TITLE 24, PART 6 | 2028 CODE CYCLE

Controlled Environment Horticulture: Lighting Efficacy

Codes and Standards Enhancement (CASE) Proposal

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CALIFORNIA ENERGY CODES & STANDARDS
A STATEWIDE UTILITY PROGRAM

Revisiting the Proposed Code Change

Raise the minimum Photosynthetic Photon Efficacy (PPE) of horticultural light sources from **2.3 to 2.5 micromoles per joule** (µmol/J).

Who it applies to: No change from current rules — applies to new construction and alterations of indoor grow spaces and greenhouses with more than 40 kilowatts of lighting.

See Title24stakeholders.com for proposal description, justification, draft code language, and requested data

Background Information: How Energy is Saved

- Photosynthetic Photon Efficacy (PPE) measures how efficiently horticultural light fixtures convert electricity into light usable for photosynthesis.

- By increasing the required PPE from **2.3 to 2.5 µmol/J**, the same light intensity can be achieved with **less electrical input**, reducing total energy use.

- More efficient fixtures produce **less waste heat**, lowering the **cooling load** on HVAC systems and further reducing facility energy use.

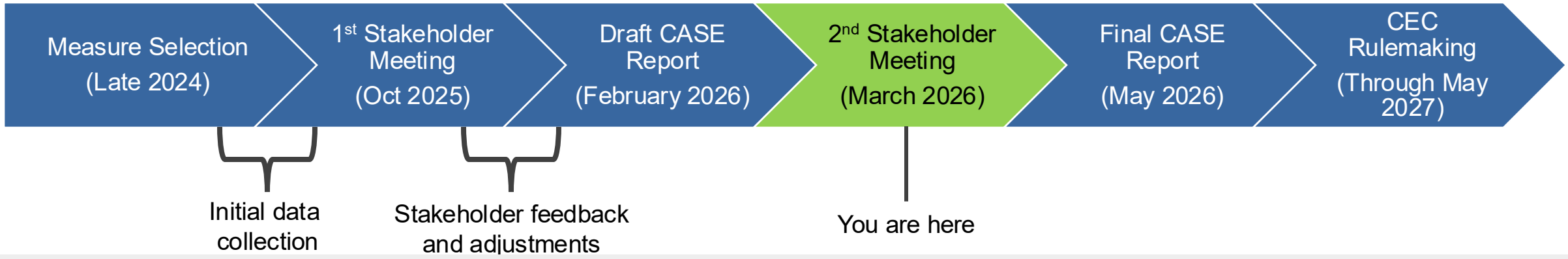
What's New Since Our Last Stakeholder Meeting?

New / Updated

- ✓ Estimated Useful Life
- ✓ Incremental First & Maintenance Costs
- ✓ Cost-Effectiveness Results & Benefit-to-Cost Ratio
- ✓ Statewide Energy & Energy Cost Savings

Still Under Consideration

- Updated PPFD target for indoor cannabis flowering rooms
- Market Share



Poll

Market Share

In your experience, how common is CEH lighting with ≥2.5 PPE in new installations today?

a. Below half (0–50%)
b. Somewhat Common (51–60%)
c. Usually (61-75%)
d. Very common (76-90%)
e. Almost always (>90%)
f. Not sure

PPE: Current Market Share

Market share: percentage of buildings that already use the proposed technology or design practice (at or above the proposed stringency level)

New Construction & Additions	**100% of regulated CEH projects are assumed LED based on 2025 Energy Code requirements** **88% of LED fixtures on the market meet ≥ 2.5 µmol/J*** **= 88% market share**

**DesignLights Consortium (DLC) Horticulture Lighting QPL Update*

Alterations	**78% of cannabis growers are LED**** **88% of LED fixtures meet ≥ 2.5 µmol/J*** **= 68.6% market share**

***2025 Cannabis Business Times Survey Results*

Technical Considerations

LED baseline remains unchanged, but PPE requirement improves to 2.5 µmol/J.

- High-efficacy LEDs can provide **flexible spectral quality**, supporting a range of crops and production goals.
- While increases in PPE can sacrifice spectrum quality, 2.5 µmol/J level still allows for flexibility in spectrum for diverse crops.
- However, 2.5 µmol/J does **not guarantee spectrum quality**—and growers must still select spectrum-conscious fixtures for their goals.
- Important: PPE measures Photosynthetically Active Radiation (PAR) efficiency (400–700 nm) and does **not capture far-red (FR)** or **UV contributions**. Far red light (700–750 nm) can be important for some crops.

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Technical Considerations

In your experience, have you encountered situations where lighting fixtures with a Photosynthetic Photon Efficacy (PPE) of 2.5 µmol/J or higher could not achieve the desired lighting spectra?

a) Yes, rarely
b) Yes, occasionally
c) Yes, often
d) No, never
e) Not sure

Energy and Cost Savings Methodology

Based on T24 2025 Methodology

- Our calculations follow the established **Title 24 CEH lighting model**, using Excel-based hourly energy simulation.
- Maintain consistent PPFD, photoperiod, crop-specific design parameters—only PPE changes incrementally from 2.3 to 2.5 µmol/J.
- All other factors—mounting height, maintenance, controls, layout—are held constant.

Lighting Use = Wattage per square foot × Photoperiod × Area

- *Wattage* derived from canopy PPFD × photoperiod length.
- *Area per luminaire* varies based on crop type and facility type (indoor vs greenhouse).

$$\text{Efficiency Gain} = \frac{2.5 - 2.3}{2.3} \approx 8.7\%$$

Energy Modeling Assumptions

Simulating using the following prototypical buildings and climate zones

Prototypical Buildings

Building Types Included

- **Indoor** grow facilities
- **Greenhouses** with supplemental lighting

Crops Modeled

- **Cannabis**
- **Tomatoes** (vine crops)
- **Greens** (e.g., herbs, microgreens)

Climate Zones

- Climate zones 1-16

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Technical Considerations

Based on your experience, which best describes standard dimming practice for horticultural LED lighting?

a) Lights are dimmed, with low-end dim range ~10% of full output
b) Lights are dimmed, with low-end dim range ~20% of full output
c) Lights are dimmed, with low-end dim range ~50% of full output
d) Lights are not typically dimmed (on/off only)
e) Other
f) Not sure

Energy Modeling Assumptions

Prototype: Indoor & Greenhouse

Photosynthetic Photon Flux Density (µMol/m²/s)

Building Type	Cannabis Flower	Cannabis Vegetative	Cannabis Clone	Leafy Greens	Tomatoes
Indoor	1,000	600	200	200	350
Greenhouse	600	400	200	200	350

Lighting System Design Parameters

	Cannabis Flower	Cannabis Vegetative	Cannabis Clone	Leafy Greens	Tomatoes
Canopy Area per Luminaire (ft²)	20	24	10	58	56
Photoperiod (hours per day)	12	18	24	18	12
Mounting Height Above Canopy	24”	24”	24”	24”	24”

Standard Design

1. 2.3 PPE (µMol/J)
2. Title 24 2025

Proposed Design

1. 2.5 PPE (µMol/J)
2. All other assumptions are identical to Standard Design / Baseline

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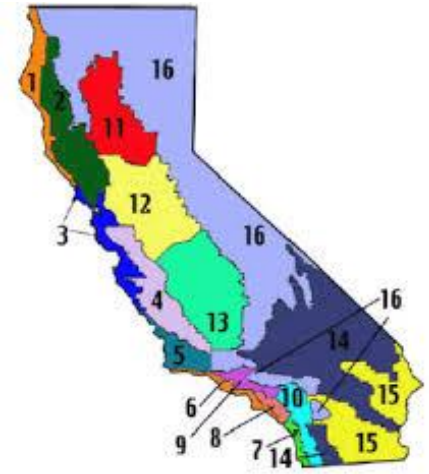
Modeling Assumption

What is the typical PPFD (Photosynthetic Photon Flux Density) you maintain in your indoor cannabis flowering rooms?

a) Below 800 µmol/m²/s
b) 801–1000 µmol/m²/s
c) 1001–1200 µmol/m²/s
d) 1201-1400 µmol/m²/s
e) Above 1400 µmol/m²/s
f) Not sure / don't have an indoor cannabis flower room

First-Year Per-Unit Energy Savings

- **Energy savings:** 0.23 to 16.26 kWh per year per canopy square foot
- **Electric demand reductions:** 0.00005 to 0.001 kW per canopy square foot
- **No natural gas savings** are associated with the proposed measure



First Year Electricity Savings (kWh) Per Canopy Square Foot by Climate Zone (CZ) – Lighting Efficacy

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Indoor (Warehouse) Cannabis	15.41	15.62	15.57	15.75	15.62	15.71	15.75	15.86	15.86	15.91	15.81	15.74	15.88	15.87	16.26	15.43
Indoor (Warehouse) Leafy Greens	4.75	4.80	4.80	4.84	4.80	4.84	4.85	4.88	4.88	4.89	4.86	4.84	4.89	4.87	5.00	4.75
Indoor (Warehouse) Tomatoes	5.55	5.63	5.61	5.68	5.63	5.66	5.67	5.72	5.72	5.73	5.70	5.67	5.72	5.72	5.86	5.56
Greenhouse Cannabis	3.52	2.80	2.65	2.17	2.15	2.06	2.12	2.10	2.03	1.99	2.89	2.64	2.32	1.86	1.81	2.83
Greenhouse Leafy Greens	0.97	0.72	0.66	0.42	0.37	0.30	0.28	0.31	0.31	0.30	0.81	0.66	0.52	0.25	0.23	0.74
Greenhouse Tomatoes	1.31	0.99	0.92	0.63	0.58	0.49	0.47	0.50	0.50	0.48	1.08	0.92	0.74	0.41	0.38	1.01

Incremental Cost Framework

Prototype(s): Greenhouse and Indoor Horticulture

Baseline

First Cost

1. Lighting Costs by plant type
2. Installation

30-Year Maintenance Costs

1. Equipment Replacement
2. Regular Maintenance (Lens cleaning)

Proposed

First Cost

1. Lighting Costs by plant type
2. Installation

30-Year Maintenance Costs

1. Equipment Replacement
2. Regular Maintenance (Lens cleaning)

Incremental First Cost per Canopy Square Foot

Building Type	Crop Type	Proposed Equipment First Cost (Dollar per Canopy Square Foot)	Incremental Equipment First Cost (Dollar per Canopy Square Foot)
Indoor (Warehouse)	Cannabis	$38.92	$1.23
	Leafy Greens	$11.27	$0.00
	Tomatoes	$14.72	$0.47
Greenhouse	Cannabis	$22.17	$0.70
	Leafy Greens	$11.27	$0.00
	Tomatoes	$14.72	$0.47

- Online cost data was obtained for a total of 37 horticultural LED fixtures (Nov. to Dec. 2025).
  - Cannabis clone: 200-330 Watts/fixture
  - Leafy greens: 345-465 Watts/fixture
  - Cannabis veg and flower, tomatoes: 600-1050 Watts/Fixture
- Costs were calculated for each fixture and averaged for each crop: $/1,000 µMol/s.
- First cost per canopy square foot = target PPFD x calculated cost per 1,000 µMol/s.

What are your thoughts on the proposed incremental first costs?

(You may share support, concerns, or general comments.)

Incremental Maintenance Cost

Fixture replacement assumed to be the equipment first cost at the calculated Estimated Useful Life (EUL):

Parameter	Cannabis – Flower	Cannabis – Vegetative	Cannabis – Clone	Leafy Greens	Tomatoes
Photoperiod (hours/day)	12	18	24	18	12
Annual Operating Hours	4,161	6,242	8,322	6,242	4,161
EUL (years) Baseline	Indoor = 12 Greenhouse = 11	Indoor = 12 Greenhouse = 11	Indoor = 12 Greenhouse = 11	8	13
EUL (years) Measure Case	Indoor = 12 Greenhouse = 12	Indoor = 12 Greenhouse = 12	Indoor = 12 Greenhouse = 12	9	14

Assumed rated life of LED luminaires in CEH applications (Design Lights Consortium, Dec. 2025):

- 58,945 hours rated life at 2.5 µmol/J PPE
- 55,826 hours rated life at 2.3 µmol/J PPE

What are your thoughts on the proposed incremental maintenance costs (replacement at end of EUL)?

(You may share support, concerns, or general comments.)

30-Year Cost-Effectiveness Summary Per Canopy Square Foot

New Construction & Additions

Prototype	Benefits LSC Savings + Other PV Savings (2029 PV$)	Costs Total Incremental PV Costs (2029 PV$)	Benefit-Cost Ratio
Indoor (Warehouse) Cannabis	$111.81	$2.66	42
Indoor (Warehouse) Leafy Greens	$40.12	$0.00	Not Applicable
Indoor (Warehouse) Tomatoes	$39.11	$0.50	77
Greenhouse Cannabis	$20.55	$0.77	27
Greenhouse Leafy Greens	$5.17	$0.00	Not Applicable
Greenhouse Tomatoes	$6.64	$0.50	13

Alterations

Prototype	Benefits LSC Savings + Other PV Savings (2029 PV$)	Costs Total Incremental PV Costs (2029 PV$)	Benefit-Cost Ratio
Indoor (Warehouse) Cannabis	$111.84	$2.66	42
Indoor (Warehouse) Leafy Greens	$40.12	$0.00	Not Applicable
Indoor (Warehouse) Tomatoes	$39.12	$0.50	77
Greenhouse Cannabis	$19.24	$0.77	25
Greenhouse Leafy Greens	$4.34	$0.00	Not Applicable
Greenhouse Tomatoes	$5.79	$0.50	11

What are your thoughts on the cost effectiveness and energy savings findings?

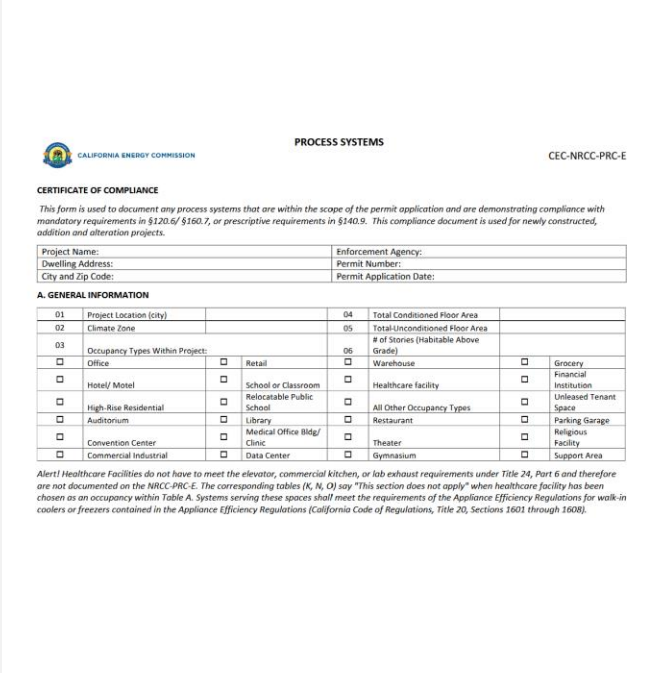
(Please share support, concerns, or general comments.)

Total First-Year Energy Savings by Crop (Statewide)

Crop Type	Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2029 PV$)
Cannabis	**New Construction & Additions**	0.65	0.05	N/A	0.68	$4.76
	Alterations	4.22	0.35	N/A	4.36	$30.59
Greens	**New Construction & Additions**	0.16	0.025	N/A	0.437	$1.48
	Alterations	0.086	0.008	N/A	0.12	$0.71
Tomatoes	**New Construction & Additions**	0.044	0.0051	N/A	0.079	$0.36
	Alterations	0.22	0.027	N/A	0.41	$1.78
All	**Total**	**2.43**	**0.21**	**N/A**	**2.64**	**$17.84**

Compliance & Enforcement

- **No significant compliance or enforcement issues** identified with current horticultural lighting requirements.
- Proposed measure updates an **existing PPE threshold from 2.3 PPE to 2.5 PPE**, with no new compliance pathway.
- **Compliance is documented through existing forms**, including the **NRCC-PRC-E.**
- Plan checkers and inspectors continue current review and verification practices.
- No field testing, diagnostic testing, or compliance software updates required.



CALIFORNIA ENERGY COMMISSION

PROCESS SYSTEMS

CEC-NRCC-PRC-E

CERTIFICATE OF COMPLIANCE

This form is used to document any process systems that are within the scope of the permit application and are demonstrating compliance with mandatory requirements in §120.6/ §160.7, or prescriptive requirements in §140.9. This compliance document is used for newly constructed, addition and alteration projects.

Project Name:	Enforcement Agency:
Dwelling Address:	Permit Number:
City and Zip Code:	Permit Application Date:

A. GENERAL INFORMATION

01	Project Location (city)			04	Total Conditioned Floor Area		
02	Climate Zone			05	Total-Unconditioned Floor Area		
03	Occupancy Types Within Project:			06	# of Stories (Habitable Above Grade)		
☐	Office	☐	Retail	☐	Warehouse	☐	Grocery
☐	Hotel/ Motel	☐	School or Classroom	☐	Healthcare facility	☐	Financial Institution
☐	High-Rise Residential	☐	Relocatable Public School	☐	All Other Occupancy Types	☐	Unleased Tenant Space
☐	Auditorium	☐	Library	☐	Restaurant	☐	Parking Garage
☐	Convention Center	☐	Medical Office Bldg/ Clinic	☐	Theater	☐	Religious Facility
☐	Commercial Industrial	☐	Data Center	☐	Gymnasium	☐	Support Area

Alert! Healthcare Facilities do not have to meet the elevator, commercial kitchen, or lab exhaust requirements under Title 24, Part 6 and therefore are not documented on the NRCC-PRC-E. The corresponding tables (K, N, O) say "This section does not apply" when healthcare facility has been chosen as an occupancy within Table A. Systems serving these spaces shall meet the requirements of the Appliance Efficiency Regulations for walk-in coolers or freezers contained in the Appliance Efficiency Regulations (California Code of Regulations, Title 20, Sections 1601 through 1608).

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More information on
CEC's 2028 proceeding website.

We want to hear from you!

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