor assumptions of various greenhouse glazing materials.

The adopted language removed the table of default values and modified the envelope requirement and instead calls for two or more glazing layers separated by air or gas fill for greenhouse roofs and walls rather than a combined U-factor of 0.7 or less. This change was due to concerns over difficulty with enforcing a U-factor because there is no official body that rates this for greenhouse glazing products.

### 3. Statewide Energy Impacts of Adopted Requirements

Table 2 shows the estimated energy savings of the adopted requirements over the first twelve months that are in effect. The first-year savings have not changed since submitting the Final CASE Report addendum, which includes changes to the lighting PPE.

**Table 2: Estimated Statewide First Year<sup>a</sup> Energy and Water Savings**

Measure	First Year Electricity Savings (GWh/yr)	First Year Peak Electrical Demand Reduction (MW)	First Year Water Savings (million gallons/yr)	First Year Natural Gas Savings (million therms/yr)
<b>Lighting Efficacy</b>	293.9	20.9	N/A	N/A
New Construction & Additions	215	14.7	N/A	N/A
Alterations	78.9	6.1	N/A	N/A
<b>Efficient Dehumidification</b>	(0.3)	(0.0)	N/A	1.2
New Construction & Additions	(0.2)	(0.0)	N/A	0.9
Alterations	(0.1)	(0.0)	N/A	0.3

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

### 4. Compliance and Enforcement

For lighting efficacy and efficient dehumidification submeasures, there were no changes to the compliance or enforcement recommendations between the time the Statewide CASE Team submitted the Final CASE Report and the CEC adopted requirements. Compliance and enforcement is discussed in Sections 2.1.5, 2.2.5, and Appendix E of the Final CASE Report, which is provided in Attachment 2: Final CASE Report.

For greenhouse envelope, due to the change in the greenhouse envelope language, building department officials will verify that the greenhouse glazing material has two or more layers separated by air or gas fill rather than a certain U-factor.



## 5. Interactions with Existing Regulations

### 5.1.1 Lighting Efficacy Requirements

No changes based on adopted code language. See Section 2.1.4 found in Attachment 2: Final CASE Report..

### 5.1.2 Efficient Dehumidification Requirements

Please note that the adopted language directly references the test procedure and standard requirements for federally covered dehumidifiers. Thus, if the federal requirements change, there will be an impact on Title 24, Part 6 requirements. See Section 2.2.4 Regulatory Context from CASE Report.

### 5.1.3 Greenhouse Envelope

No changes based on adopted code language. See Section 2.3.4 found in Attachment 2: Final CASE Report.

## 6. Evolution of Code Requirements

The Statewide CASE Team initially published the Final CASE Report in October 2020 and submitted the updated Final CASE Report to the CEC in March 2021. The Final CASE Report addresses input that was received during utility-sponsored stakeholder meetings held on September 9, 2019, and April 16, 2020, and during the CEC's pre-rulemaking workshop held on October 27, 2020. This section describes how the code change proposal evolved between the time the Final CASE Report was submitted to the CEC and the time revised standards were adopted.

### 6.1 Lowering PPE Requirement for Indoor CEH Facilities

As noted above, the Final CASE Report initially published in October 2020 proposed lighting used for plant growth in CEH facilities use luminaires with a PPE level of 2.1  $\mu\text{mol/J}$ . This would have influenced the market to use LED luminaires as only a limited number of high-intensity discharge products have a rated PPE of 2.1  $\mu\text{mol/J}$ .

After the Final CASE Report was published in October 2020, the Statewide CASE Team determined that, based on extensive stakeholder suggestions, changes to the minimum efficacy requirements were needed. Stakeholders included the cannabis grower community, trade associations, and energy consultants that serve the indoor CEH sector. These stakeholders highlighted that there is limited publicly available data comparing the yield and quality performance of LED grow lighting to that of conventional grow lighting such as ceramic metal halide and high-pressure sodium (HPS) lighting. The California legal cannabis industry is still in its early stages, and a strict energy

efficiency mandate might slow the growth of the industry and limit potential tax revenues produced by the industry. Additionally, a prominent concern from the small cannabis growers was the ability to afford the high first cost of LED lighting, given their lack of access to capital.

In response to these concerns, the Statewide CASE Team collaborated with the CEC in November and December 2020 to determine appropriate revisions to the lighting efficacy proposal. Revising the proposal to allow either lamps or luminaires to be used to meet the required PPE level of 1.9  $\mu\text{mol}/\text{J}$  would allow high-efficiency double-ended HPS lamps to be used. The Statewide CASE Team reran the energy and cost savings analysis with this new PPE level of 1.9  $\mu\text{mol}/\text{J}$ . The updated proposal was found to be cost-effective, and revised savings are presented in Appendix M of the Final CASE Report.

This modified code language was included in the CEC's Express Terms and was eventually adopted by the CEC.

## 6.2 Modifying the Stand-Alone Dehumidification Option

The 15-Day Language modified one of the four dehumidification options that would be allowed in CEH facilities: stand-alone dehumidifiers.

In the updated Final CASE Report, the Statewide CASE Team proposed allowing all stand-alone dehumidifiers that are tested to Appendix X1 to Subpart B of 10 Code of Federal Regulations Part 430 to be used if they meet the federal energy conservation standards.

In March 2021, the Statewide CASE Team was notified of concerns from manufacturers with the federal test procedure that would be used to rate the stand-alone units. These manufacturers make units that exceed the federal limit for capacity and are therefore not being regulated nor rated using the federal test procedure. The Statewide CASE Team met with the manufacturers to discuss the federal test procedure and decided on potential modifications that would make the federal test procedure more applicable for dehumidification units used in CEH facilities. The Statewide CASE Team sent modified language to the CEC later that month.

However, the 15-Day Language released by the CEC made other modifications to the stand-alone dehumidification option. The 15-Day Language had modified this language to allow dehumidifiers subject to federal regulation to be used if they were tested according to the appropriate federal procedure and met the federal energy conservation requirements. In July 2021, the Statewide CASE Team met with the CEC to discuss the changes and was informed that the CEC had legal concerns about pre-emption. Specifically, since dehumidifiers are a federally covered product and the federal definition does not explicitly exclude large dehumidifiers such as those used in

horticultural settings, the CEC could not modify the federal test procedure as requested by stakeholders. The Statewide CASE Team agreed to conduct outreach to dehumidifier manufacturers to inform them of the changes to the 15-Day Language. The Statewide CASE Team met with manufacturers in July 2021, and noted that, while manufacturers consider their dehumidifier products to be outside of the scope of federal regulations, many of the dehumidifiers would meet the federal standards and that the federal test procedure is workable. Ultimately, the modifications that the CEC made for the 15-Day Language were adopted.

### 6.3 Modifying Requirements for Greenhouse Non-Opaque Envelopes

In the Final CASE Report, the Statewide CASE Team proposed that non-opaque roof and wall assemblies for conditioned greenhouses shall have a combined U-factor of 0.7 or less. A table was provided demonstrating the default U-factor assumptions of various greenhouse glazing materials.

The Statewide CASE Team met with the CEC after the release of the Express Terms in February 2021 to discuss the greenhouse envelope language. The CEC noted that there would be difficulty enforcing a U-factor for greenhouse glazing products since there is no official body that rates those products. There was agreement to further simplify the language by only requiring two or more greenhouse glazing layers and adding a definition for greenhouse glazing. After meeting with compliance experts, the Statewide CASE Team sent proposed language to the CEC to require two or more glazing layers separated by air or gas fill for all greenhouse glazing. This language was adopted.

## 7. Adopted Code Language

The adopted code language for the standards and Reference Appendices are presented in the following sections. Additions to the 2019 Title 24, Part 6 code language are underlined and deletions are ~~struck~~.

### 7.1 California Energy Code, Title 24, Part 6

#### 7.1.1 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)” 2017 (ANSI/ASABE S640 JUL2017).

**CONDITIONED GREENHOUSE** is a greenhouse that is provided with wood heating, mechanical heating that has a capacity exceeding 10 Btu/hr-ft<sup>2</sup>, or mechanical cooling that has a capacity

exceeding 5 Btu/hr-ft<sup>2</sup>.

**CONTROLLED ENVIRONMENT HORTICULTURE (CEH) SPACE** is a building space dedicated to plant production by manipulating indoor environmental conditions, such as through electric lighting, irrigation, mechanical heating, mechanical cooling, or dehumidification. CEH space does not include building space where plants are grown solely to decorate that same space.

**DEHUMIDIFIER** is a product other than a portable air conditioner, room air conditioner, or packaged terminal air conditioner that is a self-contained, electrically operated, and mechanically encased assembly consisting of 1) a refrigerated surface (evaporator) that condenses moisture from the atmosphere, 2) a refrigerating system, including an electric motor, 3) an air-circulating fan, and 4) a means for collecting or disposing of the condensate.

**FENESTRATION PRODUCT** is any transparent or translucent material plus any sash, frame, mullions and dividers, in the facade of a building, including, but not limited to, windows, glazed doors, skylights, curtain walls, dynamic glazing, garden windows ~~and~~, glass block, ~~and~~ glazing used in greenhouses.

**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.

**IES LM-79-1908** is the ~~an~~ American National Standard authored by the Illuminating Engineering Society ~~document~~ and titled, "Approved Method: Optical and Electrical Measurements of Solid State Lighting Products ~~IES Approved Method for the Electrical and Photometric Measurements of Solid State Lighting Products~~" (200198) (ANSI/IES LM-79-19).

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

**INTEGRATED HVAC SYSTEM** is an HVAC system designed to handle both sensible and latent heat removal. Integrated HVAC systems may include, but are not limited to: HVAC systems with a sensible heat ratio of 0.65 or less and the capability of providing cooling, dedicated outdoor air systems, single package air conditioners with at least one refrigerant circuit providing hot gas reheat, and dehumidifiers modified to allow external heat rejection.

**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.

**PROCESS, COVERED** is a process that is regulated under Part 6, Sections 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 horticultural spaces.

## **7.1.2 Section 120.6 – MANDATORY REQUIREMENTS FOR COVERED PROCESS**

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

1. Indoor Growing, Dehumidification. Dehumidification equipment shall be one of the following:

A. Dehumidifiers subject to regulation under federal appliance standards tested in accordance with 10 CFR 430.23(z) and Appendix X or X1 to Subpart B of 10 CFR Part 430 as applicable, and complying with 10 CFR 430.32(v)2.

B. Integrated HVAC system with on-site heat recovery designed to fulfill at least 75 percent of the annual energy for dehumidification reheat;

C. Chilled water system with on-site heat recovery designed to fulfill at least 75 percent of the annual energy for dehumidification reheat; or

D. Solid or liquid desiccant dehumidification system for system designs that require dewpoint of 50°F or less.

2. Indoor Growing, Horticultural Lighting. In a building with CEH spaces and with more than 40 kW of aggregate horticultural lighting load, the electric lighting systems used for plant growth and plant maintenance shall meet the all of the following requirements:

A. The horticultural lighting systems shall have a photosynthetic photon efficacy (PPE) rated in accordance with ANSI/ASABE S640 for wavelengths from 400 to 700 nanometers and meet one of the following requirements:

i. Integrated, non-serviceable luminaires shall have a rated PPE of at least 1.9 micromoles per joule; or

ii. Luminaires with removable or serviceable lamps shall have lamps with a rated PPE of at least 1.9 micromoles per joule.

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).

3. Indoor Growing, Electrical Power Distribution Systems. Electrical power distribution system serving CEH spaces shall be designed so that a measurement device is capable of monitoring the electrical energy usage of aggregate horticultural lighting load.

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

A. Opaque wall and opaque roof assembly shall meet the requirements of Section 120.7; and

B. Non-opaque envelopes shall have two or more glazings separated by either air or gas fill.

5. Conditioned Greenhouses, Space-Conditioning Systems. Space-conditioning systems used for plant production shall comply with all applicable requirements.

6. Greenhouses, Horticultural Lighting. In a greenhouse with more than 40 kW of aggregate horticultural lighting load, the electric lighting system used for plant growth and plant maintenance shall meet the following requirements:

A. The horticultural lighting systems shall have a photosynthetic photon efficacy (PPE) rated in accordance with ANSI/ASABE S640 for wavelengths from 400 to 700 nanometers and meet one of the following requirements:

i. Integrated, non-serviceable luminaires shall have a rated PPE of at least 1.7 micromoles per joule; or

ii. Luminaires with removable or serviceable lamps shall have lamps with a rated PPE of at least 1.7 micromoles per joule.

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

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

### **7.1.3 Section 140.3 – PRESCRIPTIVE REQUIREMENTS FOR BUILDING ENVELOPES**

EXCEPTION to Section 140.3(a)5A: Conditioned greenhouses. The requirements of Section 120.6(h)4 apply.

...

EXCEPTION 2 to Section 140.3(a)5B: Conditioned greenhouses. The requirements of Section 120.6(h)4 apply.

...

EXCEPTION 3 to Section 140.3(a)5C: Conditioned greenhouses. The requirements of Section 120.6(h)4 apply.

...

EXCEPTION 4 to Section 140.3(a)5D: Conditioned greenhouses. The requirements of Section 120.6(h)4 apply.

...

EXCEPTION 2 to Section 140.3(a)6A: Conditioned greenhouses. The requirements of Section 120.6(h)4 apply.

...

EXCEPTION 2 to Section 140.3(a)6B: Conditioned greenhouses. The requirements of Section 120.6(h)4 apply.

...

EXCEPTION 2 to Section 140.3(a)6C: Conditioned greenhouses. The requirements of Section 120.6(h)4 apply.

...

EXCEPTION 2 to Section 140.3(a)6D: Conditioned greenhouses. The requirements of Section 120.6(h)4 apply.

...

EXCEPTION 2 to Section 140.3(a)6E: Conditioned greenhouses. The requirements of Section 120.6(h)4 apply.

#### **7.1.4 Section 140.4 PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS**

EXCEPTION 7 to Section 140.4(e)1: Where the use of an air economizer in controlled environment horticulture spaces will affect carbon dioxide enrichment systems.

#### **7.1.5 Section 140.6 PRESCRIPTIVE REQUIREMENTS FOR INDOOR LIGHTING**

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 in non-CEH spaces, if it is controlled by a multilevel astronomical time-switch control that complies with the applicable provisions of Section 110.9.

...

W. Horticultural lighting in CEH spaces (indoor growing and greenhouses) complying with Section 120.6(h).

## **7.1.6 Section 141.1 – REQUIREMENTS FOR COVERED PROCESSES IN ADDITIONS, ALTERATIONS TO EXISTING NONRESIDENTIAL, ~~HIGHRISE RESIDENTIAL,~~ AND HOTEL/MOTEL BUILDINGS**

### (c) 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)1 and 120.6(h)2.

2. Greenhouses, Building Envelope and Space-Conditioning Systems. A greenhouse being converted to a conditioned greenhouse or additions to a conditioned greenhouse shall meet the requirements of Sections 120.6(h)5 and 120.6(h)6.

3. Indoor Growing and Greenhouses, Horticultural Lighting. When alterations to horticultural lighting systems increase lighting wattage or include adding, replacing, or altering 10 percent or more of the horticultural luminaires serving an enclosed space, the newly installed, replaced, or altered lighting shall meet the requirements of Section 120.6(h)3 for indoor growing or Section 120.6(h)7 for greenhouses.

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

## **8. Bibliography**

There were no references necessary for the Results Report. See the Bibliography of the Final CASE Report for additional references used in the proposal development.



# Attachment 1: Public Comments Submitted by the Statewide CASE Team

Attachment 1 presents comments that the Statewide CASE Team submitted to the Energy Commission's docket that are relevant to this measure.

- Statewide CASE Team, Docket #19-BSTD-03, TN#236965 “Statewide Utility Codes and Standards Enhancement Team Comments -Final NR CEH CASE Report Addendum”, 3/3/2021,  
<https://efiling.energy.ca.gov/GetDocument.aspx?tn=236965&DocumentContentId=70130>
- Statewide CASE Team, Docket #21-BSTD-01 TN#238404 “Statewide Utility Codes and Standards Enhancement Team Comments on 45-Day Express Terms\_Part 1”, 6/21/2021,  
<https://efiling.energy.ca.gov/GetDocument.aspx?tn=238404&DocumentContentId=71705>
- Statewide CASE Team, Docket #21-BSTD-01 TN#238406, “Statewide Utility Codes and Standards Enhancement Team Comments -Comments on 45-Day Express Terms\_Part 2”, 6/21/2021,  
<https://efiling.energy.ca.gov/GetDocument.aspx?tn=238406&DocumentContentId=71707>
- Statewide CASE Team, Docket #21-BSTD-01 TN#238409 “Statewide Utility Codes and Standards Enhancement Team Comments on 45-Day Express Terms\_Part 3”, 6/21/2021,  
<https://efiling.energy.ca.gov/GetDocument.aspx?tn=238409&DocumentContentId=71710>
- Statewide CASE Team, Docket #21-BSTD-01 TN#239075 “Statewide Utility Codes and Standards Enhancement Team Comments - Statewide CASE Team Support for Adoption of 15-Day Express Terms Part 1”, 7/29/2021,  
<https://efiling.energy.ca.gov/GetDocument.aspx?tn=239075&DocumentContentId=72509>
- Statewide CASE Team, Docket #21-BSTD-01 TN#239074 “Statewide Utility Codes and Standards Enhancement Team Comments - Statewide CASE Team Support for Adoption of 15-Day Express Terms Part 2”, 7/29/2021,  
<https://efiling.energy.ca.gov/GetDocument.aspx?tn=239074&DocumentContentId=72510>

## Attachment 2: Final CASE Report

The final version of the CASE Report is provided in full in Attachment 2 to this report.

# Controlled Environment Horticulture



2022-NR-COV-PROC4-F | Covered Processes | March 2021 FINAL CASE REPORT (UPDATED)

Prepared by Energy Solutions and Cultivate Energy and Optimization

**Please submit comments to [info@title24stakeholders.com](mailto:info@title24stakeholders.com).**



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

Copyright 2020 Pacific Gas and Electric Company, Southern California Edison, San Diego Gas & Electric Company, Los Angeles Department of Water and Power, and Sacramento Municipal Utility District. All rights reserved, except that this document may be used, copied, and distributed without modification.

Neither Pacific Gas and Electric Company, Southern California Edison, San Diego Gas & Electric Company, Los Angeles Department of Water and Power, Sacramento Municipal Utility District or any of its employees makes any warranty, express or implied; or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any data, information, method, product, policy or process disclosed in this document; or represents that its use will not infringe any privately-owned rights including, but not limited to, patents, trademarks or copyrights.



## Document Information

<b>Category:</b>	<b>Codes and Standards</b>
<b>Keywords:</b>	Statewide Codes and Standards Enhancement (CASE) Initiative; California Statewide Utility Codes and Standards Team; Codes and Standards Enhancements; 2022 California Energy Code; 2022 Title 24, Part 6; efficiency; horticultural lighting; dehumidification; greenhouse envelope.
<b>Authors:</b>	Kyle Booth, Stefaniya Becking, Greg Barker, Simon Silverberg (Energy Solutions); Joe Sullivan (Cultivate Energy Optimization); Ryan Pollin (Energy and Resource Solutions)
<b>Prime Contractor</b>	Energy Solutions
<b>Project Management:</b>	California Statewide Utility Codes and Standards Team: Pacific Gas and Electric Company, Southern California Edison, San Diego Gas & Electric Company, Los Angeles Department of Water and Power, and Sacramento Municipal Utility District.

# Table of Contents

<b>1. Introduction</b>	<b>16</b>
<b>2. Measure Description</b>	<b>19</b>
2.1 Horticultural Lighting Minimum Efficacy	21
2.2 Efficient Dehumidification	29
2.3 Greenhouse Envelope Standards	35
<b>3. Market Analysis</b>	<b>40</b>
3.1 Market Structure	40
3.2 Technical Feasibility, Market Availability, Current Practices, and Potential Barriers	43
3.3 Market Impacts and Economic Assessments	57
3.4 Economic Impacts	62
<b>4. Energy Savings</b>	<b>68</b>
4.1 Horticultural Lighting Minimum Efficacy	68
4.2 Efficient Dehumidification	74
<b>5. Cost and Cost Effectiveness</b>	<b>80</b>
5.1 Horticultural Lighting Minimum Efficacy	80
5.2 Efficient Dehumidification	87
<b>6. First-Year Statewide Impacts</b>	<b>92</b>
6.1 Statewide Energy and Energy Cost Savings	92
6.2 Statewide Greenhouse Gas (GHG) Emissions Reductions	98
6.3 Statewide Water Use Impacts	99
6.4 Statewide Material Impacts	99
6.5 Other Non-Energy Impacts	100
<b>7. Proposed Revisions to Code Language</b>	<b>102</b>
7.1 Guide to Markup Language	102
7.2 Standards	102
7.3 Reference Appendices	108
7.4 ACM Reference Manual	108
7.5 Compliance Manuals	108
7.6 Compliance Documents	108
<b>8. Bibliography</b>	<b>110</b>

<b>Appendix A : Statewide Savings Methodology</b>	<b>124</b>
<b>Appendix B : Embedded Electricity in Water Methodology</b>	<b>126</b>
<b>Appendix C : Environmental Impacts Methodology</b>	<b>127</b>
<b>Appendix D : California Building Energy Code Compliance (CBECC) Software Specification</b>	<b>129</b>
<b>Appendix E : Impacts of Compliance Process on Market Actors</b>	<b>130</b>
<b>Appendix F : Summary of Stakeholder Engagement</b>	<b>136</b>
<b>Appendix G : Existing Codes and Standards</b>	<b>i</b>
<b>Appendix H : Source of Cost Data</b>	<b>x</b>
<b>Appendix I : Modifications to Indoor Lighting Proposal after Publication of the Draft CASE Report</b>	<b>xiv</b>
<b>Appendix J : Modifications to Dehumidification Proposal after Publication of the Draft CASE Report</b>	<b>xvi</b>
<b>Appendix K : Nominal Savings Results</b>	<b>xvii</b>
<b>Appendix L : Summary of comments and responses addressing the Draft CASE Report</b>	<b>xix</b>
<b>Appendix M : Addendum to Controlled Environment Horticulture – Final CASE Report</b>	<b>26</b>

## List of Tables

Table 1: Scope of Code Change Proposal .....	12
Table 2: Cost Effectiveness of CEH Proposals .....	13
Table 3: First-Year Statewide Energy and Impacts .....	14
Table 4: First-Year Statewide GHG Emissions Impacts .....	15
Table 5: Existing Mandatory Standards on Horticultural Lighting Efficacy.....	27
Table 6: Existing Voluntary Standards on Horticultural Lighting Efficacy .....	28
Table 7: Market Actors and Impacts.....	40
Table 8: Barriers and Solutions .....	41
Table 9: Efficacy of Horticultural Lighting Technologies .....	43
Table 10: Range of Lighting Parameters in Indoor Facilities .....	46
Table 11: Baselines for Lighting Energy Savings Analysis.....	47

Table 12: Percentage of Stacked Growing by Lighting Type.....	48
Table 13: Available Dehumidification Technologies .....	51
Table 14: Barriers and Solutions to Dehumidification Submeasure .....	54
Table 15: Common Greenhouse Envelope Materials Used .....	56
Table 16: Barriers and Solutions to Greenhouse Envelope Submeasure .....	57
Table 17: California Construction Industry, Establishments, Employment, and Payroll	58
Table 18: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard.....	59
Table 19: California Building Designer and Energy Consultant Sectors.....	60
Table 20: Employment in California State and Government Agencies with Building Inspectors.....	62
Table 21: Estimated Impact that Adoption of the Proposed Measure Would Have on the California Commercial Construction Sector.....	63
Table 22: Estimated Impact that Adoption of the Proposed Submeasure Would Have on the California Building Designers and Energy Consultants Sectors .....	64
Table 23: Estimated Impact that Adoption of the Proposed Submeasure Would Have on California Building Inspectors.....	64
Table 24: Net Domestic Private Investment and Corporate Profits, U.S. ....	66
Table 25: Assumptions Used in Indoor Lighting Energy Savings Analysis.....	68
Table 26: Assumptions Used in Greenhouse Lighting Energy Savings Analysis .....	68
Table 27: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis .....	70
Table 28: Modifications Made to Indoor Lighting Baseline Model in Each Prototype to Simulate Proposed Code Change .....	71
Table 29: Modifications Made to Greenhouse Lighting Baseline Model in Each Prototype to Simulate Proposed Code Change.....	72
Table 30: First-Year Energy Impacts Per Square Foot of Canopy – Indoor .....	73
Table 31: First-Year Energy Impacts Per Square Foot of Canopy – Greenhouse.....	73
Table 32: Baseline HVAC Assumptions .....	74
Table 33: Common Assumptions Used for Cannabis Dehumidification Energy Savings Calculations.....	76

Table 34: Common Assumptions Used for Leafy Green Dehumidification Energy Savings Calculations .....	76
Table 35: Common Assumptions Used for Tomato Dehumidification Energy Savings Calculations.....	77
Table 36: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis .....	78
Table 37: First-Year Energy Impacts Per Square Foot of Canopy – Dehumidification ..	79
Table 38: 2023 PV TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot of Canopy – New Construction, Alterations, and Additions Indoor .....	81
Table 39: 2023 PV TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot of Canopy – New Construction, Alterations, and Additions Greenhouse .....	81
Table 40: 15-Year Lighting Incremental Cost Per Square Foot of Canopy.....	83
Table 41: 15-Year Cost-Effectiveness Summary Per Square Foot of Canopy – Indoor Lighting.....	86
Table 42: 15-Year Cost-Effectiveness Summary Per Square Foot of Canopy – Greenhouse Lighting .....	87
Table 43: 2023 PV TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot of Canopy – New Construction and Alterations .....	88
Table 44: Incremental Costs for Efficient Dehumidification .....	90
Table 45: 15-Year Cost-Effectiveness Summary Per Square Foot of Canopy – Indoor Dehumidification.....	91
Table 46: CalCannabis License Types.....	92
Table 47: Facility Stock Crop Type Breakdown.....	93
Table 48: Statewide Energy and Energy Cost Impacts – New Construction – Lighting	94
Table 49: Statewide Energy and Energy Cost Impacts – Alterations – Lighting .....	95
Table 50: Statewide Energy and Energy Cost Impacts – New Construction – Dehumidification.....	96
Table 51: Statewide Energy and Energy Cost Impacts – Alterations – Dehumidification .....	97
Table 52: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions – Lighting .....	98



Table 53: Statewide Energy and Energy Cost Impacts – Dehumidification – New Construction, Alterations, and Additions.....	98
Table 54: First-Year Statewide GHG Emissions Impacts .....	99
Table 55: First-Year Statewide Impacts on Material Use .....	100
Table 56: First-year Canopy Square Footage Impacted by Proposal.....	124
Table 57: Percent of Floorspace Impacted by Proposed Measure, by Climate Zone..	125
Table 58: Roles of Market Actors in the Proposed Compliance Process .....	131
Table 59: Stakeholder Meeting Date and Information .....	137
Table 60: Stakeholders involved in the CASE process .....	138
Table 61: Existing Codes and Standards .....	i
Table 62: Lighting products used in cost analysis .....	x
Table 63: Products used for dehumidification baseline costs.....	xiii
Table 64: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot of Canopy – Lighting New Construction and Alterations Indoor.....	xvii
Table 65: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot of Canopy – Lighting New Construction and Alterations Greenhouse.....	xvii
Table 66: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot of Canopy – Dehumidification New Construction and Alterations.....	xviii
Table 1: First-Year Energy Impacts Per Square Foot of Canopy – Indoor Lighting.....	29
Table 2: First-Year Energy Impacts Per Square Foot of Canopy – Greenhouse Lighting .....	30
Table 3: 2023 PV TDV Energy Cost Savings Over 15-Year Period of Analysis Per Square Foot of Canopy – New Construction, Alterations, and Additions Indoor .....	31
Table 4: 2023 PV TDV Energy Cost Savings Over 15-Year Period of Analysis Per Square Foot of Canopy – New Construction, Alterations, and Additions Greenhouse .....	32
Table 5: 15-Year Cost-Effectiveness Summary Per Square Foot of Canopy – Indoor Lighting.....	33
Table 6: 15-Year Cost-Effectiveness Summary Per Square Foot of Canopy – Greenhouse Lighting .....	34
Table 7: Statewide Energy and Energy Cost Impacts – New Construction – Lighting ..	35
Table 8: Statewide Energy and Energy Cost Impacts – Alterations – Lighting.....	36

Table 9: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions – Lighting .....	37
--	----

## List of Figures

No table of figures entries found.

# Executive Summary

*This document presents recommended code changes that the California Energy Commission will be considering for adoption in 2021. If you have comments or suggestions prior to the adoption, please email [info@title24stakeholders.com](mailto:info@title24stakeholders.com). 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 Code (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 Final CASE Report is to present a code change proposal for controlled environment horticulture (CEH). The report contains pertinent information supporting the code change.

While Title 24, Part 6 currently applies to CEH facilities, this is the first code cycle for which standards are being proposed to specifically address the energy used by the CEH industry during the process of plant production 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.

The Draft version of this CASE Report was released for review in June 2020, and public comments were accepted until July 31, 2020. The Statewide CASE Team received roughly 50 comments from growers, trade associations, equipment manufacturers, and others. As a result of these public comments and conversations with stakeholders during the review process, the CASE Report underwent multiple changes. Modification to the indoor lighting proposal is detailed in Appendix I, and modification to dehumidification proposal is discussed in Appendix J.

Appendix L presents a summary of comments received and the Statewide CASE Team's responses. The Statewide CASE Team would like to note that this interaction, along with the public stakeholder workshops held on September 19, 2019, and April 16, 2020, was invaluable in formulating this code change proposal. The Statewide CASE Team worked with industry stakeholders including growers, industry associations and advocates, manufacturers, builders, utility incentive program managers, Title 24 energy analysts, horticultural facility designers, horticultural researchers, and code compliance subject matter experts. Prescribing cost-effective energy standards for a complex process has many challenges, and this code cycle is the first attempt to address energy usage during the process of plant production.

## Measure Description

### Background Information

Controlled environmental horticulture (CEH) is an agricultural method that uses technology to maintain optimal growing conditions under electric light in indoor warehouse and greenhouse crop production facilities. CEH is 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. Since 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 forecasted to significantly increase the energy demand from the CEH sector (New Frontier Data 2018). Legal cannabis facilities are projected to consume over 380 gigawatt-hours by 2022, an increase of 162 percent from 2017 (New Frontier 2018).

## Proposed Code Changes

The Statewide CASE Team proposes to categorize CEH operations as a covered process, and to provide definitions of several terms directly related to CEH, to clarify appropriate application of proposed submeasures. The term “photosynthetic photon efficacy (PPE)”, an industry-accepted metric for horticultural lighting efficacy would be defined as part the 2022 Title 24, Part 6 rulemaking. To address the 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
- Greenhouse envelope standards.

These 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 lighting systems or installing new dehumidification or HVAC systems in CEH facilities.

### *Horticultural Lighting Minimum Efficacy*

The horticultural lighting minimum efficacy submeasure proposes a mandatory requirement for minimum PPE of up to 2.1 micromoles per joule ( $\mu\text{Mol/J}$ ) for luminaires used for plant growth and maintenance in indoor growing facilities with more than 40 kW of total connected horticultural lighting load and a minimum PPE of 1.7  $\mu\text{Mol/J}$  in greenhouses with more than 40 kW of total connected horticultural lighting load. The submeasure requires time-switch controls and multilevel lighting controls in both types of CEH facilities. Additionally, this submeasure requires the designing of the electrical power system serving CEH spaces so horticultural lighting loads are separated from other lighting loads.

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*

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

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

- Stand-alone dehumidifiers that meet the following minimum integrated energy factors as measured by the test conditions in the Code of Federal Regulation

(CFR) Title 10, Appendix X1 to Subpart B of Part 430:

1. Minimum integrated energy factor of 1.77 L/kWh for product case volumes of 8.0 cubic feet or less
  2. Minimum integrated energy factor of 2.41 L/kWh for product case volumes greater than 8.0 cubic feet
- 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 for system designs that require a 50°F dewpoint or less.

The submeasure requires the on-site heat recovery system to be designed to fulfill at least 75 percent of the facility's annual reheat needs.

This submeasure also proposes to exempt CEH facilities from the prescriptive requirement to install an air-side economizer, when carbon dioxide (CO<sub>2</sub>) enrichment is used as a strategy to promote plant growth.

### *Greenhouse Envelope Standards*

The greenhouse envelope standards submeasure focuses on clarifying existing code language as it relates to greenhouses. Code language that is difficult to interpret and apply in practice can impede the uptake of measures that were designed to reduce energy use and benefit the facility owner over the life of the installed technology. Confusing code language can also slow down the compliance process. Therefore, the Statewide CASE Team is proposing a path of compliance for greenhouses as well as clarifying which measures apply to greenhouses to “clean up” the language to reduce the opportunity for misapplication in practice. Specifically, this submeasure proposes the following envelope requirements specific to conditioned greenhouses:

- Opaque walls and opaque roof assemblies must meet the existing mandatory insulation requirements in Section 120.7.
- Non-opaque wall assemblies must have a combined U-factor of 0.7 or less; and
- Non-opaque roof assemblies must have a combined U-factor of 0.7 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. Furthermore, this proposal applies to additions to conditioned greenhouses.

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.<sup>1</sup>

**Table 1: Scope of Code Change Proposal**

<b>Submeasure Name</b>	<b>Type of Requirement</b>	<b>Modified Section(s) of Title 24, Part 6</b>	<b>Modified Title 24, Part 6 Appendices</b>	<b>Would Compliance Software Be Modified</b>	<b>Modified Compliance Document(s)</b>
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	Mandatory	100.1, 120.6, 141.1	No	No	NRCC-PRC-E
Efficient Dehumidification	Prescriptive	140.4	No	No	N/A
Greenhouse Envelope	Mandatory	100.1, 110.6, 120.6, 141.1	No	No	NRCC-PRC-E
Greenhouse Envelope	Prescriptive	140.3	No	No	N/A

<sup>1</sup> These documents can be found on the Energy Commission's website:

<https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2019-building-energy-efficiency>

Energy Code Ace also provides a tool to navigate Title 24, Part 6 and associated documents (Reference Appendices, ACM Reference Manual, etc.). This can be found online here:

<https://energycodeace.com/content/reference-ace-2019-tool>

Additionally, Energy Code Ace offers a number of trainings and reference documents that are helpful for understanding the Title 24, Part 6 requirements and supporting documentation.

## 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 241 kWh per square foot of canopy (New Frontier 2018). Indoor facilities using HPS lamps average 282 kwh per square foot while those using LEDs average 173 kwh per square foot.

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, 114 of the 124 luminaires listed on the DesignLights Consortium's Qualified Products List for indoor growing facilities meet the proposed efficacy requirement (DesignLights Consortium 2020). 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 (City of Denver 2019). The proposed greenhouse envelope code cleanup aligns with requirements recently adopted in the IECC 2021 Energy Code (New Buildings Institute 2020).

## 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	2.3-2.8

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**

<b>Submeasure</b>	<b>Electricity Savings (GWh/yr)</b>	<b>Peak Electrical Demand Reduction (MW)</b>	<b>Natural Gas Savings (MMTherms /yr)</b>	<b>TDV Energy Savings (million TDV kBtu/yr)</b>
<b>Horticultural Lighting Minimum Efficacy (Total)<sup>a</sup></b>	<b>325.0</b>	<b>22.9</b>	<b>N/A</b>	<b>8,344.6</b>
New Construction	238.5	16.2	N/A	6,123.7
Additions and Alterations	86.5	6.6	N/A	2,220.9
<b>Efficient Dehumidification (Total)</b>	<b>(0.3)</b>	<b>(0.0)</b>	<b>1.2</b>	<b>332.2</b>
New Construction	(0.2)	(0.0)	0.9	256.0
Additions and Alterations	(0.1)	(0.0)	0.3	76.3

a. The savings calculations assume the maximum PPE of 2.1  $\mu\text{Mol/J}$  for indoor growing facilities.

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  $\mu\text{Mol/J}$  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 this measure may not be as cost effective 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 metric tons of carbon dioxide equivalent (metric tons CO<sub>2</sub>e). 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 in the cost-effectiveness analysis.

**Table 4: First-Year Statewide GHG Emissions Impacts**

<b>Submeasure</b>	<b>Avoided GHG Emissions (Metric Tons CO<sub>2</sub>e/yr)</b>	<b>Monetary Value of Avoided GHG Emissions (\$2023)</b>
Horticultural Lighting Minimum Efficacy	78,109	\$2,343,271
Efficient Dehumidification	6,361	\$190,840
<b>Total</b>	<b>84,470</b>	<b>\$2,534,111</b>

## Water and Water Quality Impacts

There are no water savings associated with the proposed submeasures.

## 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 are expected to follow California's Energy Code for the first time.
- Compliance documents need to be updated in a way that allows for understanding and implementation of the code requirements.
- Building inspectors need to have access to the tools, training, and resources to become knowledgeable about new requirements and metrics specific to CEH equipment.

### Field Verification and Acceptance Testing

Time-switch lighting controls for horticultural lighting would require acceptance testing using an existing acceptance test. Compliance would be shown through verification of permit documents.

# 1. Introduction

*This document presents recommended code changes that the California Energy Commission will be considering for adoption in 2021. If you have comments or suggestions prior to the adoption, please email [info@title24stakeholders.com](mailto:info@title24stakeholders.com). Comments will not be released for public review or will be anonymized if shared.*

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support the California Energy Commission's (Energy Commission) efforts to update the California Energy Code (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.

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 Final 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 industry stakeholders including growers, industry associations and advocates, manufacturers, builders, utility incentive program managers, Title 24 energy analysts, horticultural facility designers, horticultural researchers, and code 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 Final 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.
- Appendix I: Modifications to Lighting Proposal after Publication of the Draft CASE Report
- Appendix J: Modifications to Dehumidification Proposal after Publication of the Draft CASE Report
- Appendix K: Nominal Savings Results
- Appendix L: Summary of Draft CASE Report Comments and Responses

## 2. Measure Description

Controlled environmental horticulture (CEH) refers to agricultural methods used for greenhouses and indoor growing facilities. It is commonly used for herbs, vegetables, microgreens, flowers, and cannabis. CEH facilities are energy-intensive, sophisticated operations because 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 food 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<sup>2</sup> 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 completely on electric lighting. As noted in the Executive Summary, energy demand for cannabis grown in CEH facilities is projected to exceed 380 gigawatt-hours (GWh) of total energy use by 2022 (New Frontier 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, as well as an exemption from the current air-side economizer prescriptive requirement 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), lighting systems alterations that require a

permit and compliance with Title 24, Part 6, installing new heating, ventilation, air and air conditioning (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 2019 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. Architectural and basic mechanical systems currently go through plan review, so updating this process to account for new requirements would not be a profound change.
- **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 setting a mandatory requirement for minimum photosynthetic photon efficacy (PPE) of up to 2.1 micromoles per joule ( $\mu\text{Mol/J}$ ) for luminaires used for plant growth and maintenance in indoor growing facilities with more than 40 kW of total connected horticultural lighting load and a minimum PPE of 1.7  $\mu\text{Mol/J}$  in greenhouses with more than 40 kW of total connected horticultural lighting load. Total connected lighting load was chosen as the metric to trigger the code to allow growers and plan reviewers to easily determine the relevant lighting calculations. Additionally, using total connected lighting load would provide a clear way for building code officials to note compliance with the measure. A total connected horticultural lighting load of 40 kW was chosen as the threshold for these requirements to minimize financial burden on smaller growers by exempting them from the efficacy requirements. Calculations for energy savings and cost effectiveness utilize canopy square footage, as this allowed for scaling per-unit savings to statewide savings using the square footage of canopy using the statewide canopy forecast.

The 40 kW threshold equates to 800-1,000 square feet ( $\text{ft}^2$ ) of canopy for an indoor grower using 1,000 watt high pressure sodium lights every 20-25  $\text{ft}^2$ , which represents the lighting required for highest energy intensity crops analyzed. Growers that only use a low intensity of light to stimulate photoperiod maintain flexibility. The submeasure requires time-switch controls and multilevel lighting controls in both types of CEH facilities. Additionally, this submeasure requires the designing of the electrical power system serving CEH spaces so the horticultural lighting load can be separate from other lighting loads.

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. Second, 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). Third, less stringent requirements for greenhouses would put less burden on vegetable and flower growers, who are reported to have lower profit margins than cannabis growers. Fourth, a lower PPE for greenhouses provides an option for growers to choose greenhouse growing rather than indoor growing for more flexibility in allowable lighting technologies. Lastly, current light-emitting diode (LED) luminaire size is larger than HPS luminaires, causing 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, 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 intended for plant growth 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).

The proposed PPE level for indoor facilities has been slightly modified since the Draft CASE Report was released for public review in June 2020.<sup>2</sup> Rather than propose a PPE level of 2.1  $\mu\text{Mol/J}$ , the Statewide CASE Team is instead proposing a PPE of up to 2.1  $\mu\text{Mol/J}$  with consideration for a lower PPE based on stakeholder concerns with the minimum efficacy and its effects on the market and plant growth. This is in direct response to feedback the Statewide CASE Team received from stakeholders regarding unique circumstances of the indoor horticulture industry, such as a substantial illicit market to compete against or lack of access to traditional means of financing.<sup>3</sup> The pursuant sections of this report demonstrate that a PPE level of 2.1  $\mu\text{Mol/J}$  is a justifiable code change. Specifically, the cost-effectiveness analysis is outlined in Section 5.1, and the technical feasibility is discussed in Section 3.2.1. Additional information is provided in Appendix I. The Energy Commission will review this proposal and the information provided to support setting the minimum at 2.1  $\mu\text{Mol/J}$  and make an informed final decision.

### **2.1.2 Measure History**

The introduction of PPE, 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 based on the lighting power per  $\text{ft}^2$ , indiscriminatory of whether the light is useful for the photosynthesis process. This metric is currently used in Title 24, Part 6 to set an energy budget for illuminating spaces for general illumination

---

<sup>2</sup> The Draft CASE Report can be found online here: <https://title24stakeholders.com/wp-content/uploads/2020/06/NR-CEH-Draft-CASE-Report.pdf>

<sup>3</sup> See more details about stakeholder comments received in Appendix L.

and human occupancy. See Section 3.2.1.3 for details on horticulture lighting current practices and why PPE was chosen over lighting power density (LPD).

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” – The purpose of this new definition is to add a reference standard for definitions related to horticultural lighting. This change is necessary to add a test standard for PPE specification.
- “controlled environment horticulture (CEH) space” – The purpose of this change is to define a new process type that would be covered by the proposed measure. The change is necessary to identify which standards apply specifically to CEH spaces.
- “greenhouse” –The purpose of this change is to define a building type that would be covered by the proposed measure. This new definition is necessary to identify which standards apply specifically to greenhouses.
- “greenhouse, conditioned” –The purpose of this change is to define a type of greenhouse that would be covered by the proposed measure. This new definition is necessary to identify which standards apply to greenhouses with heating/cooling capacity.
- “horticultural lighting” –The purpose of this change is to define a new term used in the proposed measure. This new definition is set standards for lighting specifically used in grow processes.

- “indoor growing” –The purpose of this change is to define a CEH space type that would be covered by the proposed measure. This new definition is necessary to differentiate standards between indoor facilities and greenhouses.
- “integrated HVAC system” –The purpose of this change is to define a new term used in the proposed measure. This new definition is necessary allow this system to be used as HVAC system option.
- “photosynthetic photon efficacy (PPE)” –The purpose of this change is to define a new term used in the proposed measure. This new definition is necessary to set the horticultural lighting standard.
- “photosynthetic photon flux (PPF)” –The purpose of this change is to define a new term used in the proposed measure. This new definition is necessary to set the horticultural lighting standard.
- “stand-alone dehumidifier” – This purpose of this change is to define a new term used in the proposed measure. This is necessary to set the dehumidification standard.

#### Revised Definition:

- “process, covered” – This purpose of this revised definition is to add CEH spaces to the list of covered processes. This is necessary to allow the proposal to set requirements on CEH processes.
- “greenhouse or garden window”- The purpose of this change is to clarify the intended definition of this word. This is necessary to not create confusion with the proposed definition of “greenhouse”.

## **SECTION 120.6 – MANDATORY REQUIREMENTS FOR COVERED PROCESSES**

- **Section 120.6(h) – Mandatory Requirements for Controlled Environment Horticulture Spaces:** The purpose of this change is to create a new section (Section 120.6(h)) so that all requirements for CEH spaces are in one section. This includes standards related to horticultural lighting efficacy and lighting controls in indoor growing facilities and greenhouses. This change is necessary to clearly show what requirements apply to CEH facilities.

## **SECTION 130.1 – MANDATORY INDOOR LIGHTING CONTROLS**

- **Section 130.1(c) – Shut-OFF Controls:** The purpose of this change to note that separate controls should exist for horticulture lighting systems. This change is

necessary to ensure that control systems for general, display, or ornamental lighting, which require different lighting needs than plants, have different controls.

## **SECTION 140.6 – PRESCRIPTIVE REQUIREMENTS FOR INDOOR LIGHTING**

- **Section 140.6(a)3G – Prescriptive Requirements for Indoor Lighting, Lighting Wattage Excluded:** The purpose of this change is to add a clarifying statement that CEH spaces must comply with Section 120.6(h). This change is necessary to show what sections of code impact CEH facilities.
- **Section 140.6(a)3O – Prescriptive Requirements for Indoor Lighting, Lighting Wattage Excluded:** The purpose of this change is to add a clarifying statement that CEH spaces must comply with Section 120.6(h). This change is necessary to show what sections of code impact CEH facilities.
- **Section 140.6(a)3P – Prescriptive Requirements for Indoor Lighting, Lighting Wattage Excluded:** The purpose of this change is to add a clarifying statement that CEH spaces must comply with Section 120.6(h). This change is necessary to show what sections of code impact CEH facilities.

## **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:** The purpose of this change is to add 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 lighting efficacy standards in proposed Section 120.6(h). This change is necessary to align efficacy requirements for alterations with that of new construction.
- **Section 141.1(a)3 EXCEPTION:** The purpose of this change is to except horticultural lighting alterations that involve replacement of only lamps, or only ballasts, or only drivers. Also, this change exempts any alterations limited to adding lighting controls. This exception is necessary to prevent the unnecessary application of the standard.

### ***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 following sections of the Nonresidential Compliance Manual:

- NRCC-PRC-E Process Systems

Compliance information for a CEH production as a covered process would need to be added to the certificate of compliance document. Specific changes are noted in Section 7.6.

### **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 are 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  $\mu\text{Mol/J}$  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  $\mu\text{Mol/J}$  for luminaires and 1.9  $\mu\text{Mol/J}$  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 ft<sup>2</sup> of canopy for operations 5,000 ft<sup>2</sup> or more and to 50 watts per square foot of canopy for operations under 5,000 ft<sup>2</sup>. 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, two options exist for meeting lighting efficiency standards. One option involves having a maximum LPD of 36 watt per ft<sup>2</sup> of canopy, and the other option is having a PPE of at least  $\geq 2.2$  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 5 summarizes mandatory standards on horticultural lighting efficacy.

**Table 5: Existing Mandatory Standards on Horticultural Lighting Efficacy**

<b>Jurisdiction</b>	<b>Year</b>	<b>Standard Type</b>	<b>Requirements</b>
City of Seattle	2015	PPE	PPE $\geq 1.2$ 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	<ul style="list-style-type: none"> <li>LPD of 36 W/ft<sup>2</sup> of canopy for operations equal to or over 5,000 ft<sup>2</sup> of canopy; LPD of 50 W/ft<sup>2</sup> of canopy operations under 5,000 ft<sup>2</sup> of canopy or</li> <li>PPE <math>\geq 15\%</math> above the minimum DLC QPL threshold with products from DLC</li> </ul>

			QPL, which means PPE $\geq 2.2 \mu\text{Mol/J}$ as of this report writing.
State of Illinois	2019	LPD or PPE for cannabis crop	<ul style="list-style-type: none"> <li>• Either LPD of 36 W/ft<sup>2</sup> of canopy, or</li> <li>• PPE <math>\geq 2.2 \mu\text{Mol/J}</math> with products from DLC QPL</li> </ul>

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  $\mu\text{Mol/J}$  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. At the time of the Final CASE Report's publication, approximately 92 percent of the DLC QPL products had a PPE of 2.1 or higher.

Additionally, a 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  $\mu\text{Mol/J}$  (IECC 2019) was approved in the final vote in late 2019. Table 6 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 6: Existing Voluntary Standards on Horticultural Lighting Efficacy**

Organization	Voluntary Requirements
Design Lights Consortium (DLC) Horticultural Lighting Qualified Products List (QPL)	<ul style="list-style-type: none"> <li>• PPE <math>\geq 1.9</math> micromoles per joule</li> <li>• 114 luminaire models in DLC QPL Products List from over 20 manufacturers with PPE range of 1.87 to 3.2 <math>\mu\text{Mol/J}</math> (as of this report writing)</li> </ul>
International Energy Conservation Code (IECC)	PPE $\geq 1.6 \mu\text{Mol/J}$ (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 is exempt from 2019 Title 24, Part 6 compliance process. To enforce the proposed submeasure, a new compliance process would need to be established.

For non-cannabis crop types, permit applicants would need to list the electric usage of their 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 crops, compliance with the existing California Department of Food & Agriculture (CDFA) CalCannabis regulations would 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.). Thus, applicants can determine if they trigger the 40 kW threshold based upon the maximum wattages noted in their lighting diagram. 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 at least 40 kW of horticulture connected lighting load, the permit applicants would also need to install multi-level and time-switch lighting controls as well as coordinate an acceptance test 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 tools, training, and resources for building department officials and other persons responsible for compliance with the new requirements. For a complete list of specific recommendations for simplifying the compliance and enforcement process, refer to Table 58 in Appendix E.

## **2.2 Efficient Dehumidification**

### **2.2.1 Measure Overview**

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

1. Stand-alone dehumidifiers that meet the following minimum integrated energy



factors as measured by the test conditions in Appendix X1 to Subpart B of Part 430:

- a. Minimum integrated energy factor of 1.77 L/kWh for product case volumes of 8.0 cubic feet or less
  - b. Minimum integrated energy factor of 2.41 L/kWh for product case volumes greater than 8.0 cubic feet
2. Integrated HVAC system with on-site heat recovery to achieve designed to fulfill at least 75 percent of the annual energy for dehumidification reheat;
3. Chilled water system with on-site heat recovery to achieve designed to fulfill at least 75 percent of the annual energy for dehumidification reheat; or
4. Solid or liquid desiccant dehumidification system for system designs that require a 50°F dewpoint or less.

This submeasure also proposes to exempt CEH facilities from the prescriptive requirement to install an air-side economizer where the use of an air economizer in controlled environment horticulture spaces will affect crop health, or dehumidification system, or carbon dioxide enrichment system

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

Over 50 comments were received in response to the Draft CASE Report posted in June 2020, and as a result, the Statewide CASE Team modified the report in light of comments and subsequent conversations with growers, trade groups, and dehumidification experts. A comprehensive explanation of the various changes is described in Appendix J. Primarily, the proposal was modified to allow stand-alone dehumidification units in all indoor facilities with differing efficiency levels based on size. Additionally, dehumidification equipment having the ability to reuse transpired water has been stricken from the proposal based on feedback that this may lead to unexpected costs for growers.

### **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 stand-alone

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 stand-alone and integrated 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.

### **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:**

- “carbon dioxide enrichment” – The purpose of this new definition is to specify this operational practice. This change is necessary to clarify a proposed exemption on installation of an air-side economizer.
- “desiccant dehumidification systems” – The purpose of this new definition is to identify a type of dehumidification system permitted in the proposed code. This change is necessary to specify a certain dehumidification requirement.
- “greenhouse” – The purpose of this new definition is to distinguish a building type that would be covered by the proposed measure. This change is necessary to apply certain requirements only to greenhouses.

### **Revised Definitions:**

- “USDOE 10 CFR 430” – The purpose of this revised definition is to reference the testing method for measuring energy consumption of dehumidifiers. This change is necessary to ensure dehumidification requirements have a test method.

## **SECTION 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS**

**Section 140.4(e) EXCEPTION 7 – Economizers:** The purpose of this change is to add an exemption from the prescriptive requirement for an economizer in buildings with CEH spaces that use carbon dioxide enrichment strategy to promote plant growth. This

change is necessary to clarify a proposed exemption on installation of an air-side economizer.

## **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:** The purpose of this change is to mandate newly installed HVAC and dehumidification systems in existing indoor growing facilities to comply with the proposed mandatory requirements for CEH spaces. The change is necessary to establish HVAC requirements for CEH facilities.

### ***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. Specific changes are noted 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:

- Stand-alone 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<sup>2</sup> of canopy to have high-efficiency ductless split HVAC units. For facilities with 6,000 or more ft<sup>2</sup> 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 X1 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 65 °F 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 X1 incorporates by reference and leverages an earlier version of this standard, ANSI/AHAM DH-1-2008 (Legal Information Institute n.d.).

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 split-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<sub>2</sub> 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 tools, training, and resources 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.

For the dehumidification submeasure specifically, NRCC-PRC-E would need to be updated to include the minimum efficiency requirements for stand-alone dehumidifiers and the efficiency requirements for other systems. These requirements would be reviewed during the plan check.

All dehumidification systems in the grow facility would be required to meet the efficiency requirements.

Cut sheets of stand-alone dehumidifiers would include their moisture removal efficiency. Permitting of standalone dehumidification systems typically occurs during new construction since the electric load of the equipment is large enough to include on the plans sheet. While it is possible to replace a standalone unit without having a building official involved, compliance with the federal dehumidification standard constitutes compliance with the proposed Title 24, Part 6 standard, so there is no need for a separate compliance process.

There are additional compliance considerations for the 75 percent reheat energy requirement for integrated HVAC and chilled water systems. The plans reviewer would need to check the ratio of total cooling capacity to total reheat provided by the dehumidification equipment from dehumidification equipment specifications.

## **2.3 Greenhouse Envelope Standards**

### **2.3.1 Measure Overview**

The greenhouse envelope standards submeasure focuses on clarifying existing code language as it relates to greenhouses. Code language that is difficult to interpret and apply in practice, which can impede the uptake of measures that were designed to reduce energy use and benefit the facility owner over the life of the installed technology. Confusing code language can also slow down the compliance process. The Statewide CASE Team is proposing a path of compliance for greenhouses as well as clarifying which measures apply to greenhouses to “clean up” the language to reduce the

opportunity for misapplication in practice. Specifically, this submeasure proposes the following envelope requirements specific to conditioned greenhouses:

- Opaque walls and opaque roof assemblies must meet the existing mandatory insulation requirements in Section 120.7;
- Non-opaque wall assemblies must have a combined U-factor of 0.7 or less; and
- Non-opaque roof assemblies must have a combined U-factor of 0.7 or less.

For non-opaque wall assemblies, the proposed maximum U-factor value is in alignment with upcoming IECC 2021 Standards as noted in Section 2.2.4.4. For non-opaque roof assemblies, the Statewide CASE Team is also proposing the maximum U-factor value of 0.7 as opposed to the U-factor value of 0.5 for a non-opaque roof assembly or non-opaque roof assembly with an internal curtain system according to the IECC 2021 Standards. The lack of industry accepted default U-factor values for internal curtain systems makes it challenging to account for impact from internal curtain systems on the combined U-factor value.

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 submeasure applies to newly constructed greenhouses and to greenhouses being converted from unconditioned to conditioned. Furthermore, this proposal would impact additions to conditioned greenhouses.

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<sup>2</sup> or mechanical cooling with capacity greater than 5 Btu/hr-ft<sup>2</sup> 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 (e.g., 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 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**

“garden window” – The purpose of modifying the definition of “greenhouse or garden window” to “garden window” is to eliminate confusion between default U-factors for garden window in a residential dwelling and the proposed default U-factors for fenestration materials in commercial greenhouses.

#### **SECTION 120.6 – MANDATORY REQUIREMENTS FOR COVERED PROCESSES**

##### **Section 120.6(h) – Mandatory Requirements for Controlled Environment**

**Horticulture Spaces:** The purpose of this new section is for all requirements for CEH facilities to be in one location. This section also adds standards related to greenhouse envelopes to create a feasible compliance path for conditioned greenhouses. The creation of this section is necessary to clearly show the energy standards for greenhouses and indoor growing facilities.

##### **Section 120.6(h), TABLE 120.6-D DEFAULT U-FACTORS FOR GREENHOUSE**

**COVERINGS:** The purpose of the new table is to add default U-factor values for common greenhouse coverings to support the proposed U-factor requirements in conditioned greenhouses. This change is necessary in order to quickly determine compliance with the proposed greenhouse envelope standards.

#### **SECTION 140.3 – PRESCRIPTIVE REQUIREMENTS FOR BUILDING ENVELOPES**

**Section 140.3(a)5 EXCEPTION 1:** This new exemption removes greenhouses from the existing prescriptive building envelope requirement for window wall ratio. The exception is necessary due to greenhouse walls being predominantly fenestration.

**Section 140.3(a)6 EXCEPTION 1:** This new exemption removes greenhouses from the existing prescriptive building envelope requirement for skylight roof ratio. The exception is necessary due to greenhouse ceilings being predominantly fenestration.

**Section 140.3(c) EXCEPTION 1:** The purpose of this change is to modify the exemption to add CEH spaces to the list of spaces exempt from minimum daylighting



requirements. This change is necessary to ensure CEH is not impacted by unnecessary 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:** The purpose of this change is to clarify that greenhouses being converted to conditioned greenhouses shall comply with the greenhouse specific proposed requirements on building envelope and space-conditioning systems. Additionally, this change shows that additions to conditioned greenhouses are covered by the proposed code as well. These changes are necessary to provide a clear path to compliance for conditioned greenhouses.

### ***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***

Conditioned greenhouses must currently comply with nonresidential building envelope requirements for conditioned spaces in 2019 Title 24, Part 6. The existing envelope requirements are not 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 a U-factor of 0.5 Btu/(hr-ft<sup>2</sup>-°F) 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-factor values of greenhouse envelope materials based on specification sheets. Having the same U-factor value for both non-opaque wall assemblies and non-opaque roof assemblies, without the need to account for internal curtain systems, will simplify compliance determination and enforcement.

### 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 7 below summarizes the impacts of this proposal on key market actors.

**Table 7: Market Actors and Impacts**

<b>Market actor</b>	<b>How market actor could be affected by proposal</b>
Indoor facility operators with > 40 kW of total connected horticultural lighting load	When building a new facility or making qualifying additions or alterations to an existing facility, would have to: <ul style="list-style-type: none"><li>• Use lighting luminaires with a minimum lighting efficacy of 2.1 <math>\mu\text{Mol/J}</math>.</li><li>• Install time-switch and multilevel lighting controls.</li><li>• 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).</li><li>• Install thermostatic and humidity controls.</li></ul>
Greenhouse facility operators with > 40 kW of total connected horticultural lighting load	When building a new facility or making qualifying additions or alterations to an existing facility, would have to: <ul style="list-style-type: none"><li>• Use electric luminaires with a minimum lighting efficacy of 1.7 <math>\mu\text{Mol/J}</math>.</li><li>• Install time-switch lighting controls and multilevel lighting controls.</li></ul>
CEH facility designers	Become familiar with new standards and modify standard design practices to incorporate minimum code efficiencies.

<b>Market actor</b>	<b>How market actor could be affected by proposal</b>
Lighting manufacturers	Ensure the specification sheet for every model clearly reports efficacy in micromoles per joule and provide PPE ratings 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 and conduct inspections for lighting, HVAC, and dehumidification
Utilities and Program Implementers	<ul style="list-style-type: none"> <li>• Review horticultural lighting incentives. California is moving to third party-implemented energy efficiency programs, and it is uncertain what those program structures or incentives will look like.</li> <li>• Savings from demand side management (DSM) programs may be reduced because of a more efficient baseline.</li> </ul>
Equipment dealers	<ul style="list-style-type: none"> <li>• Understand code minimum baselines and technologies that are California Energy Code compliant for indoor lighting, greenhouse lighting, and indoor dehumidification.</li> </ul>

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

**Table 8: Barriers and Solutions**

<b>Barrier</b>	<b>Solution</b>
Added 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	<p>The Statewide CASE Team conducted a survey to gather information on baseline standard practices.</p> <p>Benchmarking efforts include development of tools by the industry for assessing energy use:</p> <ul style="list-style-type: none"> <li>• Indoor Cannabis Cultivator Energy Use Estimator developed by Oregon Department of Energy: <a href="https://energy.odoe.state.or.us/cannabis">https://energy.odoe.state.or.us/cannabis</a></li> <li>• Resource Innovation Institute PowerScore benchmarking tool</li> <li>• Cornell's Greenhouse Lighting and Systems Engineering (GLASE) benchmarking tool (in development)</li> </ul>
Widely accepted performance metrics for CEH operations not fully developed or accepted by industry	<p>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.</p>
Lack of CEH HVAC standards	<p>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.</p>
Reluctance of producers to switch to LED lighting	<ul style="list-style-type: none"> <li>• Educational resources such as Resource Innovation Institute's LED Lighting Best Practices Guide and Efficient Yields Seminars can help educate growers on how to grow utilizing LED lighting.</li> <li>• DOE reports show LED market saturation in the horticulture market increasing from 4 to 11 percent between 2017 and 2019 (U.S. DOE 2020) (DOE 2017). Growers across the country are beginning to take advantage of the LED technology.</li> <li>• The proposed code change offers less stringent requirements for greenhouses, which offers a new construction option to producers hesitant to use LED luminaires for plant growth.</li> </ul>

## 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 light emitting plasma (LEP) and double-ended HPS options that can meet minimum requirements, but no test data was found at the time this report was written for these technology types at the proposed minimum indoor lighting efficacy.

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.) DesignLights Consortium (DLC) currently utilizes PPE to qualify products for their horticultural qualified products list. Some industry stakeholders have indicated other metrics to include in efficacy such as ultraviolet and far-red wavelengths, and these may factor into future efficacy calculations. At the time of the reports publication, PPE in the 400-700 nanometer range was the most widely accepted metric in use (Radetsky 2018). Table 9 provides typical efficacy ranges for the common horticultural lighting technology types.

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

**Table 9: Efficacy of Horticultural Lighting Technologies**

Technology	Average 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	1.7–1.9	Yes	No
Single-ended HPS <sup>a</sup>	1.0	No	No
Metal halide luminaire <sup>b</sup>	0.8	No	No

Ceramic metal halide luminaire <sup>a</sup>	1.5	No	No
Fluorescent lighting luminaire <sup>a</sup>	0.84–0.95	No	No
LED lighting luminaire <sup>c</sup>	1.1–3.0	Yes	Yes

Sources:

- a. (Navigant 2017);
- b. (Radetsky 2018);
- c. (Radetsky 2018) and (DesignLights Consortium 2019)

Although the PPE metric is becoming widely accepted and reported for LED luminaires, high intensity discharge (HID) luminaires such as ceramic metal halide and HPS luminaires do not test or report PPE commonly. In reviewing test procedures, it was identified that there is not an existing test procedure to directly measure PPE of HID luminaires. The key standards that can inform the PPE testing of HID luminaires and lamps are:

- IES LM-46-04: *IESNA Approved Method for Photometric Testing of Indoor Luminaires Using High Intensity Discharge or Incandescent Filament Lamps*
- IES LM-51-13: *Approved Method: The Electrical and Photometric Measurement of High Intensity Discharge Lamps*
- IES LM-78-17: *Approved Method: Total Flux Measurement of Lamps Using an Integrating Sphere*

According to ANSI/ASABE S640-2017, PPE is the photosynthetic photo flux (PPF,  $\Phi_p$ ) divided by input electric power. PPF is measured or calculated without weighting factors across the wavelength interval of 400 and 700 nm, and is defined as:

$$\Phi_p = \int_{400}^{700} \frac{\lambda}{N_A \cdot h \cdot c} \Phi_\lambda(\lambda) d\lambda$$

where

- $N_A$  is Avogadro's number ( $6.022 \cdot 10^{23}$  photons per mole),
- $h$  is Planck's constant ( $6.626 \times 10^{-34}$  J·s),
- $c$  is the speed of light ( $2.998 \times 10^8$  m/s),
- $\Phi_\lambda(\lambda)$  is the spectral radiant flux (w/nm).

Spectral radiant flux may be measured using a goniometer or an integrating sphere. LM-46-04 is the most appropriate standard to inform the test setup for measuring HID luminaire spectral radiant flux using a goniometer with the following gaps:

- **Spectroradiometer detection is not specified.** LM-46 is solely specified for photometric testing. To be able to use the same setup for photon flux measurement, a spectroradiometer needs to be used in place of photodetectors. Specification of spectroradiometer already exists in other standards, including IES LM-78 Section 5.7 and LM-51 Section 7.3.3.



- **Integrating sphere is not an approved method.** Goniometer measures radiant intensity in horizontal and vertical planes. This may be a test burden if total flux is the only measurement needed, as in the case of obtaining PPF. Total flux measurement using an integrating sphere is well-described as an approved method in IES LM-51 and IES LM-78; however, both are only approved for measuring HID lamps, not HID luminaires.
- **Does not specify electrical measurement.** Measured electrical values are not specified as part of the LM-46 test report. Since the input electric power is critical for deriving PPE, electrical circuit, instrumentation, and setting need to be specified as part of the test method. Electrical measurement is well-described in IES LM-51, and while LM-51 is only for HID lamps, there should be minimal difference, if any, in electrical measurement method.

There is currently no existing test standard readily available for testing and reporting PPE of HID luminaires. LM-46 remains to be the most appropriate test standard and can be used for testing and reporting PPE of HID luminaires when the gaps highlighted above are addressed. Information needed to address the existing gaps in LM-46 already exists in other IES standards, including LM-51 and LM-78, so it is feasible to supplement LM-46 with additional specifications for testing and reporting PPE of HID luminaires. Recommendations are provided below with the caveats that 1) the supplemental specifications need to be further vetted by test procedure experts, and 2) the test method would not be considered as an IES approved method. These supplemental specifications largely borrow from other IES Standards, including LM-51-13, LM-78-17, and LM-79-19.

- Instead of photodetectors, the goniometer shall use spectroradiometer detection. Either mechanical scanning or array-type spectroradiometer may be used. The spectroradiometer shall have a minimum spectral range from 380 nm to 780 nm. The spectroradiometer system should account for light outside of 380-780 nm wavelength range that may result in stray light within the system, especially during calibration. The spectroradiometer system shall have a wavelength uncertainty within 0.5 nm, and the bandwidth (full-width at half maximum, FWHM) shall not be greater than 5 nm.
- For relatively small-size HID luminaires, photon flux may be measured using an integrating sphere with spectroradiometer detection. The sphere-spectroradiometer system shall conform with IES LM-78-17.
- The electrical conditions, either using a gonio-spectroradiometer system or a sphere-spectroradiometer system, shall confirm with the electrical conditions in LM-51-13 Section 5.0, and the electrical instrumentation shall confirm with LM-51-13 Section 6.4.



- Test report shall include measured electrical values of the HID luminaires, including volts, amperes, and watts.

### 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, plasma, and LED luminaires. As of August 2020, 114 of 124 luminaires listed on DLC's QPL met the proposed indoor growing facilities 2.1 PPE requirement (DesignLights Consortium 2020).

### 3.2.1.3 Current Practices

As stated in Section 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 ( $\text{mol}/\text{m}^2/\text{d}$ ). 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) ( $\mu\text{mol}/\text{m}^2/\text{s}$ )	Hours per day of Lighting	Daily Light Integral (DLI) ( $\text{mol}/\text{m}^2/\text{d}$ )	Source
Leafy greens and herbs	140–200	16–24	12–17	<a href="https://www.hortigrowlight.com/leafy-greens">https://www.hortigrowlight.com/leafy-greens</a> ; and PPFD calculation for DLI of 17
Flowering crops (e.g., peppers and tomatoes)	170–600	16–24	15–40	<a href="https://www.hortigrowlight.com/leafy-greens">https://www.hortigrowlight.com/leafy-greens</a> ; 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. PPE was chosen for entry into the California Energy Code because it is the metric most commonly adopted by other existing standards (Radetsky 2018) and can be published by manufacturers on marketing materials, which is accessible to specifiers and to compliance enforcement personnel.

Other jurisdictions, such as Massachusetts and Illinois, have opted to use a Lighting Power Density (LPD) metric, expressed in watts per square foot of canopy. Although this metric is used in other sections of the California Energy Code to set general illumination energy use limits, it does not consider the wavelengths needed for photosynthesis. Also, growers can bypass LPD requirements by increasing the distance between plants, 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 vulnerable to noncompliance.

Greenhouses and indoor growing facilities are different applications and require different baselines. The lighting efficiency standard for greenhouses is lower than that for indoor growing facilities. Greenhouses do not need as much electric lighting as indoor facilities since they also use sunlight. They are used for flowers and vegetables rather than just for cannabis, which has much higher lighting needs (LED Light Expert n.d.). Additionally, lower requirements for greenhouses would put less burden on vegetable and flower growers, who have lower profit margins than cannabis growers (Brentlinger 2019). A lower PPE for greenhouses provides an option for growers to switch from indoor to greenhouse growing if they want to use legacy technologies. Lastly, 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 including the surveys described in Section 4.1.2 and Appendix F.

**Table 11: Baselines for Lighting Energy Savings Analysis**

<b>Crop</b>	<b>Weight</b>	<b>Baseline PPE</b>	<b>Proposed PPE</b>
<b>Greenhouse</b>			
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
<b>Indoor</b>			
Cannabis - Flower	76.4%	1.02	2.1
Cannabis - Vegetative	13.8%	1.02	2.1
Cannabis - Clone	1.8%	1.02	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 2020 Navigant study commissioned by the U.S. Department of Energy (U.S. DOE), average lighting time is 14.25 hours a day for non-stacked configuration and 18 hours a day for stacked configuration. The data sources for the study included interviews with growers, interviews with lighting manufacturers, retailers, utilities, and industry experts, and review of product specification databases and the U.S. Agriculture and Horticulture Censuses (U.S. DOE 2020). It found lighting for indoor facilities to be distributed as shown in the following table.

**Table 12: Percentage of Stacked Growing by Lighting Type**

<b>Lighting Type</b>	<b>Unstacked</b>	<b>Stacked</b>
LED	11%	100%
HPS and Metal Halide	86%	0%
Fluorescent	3%	0%

According to a November 2019 survey conducted by the Cannabis Business Times, 21 percent of cannabis cultivators currently use LEDs. Of those who responded that 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).

According to a recent DOE report, the estimated market saturation of LED in indoor facilities is 11 percent nation-wide (U.S. DOE 2020). While it may seem premature that California is considering whether to adopt a standard that sets horticulture lighting efficacy minimums that exclude most legacy lighting technologies, there is recent and substantial precedent for the state setting forward-thinking lighting standards to which

the lighting industry was able to respond to and provide viable solutions for compliance, represented as a state leader. In the 2019 code cycle, the Energy Commission approval of the movement to an LED baseline for calculating allowable lighting power densities sent a strong signal to the lighting specification community that there were ample cost-effective solutions in the marketplace to make the switch (Statewide CASE Team 2017). At that time the proposal was submitted and initially considered by the Energy Commission, estimates noted that nationwide LED market saturation was 3 percent (DOE 2015). LEDs are now widely used across the country in general lighting applications.

Two popular high-intensity discharge (HID) light sources — HPS and metal halide — produce distinct wavelengths of light across the PAR spectrum (400-700nm); metal halide lamps 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. Some luminaires utilize a dimmer switch on each luminaire to control light intensity, and other luminaires require a centralized programmable device to control lighting intensity. 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 integrated controls as each piece of equipment having the ability to act independently (Wadsworth n.d.). Designing of the electrical power system serving CEH spaces so horticultural lighting loads are separated from other lighting loads is common practice.

#### **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 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 has potential for higher yields per kilowatt-hour compared to HPS lighting.

### **3.2.2 Efficient Dehumidification**

#### **3.2.2.1 Technical Feasibility**

Indoor growing facilities would utilize one of the following types of dehumidification equipment: stand-alone dehumidifier less than or equal to 8 cubic feet with minimum energy factor of 1.77 L/kWh; stand-alone dehumidifier greater than 8 cubic feet with minimum energy factor of 2.41 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 four solutions are technically feasible. The intent of the proposed submeasure is to set an industry-accepted code baseline that encourages heat recovery systems and high efficiency stand-alone dehumidifiers. 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**

<b>Equipment Type</b>	<b>Description</b>	<b>Market Availability</b>
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.
Desiccant dehumidification	Uses a substrate to remove moisture. Substrate requires heat to remove moisture and recharge. Used mainly for very low humidity setpoints (<40% relative humidity)	Desiccant dehumidifiers are most commonly used in drying applications. It is efficient at reaching low relative humidity levels, but it does not perform efficiently typical plant growth operating conditions.

Humidity and thermostatic controls are available from both major manufacturers such as Honeywell or from specialty manufacturers. These controls 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 Agronomic IQ, Surna, Quest, Therma-Stor LLC, KCC Manufacturing, and InSpire Transpiration (headquartered in San Francisco, California). 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 manufacturers. Additional agriculture specialists, some of which work in cannabis, include Wadsworth Controls, Autogrow, 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. This

proposal focuses on dehumidification equipment, and there are no proposed regulations on humidification equipment.

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 to all integrated HVAC units. There is no testing procedure which measures moisture removal efficiency under CEH conditions for all applicable dehumidification equipment. 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.



### 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**

<b>Barrier</b>	<b>Solution</b>
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 mold issues and negatively affect targeted CO2 concentration	Based on stakeholder feedback, the Statewide CASE Team proposes to exempt CEH facilities from air-side economizer requirements when CO2 enrichment is used.
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.

Barrier	Solution
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 wall U-factor value requirement of 0.7 or less are single-pane glass, single-layer polyethylene sheeting, and corrugated single-wall polycarbonate. Non-opaque wall U-factor value of 0.7 was chosen in order to align with the IECC 2021 Standards described in Section 2.3.4. For non-opaque roof assemblies, the Statewide CASE Team is also proposing the U-factor value of 0.7 at this time as opposed to the U-factor value of 0.5 for a roof assembly or roof assembly with an internal curtain system according to the IECC 2021 Standards. The lack of industry accepted default U-factor values for internal curtain systems makes it challenging to account for impact from internal curtain systems on the combined U-factor value.

The Statewide CASE Team decided that aligning with the IECC proposal for non-opaque walls would provide insulation values that are achievable by typical greenhouse glazing materials and provide regional consistency on conditioned greenhouse requirements. Materials that meet the proposed requirements are widely available and used currently in the greenhouse industry, including double- and triple-wall polycarbonate, double polyethylene sheeting, and double-pane glass. Alignment across building codes makes it easier for companies working in multiple regions, and states, to design facilities and procure materials in a more efficient manner.

#### 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**

<b>Greenhouse Covering</b>	<b>R-Value</b>	<b>U-Value</b>	<b>Light Transmittance</b>	<b>Cost / Ft<sup>2</sup></b>	<b>Useful Life (Years)</b>
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.

### **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 due to the lack of a clear path to compliance using conventional greenhouse construction methods and materials.

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 applies to newly constructed conditioned greenhouses, the conversion of an unconditioned greenhouse to conditioned, and additions 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**

<b>Barrier</b>	<b>Solution</b>
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 clean up would create greenhouse-specific requirements that utilize common industry technologies.
Compliance with existing envelope requirements is not widely enforced across the state	Proposed code language would allow for wider compliance enforcement by providing required insulation values and construction practices that are commonly employed in the greenhouse industry.

### **3.3 Market Impacts and Economic Assessments**

#### **3.3.1 Impact on Builders**

Builders of CEH structures would be 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).<sup>4</sup> 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**

<b>Construction Sectors</b>	<b>Establishments</b>	<b>Employment</b>	<b>Annual payroll (billions \$)</b>
<b>Commercial</b>	<b>17,273</b>	<b>343,513</b>	<b>\$27.8</b>
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
<b>Industrial, Utilities, Infrastructure, &amp; Other</b>	<b>4,103</b>	<b>96,550</b>	<b>\$9.2</b>
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.

---

<sup>4</sup> 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**

<b>Construction Subsector</b>	<b>Establishments</b>	<b>Employment</b>	<b>Annual Payroll (billions \$)</b>
Commercial building construction	4,508	75,558	\$7.0
Nonresidential poured foundation contractors	504	14,917	\$1.1
Nonresidential structural steel contractors	318	12,044	\$0.9
Nonresidential glass and glazing contractors	280	5,244	\$0.4
Nonresidential roofing contractors	347	8,939	\$0.6
Nonresidential siding contractors	25	396	\$0.1
Nonresidential electrical contractors	3,115	66,951	\$5.6
Nonresidential plumbing and HVAC contractors	2,394	52,977	\$4.5
Nonresidential site preparation contractors	1,157	17,059	\$1.3
All other nonresidential trade contractors	988	17,960	\$1.4

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 regulation 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<sup>5</sup> 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.<sup>6</sup> 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**

<b>Sector</b>	<b>Establishments</b>	<b>Employment</b>	<b>Annual Payroll (billions \$)</b>
Architectural Services <sup>a</sup>	3,704	29,611	\$2.9
Building Inspection Services <sup>b</sup>	824	3,145	\$0.2

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

---

<sup>5</sup> 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 Estadística y Geografía 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.

<sup>6</sup> 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<sup>2</sup> of canopy to tens of thousands of ft<sup>2</sup> 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 one 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**

Sector	Govt.	Establishments	Employment	Annual Payroll (millions \$)
Administration of Housing Programs <sup>a</sup>	State	17	283	\$29.0
	Local	36	2,882	\$205.7
Urban and Rural Development Admin <sup>b</sup>	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.<sup>7</sup> 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

---

<sup>7</sup> 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 Measure Would Have on the California Commercial Construction Sector**

<b>Type of Economic Impact</b>	<b>Employment (jobs)</b>	<b>Labor Income (millions \$)</b>	<b>Total Value Added (millions \$)</b>	<b>Output (millions \$)</b>
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
<b>Total Economic Impacts</b>	<b>1,703</b>	<b>\$109.51</b>	<b>\$161.29</b>	<b>\$272.96</b>

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
<b>Total Economic Impacts</b>	<b>7</b>	<b>\$0.50</b>	<b>\$0.63</b>	<b>\$1.06</b>

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
<b>Total Economic Impacts</b>	<b>5</b>	<b>\$0.44</b>	<b>\$0.60</b>	<b>\$0.82</b>

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.<sup>8</sup> 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 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).<sup>9</sup> 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

---

<sup>8</sup> 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.

<sup>9</sup> 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.**

<b>Year</b>	<b>Net Domestic Private Investment by Businesses, Billions of Dollars</b>	<b>Corporate Profits After Taxes, Billions of Dollars</b>	<b>Ratio of Net Private Investment to Corporate Profits</b>
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**

### **3.4.6 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.

### **3.4.7 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.

### **3.4.8 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, ERS, 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, including photoperiod, used in the energy savings analysis are summarized in Table 25 and Table 26.

**Table 25: Assumptions Used in Indoor Lighting Energy Savings Analysis**

<b>Parameter</b>	<b>Cannabis - Flower</b>	<b>Cannabis - Vegetative</b>	<b>Cannabis - Clone</b>	<b>Leafy Greens</b>	<b>Tomatoes</b>
Canopy Area per Luminaire (ft <sup>2</sup> )	20	24	10	58	56
Photoperiod (hours per day)	12	18	24	18	12
PPFD (μMol/m <sup>2</sup> /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**

<b>Parameter</b>	<b>Cannabis - Flower</b>	<b>Cannabis - Vegetative</b>	<b>Cannabis - Clone</b>	<b>Leafy Greens</b>	<b>Tomatoes</b>
Canopy Area per Luminaire (ft <sup>2</sup> )	20	24	10	58	56
Photoperiod (hours per day)	12	18	24	18	12

PPFD ( $\mu\text{Mol}/\text{m}^2/\text{s}$ )	600	400	200	200	350
Baseline PPE ( $\mu\text{Mol}/\text{J}$ )	1.02	1.02	1.02	1.02	1.02
Proposed PPE ( $\mu\text{Mol}/\text{J}$ )	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. Photoperiod estimates were determined by collecting data from informed stakeholders and market research.

The proposed indoor CEH facility minimum PPE of 2.1 was determined by surveying existing lighting technologies available, analyzing the DesignLights Consortium (DLC) qualified products list (QPL), and vetting the requirement with lighting technology experts. The primary technology type that qualifies is LED lighting technology, but light emitting plasma (LEP) technology may also qualify. Efficacy data listed as PPE for lighting technologies other than LEDs is sparse, and additional test data may prove additional technologies to be eligible.

The proposed PPE level for indoor facilities has been slightly modified since the Draft CASE Report was released for public review in June 2020.<sup>10</sup> Rather than propose a PPE level of 2.1  $\mu\text{Mol}/\text{J}$  the Statewide CASE Team is instead proposing a PPE of up to 2.1  $\mu\text{Mol}/\text{J}$  with consideration for a lower PPE based on stakeholder concerns with the minimum efficacy and its effects on the market and plant growth. This is in direct response to feedback that the Statewide CASE Team has received from stakeholders regarding unique circumstances of the indoor horticulture industry, such as a substantial illicit market to compete against or lack of access to traditional means of financing. The analysis presented in this report demonstrate that a PPE level of 2.1  $\mu\text{Mol}/\text{J}$  is a justifiable code change. Specifically, the cost-effectiveness analysis is outlined in Section 5.1, and the technical feasibility is discussed in Section 3.2.1. Additional

---

<sup>10</sup> The Draft CASE Report can be found online here: <https://title24stakeholders.com/wp-content/uploads/2020/06/NR-CEH-Draft-CASE-Report.pdf>



information is provided in Appendix I. The Energy Commission will review this proposal, the information provided to support setting the minimum at 2.1  $\mu\text{Mol/J}$ , and make an informed final decision.

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 loads were assumed to decrease due to the use of LED lighting. 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.<sup>11</sup>

There are no existing requirements in Title 24, Part 6 that cover the horticultural lighting process loads 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.

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**

<b>Prototype ID</b>	<b>Climate Zone</b>	<b>Parameter Name</b>	<b>Baseline Parameter Value</b>	<b>Proposed Parameter Value</b>
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

<sup>11</sup> 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>.

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 grow facilities 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.

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**

<b>Climate Zone</b>	<b>Electricity Savings (kWh/yr)</b>	<b>Peak Electricity Demand Reductions (kW)</b>	<b>Natural Gas Savings (therms/yr)</b>	<b>TDV Energy Savings (TDV kBtu/yr)</b>
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**

<b>Climate Zone</b>	<b>Electricity Savings (kWh/yr)</b>	<b>Peak Electricity Demand Reductions (kW)</b>	<b>Natural Gas Savings (therms/yr)</b>	<b>TDV Energy Savings (TDV kBtu/yr)</b>
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

### 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 management consulting firm, ERS, 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 are 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 ( $\leq 0.61$ kW/ton full load and $\leq 0.55$ kW/ton IPLV) with no heat recovery for dehumidification air reheat (Table 110.2-D)	2.5%

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 was assumed. Cannabis facilities require different environmental conditions for cloning, vegetative growth, and flowering, and each growth stage was modeled separately.

Table 33 and Table 34 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. Environmental condition estimates were provided by manufacturers, designers, and growers, and the values were vetted by a third-party technical reviewer. The Statewide CASE Team has learned through stakeholder feedback that indoor facilities that install an air-side economizer will often only include the economizer to pass commissioning checks and then disconnect the economizer due to contamination concerns. Thus, there were no economizers included in the HVAC analysis. Accordingly, there was no assumed impact on energy usage of the proposed exception from installing air-side economizers if carbon dioxide enrichment is used.

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

	<b>Flower Room Lights On</b>	<b>Flower Room Lights Off</b>	<b>Veg Room Lights On</b>	<b>Veg Room Lights Off</b>	<b>Clone Room Lights On</b>	<b>Clone Room Lights Off</b>
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 <sup>2</sup> )	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 <sup>1</sup>	N/A	24	N/A
Schedule (hr/day)	12	12	18	6	24	0
Watering rate (gal/ft <sup>2</sup> /day)	0.1138	0.1138	0.0719	0.0719	0.0359	0.0359

1. Lights were assumed to be on from 7AM until 1AM the next day.

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

	<b>Lights On</b>	<b>Lights Off</b>
Temperature (°F)	75	65
RH (%)	60%	60%
Wet bulb temperature (°F)	65.3	56.6
Lighting Power density (W/ft <sup>2</sup> )	17.82	0.0
Lights on (Hour)	7	N/A
Lights off (Hour)	25 <sup>1</sup>	N/A
Schedule (hr/day)	18	6
Watering rate (gal/ ft <sup>2</sup> /day)	0.0719	0.0719

1. Lights were assumed to be on from 7AM until 1AM the next day.



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

	<b>Lights On</b>	<b>Lights Off</b>
Temperature (°F)	75	65
RH (%)	60	60
Wet bulb temperature (°F)	65.3	56.6
Lighting Power density (W/ft <sup>2</sup> )	31.19	0
Lights on (Hour)	7	N/A
Lights off (Hour)	25 <sup>1</sup>	N/A
Schedule (hr/day)	18	6
Watering rate (gal/ft <sup>2</sup> /day)	0.0839	0.0839

<sup>1</sup> Lights were assumed to be on from 7AM until 1AM the next day.

## **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. The prototype facilities were vetted by a third-party technical reviewer, ERS, who have significant experience conducting in energy modeling of CEH facilities. Manufacturers also provided input on watering rates and system sizing. 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<sup>2</sup> 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. Three major crop types were analyzed, tomatoes, greens, and cannabis. These crops represent the typical growth requirements of others crops as well, such as flowers and herbs. 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 <sup>2</sup> )	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<sup>2</sup> of canopy of the prototype building. The 2022 TDV factors<sup>12</sup> 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. The heating and cool loads a building incurs due to outside temperature pales in comparison to the loads used for internal processes. Thus, regardless if the location is predominantly a heating or cooling climate zone, savings will be similar.

Energy savings and peak demand reductions per unit are presented in Table 37 and apply to both new construction, alterations, and additions. Electricity increases associated with this measure are due to an electric penalty for the proposed heat

---

<sup>12</sup> 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>.

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 electricity savings for the first year are expected to range from -0.5 to 0.5 kWh/yr and 0.8 therms/yr depending on climate zone. While electricity savings vary slightly by climate zone, there is minimal difference for natural gas savings.

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

<b>Climate Zone</b>	<b>Electricity Savings (kWh/yr)</b>	<b>Peak Electricity Demand Reductions (W)</b>	<b>Natural Gas Savings (therms/yr)</b>	<b>TDV Energy Savings (TDV kBtu/yr)</b>
1	0.5	0.06	0.8	255
2	0.2	0.02	0.8	246
3	0.3	0.03	0.8	250
4	0.0	(0.01)	0.8	243
5	0.3	0.04	0.8	249
6	0.2	0.02	0.8	251
7	0.2	0.02	0.8	252
8	(0.1)	0.00	0.8	245
9	(0.2)	(0.03)	0.8	242
10	(0.2)	(0.03)	0.8	240
11	(0.4)	(0.05)	0.8	231
12	(0.1)	(0.01)	0.8	240
13	(0.4)	(0.05)	0.8	230
14	(0.5)	(0.04)	0.8	234
15	(1.2)	(0.11)	0.8	212
16	0.1	(0.01)	0.8	250

## 5. Cost and Cost Effectiveness

### 5.1 Horticultural Lighting Minimum Efficacy

#### 5.1.1 Energy Cost Savings Methodology

As with other CASE Reports, 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 in the California Energy Code, the Statewide CASE Team conducted stakeholder outreach in order to determine baseline technologies. The Statewide CASE Team conducted a survey with growers across the state to gather standard practice baseline information. However, due to the low response rate and lack of statistically significant data from the survey, the baseline lighting technology was based on the 2017 U.S. DOE Report on Horticultural Lighting (DOE 2017) and was determined to be single-ended metal halide and HPS luminaires.

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 most popular lighting technology in for vertical farming, and HPS and metal halide lamps comprise over 80 percent of lighting used in 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 2023 dollars in Table 38 and Table 39.

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

<b>Climate Zone</b>	<b>15-Year TDV Electricity Cost Savings (2023 PV\$)</b>	<b>15-Year TDV Natural Gas Cost Savings (2023 PV\$)</b>	<b>Total 15-Year TDV Energy Cost Savings (2023 PV\$)</b>
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 39: 2023 PV TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot of Canopy – New Construction, Alterations, and Additions Greenhouse**

<b>Climate Zone</b>	<b>15-Year TDV Electricity Cost Savings (2023 PV\$)</b>	<b>15-Year TDV Natural Gas Cost Savings (2023 PV\$)</b>	<b>Total 15-Year TDV Energy Cost Savings (2023 PV\$)</b>
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

Incremental first cost is the initial cost to adopt more efficient equipment or building practices when compared to the cost of an equivalent baseline project. Therefore, it was important that the Statewide CASE Team consider first costs in evaluating overall measure cost effectiveness. Incremental first costs are based on data available today and can change over time as markets evolve and professionals become familiar with new technology and building practices.

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 online for many products. Additionally, the Statewide CASE Team directly reached out to Fluence, Lumigrow, Thrive LED, Signify, and Illumitex to obtain price estimates.

The cost 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 luminaires and lamps were used to conduct this cost-effectiveness analysis. The specific luminaires and lamps used in the cost analysis were added to Appendix H. An average cost for single-ended HPS luminaires and lamps was the baseline cost for greenhouse lighting, and the average cost for single-ended HPS luminaires and lamps was the baseline for indoor lighting and also the proposed cost for greenhouse lighting. The average costs for the LED luminaires with a PPE at or above 2.1 was the proposed cost for indoor lighting.

There was no assumed increase in labor costs with this submeasure due to equipment changes, as the proposed submeasure can replace the baseline technology on a one-for-one basis. An assumed labor cost increase of \$400 for an acceptance test technician to verify the proposed lighting controls was included. 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 40 shows the total incremental costs per luminaire for the horticulture lighting submeasure in both greenhouses and indoor facilities. Maintenance costs are described in Section 5.1.4.

**Table 40: 15-Year Lighting Incremental Cost Per Square Foot of Canopy**

<b>Building Type</b>	<b>Incremental Equipment Cost</b>	<b>Incremental Maintenance Cost</b>	<b>Total Incremental Cost</b>
Indoor	\$109.96	(\$37.35)	\$72.61
Greenhouse	\$4.32	\$13.49	\$17.81

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. A 650-watt LED luminaire was utilized as the basis for comparison to a double-ended HPS luminaire. The average proposed indoor lighting equipment cost per luminaire was \$1,274. Horticultural luminaires have an expected useful life of approximately 10 years. A luminaire replacement was factored into the 15-year evaluation period for a total luminaire cost of \$2,548 over the 15-year evaluation period. 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. Due to the required luminaire replacement at year 10 of the 15-year evaluation period, it was assumed that a second luminaire would have to be purchased. Total equipment cost over the 15-year period is \$522.

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 \$175. Total baseline equipment cost per luminaire over the 15-year evaluation period was assumed to be \$350. Cost information for equipment at both the baseline and proposed level of efficiency is noted in Appendix H.

In order to determine per canopy incremental cost, it was assumed that each indoor luminaire illuminates 20 square feet of canopy or 40 square feet of greenhouse space. These average areas per fixture have been provided by lighting designers, growers, and manufacturers and are derived from the required PPFD and listed in Table 25 and Table 26. Incremental equipment cost was derived from subtracting baseline equipment cost from the proposed equipment cost and dividing by the appropriate square footage covered per luminaire.



Incremental costs were calculated in terms of canopy square footage to establish a uniform metric to compare the baseline and proposed scenarios. In getting a cost difference per square foot of canopy, the Statewide CASE Team was able to determine cost savings per square foot of canopy. This will allow growers to assess what degree of savings they can expect depending on the size of their operation. Code language was written in terms of total connected lighting load since this is a metric enforceable by building officials and one that can be easily determined by growers.

There was no assumed incremental cost for the requirement to design the electrical power system serving CEH spaces so horticultural lighting loads are separated from other lighting loads since this is common industry practice.

#### 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 three 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<sup>th</sup> 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 DLC Horticultural QPL (DesignLights Consortium 2019) utilizes 50,000 hours for the expected life of horticultural lighting, as does the CA Electronic Technical Reference Manual (eTRM) entry for high- and low-bay LEDs (California Technical Form n.d.). The CA eTRM entry equates this to a 12-year useful life. Given the average daily run time of 12-18 hours per day for horticultural lighting, a 10-year useful life was used instead of 12 years. The proposed indoor standard did not have maintenance costs assumed as there is no lamp replacement associated with horticultural LED luminaires.

A maintenance cost of \$747 was assumed for baseline code compliance over the 15-year period of analysis for both greenhouse and indoor lighting. This figure was derived from the cost replacement of a single-ended lamp every year. Thus, the indoor LED proposal would save \$747 in maintenance cost over 15 years; this \$747 savings

translates to a reduction in maintenance cost of \$37.35 per canopy square foot using the assumption of 20 square feet per luminaire for indoor grows.

The maintenance cost increase for greenhouse lighting is due to increase in price for a double-ended HPS lamp compared to a single-ended HPS lamp. A single-ended lamp is estimated to be \$50, and a double-ended lamp is estimated to cost \$86. Over 15 years, the incremental maintenance cost per luminaire is \$540. To derive the incremental maintenance cost per square foot, the incremental maintenance cost per luminaire is divided by the 40 square foot of canopy per luminaire to get an incremental maintenance cost per square foot of \$13.49.

There was no assumed change in labor for either indoor or greenhouse lighting.

The baseline and proposed levels for greenhouse facilities assumed a lamp replacement every year and a luminaire replacement every 10 years.

### **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 41 and Table 42 for indoor grow and greenhouse facilities. Cost effectiveness is identical for new construction, alterations, and additions. 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. In fact, the B/C ratio never falls below 2.0 in any climate zone.

**Table 41: 15-Year Cost-Effectiveness Summary Per Square Foot of Canopy – Indoor Lighting**

<b>Climate Zone</b>	<b>Benefits TDV Energy Cost Savings + Other PV Savings<sup>a</sup> (2023 PV\$)</b>	<b>Costs Total Incremental PV Costs<sup>b</sup> (2023 PV\$)</b>	<b>Benefit-to- Cost Ratio</b>
1	\$384.34	\$72.61	5.3
2	\$434.87	\$72.61	6.0
3	\$412.66	\$72.61	5.7
4	\$446.06	\$72.61	6.1
5	\$400.59	\$72.61	5.5
6	\$430.99	\$72.61	5.9
7	\$410.39	\$72.61	5.6
8	\$463.99	\$72.61	6.4
9	\$463.71	\$72.61	6.4
10	\$446.80	\$72.61	6.2
11	\$441.14	\$72.61	6.1
12	\$434.48	\$72.61	6.0
13	\$440.43	\$72.61	6.1
14	\$458.05	\$72.61	6.3
15	\$453.96	\$72.61	6.3
16	\$391.09	\$72.61	5.4

- a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2020). 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 42: 15-Year Cost-Effectiveness Summary Per Square Foot of Canopy – Greenhouse Lighting**

<b>Climate Zone</b>	<b>Benefits TDV Energy Cost Savings + Other PV Savings<sup>a</sup> (2023 PV\$)</b>	<b>Costs Total Incremental PV Costs<sup>b</sup> (2023 PV\$)</b>	<b>Benefit-to- Cost Ratio</b>
1	\$53.16	\$14.50	3.7
2	\$42.12	\$14.50	2.9
3	\$42.60	\$14.50	2.9
4	\$39.85	\$14.50	2.7
5	\$37.18	\$14.50	2.6
6	\$38.18	\$14.50	2.6
7	\$34.74	\$14.50	2.4
8	\$39.43	\$14.50	2.7
9	\$36.93	\$14.50	2.5
10	\$35.44	\$14.50	2.4
11	\$41.72	\$14.50	2.9
12	\$41.37	\$14.50	2.8
13	\$40.72	\$14.50	2.8
14	\$29.49	\$14.50	2.0
15	\$30.60	\$14.50	2.1
16	\$40.25	\$14.50	2.8

- a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2020). 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

### 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 assumed to be the same since the equipment and labor costs are 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 43.

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 43: 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	\$1.18	\$21.55	\$22.74
2	\$0.31	\$21.55	\$21.86
3	\$0.71	\$21.56	\$22.27
4	\$0.04	\$21.56	\$21.59
5	\$0.62	\$21.55	\$22.17
6	\$0.54	\$21.79	\$22.33
7	\$0.53	\$21.91	\$22.44
8	\$0.00	\$21.79	\$21.79
9	(\$0.26)	\$21.79	\$21.53
10	(\$0.40)	\$21.79	\$21.39
11	(\$1.03)	\$21.56	\$20.52
12	(\$0.23)	\$21.56	\$21.32
13	(\$1.13)	\$21.56	\$20.43
14	(\$1.00)	\$21.79	\$20.79
15	(\$2.92)	\$21.79	\$18.87
16	\$0.45	\$21.79	\$22.24

### 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<sup>2</sup> 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 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<sup>2</sup> of canopy. Baseline lighting equipment described in Section 5.1.3 was used to determine internal heat load for HVAC equipment sizing. The total baseline equipment cost for a 5,000 ft<sup>2</sup> facility is \$60,456.

Two code minimum equipment designs were blended based on information from growers, designers, and dehumidification manufacturers on the percent of facilities designed each way. Approximately 90% of the industry utilizes unitary AC and stand-alone dehumidifiers. The other 10% of the industry uses integrated HVAC and dehumidification systems. The total blended code minimum equipment cost for a 5,000 ft<sup>2</sup> facility is \$101,008.

For equipment cost at the proposed efficiency level, equipment cost from manufacturers was provided for the specified operating conditions and canopy size for integrated HVAC and dehumidification units. Costs were found online from grower supply houses for stand-alone dehumidifiers. All incremental costs were then broken down to a cost per square foot of canopy.

As noted in Section 4.2.1, economizers were not assumed to be a part of the HVAC analysis since they are often disconnected. Thus, no cost was assumed.

Table 44 depicts total incremental costs for the efficient dehumidification submeasure. Maintenance cost changes are described in Section 5.2.4.

**Table 44: Incremental Costs for Efficient Dehumidification**

<b>Building Type</b>	<b>Incremental Equipment Cost</b>	<b>Incremental Maintenance Cost</b>	<b>Total Incremental Cost</b>
Indoor – per Square Foot of Canopy	\$8.11	\$0.00	\$8.11

#### **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<sup>th</sup> year is calculated as follows:

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

Maintenance costs were assumed to be negligible. Approximately 90 percent of the facility stock utilizes stand-alone dehumidifiers, and the code minimum requirement for that technology option is a more efficient stand-alone dehumidifier. Maintenance for both baseline and code minimum stand-alone dehumidifiers are equivalent. For systems with baseline equipment that is either a chilled water system or integrated HVAC system, the code minimum version of that equipment has similar maintenance practices and they were assumed to have negligible cost differences between baseline and code minimum equipment.

#### **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.

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 45.

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 45: 15-Year Cost-Effectiveness Summary Per Square Foot of Canopy – Indoor Dehumidification**

<b>Climate Zone</b>	<b>Benefits TDV Energy Cost Savings + Other PV Savings<sup>a</sup> (2023 PV\$)</b>	<b>Costs Total Incremental PV Costs<sup>b</sup> (2023 PV\$)</b>	<b>Benefit-to- Cost Ratio</b>
1	\$22.74	\$8.110	2.80
2	\$21.86	\$8.110	2.70
3	\$22.27	\$8.110	2.75
4	\$21.59	\$8.110	2.66
5	\$22.17	\$8.110	2.73
6	\$22.33	\$8.110	2.75
7	\$22.44	\$8.110	2.77
8	\$21.79	\$8.110	2.69
9	\$21.53	\$8.110	2.65
10	\$21.39	\$8.110	2.64
11	\$20.52	\$8.110	2.53
12	\$21.32	\$8.110	2.63
13	\$20.43	\$8.110	2.52
14	\$20.79	\$8.110	2.56
15	\$18.87	\$8.110	2.33
16	\$22.24	\$8.110	2.74

- a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2020). 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 46:

**Table 46: CalCannabis License Types**

<b>License Type</b>	<b>Indoor Size (ft<sup>2</sup>)</b>	<b>Greenhouse (ft<sup>2</sup>)</b>
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 meets the Title 24, Part 6 alterations threshold, based on equipment useful life for horticultural lighting and HVAC equipment, and would have to comply with the alterations requirements. Table 47 shows estimated crop breakdown for both indoor and greenhouse facility stock:

**Table 47: Facility Stock Crop Type Breakdown**

<b>Building Type</b>	<b>Crop Type</b>	<b>% of Facility Stock</b>
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 48 and Table 49 present the first-year statewide energy and energy cost savings for lighting by climate zone from new constructions and alterations, respectively. Table 50 and Table 51 present the first-year statewide energy and energy cost savings for dehumidification by climate zone from new constructions and alterations, respectively.

**Table 48: Statewide Energy and Energy Cost Impacts – New Construction – Lighting**

<b>Climate Zone</b>	<b>Statewide New Construction Impacted by Proposed Change in 2023 (ft<sup>2</sup> of canopy)</b>	<b>First-Year<sup>a</sup> Electricity Savings (GWh)</b>	<b>First-Year Peak Electrical Demand Reduction (MW)</b>	<b>First-Year Natural Gas Savings (MMTherms)</b>	<b>15-Year Present Valued Energy Cost Savings (million 2023 PV\$)</b>
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
<b>TOTAL</b>	<b>2,678,458</b>	<b>238.50</b>	<b>16.22</b>	<b>N/A</b>	<b>\$545.01</b>

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

**Table 49: Statewide Energy and Energy Cost Impacts – Alterations – Lighting**

<b>Climate Zone</b>	<b>Statewide Alterations Impacted by Proposed Change in 2023 (ft<sup>2</sup> of canopy)</b>	<b>First-Year<sup>a</sup> Electricity Savings (GWh)</b>	<b>First-Year Peak Electrical Demand Reduction (MW)</b>	<b>First-Year Natural Gas Savings (MMTherms)</b>	<b>15-Year Present Valued Energy Cost Savings (million 2023 PV\$)</b>
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
<b>TOTAL</b>	<b>1,617,544</b>	<b>86.47</b>	<b>6.65</b>	<b>N/A</b>	<b>\$197.66</b>

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

**Table 50: Statewide Energy and Energy Cost Impacts – New Construction – Dehumidification**

<b>Climate Zone</b>	<b>Statewide New Construction Impacted by Proposed Change in 2023 (ft<sup>2</sup> of canopy)</b>	<b>First-Year<sup>a</sup> Electricity Savings (GWh)</b>	<b>First-Year Peak Electrical Demand Reduction (MW)</b>	<b>First-Year Natural Gas Savings (MMTherms)</b>	<b>15-Year Present Valued Energy Cost Savings (million 2023 PV\$)</b>
1	24,122	0.01	0.00	0.02	\$0.55
2	46,370	0.01	0.00	0.04	\$1.01
3	175,995	0.05	0.01	0.15	\$3.92
4	32,904	0.00	(0.00)	0.03	\$0.71
5	2,459	0.00	0.00	0.00	\$0.05
6	19,204	0.00	0.00	0.02	\$0.43
7	4,684	0.00	0.00	0.00	\$0.11
8	93,911	(0.00)	0.00	0.08	\$2.05
9	234,074	(0.04)	(0.01)	0.20	\$5.04
10	14,520	(0.00)	(0.00)	0.01	\$0.31
11	20,843	(0.01)	(0.00)	0.02	\$0.43
12	135,831	(0.01)	(0.00)	0.11	\$2.90
13	36,534	(0.01)	(0.00)	0.03	\$0.75
14	85,714	(0.04)	(0.00)	0.07	\$1.78
15	141,451	(0.17)	(0.02)	0.12	\$2.67
16	3,864	0.00	(0.00)	0.00	\$0.09
<b>TOTAL</b>	<b>1,072,478</b>	<b>(0.21)</b>	<b>(0.02)</b>	<b>0.91</b>	<b>\$22.78</b>

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

**Table 51: Statewide Energy and Energy Cost Impacts – Alterations – Dehumidification**

<b>Climate Zone</b>	<b>Statewide Alterations Impacted by Proposed Change in 2023 (ft<sup>2</sup> of canopy)</b>	<b>First-Year<sup>a</sup> Electricity Savings (GWh)</b>	<b>First-Year Peak Electrical Demand Reduction (MW)</b>	<b>First-Year Natural Gas Savings (MMtherms)</b>	<b>15-Year Present Valued Energy Cost Savings (million 2023 PV\$)</b>
1	7,185	0.00	0.00	0.01	\$0.16
2	13,813	0.00	0.00	0.01	\$0.30
3	52,425	0.02	0.00	0.04	\$1.17
4	9,801	0.00	(0.00)	0.01	\$0.21
5	732	0.00	0.00	0.00	\$0.02
6	5,720	0.00	0.00	0.00	\$0.13
7	1,395	0.00	0.00	0.00	\$0.03
8	27,974	(0.00)	0.00	0.02	\$0.61
9	69,726	(0.01)	(0.00)	0.06	\$1.50
10	4,325	(0.00)	(0.00)	0.00	\$0.09
11	6,209	(0.00)	(0.00)	0.01	\$0.13
12	40,461	(0.00)	(0.00)	0.03	\$0.86
13	10,883	(0.00)	(0.00)	0.01	\$0.22
14	25,532	(0.01)	(0.00)	0.02	\$0.53
15	42,135	(0.05)	(0.00)	0.04	\$0.79
16	1,151	0.00	(0.00)	0.00	\$0.03
<b>TOTAL</b>	<b>319,468</b>	<b>(0.06)</b>	<b>(0.01)</b>	<b>0.27</b>	<b>\$6.79</b>

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

Table 52 and Table 53 present first-year statewide savings from new construction, additions, and alterations for lighting and dehumidification, respectively.

**Table 52: 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 (MMTherms )	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
<b>TOTAL</b>	<b>325.0</b>	<b>22.9</b>	<b>N/A</b>	<b>\$742.67</b>

**Table 53: 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 (MMTherms )	15-Year Present Valued Energy Cost Savings (PV\$ million)
New Construction	(0.1)	0.0	0.9	\$256.0
Additions and Alterations	(0.2)	0.0	0.3	\$76.3
<b>TOTAL</b>	<b>(0.3)</b>	<b>0.0</b>	<b>1.2</b>	<b>\$332.2</b>

## 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 of carbon dioxide equivalents (CO<sub>2</sub>e) per GWh based on the average emission factors for the CACX EGRID subregion.



Table 54 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 84.470 metric tons of CO<sub>2</sub>e would be avoided.

**Table 54: First-Year Statewide GHG Emissions Impacts**

Submeasure	Electricity Savings <sup>a</sup> (GWh/yr)	Reduced GHG Emissions from Electricity Savings <sup>a</sup> (Metric Tons CO <sub>2</sub> e)	Natural Gas Savings <sup>a</sup> (MMTherms/yr)	Reduced GHG Emissions from Natural Gas Savings <sup>a</sup> (Metric Tons CO <sub>2</sub> e)	Total Reduced CO <sub>2</sub> e Emissions <sup>a,b</sup> (Metric Tons CO <sub>2</sub> e)
Horticultural Lighting Minimum Efficacy	324.97	78,109	N/A	N/A	78,109
Efficient Dehumidification	(0.27)	(66)	1.18	6,427	6,361
<b>Total</b>	<b>324.70</b>	<b>78,043</b>	<b>1.18</b>	<b>6,427</b>	<b>84,470</b>

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

b. Assumes the following emission factors: 240.4 MTCO<sub>2</sub>e/GWh and 5,454.4 MTCO<sub>2</sub>e/million therms.

### 6.3 Statewide Water Use Impacts

This proposal does not include water savings.

### 6.4 Statewide Material Impacts

For the purposes of this section, the material impacts of a PPE level of 2.1 micromoles per Joule were analyzed. The Statewide CASE Team does not expect any significant material impacts in the dehumidification or greenhouse envelope proposals.

The material impacts from the lighting proposal would come from the transition of HID lights to LEDs. In order to assess the material impact of this proposal, the Statewide CASE Team analyzed online reports documenting material contents of LED, CFL and incandescent lamps and also conducted general research for the contents of HPS lamps. The reports on LEDs, CFLs, and incandescents provided precise estimates of materials in each type of lamp, while the Statewide CASE Team was unable to find such specific analysis for HPS lamps. However, typical material contents of HPS lamps were determined. While material content of LED lamps used for indoor lighting may not directly translate to that of LED grow lights, it was determined that this was the best available information.

Notably, the Statewide CASE Team expects to see a decrease of mercury since HID's contain mercury while LEDs do not. One single-ended HPS grow lamp contains an estimated 39 mg of mercury (LEDVANCE n.d.). This level was used as an estimation for the typical HPS lamp. When extrapolated out to the estimate statewide canopy stock, mercury content is expected to decrease by roughly 11 pounds in the first year. Based on relevant studies and online research, the Statewide CASE Team does not expect a change in the use of lead, steel, or plastic (Lim, et al. 2013). According to a study, the LEDs examined did not contain detectable levels of arsenic, so for the purposes of this code proposal, there is no assumed change in arsenic impacts (Lim, et al. 2013). Similarly, in this study, LED lamps contain levels of copper in between that of CFLs and incandescents, and as mentioned, the Statewide CASE Team, was unable to find specific levels of copper in HPS bulbs, so there was no assumed change in the copper impacts. While the Statewide CASE Team is not aware of information showing precise estimates of copper in HPS lamps, many lamps do contain copper ballasts.

The study mentioned above indicates increases in silver, chromium, and gallium in LEDs compared to incandescents and CFLs (Lim, et al. 2013). HPS lamps do not typically contain detectable levels of these elements, so increases in these metals are expected.

**Table 55: First-Year Statewide Impacts on Material Use**

Material	Impact (I, D, or NC) <sup>a</sup>	Impact on Material Use (pounds/year)	
		Per-Unit Impacts	First-Year <sup>b</sup> Statewide Impacts
Mercury	D	0.00017	11.95
Lead	NC	N/A	N/A
Copper	NC	N/A	N/A
Steel	NC	N/A	N/A
Plastic	NC	N/A	N/A
Arsenic	NC	N/A	N/A
Silver	I	0.00024	16.70
Chromium	I	0.00018	12.56
Gallium	I	0.00016	11.34

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.

## 6.5 Other Non-Energy Impacts

The proposed indoor horticultural lighting minimum efficacy requirement would require the use of LED lighting. Anecdotal evidence from a couple of 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 adjusting to the technology to produce similar yields to the legacy technologies that are more familiar to many growers. Yield concerns were addressed in Section 3.2.1 as part of the market barriers and solutions. Stakeholder comments related to yield and quality concerns are listed in Appendix L.

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.

One non-energy benefit associated with the proposed indoor lighting minimum efficacy is reduced maintenance cost. The baseline technology requires lamp replacement annually to maintain rated light intensity, whereas LED technology commonly has a 50,000-hour rated life. This results in elimination of lamp replacements.

The Statewide CASE Team received comments noting that cannabis growers already must abide by the California Environmental Quality Act (CEQA) and that this proposal may be redundant. CEQA does not mandate specific efficiency levels for lighting or dehumidification technology. In fact, one potential environment impact that CEQA attempts to prevent is the wasteful use of energy (Bureau of Cannabis Control 2017). This proposal is in line with the CEQA aim.

## 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).

~~GREENHOUSE or~~ GARDEN WINDOW (also known as greenhouse window) is a window unit that consists of a three-dimensional, five-sided structure generally protruding from the wall in which it is installed. Operating sash may or may not be included.

**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, controlled environment horticulture spaces, refrigerated warehouses, commercial refrigeration, compressed air systems, and process boilers.

**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 X1 to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Dehumidifiers.”

**CONTROLLED ENVIRONMENT HORTICULTURE** definitions:

**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, mechanical heating, mechanical cooling, or dehumidification. 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 system** is mechanical dehumidification technology that uses 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 percent or more above the growing area.

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

**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 percent. Growing plants in a warehouse with or without skylights is an example of an indoor growing.

**Integrated HVAC system** is an HVAC system designed to handle both sensible and latent heat removal. Integrated HVAC systems may include, but are not limited to, HVAC systems with a sensible heat ratio of 0.65 or less and the capability of providing cooling, dedicated outdoor air systems, single package air conditioners with at least one refrigerant circuit providing hot gas reheat, and stand-alone dehumidifiers modified to allow external heat rejection.

**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.

**Stand-Alone Dehumidifier** means a product with the sole purpose of dehumidifying the space and does not include a portable air conditioner, room air conditioner, or packaged terminal air conditioner. Stand-alone dehumidifier is a self-contained, electrically operated, and mechanically encased assembly consisting of 1) a refrigerated surface (evaporator) that condenses moisture from the atmosphere, 2) a refrigerating system, including an electric motor, 3) an air-circulating fan, and 4) a means for collecting or disposing of the condensate.

## SECTION 110.6 – MANDATORY REQUIREMENTS FOR FENESTRATION PRODUCTS AND EXTERIOR DOORS

### (a) Certification of Fenestration Products and Exterior Doors other than Field-fabricated.

[...]

2. **U-factor.** The fenestration product and exterior door's U-factor shall be rated in accordance with NFRC 100, or use the applicable default U-factor set forth in TABLE 110.6-A.

TABLE 110.6-A DEFAULT FENESTRATION PRODUCT U-FACTORS

Frame	Product Type	Single Pane	Double Pane	Glass Block
-------	--------------	-------------	-------------	-------------

		U-Factor	U-Factor	U-Factor
Metal	Operable	1.28	0.79	0.87
	Fixed	1.19	0.71	0.72
	Greenhouse/garden window	2.26	1.40	N.A.
	Glazed Doors	1.25	0.77	N.A.
	Skylight	1.98	1.30	N.A.
Metal, Thermal Break	Operable	N.A.	0.66	N.A.
	Fixed	N.A.	0.55	N.A.
	Greenhouse/garden window	N.A.	1.12	N.A.
	Glazed Doors	N.A.	0.59	N.A.
	Skylight	N.A.	1.11	N.A.
Nonmetal	Operable	0.99	0.58	0.60
	Fixed	1.04	0.55	0.57
	Glazed Doors	0.99	0.53	N.A.
	Greenhouse/garden windows	1.94	1.06	N.A.
	Skylight	1.47	0.84	N.A.

## 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. Space-conditioning systems and insulation used for plant production shall comply with all applicable requirements of Part 6.
2. Indoor Growing, Dehumidification. Dehumidification equipment shall be one of the following:
  - A. Stand-alone dehumidifiers that meet the following minimum integrated energy factors as measured by the test conditions in Appendix X1 to Subpart B of Part 430:
    - i. Minimum integrated energy factor of 1.77 L/kWh for product case volumes of 8.0 cubic feet or less;
    - ii. Minimum integrated energy factor of 2.41 L/kWh for product case volumes greater than 8.0 cubic feet.
  - B. Integrated HVAC system with on-site heat recovery designed to fulfill at least 75 percent of the annual energy for dehumidification reheat;
  - C. Chilled water system with on-site heat recovery designed to fulfill at least 75 percent of the annual energy for dehumidification reheat; or
  - D. Solid or liquid desiccant dehumidification system for system designs that require dewpoint of 50°F or less.

3. **Indoor Growing, Horticultural Lighting.** In a building with CEH spaces and with more than 40 kW of aggregate horticultural lighting load, 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 at least 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).
4. **Indoor Growing, Electrical Power Distribution Systems.** Electrical power distribution system serving CEH spaces shall be designed so that a measurement device is capable of monitoring the electrical energy usage of aggregate horticultural lighting load.
5. **Conditioned Greenhouses, Building Envelope.** Conditioned greenhouse shall meet the following requirements:
  - A. Opaque wall and opaque roof assembly shall meet the requirements of Section 120.7.
  - B. Non-opaque wall assembly shall have a combined U-factor of 0.7 or less. Non-opaque roof assembly shall have a combined U-factor of 0.7 or less. Refer to Table 120.6-D for default U-factors for greenhouse coverings.

**TABLE 120.6-D DEFAULT U-FACTORS FOR GREENHOUSE COVERINGS**

<b><u>Greenhouse Covering</u></b>	<b><u>U-Factor</u></b>
<u>Glass, Single Pane, 3mm</u>	<u>1.05</u>
<u>Glass, Double Pane</u>	<u>0.7</u>
<u>Polycarbonate, Corrugated Single Wall</u>	<u>1.2</u>
<u>Polycarbonate, Double Wall, 4mm</u>	<u>0.7</u>
<u>Polycarbonate, Double Wall, 6mm</u>	<u>0.65</u>
<u>Polycarbonate, Double Wall, 8mm</u>	<u>0.63</u>
<u>Polycarbonate, Double Wall, 10mm</u>	<u>0.53</u>
<u>Polycarbonate, Triple Wall, 8mm</u>	<u>0.5</u>
<u>Polyethylene Film, Single</u>	<u>1.2</u>
<u>Polyethylene Film, Double</u>	<u>0.7</u>

6. **Conditioned Greenhouses, Space-Conditioning Systems.** Space-conditioning systems used for plant production shall comply with all applicable requirements of Part 6.
7. **Greenhouses, Horticultural Lighting.** In a greenhouse with more than 40 kW of aggregate horticultural lighting load, the electric lighting system used for plant growth and plant maintenance shall meet the following requirements:
  - A. Luminaires shall have photosynthetic photon efficacy of at least 1.7 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, applicable sections of NA7.6.2.
- C. Multilevel lighting controls shall be installed and comply with Section 130.1(b).

## SECTION 130.1 – MANDATORY INDOOR LIGHTING CONTROLS

### (c) Shut-OFF Controls.

1. In addition to lighting controls installed to comply with Sections 130.1(a) and (b), all installed indoor lighting shall be equipped with controls that meet the following requirements:

[...]

- D. Separate controls for general, display, ornamental, ~~and~~ display case lighting, and horticultural lighting; and

[...]

4. If an automatic time-switch control, other than an occupant sensing control, is installed to comply with Section 130.1(c)1, it shall incorporate an automatic holiday "shut-OFF" feature that turns OFF all loads for at least 24 hours, and then resumes the normally scheduled operation.

**EXCEPTION to Section 130.1(c)4:** In retail stores and associated malls, restaurants, grocery stores, churches, ~~and~~ theaters, and controlled environment horticulture spaces, the automatic time-switch control is not required to incorporate an automatic holiday shut-OFF feature.

## 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)5 apply.

### (a) 6. Skylights.

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

### (c) Minimum Daylighting Requirement for Large Enclosed Spaces.

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

## SECTION 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS



(e) Economizers.

**EXCEPTION 7 to Section 140.4(e)1:** Where the use of an air economizer in controlled environment horticulture spaces will affect crop health, or dehumidification system, or carbon dioxide enrichment system.

## 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)1 and 120.6(h)2.
2. **Greenhouses, Building Envelope and Space-Conditioning Systems.** A greenhouse being converted to the conditioned greenhouse or additions to a conditioned greenhouse shall meet the requirements of Sections 120.6(h)5 and 120.6(h)6.
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 horticultural luminaires serving an enclosed space shall meet the requirements of Section 120.6(h)3 for indoor growing or Section 120.6(h)7 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. The Statewide CASE Team does not propose new acceptance test(s).

### 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)).

The Compliance Manual should also clarify that water economizers are required for CEH facilities under prescriptive compliance path when water chilled systems are installed for cooling.

### 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. Specifically, horticulture facilities would need to be added as a building option from which to choose. Additionally, new tables would be added to note whether the relevant

dehumidification efficiency, lighting efficacy, and greenhouse envelope requirements have been met.

## 8. Bibliography

n.d. [http://bees.archenergy.com/Documents/Software/CBECC-Com\\_2016.3.0\\_SP1\\_Prototypes.zip](http://bees.archenergy.com/Documents/Software/CBECC-Com_2016.3.0_SP1_Prototypes.zip).

Akbari, Hasheem. 2006. *Inclusion of Solar Reflectance*. May 18. Accessed December 3, 2019. [http://title24stakeholders.com/wp-content/uploads/2017/10/2008\\_CASE-Report\\_PGE-Inclusion-of-Solar-Reflectance-and-Thermal-Emittance-Prescriptive-Requirements.pdf](http://title24stakeholders.com/wp-content/uploads/2017/10/2008_CASE-Report_PGE-Inclusion-of-Solar-Reflectance-and-Thermal-Emittance-Prescriptive-Requirements.pdf).

Akbari, Hashem. 2003. "2005 CASE Report Inclusion of Cool Roofs in Nonresidential Title 24 Prescriptive Requirements."

Akbari, Hashem. 2001. "Cool Surfaces and Shade Trees to Reduce Energy Use and Improve Air Quality in Urban Areas ." Berkeley, CA.

—. 2001. *Cool Surfaces and Shade Trees to Reduce Energy Use and Improve Air Quality in Urban Areas*. Accessed December 19, 2019. [https://www.researchgate.net/publication/222581591\\_Cool\\_Surfaces\\_and\\_Shade\\_Trees\\_to\\_Reduce\\_Energy\\_Use\\_and\\_Improve\\_Air\\_Quality\\_in\\_Urban\\_Areas](https://www.researchgate.net/publication/222581591_Cool_Surfaces_and_Shade_Trees_to_Reduce_Energy_Use_and_Improve_Air_Quality_in_Urban_Areas).

Akbari, Hashem. 2001. "Cool Surfaces and Shade Trees to Reduce Energy Use and Improve Air Quality in Urban Areas."

Akbari, Hashem. 2001. "Cool Surfaces and Shade Trees to Reduce Energy Use and Improve Air Quality in Urban Areas."

—. 2001. *Cool Surfaces and Shade Trees to Reduce Energy Use and Improve Air Quality in Urban Areas*. Accessed 2020. <https://www.sciencedirect.com/science/article/abs/pii/S0038092X0000089X>.

—. 2006. *Inclusion of Solar Reflectance and Thermal Emittance Prescriptive Requirements for Steep-Sloped Nonresidential Roofs in Title 24*. Accessed December 18, 2019. <https://eta.lbl.gov/publications/inclusion-solar-reflectance-thermal>.

Akbari, Hashem, and Ronnen Levinson. 2008. *Status of cool roof standards in the United States*. June. Accessed 2020. <https://pdfs.semanticscholar.org/a2fa/a1e838b83d062dd4b9b603bbb7811d77fe86.pdf>.

Alibaba. n.d. *6063-T5 Aluminum extruded blade with powder coating*. Accessed January 20, 2020. [https://sunlouver.en.alibaba.com/productgroupdetail-804911927/Aluminum\\_Sunshade.html?spm=a2700.icbuShop.98.4.681b213ftDkl8z](https://sunlouver.en.alibaba.com/productgroupdetail-804911927/Aluminum_Sunshade.html?spm=a2700.icbuShop.98.4.681b213ftDkl8z).

- Alpen HPP. n.d. "Advantages of Insulated Glass." Accessed March 2, 2020.  
<https://thinkalpen.com/wp-content/uploads/advantages-of-suspended-film-proof-revised20121126.pdf>.
- Altan, Hasim, et al. 2019. *An experimental study of the impact of cool roof on solar PV electricity generations on building rooftops in Sharjah, UAE*. February. Accessed 2020. <https://academic.oup.com/ijlct/article/14/2/267/5307064>.
- American Society of Agricultural and Biological Engineers. 2017. "Quantities and Units of Electromagnetic Radiation for Plants (Photosynthetic Organisms)." *ASABE*. July. Accessed December 11, 2019.  
<https://elibrary.asabe.org/abstract.asp?aid=48303&t=2&redir=&redirType>.
- ASHRAE. 2019. "ASHRAE Plant and Animal Environment, Technical Committee 2.2." January. Accessed April 4, 2020.  
<http://tc0202.ashraetcs.org/documents/meeting-information/TC0202%20Draft%20Atlanta%20Minutes%2020190114.docx>.
- ASHRAE Journal. 2019. "Eliminating Overcooling Discomfort While Saving Energy." April. Accessed 2020.  
[http://www.nxtbook.com/nxtbooks/ashrae/ashraejournal\\_201904/index.php#/16](http://www.nxtbook.com/nxtbooks/ashrae/ashraejournal_201904/index.php#/16).
- ASHRAE. 2015. "Research Project (RP) 1515." *Effects of Diffuser Airflow Minima on Occupant Comfort, Air Mixing, and Building Energy Use*. Accessed 2020.  
<https://escholarship.org/uc/item/6kj9t7cj>.
- ASHRAE. 2019. "Standard 90.1." In *Energy Standard for Buildings Except Low-Rise Residential Buildings*, by ASHRAE.
- BDS Analytics. 2019. *California: The Golden Opportunity?* Accessed 2020.  
[https://bdsanalytics.com/wp-content/uploads/2019/01/BDS\\_2018\\_California\\_Golden\\_Opportunity\\_Exec\\_Summary.pdf](https://bdsanalytics.com/wp-content/uploads/2019/01/BDS_2018_California_Golden_Opportunity_Exec_Summary.pdf).
- BESS Labs. n.d. *Agricultural and Biological Engineering, University of Illinois at Urbana-Champaign*. Accessed December 6, 2019. <http://bess.illinois.edu/type.asp#>.
- Brentlinger, Paul. 2019. *Five Factors to Consider Before You Begin Growing Cannabis*.  
<https://www.greenhousegrower.com/production/five-factors-to-consider-before-you-begin-growing-cannabis/>.
- Bureau of Cannabis Control. 2017. *Commercial Cannabis*.  
[https://www.bcc.ca.gov/law\\_regs/ceqa\\_executive\\_summary.pdf](https://www.bcc.ca.gov/law_regs/ceqa_executive_summary.pdf).
- BW Research Partnership. 2016. *Advanced Energy Jobs in California: Results of the 2016 California Advanced Energy*. Advanced Energy Economy Institute.

- CA Department of Food & Agriculture. 2020. *CalCannabis Cultivation Licensing*. Accessed 2020.  
<https://aca6.accela.com/CALCANNABIS/Cap/CapHome.aspx?module=Licenses>.
- CalCannabis. 2017. *Cannabis Cultivation Update*.  
<https://static.cdfa.ca.gov/MCCP/document/2017%201206%20Cannabis%20Cultivation%20Regulations%20Update.pdf>.
- California Air Resources Board. 2019. "Global Warming Potentials."  
<https://www.arb.ca.gov/cc/inventory/background/gwp.htm#transition>.
- California Code of Regulations (CCR). n.d. "Title 3." *CDFA*. Accessed December 11, 2019.  
[https://static.cdfa.ca.gov/MCCP/document/CDFA%20Final%20Regulation%20Text\\_01162019\\_Clean.pdf](https://static.cdfa.ca.gov/MCCP/document/CDFA%20Final%20Regulation%20Text_01162019_Clean.pdf).
- California Department of Water Resources. 2016. "California Counties by Hydrologic Regions." Accessed April 3, 2016.  
<http://www.water.ca.gov/landwateruse/images/maps/California-County.pdf>.
- California Energy Commission. 2001. "2001 Energy Efficiency Standards for Residential and Nonresidential Buildings."
- . 2015. *2016 Building Energy Efficiency Standards: Frequently Asked Questions*.  
[http://www.energy.ca.gov/title24/2016standards/rulemaking/documents/2016\\_Building\\_Energy\\_Efficiency\\_Standards\\_FAQ.pdf](http://www.energy.ca.gov/title24/2016standards/rulemaking/documents/2016_Building_Energy_Efficiency_Standards_FAQ.pdf).
- California Energy Commission. 2012. "Building Energy Efficiency Standards for Residential and Nonresidential Buildings."
- . 2018. *California's Fourth Climate Change Assessment*. August. Accessed January 21, 2020. <https://www.energy.ca.gov/sites/default/files/2019-07/Statewide%20Reports-%20SUM-CCCA4-2018-013%20Statewide%20Summary%20Report.pdf>.
- . 2006. *Cool Roofs in California's Title 24 Building Energy Efficiency Code*. February 13. Accessed November 22, 2019.  
<https://coolroofs.org/documents/CRRCLasVegasupdatedOct06.ppt>.
- . 2022. "Energy Code Data for Measure Proposals." *energy.ca.gov*.  
[https://www.energy.ca.gov/title24/documents/2022\\_Energy\\_Code\\_Data\\_for\\_Measure\\_Proposals.xlsx](https://www.energy.ca.gov/title24/documents/2022_Energy_Code_Data_for_Measure_Proposals.xlsx).
- . 2019. "Housing and Commercial Construction Data - Excel."  
[https://ww2.energy.ca.gov/title24/documents/2022\\_Energy\\_Code\\_Data\\_for\\_Measure\\_Proposals.xlsx](https://ww2.energy.ca.gov/title24/documents/2022_Energy_Code_Data_for_Measure_Proposals.xlsx).

- . 2018. "Impact Analysis: 2019 Update to the California Energy Efficiency Standards for Residential and Non-Residential Buildings." *energy.ca.gov*. June 29. [https://www.energy.ca.gov/title24/2019standards/post\\_adoption/documents/2019\\_Impact\\_Analysis\\_Final\\_Report\\_2018-06-29.pdf](https://www.energy.ca.gov/title24/2019standards/post_adoption/documents/2019_Impact_Analysis_Final_Report_2018-06-29.pdf).
- California Legislative Information. 2019. *AB-660 Building energy efficiency standards: solar reflectance of roofs*. Accessed 2020. [https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill\\_id=201920200AB660](https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200AB660).
- California Public Utilities Commission (CPUC). 2015b. "Water/Energy Cost-Effectiveness Analysis: Revised Final Report." Prepared by Navigant Consulting, Inc. <http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5360>.
- California Public Utilities Commission. 2015a. "Water/Energy Cost-Effectiveness Analysis: Errata to the Revised Final Report." Prepared by Navigant Consulting, Inc. . <http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5350>.
- California Technical Form. n.d. *CA Electronic Technical Reference Manual*. <https://www.caetrm.com/measure/SWLG011/02/>.
- Cannabis Business Times. 2020. *Cannabis Cultivation Lighting Research Shows Shifts in Technology, Grower Practices*. October. <https://www.cannabisbusinesstimes.com/article/cannabis-lighting-research-2020-cultivators-growers/>.
- . 2019. *State of the Cannabist Lighting Market*. <https://www.cannabisbusinesstimes.com/form/2019-state-lighting-industry/>.
- CASE, California Statewide Codes and Standards Enhancement Team. 2019. *Nonresidential Envelope Part 1*. October 24. [https://title24stakeholders.com/wp-content/uploads/2019/07/Nonresidential-High-Performance-Envelope-%E2%80%93-Part-1\\_MASTER.pdf](https://title24stakeholders.com/wp-content/uploads/2019/07/Nonresidential-High-Performance-Envelope-%E2%80%93-Part-1_MASTER.pdf).
- CASE: Fan Control and Economizer, Codes and Standards Enhancement Initiative. 2011. "Fan Control and Economizer." 2013. September. [https://title24stakeholders.com/wp-content/uploads/2020/01/2013\\_CASE-Report\\_Fan-Control-and-Integrated-Economizers.pdf](https://title24stakeholders.com/wp-content/uploads/2020/01/2013_CASE-Report_Fan-Control-and-Integrated-Economizers.pdf).
- CASE: Light Commercial Unitary, Codes and Standards Enhancement Initiative. 2011. "Light Commercial Unitary." 2013. November. Accessed 2020. [http://title24stakeholders.com/wp-content/uploads/2017/10/2013\\_CASE-Report\\_Light-Commercial-Unitary-HVAC.pdf](http://title24stakeholders.com/wp-content/uploads/2017/10/2013_CASE-Report_Light-Commercial-Unitary-HVAC.pdf).
- CASE: Reduce Reheat, Codes and Standards Enhancement Initiative. 2011. "Reduce Reheat." 2013. September. [http://title24stakeholders.com/wp-content/uploads/2017/10/2013\\_CASE-Report\\_Reduce-Reheat.pdf](http://title24stakeholders.com/wp-content/uploads/2017/10/2013_CASE-Report_Reduce-Reheat.pdf).



- Caulkins, Jonathan, Matthew Cohen, and Luigi Zamarra. 2014. *Estimating Adequate Licensed Square Footage for Production*. Accessed 2020.  
[https://lcb.wa.gov/publications/Marijuana/BOTEC%20reports/5a\\_Cannabis\\_Yields-Final.pdf](https://lcb.wa.gov/publications/Marijuana/BOTEC%20reports/5a_Cannabis_Yields-Final.pdf).
- CBECC-Com. 2019.
- . 2019. <http://www.bwilcox.com/BEES/cbecc2019.html>.
- . 2022. <http://bees.archenergy.com/software2022.html>.
- Chao, Julie. 2018. "'Super Window' Could Save \$10 Billion Annually in Energy Costs." June 6. <https://newscenter.lbl.gov/2018/06/06/super-window-could-save-billions-in-energy-costs/>.
- City of Denver. 2019. *AMENDMENTS TO THE BUILDING AND FIRE CODE*. Accessed 2020.  
[https://www.denvergov.org/content/dam/denvergov/Portals/696/documents/Denver\\_Building\\_Code/2019-code-update/2019\\_final\\_amendments.pdf](https://www.denvergov.org/content/dam/denvergov/Portals/696/documents/Denver_Building_Code/2019-code-update/2019_final_amendments.pdf).
- . 2019. *Amendments to the Building and Fire Code*. Accessed 2020.  
[https://www.denvergov.org/content/dam/denvergov/Portals/696/documents/Denver\\_Building\\_Code/2019-code-update/2019\\_final\\_amendments.pdf](https://www.denvergov.org/content/dam/denvergov/Portals/696/documents/Denver_Building_Code/2019-code-update/2019_final_amendments.pdf).
- City of Santa Rosa. n.d. *Building and Fire Code Requirements for Cannabis Related Occupancies*. Accessed December 3, 2019.  
<https://www.srcity.org/DocumentCenter/View/22641/Cannabis-Related-Occupancies---Building-and-Fire-Code-Requirements?bidId=>.
- City of Seattle. n.d. *Commercial Energy Efficiency*. Accessed December 3, 2019.  
<http://www.seattle.gov/documents/Departments/SDCI/Codes/SeattleEnergyCode/2015SECCCommercialChapter4.pdf>.
- ConstructConnect Research. 2020. *Construct Connect Insight*. 02 01. Accessed 02 01, 2020. <https://www.constructconnect.com/>.
- Cool Roof Rating Council. 2016. "ANSI/CRRC S100 (2016)." *Cool Roof Rating Council*. Accessed December 17, 2019. [https://coolroofs.org/documents/ANSI-CRRC\\_S100-2016\\_Final.pdf](https://coolroofs.org/documents/ANSI-CRRC_S100-2016_Final.pdf).
- . n.d. *Cool Roof Rating Council*. Accessed December 10, 2019.  
<https://coolroofs.org/directory>.
- . n.d. *Rapid Rating*. Accessed January 13, 2020. <https://coolroofs.org/product-rating/rate-a-product#tab-6>.
- . 2008. *Title 24 Updated: Summary of 2008 Changes to California's Cool Roof Requirements*. May. Accessed November 22, 2019.  
[https://coolroofs.org/documents/California\\_Title\\_24\\_2008\\_Summary.pdf](https://coolroofs.org/documents/California_Title_24_2008_Summary.pdf).



- CRRC. n.d. *Why Cool Roofs Are Way Cool*. Accessed January 21, 2020.  
[https://coolroofs.org/documents/IndirectBenefitsofCoolRoofs-WhyCRareWayCool\\_000.pdf](https://coolroofs.org/documents/IndirectBenefitsofCoolRoofs-WhyCRareWayCool_000.pdf).
- Curcija, Charlie, Howdy Goudey, Robert Hart, and Steve Selkowitz. 2019. "Triple Glazing with Thin Non-Structural Center Glass." *Lawrence Berkeley National Laboratory, Windows & Daylighting*. <https://windows.lbl.gov/triple-glazing-thin-non-structural-center-glass>.
- Dean, Edward. 2014. *Zero Net Energy Case Study Buildings, Volume 1*. Pacific Gas and Electric Company.
- Dean, Edward, and Peter Turnbull. 2018. *Zero Net Energy Cast Study Buildings, Vol 1, 2, 3*. PG&E.
- Deng, Shihan. 2014. *Energy Benefits of Different Dedicated Outdoor Air Systems Configurations In Various Climates*. Dissertation, University of Nebraska-Lincoln.
- Denver GOV. 2019. *Denver Gov.org*. 04 25. Accessed 02 12, 2020.  
[https://www.denvergov.org/content/dam/denvergov/Portals/696/documents/Denver\\_Building\\_Code/2019-code-update/iecc/\(p54\)352\\_IECC\\_C406\\_PointsOptions.pdf](https://www.denvergov.org/content/dam/denvergov/Portals/696/documents/Denver_Building_Code/2019-code-update/iecc/(p54)352_IECC_C406_PointsOptions.pdf).
- Design Light Consortium. n.d. *Technical Requirements for Horticultural Lighting V1.2*. Accessed December 2019, 2019. <https://www.designlights.org/horticultural-lighting/technical-requirements/>.
- DesignLights Consortium. 2020. *Horticultural Lighting*. Accessed May 2020.  
<https://www.designlights.org/horticultural-lighting/search/>.
- . 2019. "Qualified Products List." *DesignLights Consortium*. Accessed December 2019, 2019. <https://www.designlights.org/horticultural-lighting/search/>.
- DiPetro, Michael et al. 2014. *Study Targets Cool Roofs*. Accessed 2020.  
<https://www.roofingcontractor.com/articles/90602-study-targets-cool-roofs>.
- Dodson, Marc, interview by Simon Silverberg. 2019. *Western Roofing market survey* (November 1).
- DOE. 2015. *Adoption of LightEmitting Diodes in*.  
[https://www.energy.gov/sites/prod/files/2015/07/f25/led-adoption-report-summary\\_2015\\_1.pdf](https://www.energy.gov/sites/prod/files/2015/07/f25/led-adoption-report-summary_2015_1.pdf).
- . 2017. *Energy Savings Potential of SSL in Horticultural Applications*. Accessed 2020.  
[https://www.energy.gov/sites/prod/files/2017/12/f46/ssl\\_horticulture\\_dec2017.pdf](https://www.energy.gov/sites/prod/files/2017/12/f46/ssl_horticulture_dec2017.pdf).
- Dorbian, Iris. 2019. *California Is World's Biggest Legal Pot Market, Says New Report*.  
<https://www.forbes.com/sites/irisdorbian/2019/08/15/california-is-worlds-biggest-legal-pot-market-says-new-report/#2028aabd4cd7>.

- Dregger, Phil. 2012. *Cool Roofs Cause Condensation, Fact or Fiction?* . Accessed January 21, 2020. <http://rci-online.org/wp-content/uploads/2013-03-dregger.pdf>.
- Edwards, L., and P. Torcellini. 2002. *A Literature Review of the Effects of Natural Light on Building Occupants*. Golden, CO: National Renewable Energy Laboratory.
- Efficient Windows Collaborative. 2019. *Incentives and Rebates for Energy-Efficient Windows Offered through Utility and State Programs*. <https://www.efficientwindows.org/downloads/UtilityIncentivesWindows.pdf>.
- Energy + Environmental Economics. 2016. "Time Dependent Valuation of Energy for Developing Building Efficiency Standards: 2019 Time Dependent Valuation (TDV) Data Sources and Inputs." Prepared for the California Energy Commission. July. [http://docketpublic.energy.ca.gov/PublicDocuments/16-BSTD-06/TN212524\\_20160801T120224\\_2019\\_TDV\\_Methodology\\_Report\\_7222016.pdf](http://docketpublic.energy.ca.gov/PublicDocuments/16-BSTD-06/TN212524_20160801T120224_2019_TDV_Methodology_Report_7222016.pdf).
- Energy + Environmental Economics. 2020. "Time Dependent Valuation of Energy for Developing Building Efficiency Standards: 2022 Time Dependent Valuation (TDV) and Source Energy Metric Data Sources and Inputs."
- Energy Efficient Codes Coalition. 2020. *Summary of IECC2021 Proposals*. March 20. <https://energyefficientcodes.org/wp-content/uploads/EECC-CE-Online-Voting-Guide-11-8-19.pdf>.
- ENERGY STAR. 2019. *Dehumidifiers Key Efficiency Criteria*. October. Accessed April 4, 2020. [https://www.energystar.gov/products/appliances/dehumidifiers/key\\_efficiency\\_criteria](https://www.energystar.gov/products/appliances/dehumidifiers/key_efficiency_criteria).
- . n.d. *Qualified Products List*. Accessed December 18, 2019. <https://www.energystar.gov/productfinder/product/certified-roof-products/>.
- Energy Trust of Oregon. 2017. *Cannabis Market Research*. August. Accessed 2020. [https://www.energytrust.org/wp-content/uploads/2017/11/Cannabis-Market-Research\\_FORWEBPOSTING\\_2017\\_FINAL.pdf](https://www.energytrust.org/wp-content/uploads/2017/11/Cannabis-Market-Research_FORWEBPOSTING_2017_FINAL.pdf).
- . 2017b. "Hifi Farms shines a new light on cannabis cultivation." *Energy Trust of Oregon*. July. Accessed December 2019, 2019. <https://blog.energytrust.org/hifi-farms-shines-new-light-cannabis-cultivation/>.
- Energy Upgrade California. 2014. "Radiant Heating and Cooling + Dedicated Outdoor Air Systems." *Zero Net Energy Technology Application Guide*.
- EPA. n.d. *Heat Island Effect*. Accessed December 30, 2019. <https://www.epa.gov/heat-islands>.

- EPCA, Energy Policy Act of 2005. 2005. [https://www.ecfr.gov/cgi-bin/text-idx?SID=7f0e02c7c5c8e6367edd977ee4f79032&mc=true&node=se10.3.429\\_143&rqn=div8](https://www.ecfr.gov/cgi-bin/text-idx?SID=7f0e02c7c5c8e6367edd977ee4f79032&mc=true&node=se10.3.429_143&rqn=div8).
- Ettenson, Lara , and Christa Heavey. 2015. *California's Golden Energy Efficiency Opportunity: Ramping Up Success to Save Billions and Meet Climate Goals*. Natural Resources Defense Council & Environmental Entrepreneurs (E2).
- Farahmand, Fahad. 2016b. "City of Palo Alto 2016 Building Energy." Reach Code.
- Farahmand, Farhad. 2016. *Cost-Effectiveness Study for Cool Roofs*. Title 24 Codes and Standards, Pacific Gas & Electric Company.
- Federal Reserve Economic Data . n.d. <https://fred.stlouisfed.org>.
- Georges, Benoit, Roger Watson, and Olivier Corbeil, interview by Kiri Coakley. 2020. *Proposed High Performance Window Code Changes* (January 10).
- Goldman, Charles, Merrian C. Fuller, Elizabeth Stuart, Jane S Peters, Marjorie McRay, Nathaniel Albers, Susan Lutzenhiser, and Mersiha Spahic. 2010. *Energy Efficiency Services Sector: Workforce Size and Expectations for Growth*. Lawrence Berkeley National Laboratory.
- Green Building Alliance. n.d. *Cool Roofs*. Accessed January 16, 2020. <https://www.go-gba.org/resources/green-building-methods/cool-roofs/>.
- Hart, R., S. Selkowitz, and C. Curcija. 2018. "Breaking the 20 Year Logjam to Better Insulating Windows." *Proceedings of the 2018 ACEEE Summer Study on Energy Efficiency in Buildings*. Pacific Grove, CA.
- ICC. 2020. "Final Action Results on the 2019 Proposed Changes to the International Codes." Accessed May 6, 2020. [https://www.iccsafe.org/wp-content/uploads/2019-Group-B-Final-Action\\_incl-OGCV.pdf](https://www.iccsafe.org/wp-content/uploads/2019-Group-B-Final-Action_incl-OGCV.pdf).
- IECC. 2019. *Indoor Horticulture Lighting*. Accessed December 3, 2019. [https://newbuildings.org/wp-content/uploads/2019/02/Indoor\\_Horticultural\\_Lighting-NBI-5155.pdf](https://newbuildings.org/wp-content/uploads/2019/02/Indoor_Horticultural_Lighting-NBI-5155.pdf).
- . 2018. "International Energy Conservation Code." Accessed 2020. <https://codes.iccsafe.org/content/IECC2018P3>.
- IgCC. 2018. "International Green Construction Code." <https://codes.iccsafe.org/content/IGCC2018/chapter-7-energy-efficiency>.
- Illinois General Assembly . 2019. *Public Act 101-0027*. June. Accessed December 9, 2019. <http://www.ilga.gov/legislation/publicacts/101/101-0027.htm>.
- Illinois. n.d. *Public Act 101-0027*. Accessed December 3, 2019. <http://www.ilga.gov/legislation/publicacts/101/101-0027.htm>.

- Jessica Prenger, Peter Ling. n.d. "Greenhouse Condensation Control: Understanding and Using Vapor Pressure Deficit (VPD)." *Ohio State University Extension*. Accessed December 2019, 2019. <http://www.ecaa.ntu.edu.tw/weifang/class-cea/Greenhouse%20Condensation%20Control%20VPD,%20AEX-804-01.htm>.
- Jonlin, Duane, and Duane Lewellen. 2017. *A Low-energy High Managing Energy Use for Commercial Indoor Cannabis Cultivation*. April. Accessed 2020. <https://www.tandfonline.com/doi/abs/10.1080/01998595.2017.11876936>.
- Kehrer, Manfred. 2013. *Condensation Risk of Mechanically Attached*. RCI International.
- Kehrer, Manfred, and Mike Ennis. 2011. "The Effects of Roof Membrane Color on Moisture Accumulation in Low-slope Commercial Roof Systems."
- . 2011. *The Effects of Roof Membrane Color on Moisture Accumulation in Low-slope Commercial Roof Systems*. Accessed February 11, 2020. <https://www.coolrooftoolkit.org/wp-content/uploads/2013/03/SPRI-Roof-Membrane-Color-and-Moisture-Impact.pdf>.
- Kolwey, Neil. 2017. "A Budding Opportunity: Energy efficiency best practices for cannabis grow operations." *Southwest Energy Efficiency Project*. December. Accessed December 11, 2019. <https://www.swenergy.org/data/sites/1/media/documents/publications/documents/A%20Budding%20Opportunity%20%20Energy%20efficiency%20best%20practices%20for%20cannabis%20grow%20operations.pdf>.
- Kruis, Neal, Bruce Wilcox, Jim Lutz, and Chip Barnaby. 2017. "Development of Realistic Water Draw Profiles for California Residential Water Heating Energy Estimation." *Building Simulation 2017*. San Francisco.
- Lawrence Berkeley Lab. n.d. *Solar Reflectance Index Calculator*. Accessed January 15, 2020. <https://coolcolors.lbl.gov/assets/docs/SRI%20Calculator/SRI-calc10.xls>.
- LED Light Expert. n.d. *LED grow light buyers guide*. [https://www.ledlightexpert.com/LED\\_Grow\\_Lights\\_Guide\\_ep\\_1](https://www.ledlightexpert.com/LED_Grow_Lights_Guide_ep_1).
- LEDTonic. 2019. *DLI (Daily Light Integral) Chart - Understand your plants' PPFD & photoperiod requirements*. <https://www.ledtonic.com/blogs/guides/dli-daily-light-integral-chart-understand-your-plants-ppfd-photoperiod-requirements>.
- LEDVANCE. n.d. *NAV-T 1000 W E40*. <https://www.ledvance.com/professional/products/lamps/high-intensity-discharge-lamps/high-pressure-sodium-vapor-lamps-for-open-and-enclosed-luminaires/vialox-nav-t/index.jsp>.

- Legal Information Institute . n.d. *Uniform Test Method for Measuring the Energy Consumption of Dehumidifiers*. [https://www.law.cornell.edu/cfr/text/10/appendix-X1\\_to\\_subpart\\_B\\_of\\_part\\_430](https://www.law.cornell.edu/cfr/text/10/appendix-X1_to_subpart_B_of_part_430).
- Levinson, Ronnen. 2009. *LBL*. July 29. Accessed November 22, 2019. <https://heatisland.lbl.gov/sites/all/files/Cool-roof-Q+A.pdf>.
- Levinson, Ronnen. 2010. *Potential Benefits of Cool Roofs on Commercial Buildings*. Springer.
- Levinson, Ronnen, and Hashem Akbair. 2009. *Potential benefits of cool roofs on commercial buildings: conserving energy, saving money, and reducing emission of greenhouse gases and air pollutants*. March. Accessed February 3, 2020. <https://link.springer.com/article/10.1007/s12053-008-9038-2>.
- Levinson, Ronnen, and Hashem Akbari. 2010. *Potential benefits of cool roofs on commercial buildings: conserving energy, saving money, and reducing emission of greenhouse gases and air pollutants*. Report, Berkeley, CA: Springer.
- Lim, Seong-Rin, Daniel Kang, Oladele Ogunseitan, and Julie Schoenung. 2013. *Potential Environmental Impacts from the Metals in Incandescent*. <https://pubs.acs.org/doi/pdf/10.1021/es302886m>.
- Magallanes, Michael. 2011. *Cool Roofs and Photovoltaics*. Accessed 2020. <https://coolroofs.org/documents/711CoatNCoolFMJArticle.pdf>.
- Marijuana Policy Project. n.d. *Overview of the Illinois Cannabis Regulation and Tax Act*. Accessed December 9, 2019. <https://www.mpp.org/states/illinois/overview-of-the-illinois-cannabis-regulation-and-tax-act/>.
- Markets and Markets. 2019. *Dedicated Outdoor Air System Market Report*. May 1. Accessed 02 24, 2020. <https://www.marketsandmarkets.com/Market-Reports/dedicated-outdoor-air-system-market-1899977.html>.
- MechaTronix. n.d. *Typical PPFD and DLI values per crop*. Accessed 2020. <https://www.horti-growlight.com/typical-ppfd-dli-values-per-crop>.
- Meckler, Gershon. 1986. "Innovative ways to save energy in new buildings." *Heat., Piping Air Cond.*
- Mumma, Stanley. 2001. "Overview of Integrating Dedicated Outdoor Air Systems with Parallel Terminal Systems." *ASHRAE*.
- National Coatings. n.d. *Frequently Asked Roof Coating Questions*. Accessed December 18, 2019. <https://www.nationalcoatings.com/roof-coating-questions>.
- National Energy Assistance Directors' Association. 2011. *2011 National Energy Assistance Survey Final Report*. <http://www.appriseinc.org/reports/Final%20NEADA%202011%20Report.pdf>.

- National Resources Canada. 2019. *Canada's National Energy Code*. 11 27. Accessed February 12, 2020. <https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-buildings/energy-efficiency-new-buildings/canadas-national-energy-code/20675>.
- Navigant. 2017.  
"https://www.energy.gov/sites/prod/files/2017/12/f46/ssl\_horticulture\_dec2017.pdf." *DOE*. December. Accessed December 11, 2019.  
[https://www.energy.gov/sites/prod/files/2017/12/f46/ssl\\_horticulture\\_dec2017.pdf](https://www.energy.gov/sites/prod/files/2017/12/f46/ssl_horticulture_dec2017.pdf).
- New Buildings Institute. 2020. *2021 IECC National Model Energy Code*.  
[https://newbuildings.org/code\\_policy/2021-iecc-base-codes/](https://newbuildings.org/code_policy/2021-iecc-base-codes/).
- . 2019. *Indoor Horticulture Lighting*. February. Accessed December 11, 2019.  
[https://newbuildings.org/wp-content/uploads/2019/02/Indoor\\_Horticultural\\_Lighting-NBI-5155.pdf](https://newbuildings.org/wp-content/uploads/2019/02/Indoor_Horticultural_Lighting-NBI-5155.pdf).
- . 2019. *NBI Releases Zero Energy Building Count and Trends for 2019*. 5 9. Accessed 02 12, 2020. <https://newbuildings.org/nbi-releases-zero-energy-building-count-and-trends-for-2019/>.
- New Buildings Institute. 2016. *Zero Net Energy Building Controls: Characteristics, Impacts and Lessons*. white paper, ACEEE.
- New Frontier. 2018. "The 2018 Cannabis Energy Report." *New Frontier*. October. Accessed December 11, 2019. <https://newfrontierdata.com/product/2018-cannabis-energy-report/>.
- Northwest Power and Conservation Council. 2018. *Electricity Demands from Recreational Cannabis Producers*.  
[https://www.nwcouncil.org/sites/default/files/2018\\_0612\\_p4.pdf](https://www.nwcouncil.org/sites/default/files/2018_0612_p4.pdf).
- NRCA. 2015. *2015-2016 Market Survey*. Accessed 2020. <https://iibec.org/nrca-releases-2015-16-market-survey/>.
- Radetsky, Leora. 2018. *LED and HID Horticultural*. May 3. Accessed 2020.  
<https://www.lrc.rpi.edu/programs/energy/pdf/HorticulturalLightingReport-Final.pdf>.
- Ramamurthy, P. 2015. *The Joint Influence of Albedo and Insulation on Roof Performance: An Observational Study*. Princeton Plasma Physics Lab.
- Remillard, Jesse, and Nick Collins. 2017. *Trends and Observations of Energy Use in the Cannabis Industry*. Accessed 2020.  
[https://www.aceee.org/files/proceedings/2017/data/polopoly\\_fs/1.3687880.1501159058!/fileserver/file/790266/filename/0036\\_0053\\_000046.pdf](https://www.aceee.org/files/proceedings/2017/data/polopoly_fs/1.3687880.1501159058!/fileserver/file/790266/filename/0036_0053_000046.pdf).
- Resource Innovation Institute. n.d. *Cannabis PowerScore*.  
<https://cannabispowerscore.org/>.



- RSMeans Online. 2020. "RSMeans Online." *RSMeans Online*. Accessed January 2020. <https://www.rsmeansonline.com/>.
- Runkle, Erik, and Bruce Bugbee. 2017. *Plant Lighting Efficiency and Efficacy:  $\mu\text{mols per joule}$* . July. Accessed 2020. <https://gpnmag.com/article/plant-lighting-efficiency-and-efficacy-%CE%BCmol%C2%B7j-%C2%B9/>.
- Sarfraz, Omer, Christian Bach, and Christopher Wikins. 2018. "ASHRAE 1742." *ASHRAE Journal* 14-19.
- Shoemaker, Lee, and Rick Haws, interview by Simon Silverberg. 2019. (November 21).
- SMUD. 2018a. "Amplified Farms 2017 Indoor Horticulture Lighting Study." *SMUD*. March. Accessed December 11, 2019. <https://www.smud.org/-/media/Documents/Business-Solutions-and-Rebates/Advanced-Tech-Solutions/LED-Reports/Amplified-Farms-Indoor-Horticulture-LED-Study-Final.ashx>.
- . 2018b. "Seven Leaves 2017 Indoor Horticulture Lighting Study." *SMUD*. March. Accessed December 11, 2019. <https://www.smud.org/-/media/Documents/Business-Solutions-and-Rebates/Advanced-Tech-Solutions/LED-Reports/Seven-Leaves-Indoor-Horticulture-LED-Study-Final.ashx?la=en&hash=BAF42446B3952D90CF49B6A564A7C3269252835C>.
- Southwest Energy. n.d. *Proposed Building Code Amendments for Lighting for Indoor Ag*. Accessed December 3, 2019. <http://swenergy.org/Data/Sites/1/media/aaa-documents-2019/industrial/proposed-building-code-amendments-for-lighting-for-indoor-ag-9-10.pdf>.
- Spring, Andy, interview by Simon Silverberg. 2019. *CWI Roofing & Waterproofing* (November 15).
- State of California, Employment Development Department. n.d. <https://www.labormarketinfo.edd.ca.gov/cgi/dataanalysis/areaselection.asp?table name=industry>.
- State of Massachusetts. n.d. *Cannabis Control Commission*. Accessed December 3, 2019. <https://www.mass.gov/doc/935-cmr-500-adult-use-of-marijuana/download>.
- Statewide CASE Team. 2017. *Indoor Lighting Power Densities – Final*. [http://title24stakeholders.com/wp-content/uploads/2017/09/2019-T24-CASE-Report\\_NR-Indoor-Light-Sources\\_Final\\_Sepember-2017.pdf](http://title24stakeholders.com/wp-content/uploads/2017/09/2019-T24-CASE-Report_NR-Indoor-Light-Sources_Final_Sepember-2017.pdf).
- Statewide CASE Team: HVAC Part 1. 2019. "Stakeholder Presentation." October 15. Accessed 2020. [https://title24stakeholders.com/wp-content/uploads/2019/07/T24-Utility-Sponsored-Stakeholder-Meeting-1\\_NR-HVAC-Part-1\\_MASTER\\_Final.pdf](https://title24stakeholders.com/wp-content/uploads/2019/07/T24-Utility-Sponsored-Stakeholder-Meeting-1_NR-HVAC-Part-1_MASTER_Final.pdf).

- Statewide CASE Team: HVAC Part 2. 2019. "Stakeholder Presentation." Accessed 2020. [https://title24stakeholders.com/wp-content/uploads/2019/09/Nonresidential-HVAC-and-Envelope-%E2%80%93-Part-2\\_-MASTER.pdf](https://title24stakeholders.com/wp-content/uploads/2019/09/Nonresidential-HVAC-and-Envelope-%E2%80%93-Part-2_-MASTER.pdf).
- Stone, Nehemiah, Jerry Nickelsburg, and William Yu. 2015. *Codes and Standards White Paper: Report - New Home Cost v. Price Study*. Pacific Gas and Electric Company. Accessed February 2, 2017. <http://docketpublic.energy.ca.gov/PublicDocuments/Migration-12-22-2015/Non-Regulatory/15-BSTD-01/TN%2075594%20April%202015%20Codes%20and%20Standards%20White%20Paper%20-%20Report%20-%20New%20Home%20Cost%20v%20Price%20Study.pdf>.
- SWEEP. 2019. *Denver Approves New Energy Efficiency Requirements for Indoor Agriculture/Cannabis Growing Facilities*. September. Accessed 2020. <https://swenergy.org/denver-approves-new-energy-efficiency-requirements-for-indoor-agriculturecannabis-growing-facilities>.
- Thornberg, Christopher, Hoyu Chong, and Adam Fowler. 2016. *California Green Innovation Index - 8th Edition*. Next 10.
- Title 24, Part 4. 2019. "2019 California Mechanical Code." <http://epubs.iapmo.org/2019/CMC/index.html>.
- Title 24, Part 6. 2019. "2019 California Energy Code." Accessed 2020. <https://codes.iccsafe.org/content/CAEC2019/cover>.
- U.S. Census Bureau, Population Division. 2014. "Annual Estimates of the Resident Population: April 1, 2010 to July 1, 2014." <http://factfinder2.census.gov/bkmk/table/1.0/en/PEP/2014/PEPANNRES/0400000US06.05000>.
- U.S. Department of Energy. n.d.
- U.S. DOE. 2020. *Energy Savings Potential of SSL in Agricultural Applications*. <https://www.energy.gov/sites/prod/files/2020/07/f76/ssl-agriculture-jun2020.pdf>.
- U.S. EPA (United States Environmental Protection Agency). 2011. "Emission Factors for Greenhouse Gas Inventories." Accessed December 2, 2013. <http://www.epa.gov/climateleadership/documents/emission-factors.pdf>.
- United States Environmental Protection Agency. 1995. "AP 42, Fifth Edition Compilation of Air Pollutant Emissions Factors, Volume 1: Stationary Point and Area Sources." <https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors#5thed>.



- United States Environmental Protection Agency. 2018. "Emissions & Generation Resource Integrated Database (eGRID) 2016."  
<https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid>.
- US Census. 2016. *Top 15 Most Populous Cities*. July 1. Accessed January 2020.  
<https://www.census.gov/content/dam/Census/newsroom/releases/2017/cb17-81-table3-most-populous.pdf>.
- USDA. 2019. *California*. April. Accessed 2020.  
[https://www.nass.usda.gov/Publications/AgCensus/2017/Full\\_Report/Volume\\_1,\\_Chapter\\_1\\_State\\_Level/California/cav1.pdf](https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_State_Level/California/cav1.pdf).
- . 2017. *Census of Agriculture*. Accessed 2020.  
[https://www.nass.usda.gov/Publications/AgCensus/2017/Full\\_Report/Volume\\_1,\\_Chapter\\_1\\_State\\_Level/California/cav1.pdf](https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_State_Level/California/cav1.pdf).
- Wadsworth. n.d. *Controls*. <https://wadsworthcontrols.com/controls/>.
- Washington State. 2015. *Washington State Energy Code*. Accessed December 3, 2019.  
[http://www.energy.wsu.edu/Documents/2015WSEC\\_C\\_final.pdf](http://www.energy.wsu.edu/Documents/2015WSEC_C_final.pdf).
- Washington-State. 2015. *2015 Washington State Energy Code*. 01 01. Accessed 02 14, 2020. <https://fortress.wa.gov/ga/apps/SBCC/File.ashx?cid=6195>.
- Zabin, Carol, and Karen Chapple. 2011. *California Workforce Education & Training Needs Assessment: For Energy Efficiency, Distributed Generation, and Demand Reponse*. University of California, Berkeley Donald Vial Center on Employment in the Green Economy. Accessed February 3, 2017.  
[http://laborcenter.berkeley.edu/pdf/2011/WET\\_Appendices\\_ALL.pdf](http://laborcenter.berkeley.edu/pdf/2011/WET_Appendices_ALL.pdf).

## 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 56. 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 56: First-year Canopy Square Footage Impacted by Proposal**

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

**Table 57: Percent of Floorspace Impacted by Proposed Measure, by Climate Zone**

Climate Zone	Percent of Square Footage Impacted	
	New Construction	Existing Building Stock (Alterations) <sup>a</sup>
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

There are no water savings associated with this proposal.

## 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 tonsCO<sub>2</sub>e per GWh. The Summary Table from eGrid 2016 reports an average emission rate of 529.9 pounds CO<sub>2</sub>e/MWh for the WECC CAMX subregion. This value was converted to metric tons CO<sub>2</sub>e/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<sub>2</sub> (Carbon Dioxide), 0.64 pounds of N<sub>2</sub>O (Nitrous Oxide) and 2.3 pounds of CH<sub>4</sub> (Methane). The emission value for N<sub>2</sub>O assumed that low NO<sub>x</sub> burners are used in accordance with California air pollution control requirements. The carbon equivalent values of N<sub>2</sub>O and CH<sub>4</sub> 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<sub>2</sub>O and CH<sub>4</sub> 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 CO<sub>2</sub>e 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). To demonstrate the cost savings of avoided GHG emissions, the Statewide CASE Team disaggregated the value of avoided GHG emissions from the other economic impacts. The authors used the same monetary values that are used in the TDV factors – \$106 per metric tons CO<sub>2</sub>e.

## **Water Use and Water Quality Impacts Methodology**

There are no water savings associated with this proposal.

## 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 58 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 58 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.

Since navigating compliance procedures can be a daunting task, industry groups have developed tools to help growers show compliance. The PowerScore developed by Resource Innovation Institute is used by the state of Massachusetts to confirm energy and water performance for grow facilities (Resource Innovation Institute n.d.). Facilities outside of the state can use the free platform to analyze their respective efficiency levels.



**Table 58: Roles of Market Actors in the Proposed Compliance Process**

<b>Market Actor</b>	<b>Task(s) In Compliance Process</b>	<b>Objective(s) in Completing Compliance Tasks</b>	<b>How Proposed Code Change Could Impact Work Flow</b>	<b>Opportunities to Minimize Negative Impacts of Compliance Requirement</b>
California Energy Commission	Did not previously regulate luminaires used for plant growth as a process measure and dehumidification efficiency standards in controlled environment horticulture facilities.	Make the process of demonstrating compliance as simple as possible.	<ul style="list-style-type: none"> <li>• Update the Nonresidential Compliance Manual and certificate of compliance document (NRCC-PRC-E Process Systems).</li> <li>• Develop a new certificate of acceptance document.</li> </ul>	<p>The Statewide CASE Team recommends including the following data fields in the certificate of compliance document:</p> <ul style="list-style-type: none"> <li>• Canopy size.</li> <li>• PPE ratings of lighting luminaires in micromoles per joule.</li> <li>• Type of dehumidification system and its moisture removal efficiency in pounds of moisture per kilowatt-hour.</li> <li>• Type of HVAC system</li> <li>• Yes/no on the use of carbon dioxide.</li> </ul>

<b>Market Actor</b>	<b>Task(s) In Compliance Process</b>	<b>Objective(s) in Completing Compliance Tasks</b>	<b>How Proposed Code Change Could Impact Work Flow</b>	<b>Opportunities to Minimize Negative Impacts of Compliance Requirement</b>
Indoor Horticulture Facility Designer	<ul style="list-style-type: none"> <li>• Design facility to the needs and plans of the facility owner.</li> <li>• Comply with relevant non-energy efficiency related building codes.</li> </ul>	Produce building plans for a facility that is compliant with Title 24, Part 6.	<ul style="list-style-type: none"> <li>• Design a facility that meets applicable Title 24, Part 6 requirements and other building standards.</li> <li>• Complete or assist in completing a certificate of compliance document for permit application.</li> <li>• Ensure building plans are consistent with the information in the certificate of compliance.</li> <li>• Would have to document compliance with the proposed requirements.</li> </ul>	<p>The Statewide CASE Team recommends including the following in the Nonresidential Compliance Manual:</p> <ul style="list-style-type: none"> <li>• Examples showing facilities that are compliant with Title 24, Part 6.</li> <li>• Examples showing facilities that are not compliant with Title 24, Part 6 with explanations as to why.</li> </ul>
Greenhouse Designer	<ul style="list-style-type: none"> <li>• Design facility to the needs of the owner.</li> <li>• Comply with non-energy standards in Title 24, Part 6.</li> <li>• If a conditioned greenhouse, comply with required nonresidential envelope requirements.</li> </ul>	Design a greenhouse that meets the updated Title 24, Part 6 envelope and lighting efficacy requirements.	<ul style="list-style-type: none"> <li>• Would now have more practical envelope requirements to meet for both conditioned and unconditioned greenhouses</li> <li>• Would have to design lighting systems that meet the proposed requirements.</li> </ul>	<p>The Statewide CASE Team recommends including the following in the Nonresidential Compliance Manual:</p> <ul style="list-style-type: none"> <li>• Examples showing facilities that are compliant with Title 24, Part 6.</li> <li>• Examples showing facilities that are not compliant with Title 24, Part 6 with explanations as to why.</li> </ul>

<b>Market Actor</b>	<b>Task(s) In Compliance Process</b>	<b>Objective(s) in Completing Compliance Tasks</b>	<b>How Proposed Code Change Could Impact Work Flow</b>	<b>Opportunities to Minimize Negative Impacts of Compliance Requirement</b>
Lighting Designer	<ul style="list-style-type: none"> <li>• Identify lighting luminaires and lighting controls that suit the needs of the facility.</li> <li>• Coordinate design with HVAC designers to account for interaction between lighting and HVAC/dehumidification systems.</li> <li>• Serve as an expert in lighting technology.</li> </ul>	Design lighting system design that meets the needs of the occupant and is compliant with Title 24, Part 6.	<ul style="list-style-type: none"> <li>• Would have to design lighting systems that meet the proposed requirements.</li> <li>• May need to document compliance with the proposed requirements.</li> <li>• Identify lighting luminaires and lighting controls that meet the proposed standards.</li> <li>• Assist in completing or complete a certificate of compliance for permit application.</li> </ul>	The Statewide CASE Team recommends setting a standard that uses metrics that can be met with widely available and familiar technologies.
Mechanical HVAC Designer	<ul style="list-style-type: none"> <li>• Serve as an expert for specifying HVAC / dehumidification system.</li> </ul>	Produce specification for a dehumidification system that is compliant with Title 24, Part 6.	<ul style="list-style-type: none"> <li>• Design a dehumidification system that meets the proposed standards.</li> <li>• Assist in completing or complete a certificate of compliance for permit application.</li> </ul>	Support horticulture industry efforts to develop a testing protocol for dehumidification systems.

<b>Market Actor</b>	<b>Task(s) In Compliance Process</b>	<b>Objective(s) in Completing Compliance Tasks</b>	<b>How Proposed Code Change Could Impact Work Flow</b>	<b>Opportunities to Minimize Negative Impacts of Compliance Requirement</b>
Enforcement Agency Plans Examiner	<ul style="list-style-type: none"> <li>No relevant tasks under current code.</li> </ul>	Validate quickly and easily that the horticulture facility meets Title 24, Part 6 requirements based on submitted plans.	<ul style="list-style-type: none"> <li>Would need to verify horticultural lighting load calculations and equipment specifications are compliant with the proposed requirements.</li> <li>Become aware of relevant code requirements and updated compliance documents.</li> <li>Review submitted building plans and compliance documents to verify compliance.</li> </ul>	<ul style="list-style-type: none"> <li>Develop training for building department officials to handle new code requirements.</li> <li>Develop compliance document that auto-verifies compliance status of entered data.</li> </ul>
General Contractor	<ul style="list-style-type: none"> <li>Build the horticulture facility in accordance with the building plans.</li> </ul>	Build a horticulture facility that is compliant with Title 24, Part 6.	<ul style="list-style-type: none"> <li>Would have to build a horticulture facility that meets the proposed requirements.</li> <li>When field changes result in noncompliance, obtain an approval from the enforcement agency of the revised certificate of compliance document.</li> <li>Complete a certificate of installation document.</li> </ul>	Provide an option to contractors for getting answers related to compliance over the phone.
Lighting Contractor or Electrician	<ul style="list-style-type: none"> <li>Build lighting system in accordance with the building plans.</li> </ul>	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.

<b>Market Actor</b>	<b>Task(s) In Compliance Process</b>	<b>Objective(s) in Completing Compliance Tasks</b>	<b>How Proposed Code Change Could Impact Work Flow</b>	<b>Opportunities to Minimize Negative Impacts of Compliance Requirement</b>
Building Automation Controls Contractor	<ul style="list-style-type: none"> <li>• Serve as an expert for selecting, installing, and commissioning environmental and irrigation controls.</li> </ul>	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	<ul style="list-style-type: none"> <li>• Coordinate final inspection with the permit applicant.</li> <li>• Verify that the horticulture facility is constructed in accordance with the building plans.</li> </ul>	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 Final 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](https://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 59: 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	<a href="https://title24stakeholders.com/event/covered-processes-utility-sponsored-stakeholder-meeting/">https://title24stakeholders.com/event/covered-processes-utility-sponsored-stakeholder-meeting/</a>
Second Round of Controlled Environment Horticulture Utility-Sponsored Stakeholder Meeting	Thursday, April 16, 2020	<a href="https://title24stakeholders.com/event/covered-processes-part-2-controlled-environment-horticulture-utility-sponsored-stakeholder-meeting/">https://title24stakeholders.com/event/covered-processes-part-2-controlled-environment-horticulture-utility-sponsored-stakeholder-meeting/</a>

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](mailto: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<sup>13</sup> (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,

---

<sup>13</sup> 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. Over 65 companies and individuals provided their input to the CASE Report. These stakeholders included policy makers, research groups, growers, consultants, engineers, and others are found in Table 60 below. In addition to these stakeholders, the Statewide CASE Team also contacted numerous growers through a survey effort discussed below.

**Table 60: Stakeholders involved in the CASE process**

<b>Organization</b>		
ACEEE	Farmer's Reserve	Phat Buddha Farms
Agnetix	Gold Flora	Quest Climate
AHRI	Greenhouse Lighting and Systems Engineering (GLASE)	Resource Innovation Institute
Altman Plants	Hawthorne Gardening	Rocket Farms
Anden	Humboldt's Finest	Seinergy
CA Farm Bureau Federation	Hydrofarm	SMUD
California Association of Flower Growers and Shippers	International Cannabis Farmer's Association	SNAP Inc
California Cannabis Industry Association	KCC International	Solid State Lighting Services
California Efficiency + Demand Management Council	Kultured Cannabis	Source Cannabis
California Lighting Technology Center (CLTC)	Leaf CA	Southern California Coalition
Canndescent	Legrand	Southern California Edison
Cascade Energy	LivWell	Sovereign
Ceres Greenhouse Solutions	Madison Indoor Air Quality	Suntracker
Cloud Cannabis	McGill University	SWEEP



<b>Organization</b>		
Creek's Edge	National Cannabis Industry Association	TEP Engineering
Desert Aire	New Buildings Institute	Terraform Genetics
DesignLights Consortium	NIST	The Higher Path
Dr. Greenhouse	NorCal Cannabis	Trane
EBM Papst	NRDC	UC Davis Agricultural Extension
Efficiency Vermont	Otter Brands	United Cannabis Business Association
Energy 350	PG&E	US Davis Agricultural Extension

## 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 need to use a metric that product specification sheets often note.

The California Lighting Technology Center, UC Davis 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 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 broad spectrum LEDs are able to address concerns that quality and yields will be negatively impacted as a result of selecting LED products.

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***

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.

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

### ***Greenhouse Outreach***

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.

The California Farm Bureau met with the Statewide CASE Team to discuss concerns of the impacts the proposed code could have on the agricultural industry. Specifically, the California Farm Bureau encouraged the Statewide CASE Team to reach out to conventional agricultural growers and industry associations to ensure they are aware of the proposal. The Statewide CASE Team reached out to 18 conventional growers and industry associations via both email and phone in August 2020 in direct response to the California Farm Bureau's feedback. Likewise, the California Farm Bureau also recommended that the Statewide CASE Team note other environmental regulations that may impact cannabis cultivation. This is noted in Section 6.5. Additionally, the California Farm Bureau encouraged the consideration of the potential impacts on utility incentive programs that many greenhouse growers participate in. While baselines would be re-evaluated with a code update, third-party implementers may still maintain the ability to incent highly efficient lighting technology that exceeds baseline standards.

## 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 the Statewide CASE Team contacted growers who expressed interest in the survey. 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 2020, 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.

## Webinars and Focus Groups

The Statewide CASE Team presented at the following webinars to inform stakeholders of the proposed code, provide details on the code change cycle, and clarify who would be affected by the proposed code:

- July 14, 2020: United Cannabis Business Association webinar
- July 21, 2020: International Cannabis Farmers Association webinar
- July 23, 2020: California Cannabis Industry Association webinar
- August 3, 2020: Coachella Valley Cannabis Alliance Network webinar

The Statewide CASE Team hosted CEH industry focus group meetings on August 6 and August 17, 2020 to gather more detail on concerns and suggested resolutions to concerns. The focus group consisted of cannabis growers, CEH facility designers, LED manufacturers, energy efficiency consultants, and cannabis industry association representatives.

# Appendix G: Existing Codes and Standards

Table 61 provides actual language of codes and standards related to energy and water efficiency of CEH facilities listed in alphabetical order by regulating authority.

**Table 61: Existing Codes and Standards**

Regulating Authority	Language
Various	<ul style="list-style-type: none"> <li> <b>Definitions of Occupancy Group F1 and U</b>  Source: 2019 California Building Code (CBC), Title 24, Part 2, Volume 1, Chapter 3 Occupancy Classification and Use;  <a href="https://codes.iccsafe.org/content/chapter/15437/">https://codes.iccsafe.org/content/chapter/15437/</a>  “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 ...” </li> <li> <b>Definition of Controlled Plant Growth Environment</b>  Source: 2015 Washington State Energy Code;  <a href="http://www.energy.wsu.edu/Documents/2015WSEC_C_final.pdf">http://www.energy.wsu.edu/Documents/2015WSEC_C_final.pdf</a>  “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.” </li> <li> <b>Definition of Indoor Cultivation</b>  Source: CCR, Title 3, Division 8 Cannabis Cultivation, Chapter 1, Article 1  <a href="https://static.cdfa.ca.gov/MCCP/document/CDFA%20Final%20Regulation%20Text_01162019_Clean.pdf">https://static.cdfa.ca.gov/MCCP/document/CDFA%20Final%20Regulation%20Text_01162019_Clean.pdf</a>  “(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.” </li> </ul>

- **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](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 ( $\mu\text{mol} \times \text{s}^{-1} \times \text{W}_e^{-1}$ ), or micromoles per joule ( $\mu\text{mol} \times \text{J}^{-1}$ ).”

**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	$\geq 1.9 \mu\text{mol/J}$ , with -5%	Required/Threshold	(ANSI/IES LM-79) 400-700nm

	(PPE) (μmol/J)	tolerance		range						
International Energy Conservation Code (IECC) 2021 (voluntary )	<p>Source: <a href="https://newbuildings.org/wp-content/uploads/2019/02/Indoor_Horticultural_Lighting-NBI-5155.pdf">https://newbuildings.org/wp-content/uploads/2019/02/Indoor Horticultural Lighting-NBI-5155.pdf</a></p> <p>“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.”</p> <p>Source: <a href="http://www.cdpassess.com">www.cdpassess.com</a></p> <p>“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:</p> <p>1. Exterior opaque envelope assemblies comply with Sections C402.2 and C402.4.5.</p> <p>Exception: Low energy greenhouses that comply with Section C402.1.1.</p> <p>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.</p> <p>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.</p> <p>Exception: Unconditioned greenhouses.</p> <p>TABLE C402.1.1.1 FENESTRATION THERMAL ENVELOPE MAXIMUM REQUIREMENTS</p> <table><tr><th>Component</th><th>U-factor (BT U/h-ft 2-°F)</th></tr><tr><td>Skylight</td><td>0.5</td></tr><tr><td>Vertical fenestration</td><td>0.7</td></tr></table>				Component	U-factor (BT U/h-ft 2-°F)	Skylight	0.5	Vertical fenestration	0.7
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](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  $\mu\text{mol/J}$  (luminaires), or 1.9  $\mu\text{mol/J}$  (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  $\mu\text{mol/J}$  or greater, used with any reflector and ballast combination, satisfy the requirements of this section. Compliance with this efficacy requirement



	<p>must be demonstrated by a third-party test report providing the lamps' photosynthetic photon efficacy (measured in <math>\mu\text{mol/J}</math>), generated by a facility accredited to the ANSI/IES LM-51 standard.</p> <p>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 <math>\mu\text{mol/J}</math>), generated by a facility accredited to the ANSI/ASABE S642, ANSI/IES LM-79, or ANSI/IES LM-51 standards.</p> <p><b>C502.2.6.4 Lighting Systems for Plant Growth Vegetation Areas.</b> 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.</p> <p><b>C503.6.2 Lighting Systems for Plant Growth Vegetation Areas.</b> 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.</p> <p><b>Exceptions:</b></p> <ol style="list-style-type: none"> <li>1. Replacement luminaires in existing plant growth and maintenance areas.</li> <li>2. New lighting in new canopy areas where the building ceiling height is 9 feet or less."</li> </ol>
<p><b>City of Santa Rosa</b> (mandatory)</p>	<p>Source: <a href="https://www.srcity.org/DocumentCenter/View/22641/Cannabis-Related-Occupancies---Building-and-Fire-Code-Requirements?bidId=">https://www.srcity.org/DocumentCenter/View/22641/Cannabis-Related-Occupancies---Building-and-Fire-Code-Requirements?bidId=</a></p> <p>"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.</p> <p>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.</p> <p>...</p> <p>5. Grow lights must be installed per the manufacture instructions and wired per CEC article 410.</p> <ol style="list-style-type: none"> <li>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).</li> <li>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).</li> <li>C. All grow lights shall be controlled by a multi-level astronomical time</li> </ol>

	<p>switch.</p> <p>...</p> <p>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 &amp; CEC subchapter 120.1(b)."</p>
<b>City of Seattle</b> (mandatory)	<p>Source: <a href="http://www.seattle.gov/documents/Departments/SDCI/Codes/SeattleEnergyCode/2015SECCCommercialChapter4.pdf">http://www.seattle.gov/documents/Departments/SDCI/Codes/SeattleEnergyCode/2015SECCCommercialChapter4.pdf</a></p> <p>"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."</p>
<b>State of Illinois</b> (mandatory)	<p>Source: <a href="http://www.ilga.gov/legislation/publicacts/101/101-0027.htm">http://www.ilga.gov/legislation/publicacts/101/101-0027.htm</a></p> <p>"(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.</p> <p>(C) HVAC.</p> <p>(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.</p> <p>(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.</p> <p>(D) Water application.</p> <p>(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.</p> <p>(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.</p>

	<p>(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."</p>
<p><b>Cannabis Control Commission, State of Massachusetts</b> (mandatory)</p>	<p>Source: <a href="https://www.mass.gov/doc/935-cmr-500-adult-use-of-marijuana/download">https://www.mass.gov/doc/935-cmr-500-adult-use-of-marijuana/download</a></p> <p>"(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:</p> <p>(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.</p> <p>(b) Lighting used for Cannabis Cultivation must meet one of the following compliance requirements:</p> <ol style="list-style-type: none"> <li>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</li> </ol>

	<p>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).</p> <p>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.</p> <p>(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)."</p>
<p><b>State of Washington</b> (mandatory)</p>	<p>Source: <a href="http://www.energy.wsu.edu/Documents/2015WSEC_C_final.pdf">http://www.energy.wsu.edu/Documents/2015WSEC_C_final.pdf</a>  <a href="https://www.sbcc.wa.gov/sites/default/files/2020-02/2018%20WSEC_C%20Final%20Package.pdf">https://www.sbcc.wa.gov/sites/default/files/2020-02/2018%20WSEC_C%20Final%20Package.pdf</a></p> <p><b>"C402.1.1.3 Greenhouses.</b> Greenhouse structures or areas that comply with all of the following shall be exempt from the building envelope requirements of this code:</p> <p>1. Exterior opaque envelope assemblies complying with Sections C402.2 and C402.4.4.</p> <p><b>Exception:</b> Low energy greenhouses that comply with Section C402.1.1.1.</p> <p>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.</p> <p>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.</p> <p><b>Exception:</b> Unheated greenhouses.</p>

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**

<b>Component U-Factor Btu/hr-ft<sup>2</sup> -°F</b>	<b>Climate Zone 5 and Marine 4</b>
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 62: Lighting products used in cost analysis**

<b>Name/Manufacturer</b>	<b>Type</b>	<b>Source</b>	<b>Cost (\$)</b>	<b>HID equivalent wattage (watts)</b>
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	\$1,350	1000
MaxLite PhotonMax	LED Fixture	MaxLite	\$994	1000
Growers Choice Grow Light	LED Fixture	Hydrobuilder	\$1,000	1000
Gavita Pro 1700e	LED Fixture	Hydrobuilder	\$1,299	1000
Photobio M Flowering	LED Fixture	Hydrobuilder	\$1,391	1000
Photobio M Full Spectrum	LED Fixture	Hydrobuilder	\$1,416	1000
NextLight Mega Grow Light	LED Fixture	Hydrobuilder	\$1,526	1000
VIVOSUN	Single-ended Metal Halide Fixture	Amazon	\$160	
SPL Hydroponic	Single-ended Metal Halide Fixture	Amazon	\$180	
iPower Grow Light	Single-ended Metal Halide Fixture	Amazon	\$200	
VIVOSUN	Single-ended Metal Halide Fixture	Amazon	\$190	
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 63: Products used for dehumidification baseline costs**

<b>Equipment Type<sup>a</sup></b>	<b>Cost (\$)</b>	<b>Source</b>
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

## Appendix I: Modifications to Indoor Lighting Proposal after Publication of the Draft CASE Report

After receiving significant feedback from stakeholders, the Statewide CASE Team has modified the lighting proposal to recommend a PPE level of up to 1.7  $\mu\text{Mol/J}$  for greenhouses and 2.1  $\mu\text{Mol/J}$  for luminaires used for plant growth and maintenance in indoor growing facilities. Originally, the Statewide CASE Team was recommending levels of 1.7 and 2.1, but has since clarified that these levels now represent the maximum recommended requirement, and that the Energy Commission has all the information needed to determine whether to choose the Statewide CASE Team's maximum recommended level or a less stringent level. While a PPE level of 2.1  $\mu\text{Mol/J}$  is cost effective and would lead to more energy savings, the Statewide CASE Team has learned that limiting growers to LED technology may present issues for growers in certain circumstances and the initial investment for LEDs can present financial difficulties, particularly for small growers. Additionally, growers are not as familiar with LED technology as with HID lighting. Thus, the Statewide CASE Team has modified the proposal to recommend either a PPE level of 1.7  $\mu\text{Mol/J}$ , which would allow double-ended HPS lights, or 2.1  $\mu\text{Mol/J}$ , which would require growing exclusively with LEDs.

The Statewide CASE Team received numerous comments from stakeholder regarding the proposal in the Draft CASE Report to require indoor growers to use lamps with an efficacy of 2.1  $\mu\text{Mol/J}$ . A comprehensive overview of these comments is presented in Appendix L. Primary concerns were that that a PPE level that requires use of LEDs would negatively impact plant growth and bring added financial burdens. Additionally, there were concerns that this code proposal would benefit the illegal market and the market saturation of LEDs is not high enough to warrant a code proposal.

While the Statewide CASE Team acknowledges that LED grow lights are more expensive than legacy technology and currently not as widely used, as Section 5.1.5 demonstrates, growing with LEDs has a cost-effectiveness ratio above 6 to 1 in all climate zones, and Section 3.2.1.4 demonstrates that growers have had successful yields growing with LEDs. Furthermore, in proposing a PPE level of up to 2.1  $\mu\text{Mol/J}$ , the Statewide CASE Team notes that while the proposal would have an effect on incentives, third party implementers would still be able to design programs that take into account this code change and offer incentives for highly efficacious lighting technologies.

With regards to concerns that the code would further benefit the illegal market, the Statewide CASE Team acknowledges that the legal market faces administrative fees and burdens that the illegal market does not. However, there are many economic areas with illicit sectors for which Title 24, Part 6 sets standards, Additionally, as noted in

Section 2, the legal horticulture market is rapidly expanding and consuming increasing amounts of energy. Subsequently, the Statewide CASE Team believes that though not a plurality of the market, there is a sizeable share of growers who have taken advantage of LED technology. DOE estimates that LEDs have an 11 percent saturation in the indoor market (U.S. DOE 2020), an increase from 4 percent in a 2017 report (DOE 2017). With LED saturation more nearly tripling in three years, the Statewide CASE is confident that growers are able to effectively grow with LED technology in terms of both yield and quality.

While the Statewide CASE Team's analysis and research demonstrates that a transition to LED technology is both cost effective and capable of producing similar yield and quality with proper education, the lighting proposal has been modified to recommend a PPE level of up to 2.1  $\mu\text{Mol/J}$  rather than a PPE level of 2.1  $\mu\text{Mol/J}$ . This change will demonstrate to the Energy Commission that while a transition to a 2.1 PPE meets the justified criteria for a code change, the indoor cannabis market has unique considerations at play, that have been noted by many stakeholders, such as less access to financing and a substantial illegal market to compete against.

## Appendix J: Modifications to Dehumidification Proposal after Publication of the Draft CASE Report

The Statewide CASE Team adjusted the dehumidification proposal after release of the Draft CASE Report. First, the requirement that dehumidification systems reuse transpired water has been dropped. While survey data and discussion with designers indicated that the majority of existing growers do reuse water from dehumidification equipment, the Statewide CASE Team determined that regulating such a process would be difficult for the Energy Commission and would only lead to limited water savings. Additionally, through stakeholder feedback, the team learned that occasionally water will be contaminated by oil or refrigerant from the HVAC system, and filtration will be needed before the water is reused. The Statewide CASE Team determined that this added process would create an unnecessary burden for growers.

The Statewide CASE Team has modified the proposed exception for stand-alone dehumidification units. Instead of only permitting stand-alone dehumidification units in spaces with less than 2,000 ft<sup>2</sup> of canopy, this Final CASE Report proposes allowing stand-alone units in any grow setting provided they meet the applicable proposed efficiency requirements. Dehumidification manufacturers provided analysis showing the efficiencies of various technologies based on the proposed code language in the Draft CASE Report, and it was determined that the initially proposed code language did not align with the intention of eliminating the lower efficiency units available on the market. The proposed code language in this Final CASE Report better aligns with that intention.

The Statewide CASE Team has added definitions for integrated HVAC systems and stand-alone dehumidifiers based on stakeholder feedback. The proposed reheat requirement has been modified to align with the ASHRAE 90.1 method of specifying reheat in terms of annual energy use. This eliminates the concern related to the “peak dehumidification” language in the proposed reheat requirement code language in the Draft CASE Report. The dehumidification reheat requirement was changed to 75 percent from 60 percent in alignment with ASHRAE 90.1.

## Appendix K: Nominal Savings Results

This appendix presents energy cost savings in nominal dollars. Energy costs are escalating as in the TDV analysis but the time value of money is not included so the results are not discounted.

**Table 64: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot of Canopy – Lighting New Construction and Alterations Indoor**

<b>Climate Zone</b>	<b>15-Year TDV Electricity Cost Savings (Nominal \$)</b>	<b>15-Year TDV Natural Gas Cost Savings (Nominal \$)</b>	<b>Total 15-Year TDV Energy Cost Savings (Nominal \$)</b>
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 65: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot of Canopy – Lighting New Construction and Alterations Greenhouse**

<b>Climate Zone</b>	<b>15-Year TDV Electricity Cost Savings (Nominal \$)</b>	<b>15-Year TDV Natural Gas Cost Savings (Nominal \$)</b>	<b>Total 15-Year TDV Energy Cost Savings (Nominal \$)</b>
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 66: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot of Canopy – Dehumidification New Construction and Alterations**

<b>Climate Zone</b>	<b>15-Year TDV Electricity Cost Savings (Nominal \$)</b>	<b>15-Year TDV Natural Gas Cost Savings (Nominal \$)</b>	<b>Total 15-Year TDV Energy Cost Savings (Nominal \$)</b>
1	\$1.67	\$30.61	\$32.28
2	\$0.44	\$30.60	\$31.04
3	\$1.00	\$30.61	\$31.61
4	\$0.05	\$30.61	\$30.66
5	\$0.87	\$30.61	\$31.48
6	\$0.76	\$30.94	\$31.70
7	\$0.75	\$31.11	\$31.86
8	\$0.01	\$30.94	\$30.94
9	(\$0.37)	\$30.94	\$30.57
10	(\$0.57)	\$30.94	\$30.37
11	(\$1.46)	\$30.61	\$29.15
12	(\$0.33)	\$30.61	\$30.28
13	(\$1.59)	\$30.61	\$29.02
14	(\$1.41)	\$30.94	\$29.53
15	(\$4.12)	\$30.94	\$26.82
16	\$0.64	\$30.94	\$31.58

## Appendix L: Summary of comments and responses addressing the Draft CASE Report

### Horticultural Lighting Minimum Efficacy

Stakeholder Comment	Number of Commenters	Statewide CASE Team Response
Proposed 2.1 $\mu\text{Mol/J}$ PPE is too high.	16	The proposal has been modified to recommend a PPE range of up to 2.1 $\mu\text{Mol/J}$ .
LEDs do not produce same yields/quality.	11	Section 3.2.1.4 notes multiple sources that show the impacts of LEDs on plant growth and that growers can achieve similar yields and quality. As discussed in Section 3.2.1.3, the market share of LEDs in horticulture lighting nearly tripled from 4 to 11 percent from 2017 to 2019. If LEDs presented significant obstacles to growing effectively, such an increase in their usage would not be occurring. The Statewide CASE Team acknowledges that growing with LEDs may necessitate a change in practices for some growers and is working to develop education materials to ease this potential transition.
Increased stringency will encourage growth of illicit markets.	7	The Statewide CASE Team acknowledges noncompliance does occur, but having met the criteria of cost-effectiveness and market readiness, cannot cite this as sufficient reason not to regulate the legal market.
Code will require an immediate switch to LEDs.	6	This code proposal would not require the immediate transition to LEDs. The proposal would impact new construction and significant alterations and take effect in 2023. Existing facilities would only need to switch to LEDs if going through a major renovation; the facility would need to replace 10 percent or more of its grow lights to trigger the major renovation requirements. At that point, only the grow lights being replaced would need to be LEDs. The Statewide CASE Team has participated in multiple webinars discussed in Appendix F and supported the Resource Innovation

		Institute and ACEEE in the publication of a <a href="#">blog post</a> to dispel this misinformation.
LED mandate may eliminate or reduce energy efficiency program incentives.	6	The Statewide CASE Team recognizes that code changes effect program incentives, but also recognizes that the third-party implementers who design incentive programs are continuously adapting programs to adjust for code and market changes.
High entry costs / limited access to loans to cover entry cost are an unfairly burdensome.	5	As noted above, incentive programs that can help with the initial cost of CEH facilities will still have the ability to offer their incentives. It is uncertain what incentives will be available due to the transition in CA to third-party implemented programs. Additionally, as Section 5.1.5 notes, the proposal is cost effective and growers can expect to quickly see returns on their investment. Assembly Bill 1525 was recently passed and should help increase access to banking and financing for cannabis businesses in CA.
LED market saturation is too low.	4	The determination of sufficient market saturation was based on U.S. DOE research indicating the LED market increased from 4-11% in three years (DOE 2015) and firsthand feedback from stakeholders via interviews and meeting surveys. California has a noted history of leading the country in pursuing highly efficient lighting technology.
Other costs such as HVAC, operating procedures should be considered.	2	These costs are included in the Statewide CASE Team's analysis. Please see Section 5 for more details.
Code proposal doesn't provide allowance for different PPE in different grow areas.	2	The option to require a 2.1 PPE in propagation and vegetative growth areas and a lower PPE in flowering growth areas is a viable alternative that the Energy Commission could consider to phase the industry transition to LED technology. Growers and other industry stakeholders acknowledged more willingness to utilize



		LED horticultural lighting in propagation and vegetative growth stages than in flowering.
1000 ft <sup>2</sup> threshold is not enough to protect small grows.	1	The Statewide CASE Team has modified this proposal to establish a threshold of 40 kW horticulture lighting load. If facilities are using less than 40 kW, then they are not required to comply with the lighting proposal. This change to a connected kW threshold will protect small grow facilities.
PAR must be redefined/ limited calculation of PPE	1	The Statewide CASE Team chose to follow industry-accepted metric of PPE and PPFD rather than create new definitions.
Credit for introducing natural light	1	This option could be considered in future code cycles when a performance option becomes available.
Operational PPE may be different than equipment level for luminaires with wavelength tunability	1	The PPE of equipment will be rated at the default equipment settings.
A hybrid LED/HID should be allowed	1	The Statewide CASE Team acknowledges this as a viable alternative to the proposed PPE requirement of 2.1 for indoor facilities. A system-level PPE requirement would complicate the compliance process, but it would allow for hybrid lighting designs utilizing both LED and HID technology.
PPFD should be mentioned so photons aren't scattered	1	PPFD is included in the calculations. See Section 4.1 Horticultural Lighting Minimum Efficacy for details.
Transition to LED may lead to more stacked canopies and more costs	1	Due to compliance considerations, the Statewide CASE Team cannot issue a proposal that prohibits the stacking of canopies.
Need to show LED has higher yields	1	Research shown in Section 3.2.1.4 demonstrates that LEDs can achieve similar grow results as HIDs. The Statewide CASE Team is not claiming that LEDs produce higher yields.
More advanced controls should be allowed	1	The Statewide CASE Team has modified code language in Section 7.2 to allow for multiple types of controls.

## Efficient Dehumidification

Stakeholder Comment	Number of Commenters	Statewide CASE Team Response
Enforce a minimum efficacy that allows standalone dehumidification that can be used in any facility.	10	The Statewide CASE Team has removed the square footage exception and added minimum efficiency requirements for standalone dehumidifiers.
2000 ft <sup>2</sup> exception should not exist.	7	The Statewide CASE Team has removed the square footage exception and added minimum efficiency requirements for standalone dehumidifiers.
Integrated dehumidification should not be required as standalone can be just as efficient.	5	The Statewide CASE Team has modified language to include standalone dehumidifiers as an option.
Desiccant dehumidification systems should have limits to where they're allowed.	3	The Statewide CASE Team has added design limits.
Should be a distinction between different types of standalone dehumidifiers.	2	The Statewide CASE Team has modified the proposal to show two distinct standalone categories.
Peak dehumidification load requirement will cause confusion.	2	The Statewide CASE Team has modified the proposal to change the proposal to specify annual energy use for reheat.
Current level of 1.9 L/kWh is too low for standalone units and should be raised.	1	The Statewide CASE Team has added another higher level for units above the federal regulation size. The lower size category needs to stay at federal minimum efficiency to avoid preemption concerns.
There's no current standard for measuring dehumidification efficiency.	1	The Statewide CASE Team modified the proposal to follow U.S. DOE CFR 430 Appendix X1 (Legal Information Institute n.d.).
Variable frequency drives (VFDs) should be required on fans greater than 5 HP.	1	This recommendation will not be added this code cycle.

Integrated dehumidification should have heat recovery sized at 100% of cooling capacity.	1	The Statewide CASE Team has set the heat recovery level to 75% of cooling capacity to align with ASHRAE 90.1 guidance for process spaces.
Consider impacts of LEDs on HVAC and dehumidification.	1	HVAC interactive effects were accounted for in calculating lighting savings.

## Other Topics

Stakeholder Comment	Number of Commenters	Statewide CASE Team Response
Regarding the reuse of transpired water submeasure: Proposal should be better defined and clarify if all drainage needs to be reused.	1	The Statewide CASE Team decided, based on stakeholder input and further investigation, to discontinue the pursuit of a water reuse capability requirement due to lack of savings and compliance concerns.
There should be an exemption from requirements for facilities using off-grid generation or renewables.	2	As with other Title 24, Part 6 requirements, there is no exception based upon where buildings source their electricity.
Consider facilities that have heating capacity but rarely do use it.	1	The Statewide CASE Team could not determine a viable means to verify compliance when people claim sporadic heating use.
There should be an exemption for temporary greenhouses.	1	Unconditioned greenhouses are exempt from the greenhouse envelope definition. Greenhouses that trigger conditioned space requirements are not likely to be temporary.
IECC shouldn't be referenced due to California climate.	1	IECC is referenced to demonstrate precedent, not to equate climate.
There should be considerations of other environmental	1	CEQA considerations are noted in Section 6.5.

regulations such as CEQA.		
Should consider impacts of COVID.	4	Since the proposal would take effect in 2023, the Statewide CASE Team is not considering the current economic situation as reason to avoid making any proposed changes.
There should be more outreach to growers.	4	The Statewide CASE Team has directly reached out to growers. See Appendix F: Summary of Stakeholder Engagement for a list.
Performance based code requirements would be more appropriate.	3	This option could be considered in future code cycles when a performance option becomes available.
2023 is too soon of a date for compliance.	3	The Statewide CASE Team has participated in multiple industry events and conducted outreach to an extensive list of contacts to alert the market of the potential upcoming changes. Please see Appendix F for more details.
Different requirements by crop type.	2	Compliance with such a proposal would not be enforceable.
Mandatory requirements should only be for new construction.	1	Incentive programs can often claim existing baseline for retrofits rather than code baseline.
Education on LED and HVAC is key.	1	The Statewide CASE Team has added education as recommendation to support the code implementation.
Social equity applicants won't be building facilities until 2023 and are likely to be harmed more.	1	The code applies when pulling a permit. Growers may pull permits before 2023. Equity concerns may also be addressed through additional outreach and education to support implementation, as well as other means outside of the code adoption process.
Need to show it's feasible for growers to switch from indoor to greenhouse or outdoor.	1	The Statewide CASE Team clarified which growers the code would apply to (new construction and existing growers constructing expansion that trigger a building permit).
Need to show why cannabis is being	1	Numerous other covered processes have Title 24, Part 6 requirements such as

regulated more than other industries		refrigeration, air filtration, and process boilers.
California's ability to compete nationally will be harmed by too much regulation.	1	Numerous other states have cannabis efficiency regulations as shown in Section 2.1.4.3 and Section 2.2.4.3.
Regional electric rates should be used.	1	The Statewide CASE Team clarified the formal TDV process in response to the commenter. More information can be found in Section 5.1.
Compliance costs should be addressed	1	Compliance costs are included and can be found in Section 5.
Proposed greenhouse envelope U-factor value needs to be clarified.	1	The Statewide CASE Team has modified the greenhouse envelope proposal to proposal a U-factor of 0.7 for non-opaque wall assemblies and 0.5 for non-opaque roof assemblies.

## Appendix M: Addendum to Controlled Environment Horticulture – Final CASE Report

The Statewide CASE Team originally proposed a horticultural lighting minimum efficacy of 2.1 micromoles ( $\mu\text{mol}$ ) per joule (J) for indoor luminaires and 1.7  $\mu\text{mol}/\text{J}$  for greenhouse luminaires in the Final CASE Report that was published in October 2020. This proposal also included time-switch and multilevel lighting controls for both indoor growing facilities and greenhouses and designing electrical power distribution systems serving controlled environment horticulture (CEH) spaces to allow energy use monitoring of aggregate horticultural lighting load.

The proposed lighting efficacy requirements in the Final CASE Report applied 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 lighting alterations that involve replacing 10 percent or more of the horticultural luminaires serving an enclosed space. For lighting alterations involving replacement of 10 percent or more of luminaires serving an enclosed space, only the newly installed lighting would be subject to the proposed code. Lighting alterations involving replacing lamps only, ballasts only, or drivers only would not be subject to the proposed code.

Since the Final CASE Report's publication in October 2020, the Statewide CASE Team determined that changes to the minimum efficacy requirements are needed based on extensive stakeholder suggestions. Stakeholders included the cannabis grower community, trade associations, and energy consultants that serve the indoor CEH sector. The Statewide CASE Team also conducted targeted outreach to conventional greenhouse agricultural interests including producers of leafy greens and other food crops to understand potential impacts to their industry. This adjustment only impacts the efficacy of lighting for growing plants in indoor controlled environment horticulture applications. No change in lighting efficacy stringency is recommended for the greenhouse lighting proposal. Minor language clarifications for impacted products are also added. Highlights of the suggestions received by industry members are noted below:

1. Stakeholders raised concerns regarding the proposed 2.1 micromole per joule luminaire efficacy. One of their most prominent concerns was the ability of small cannabis growers to afford the high first cost of LED lighting while suffering from a lack of access to capital.
2. Stakeholders also expressed reluctance to switch to LED until more research is completed. These stakeholders highlighted that there is limited publicly available data comparing the yield and quality performance of LED

grow lighting to conventional grow lighting such as ceramic metal halide (CMH) and High-pressure sodium (HPS) lighting.

3. The California legal cannabis industry is still in its early stages, and a strict energy efficiency mandate may slow the growth of the industry and potential tax revenues produced by the industry.

In lowering the required minimum PPE from 2.1 to 1.9  $\mu\text{mol}/\text{J}$  for indoor horticulture luminaires and lamps that are a part of luminaires, the proposal now will allow indoor growers to use the highly efficient doubled-ended HPS grow lights in addition to LEDs. Some growers expressed more confidence in the outcomes and experience with HPS lights than LEDs. After additional discussions with the Energy Commission, it was determined that the reduced minimum efficacy requirement would be more feasible for the market while the cost of LED horticultural luminaires continues to drop, confidence increases in the ability of LEDs to provide high yields of high-quality product, the industry matures, and additional data is made available.

### Updated Recommendation for Horticultural Lighting Minimum Efficacy Proposal

The Statewide CASE Team recommended revisions to code language in Sections 120.6(h)3, 120.6(h)7, and 100.1 which were presented in the Final CASE Report as described below.

- Section 120.6(h)3 was revised to require horticultural luminaires with removable lamps to have lamps with a lamp PPE of at least 1.9  $\mu\text{mol}/\text{J}$ , and to require that all other horticultural luminaires have a luminaire PPE of at least 1.9  $\mu\text{mol}/\text{J}$ .
- Section 120.6(h)7 was revised to require horticultural luminaires with removable lamps have lamps with a lamp PPE of at least 1.7  $\mu\text{mol}/\text{J}$ , and to require that all other horticultural luminaires have a luminaire PPE of at least 1.7  $\mu\text{mol}/\text{J}$ .
- Section 100.1 was updated with two definitions to clarify the meaning of lamp photosynthetic photon efficacy and luminaire photosynthetic photon efficacy.

### Updated Savings

The Statewide CASE Team conducted additional analysis to demonstrate the savings impact of lowering the required PPE levels from 2.1  $\mu\text{mol}/\text{J}$  to 1.9  $\mu\text{mol}/\text{J}$  and creating the path for lamp efficacy. The updated minimum efficacy requirements for indoor and greenhouse horticultural lighting affect the per-unit energy savings, statewide energy savings, and cost-effectiveness. Several new assumptions were utilized in addition to the existing assumptions presented in the Final CASE Report.

The updated indoor lighting energy savings analysis assumes that 20 percent of growers would install LED luminaires with a luminaire efficacy of at least 1.9  $\mu\text{mol}/\text{J}$  and 80 percent of growers would be installing HPS products with a lamp efficacy of at least 1.9  $\mu\text{mol}/\text{J}$ . For HPS lamp products, the Statewide CASE Team made an additional correction to account for the impact of ballast inefficiencies, resulting in a full luminaire efficacy of 1.70  $\mu\text{mol}/\text{J}$  for compliant HPS products. Lamp efficacy does not account for ballast losses or optical losses of the luminaire, so a 0.2  $\mu\text{mol}/\text{J}$  correction factor was utilized on lamp efficacy to obtain luminaire efficacy. Combining the expected market share of these two compliance pathways resulted in a blended luminaire PPE of 1.74  $\mu\text{mol}/\text{J}$ . This blended luminaire PPE was used in the updated indoor lighting savings calculations and is a conservative assumption as there is evidence that the market prevalence of LEDs will be above the 20 percent when these requirements come into effect. A study from the Cannabis Business Times 2020 State of the Lighting Market report found that 38 percent of growers plan on implementing LED lighting in the next 12 months during the flowering period (U.S. DOE 2020) (Cannabis Business Times 2020). The study also found a rapid increase in LED adoption from 4 to 11 percent in the last three years (2018 to 2020)

For greenhouse lighting energy savings analysis, the Statewide CASE Team assumed that 80 percent of growers would meet the requirement by using a double-ended HPS lamps with PPE of 1.9  $\mu\text{mol}/\text{J}$  while 20 percent would use CMH lamps with a PPE of 1.7  $\mu\text{mol}/\text{J}$ . In both of these cases, the Statewide CASE Team used a 0.2  $\mu\text{mol}/\text{J}$  correction factor to account for ballast and optical losses for a blended luminaire PPE of 1.66  $\mu\text{mol}/\text{J}$ .

The baseline assumptions remain unchanged from what was done in the Final CASE Report. As noted in Table 25 and 26 of Section 4.1.1, the baseline PPE assumed for the purposes of the energy savings analysis was 1.02  $\mu\text{mol}/\text{J}$  for both greenhouses and indoor grows. As Table 9 of the Final CASE Report shows, single-ended HPS lamps, CMH, and fluorescent luminaires have PPEs around 1.0  $\mu\text{mol}/\text{J}$ .

The following tables detail the savings and cost effectiveness of the updated horticultural lighting proposal. The submeasures are still cost effective across all climate zones. With a 15-year benefit-to-cost ratio ranging from 6.9 to 8.4 as shown by Table 5, the simple payback period for indoor facilities ranges is roughly 2 years depending on climate zone. For greenhouses, with a 15-year benefit-to-cost ratio ranging from 2.0 to 3.5 as shown by Table 6, the simple payback period ranges from 4 to 8 years.<sup>14</sup>

---

<sup>14</sup> Please note that costs included in this calculation have a discount rate and determining a simple payback period does not factor this in.



As can be seen from the below tables, the indoor lighting proposal yields significantly more savings than the greenhouse proposal. This occurs primarily for two reasons. First, as noted in Section 4.1.1 of the Final CASE Report, indoor grows have lights on for a longer period of time compared to greenhouses which utilize sunlight for much of the day. Additionally, the higher PPE of 1.9  $\mu\text{mol}/\text{J}$  will lead to higher savings for indoor grows since the greenhouse level of 1.7  $\mu\text{mol}/\text{J}$  was compared to the same baseline PPE level.

**Table 67: First-Year Energy Impacts Per Square Foot of Canopy – Indoor Lighting**

<b>Climate Zone</b>	<b>Electricity Savings (kWh/ft<sup>2</sup>)</b>	<b>Peak Electricity Demand Reductions (kW/ ft<sup>2</sup>)</b>	<b>Natural Gas Savings (therms/ ft<sup>2</sup>)</b>	<b>TDV Energy Savings (TDV kBtu/ ft<sup>2</sup>)</b>
1	169.3	0.010	N/A	3,801.2
2	171.7	0.010	N/A	4,295.4
3	170.9	0.011	N/A	4,077.5
4	172.3	0.011	N/A	4,390.6
5	171.1	0.010	N/A	3,956.0
6	172.7	0.011	N/A	4,261.3
7	172.2	0.011	N/A	4,062.9
8	173.2	0.011	N/A	4,576.3
9	173.4	0.011	N/A	4,573.4
10	174.0	0.011	N/A	4,418.5
11	173.5	0.011	N/A	4,341.3
12	172.8	0.010	N/A	4,282.4
13	173.7	0.011	N/A	4,335.8
14	173.9	0.010	N/A	4,513.5
15	177.8	0.011	N/A	4,481.9
16	169.7	0.010	N/A	3,842.9

**Table 68: First-Year Energy Impacts Per Square Foot of Canopy – Greenhouse Lighting**

<b>Climate Zone</b>	<b>Electricity Savings (kWh/ ft<sup>2</sup>)</b>	<b>Peak Electricity Demand Reductions (kW/ ft<sup>2</sup>)</b>	<b>Natural Gas Savings (therms/ ft<sup>2</sup>)</b>	<b>TDV Energy Savings (TDV kBtu/ ft<sup>2</sup>)</b>
1	22.3	0.002	N/A	575.7
2	17.9	0.002	N/A	456.1
3	18.0	0.002	N/A	461.4
4	17.0	0.002	N/A	431.5
5	15.4	0.002	N/A	402.7
6	15.8	0.002	N/A	413.5
7	14.9	0.002	N/A	376.2
8	15.7	0.002	N/A	427.0
9	15.3	0.002	N/A	399.9
10	15.1	0.002	N/A	383.8
11	18.0	0.002	N/A	451.8
12	17.9	0.002	N/A	448.0
13	17.5	0.002	N/A	441.0
14	13.0	0.002	N/A	319.4
15	13.6	0.002	N/A	331.4
16	16.9	0.002	N/A	435.9

**Table 69: 2023 PV TDV Energy Cost Savings Over 15-Year Period of Analysis Per Square Foot of Canopy – New Construction, Alterations, and Additions Indoor**

<b>Climate Zone</b>	<b>15-Year TDV Electricity Cost Savings (2023 PV\$)</b>	<b>15-Year TDV Natural Gas Cost Savings (2023 PV\$)</b>	<b>Total 15-Year TDV Energy Cost Savings (2023 PV\$)</b>
1	\$338	\$0	\$338
2	\$382	\$0	\$382
3	\$363	\$0	\$363
4	\$391	\$0	\$391
5	\$352	\$0	\$352
6	\$379	\$0	\$379
7	\$362	\$0	\$362
8	\$407	\$0	\$407
9	\$407	\$0	\$407
10	\$393	\$0	\$393
11	\$386	\$0	\$386
12	\$381	\$0	\$381
13	\$386	\$0	\$386
14	\$402	\$0	\$402
15	\$399	\$0	\$399
16	\$342	\$0	\$342

**Table 70: 2023 PV TDV Energy Cost Savings Over 15-Year Period of Analysis Per Square Foot of Canopy – New Construction, Alterations, and Additions Greenhouse**

<b>Climate Zone</b>	<b>15-Year TDV Electricity Cost Savings (2023 PV\$)</b>	<b>15-Year TDV Natural Gas Cost Savings (2023 PV\$)</b>	<b>Total 15-Year TDV Energy Cost Savings (2023 PV\$)</b>
1	\$51	\$0	\$51
2	\$41	\$0	\$41
3	\$41	\$0	\$41
4	\$38	\$0	\$38
5	\$36	\$0	\$36
6	\$37	\$0	\$37
7	\$33	\$0	\$33
8	\$38	\$0	\$38
9	\$36	\$0	\$36
10	\$34	\$0	\$34
11	\$40	\$0	\$40
12	\$40	\$0	\$40
13	\$39	\$0	\$39
14	\$28	\$0	\$28
15	\$29	\$0	\$29
16	\$39	\$0	\$39

**Table 71: 15-Year Cost-Effectiveness Summary Per Square Foot of Canopy – Indoor Lighting**

<b>Climate Zone</b>	<b>Benefits TDV Energy Cost Savings + Other PV Savings<sup>a</sup> (2023 PV\$)</b>	<b>Costs Total Incremental PV Costs<sup>b</sup> (2023 PV\$)</b>	<b>Benefit-to- Cost Ratio</b>
1	\$ 338.30	\$ 48.73	6.9
2	\$ 382.29	\$ 48.73	7.8
3	\$ 362.90	\$ 48.73	7.4
4	\$ 390.76	\$ 48.73	8.0
5	\$ 352.09	\$ 48.73	7.2
6	\$ 379.26	\$ 48.73	7.8
7	\$ 361.60	\$ 48.73	7.4
8	\$ 407.29	\$ 48.73	8.4
9	\$ 407.04	\$ 48.73	8.4
10	\$ 393.25	\$ 48.73	8.1
11	\$ 386.38	\$ 48.73	7.9
12	\$ 381.14	\$ 48.73	7.8
13	\$ 385.89	\$ 48.73	7.9
14	\$ 401.70	\$ 48.73	8.2
15	\$ 398.89	\$ 48.73	8.2
16	\$ 342.02	\$ 48.73	7.0

- a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2020). 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 72: 15-Year Cost-Effectiveness Summary Per Square Foot of Canopy – Greenhouse Lighting**

<b>Climate Zone</b>	<b>Benefits TDV Energy Cost Savings + Other PV Savings<sup>a</sup> (2023 PV\$)</b>	<b>Costs Total Incremental PV Costs<sup>b</sup> (2023 PV\$)</b>	<b>Benefit-to- Cost Ratio</b>
1	\$ 51.24	\$ 14.50	3.5
2	\$ 40.60	\$ 14.50	2.8
3	\$ 41.06	\$ 14.50	2.8
4	\$ 38.41	\$ 14.50	2.6
5	\$ 35.84	\$ 14.50	2.5
6	\$ 36.80	\$ 14.50	2.5
7	\$ 33.48	\$ 14.50	2.3
8	\$ 38.00	\$ 14.50	2.6
9	\$ 35.59	\$ 14.50	2.5
10	\$ 34.16	\$ 14.50	2.4
11	\$ 40.21	\$ 14.50	2.8
12	\$ 39.88	\$ 14.50	2.8
13	\$ 39.25	\$ 14.50	2.7
14	\$ 28.43	\$ 14.50	2.0
15	\$ 29.49	\$ 14.50	2.0
16	\$ 38.79	\$ 14.50	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 2020). 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 73: Statewide Energy and Energy Cost Impacts – New Construction – Lighting**

<b>Climate Zone</b>	<b>Statewide New Construction Impacted by Proposed Change in 2023 (ft<sup>2</sup> of canopy)</b>	<b>First-Year<sup>a</sup> Electricity Savings (GWh)</b>	<b>First-Year Peak Electrical Demand Reduction (MW)</b>	<b>First-Year Natural Gas Savings (MMTherms)</b>	<b>15-Year Present Valued Energy Cost Savings (million 2023 PV\$)</b>
1	337,875	11.08	1.03	N/A	\$24.24
2	502,266	16.11	1.51	N/A	\$36.23
3	462,964	35.24	2.45	N/A	\$75.65
4	60,974	6.14	0.40	N/A	\$13.94
5	88,338	1.74	0.18	N/A	\$3.94
6	288,303	7.57	0.69	N/A	\$17.19
7	16,780	0.99	0.07	N/A	\$2.10
8	100,695	16.37	1.00	N/A	\$38.51
9	239,564	40.68	2.48	N/A	\$95.47
10	16,245	2.55	0.16	N/A	\$5.77
11	35,278	3.88	0.25	N/A	\$8.63
12	168,313	24.05	1.50	N/A	\$53.07
13	36,583	6.35	0.38	N/A	\$14.10
14	92,694	14.99	0.91	N/A	\$34.63
15	149,275	25.25	1.52	N/A	\$56.65
16	82,311	1.98	0.20	N/A	\$4.36
<b>TOTAL</b>	<b>2,678,458</b>	<b>214.98</b>	<b>14.73</b>	<b>N/A</b>	<b>\$484.48</b>

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

**Table 74: Statewide Energy and Energy Cost Impacts – Alterations – Lighting**

<b>Climate Zone</b>	<b>Statewide Alterations Impacted by Proposed Change in 2023 (ft<sup>2</sup> of canopy)</b>	<b>First-Year<sup>a</sup> Electricity Savings (GWh)</b>	<b>First-Year Peak Electrical Demand Reduction (MW)</b>	<b>First-Year Natural Gas Savings (MMTherms)</b>	<b>15-Year Present Valued Energy Cost Savings (million 2023 PV\$)</b>
1	260,785	6.88	0.70	N/A	\$15.42
2	382,302	8.96	0.97	N/A	\$20.24
3	284,376	13.14	1.03	N/A	\$28.55
4	32,490	2.07	0.15	N/A	\$4.70
5	70,147	1.19	0.13	N/A	\$2.75
6	223,227	4.43	0.45	N/A	\$10.17
7	11,172	0.39	0.03	N/A	\$0.83
8	33,458	4.93	0.30	N/A	\$11.60
9	74,163	12.16	0.74	N/A	\$28.54
10	5,720	0.77	0.05	N/A	\$1.75
11	17,876	1.29	0.09	N/A	\$2.87
12	66,716	7.46	0.48	N/A	\$16.47
13	10,923	1.89	0.11	N/A	\$4.20
14	31,174	4.51	0.28	N/A	\$10.42
15	48,459	7.58	0.46	N/A	\$16.99
16	64,558	1.26	0.14	N/A	\$2.85
<b>TOTAL</b>	<b>1,617,544</b>	<b>78.91</b>	<b>6.14</b>	<b>N/A</b>	<b>\$178.36</b>

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



**Table 75: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions – Lighting**

<b>Construction Type</b>	<b>First-Year Electricity Savings (GWh)</b>	<b>First-Year Peak Electrical Demand Reduction (MW)</b>	<b>First - Year Natural Gas Savings (MMTherms)</b>	<b>15-Year Present Valued Energy Cost Savings (PV\$ million)</b>	<b>First-year TDV Energy Savings (million TDV kBtu/yr)</b>
New Construction	215.0	14.7	N/A	484.48	5,443.6
Additions and Alterations	78.9	6.1	N/A	178.36	2,004.0
<b>TOTAL</b>	<b>293.9</b>	<b>20.9</b>	<b>N/A</b>	<b>662.84</b>	<b>7,447.6</b>

## Proposed Code Language

The Statewide CASE Team is proposing the following code change to Section 100.1 and 120.6(h). Changes to the 2019 documents are marked with red underlining (new language) and ~~striketroughs~~ (deletions) and represent language proposed in the Final CASE Report published in October 2020. Changes to the proposed language from the October 2020 Final CASE Report are marked with blue double underlining (new language) and double ~~striketroughs~~ (deletions).

### SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

(...)

**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.

**Lamp photosynthetic photon efficacy** is the lamp photosynthetic photon flux divided by rated input electric power of the lamp in units of micromoles per second per watt, or micromoles per joule as defined by ANSI/ASABE S640.

**Luminaire photosynthetic photon efficacy** is the luminaire photosynthetic photon flux divided by rated input electric power of the luminaire 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

(...)

3. **Indoor Growing, Horticultural Lighting.** In a building with CEH spaces and with more than 40 kW of aggregate horticultural lighting load, the electric lighting systems used for plant growth and plant maintenance shall meet the following requirements:
  - A. Luminaires ~~shall have~~ with removable lamps shall contain lamps with a lamp lamp photosynthetic photon efficacy of at least ~~2.4~~ 1.9 micromoles per joule ~~rated in accordance with ANSI / ASABE S640 for wavelengths from 400 to 700 nanometers;~~ all other luminaires shall have a luminaire photosynthetic photon efficacy of at least 1.9 micromoles per joule.
  - 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).

(...)

7. **Greenhouses, Horticultural Lighting.** In a greenhouse with more than 40 kW of aggregate horticultural lighting load, the electric lighting system used for plant growth and plant maintenance shall meet the following requirements:
  - A. Luminaires ~~shall have~~ with removable lamps shall contain lamps with a lamp photosynthetic photon efficacy of at least 1.7 micromoles per joule ~~rated in accordance with ANSI / ASABE S640 for wavelengths from 400 to 700 nanometers;~~ all other luminaires shall have a luminaire photosynthetic photon efficacy of at least 1.7 micromoles per joule.
  - B. 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.
  - C. Multilevel lighting controls shall be installed and comply with Section 130.1(b).