



**TITLE 24, PART 6**

**2028 CODE CYCLE**

# Controlled Environment Horticulture (CEH) Space Conditioning

Codes and Standards Enhancement (CASE) Proposal

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March 5, 2026



# Purpose of Workshop

1. Provide background on indoor agriculture market in California
2. Explain proposed changes to Title 24, Part 6
3. Highlight stakeholder feedback and updates to proposal since September workshop
4. Review CEH prototype and savings methodology
5. Review cost effectiveness methodology, assumptions, and results
6. Explain proposed compliance process when code would take effect (January 1, 2029), including:
  - How load and sizing calculations will be used for compliance
  - How the prototype would be used for compliance
7. Solicit feedback from stakeholders regarding proposed code requirements, assumptions, and methodology

# Scope: Indoor CEH Facilities

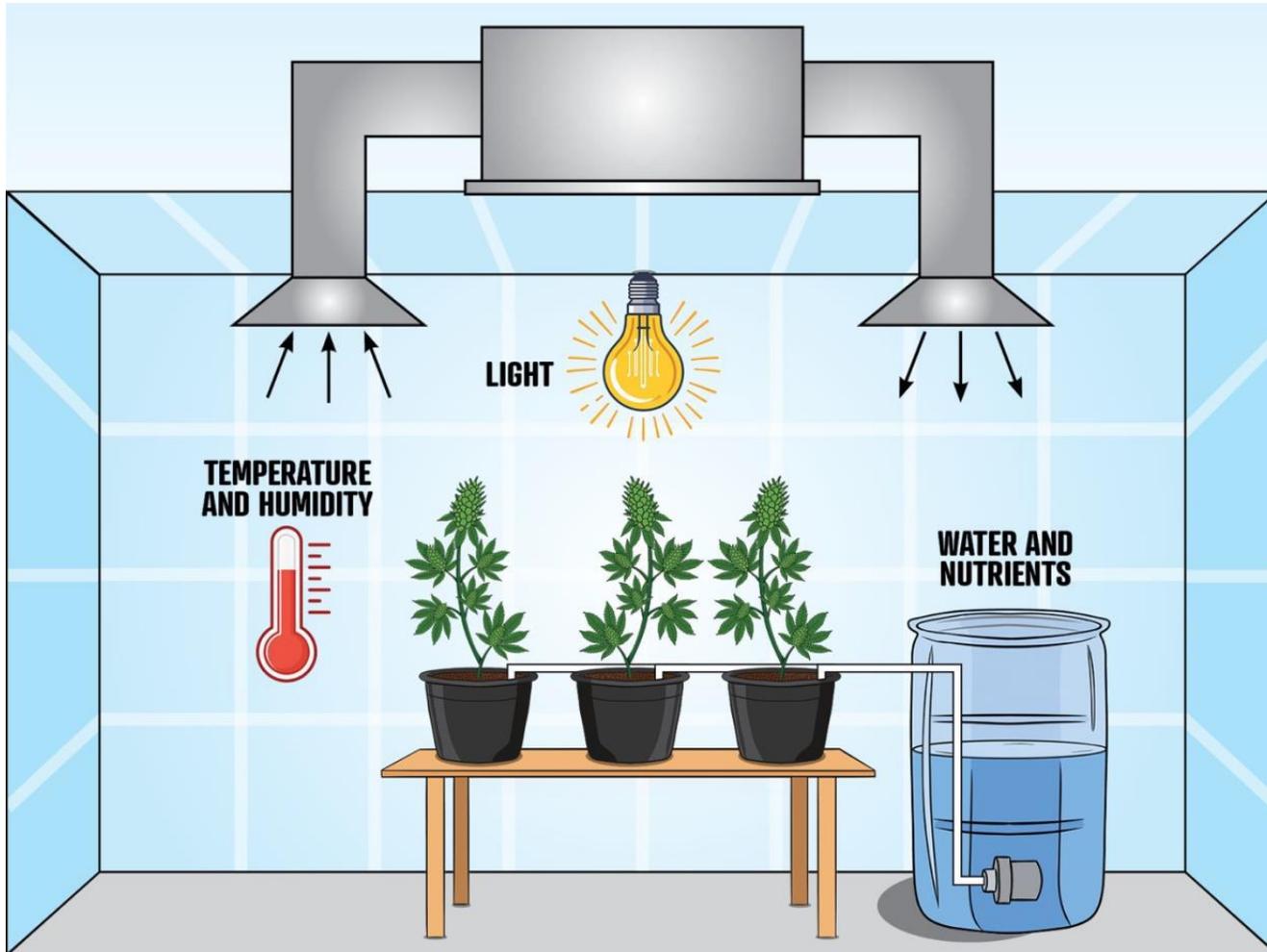
- Indoor CEH Facilities
  - Are horticultural "process spaces" designed and operated to support plant growth
  - Share some properties with other building types, but have fundamental differences
  - Have much different loads and mechanical design requirements than other buildings
  - Have highest energy use intensity (EUI) of any building type (aside from data centers)
- Proposed HVAC and dehumidification code changes focus on indoor CEH facilities with very high lighting intensity
  - Over 90% of indoor CEH in California is cannabis production
  - Nearly all indoor farms with high lighting intensity (over 30watts/sq. ft. of canopy) are used for cannabis production
  - In California, the only facilities that are likely to trigger these code requirements are facilities with cannabis flower rooms
  - New requirements would not apply to smaller indoor facilities with less than 5,000 square feet of plant canopy or to greenhouses—smaller indoor facilities would still need to comply with existing code

# 1. Background

Indoor CEH market and HVAC/D  
in California



# Fundamentals of Loads in an Indoor Cannabis Facility



- Envelope typically insulated and sealed with no glazing or outdoor air ventilation.
- Indoor air is enriched with CO<sub>2</sub>.
- Almost all loads are internal.
- Internal loads must be controlled by mechanical systems—economizing isn't an option.
- Loads include heat from lighting and fans and humidity transpired by plants.
- A typical flower room with 2000 square feet of plant canopy can generate 500 gallons of condensate each day .

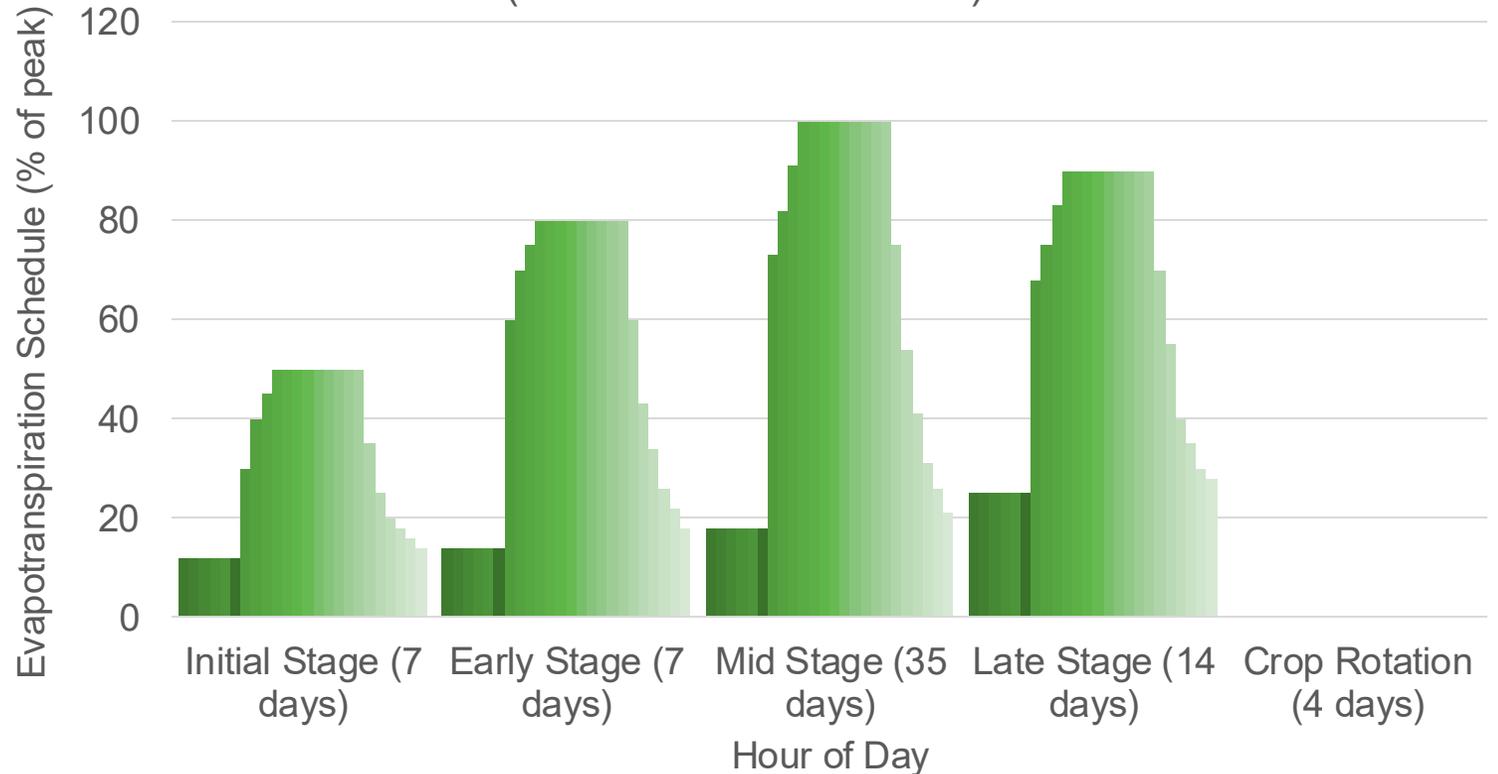
# Fundamentals of Loads in an Indoor Growing Facility

Typical nine week grow cycle



- Latent loads are highly variable between day/night and over the course of the grow cycle
- Sensible cooling loads are highest in the early grow, when evaporative cooling from transpiration is low
- Latent loads are highest later in the grow cycle

Flower Evapotranspiration Schedule  
(% of Peak Latent Load)



# Rapid Load Growth in Existing Buildings: High Energy Intensity of Indoor Farms

May 2021



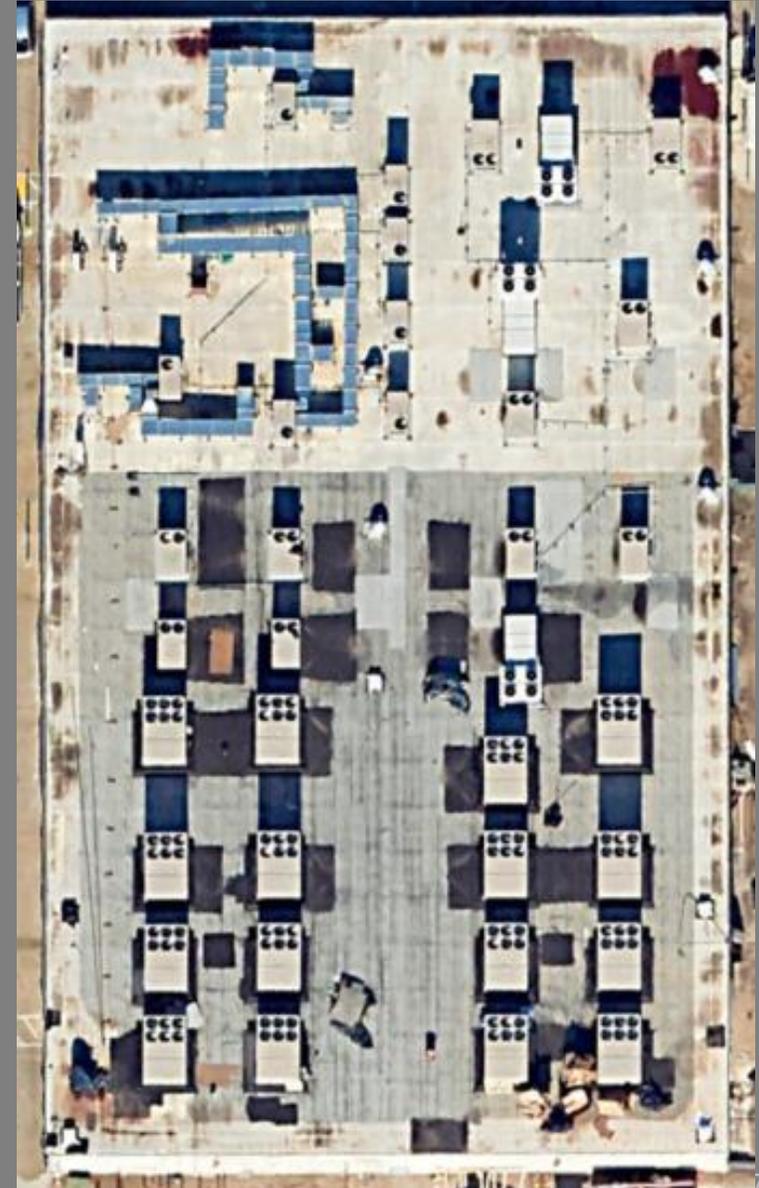
~5 tons cooling capacity

Feb 2022



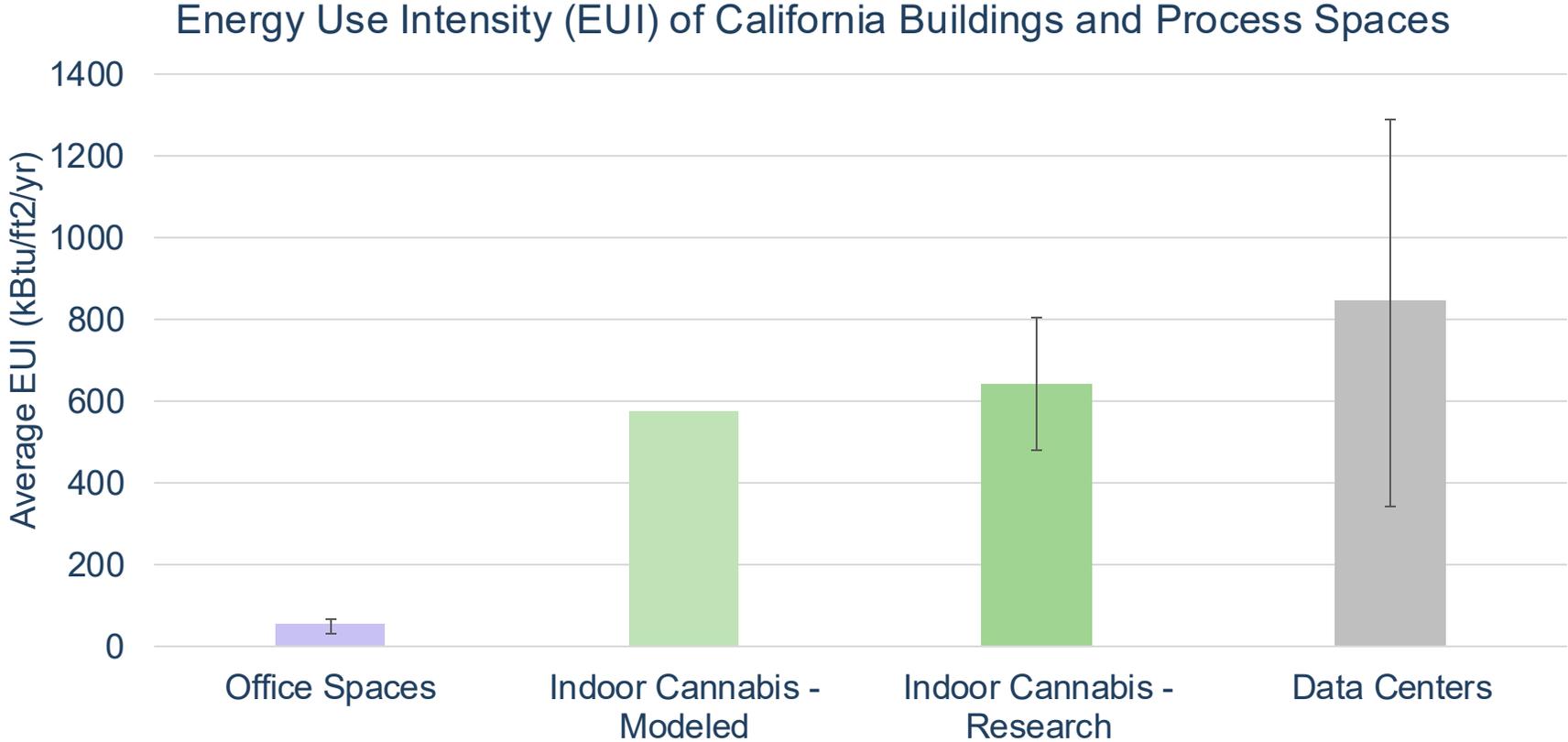
~200 tons cooling capacity

Nov 2023



~1000 tons cooling capacity

# Background: High Energy Intensity of Indoor Cannabis



**Sources**

Indoor Cannabis Modeled: Current T24 P6 CEH Model Prototype

Indoor Cannabis Research

- New Frontier Data, 2018 <https://www.trorc.org/wp-content/uploads/2020/10/NFD-TheCannabisEnergyReport-102418.pdf>
- Stober & Weitze, 2024 <https://www.etcc-ca.com/reports/controlled-environment-horticulture-energy-consumption-and-environmental-control-field>
- Sabeh, Miner, & Perman, 2022 <https://www.etcc-ca.com/reports/controlled-environment-horticulture-facility-assessment-and-industry-survey-report>

Office Spaces and Data Centers: EnergySTAR Portfolio Manager Data Explorer <https://portfoliomanager.energystar.gov/dataExplorer/>

# Background Information: Market Status and Opportunities

## Market Slow to Adopt New and Efficient Technologies

- California is an early-adopter state for indoor ag (cannabis)
- Growers initially used equipment designed for other applications (office/residential systems)
- First-generation integrated systems (pool dehumidifiers, etc.) underperformed, creating negative perceptions
- Continued reliance on inefficient equipment designed for other applications

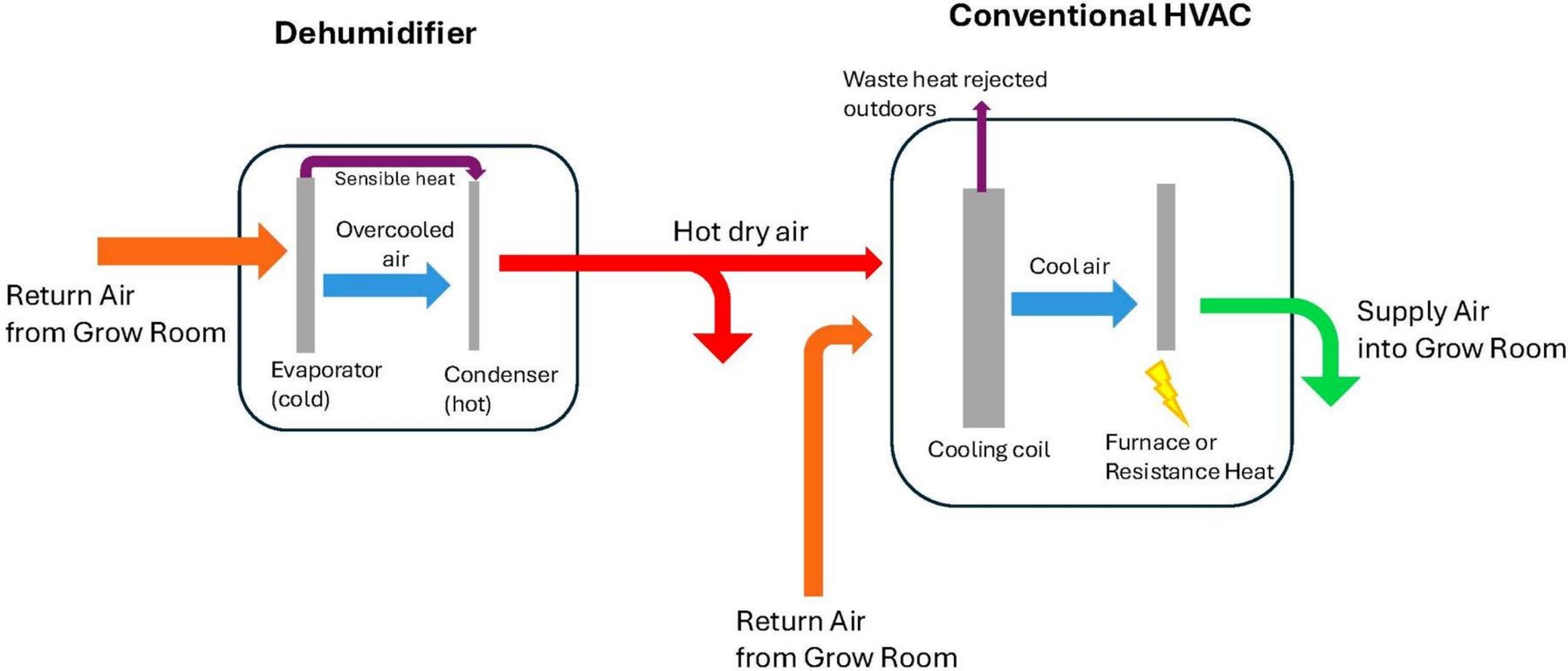
## Current Opportunities

- Variety of reliable, integrated products and controls now available
- Offer better performance and energy savings at similar cost (if properly sized)

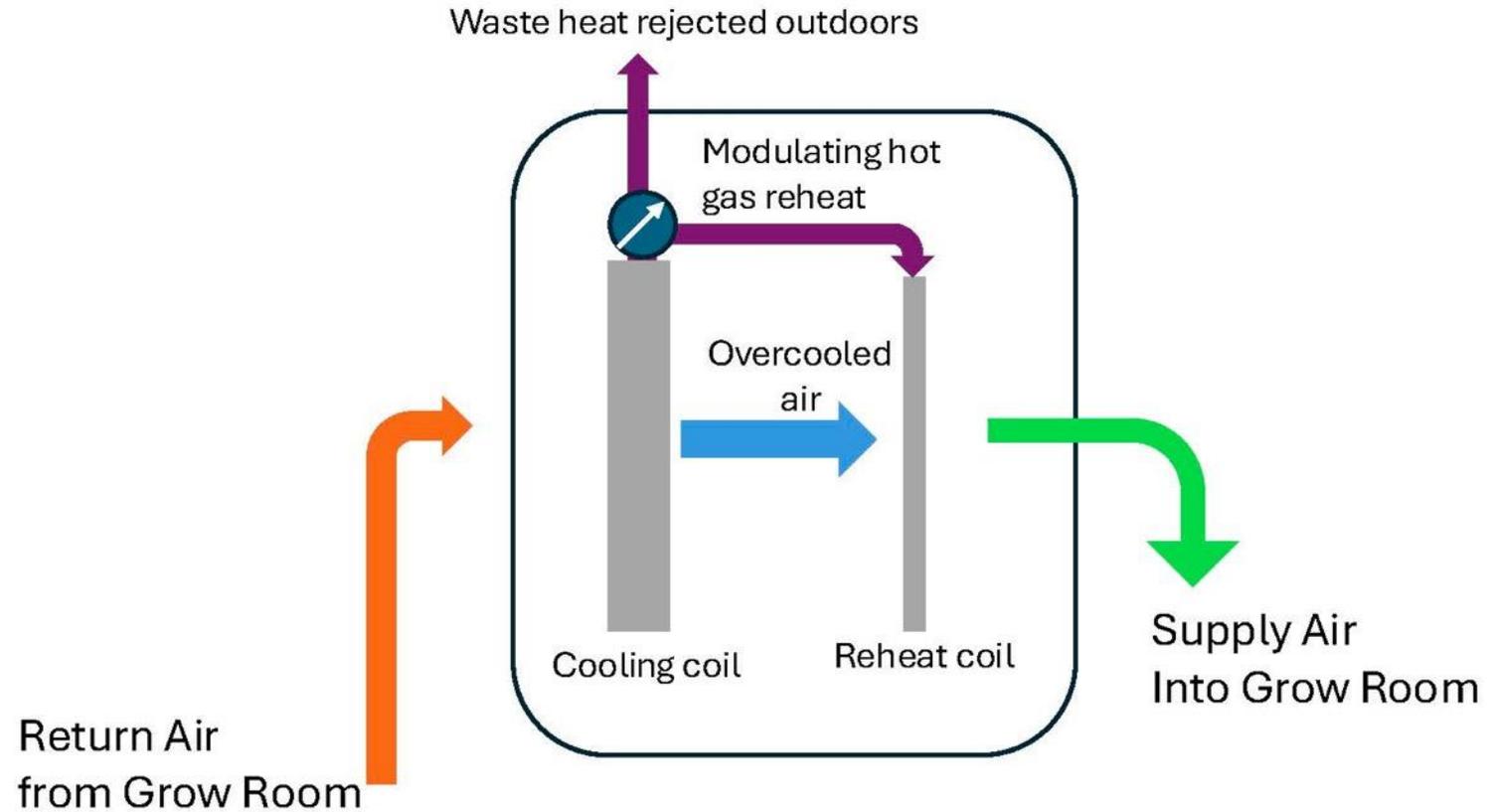
# Indoor CEH Market in California

- As the market for indoor cannabis has expanded, manufacturers and distributors have developed HVAC/D products and systems well-suited to the highly variable latent and sensible loads in cannabis farms
- These "integrated" technologies include:
  - Integrated DX systems based on DX DOAS units,
  - Reconfigured DX pool dehumidification equipment,
  - Four-pipe fan coil systems with heat recovery chillers, and
  - Liquid desiccant systems that use recovered heat for regeneration
- These efficient integrated HVAC technologies share the same key features:
  - Variable sensible heat ratio (SHR) that can modulate to control both humidity and temperature in response to highly variable loads,
  - Ability to use recovered process heat to reheat dehumidified air, and
  - Ability to reject unneeded dehumidification process heat outdoors

# Background Information: Decoupled System



# Background Information: Integrated Dehumidification, Cooling, and Reheat



# Opportunities for Savings

1. Ensure equipment is designed and sized to meet design loads and setpoint targets for the 9-week flower cycle
2. Use integrated HVAC/D equipment that can adjust to fluctuating latent and sensible loads, use recovered heat for reheat, and reject unneeded dehumidification process heat outdoors
3. Use a combination of efficient cooling and efficient standalone dehumidification equipment with integrated controls in a decoupled configuration
4. Use a combination of integrated HVAC/D equipment and supplemental dehumidification equipment controlled to operate during peak latent conditions

*“The authors have observed a trend toward lowest first cost options for HVAC systems serving grow spaces.....HVAC systems are not being thoughtfully designed for the unique conditions for the grow spaces, resulting in difficulty controlling the environment, frustration with the installed systems, and a “Band-Aid” approach to fixing the problem where more and more standalone dehumidifying equipment is added until the desired conditions are met, which ultimately increases the energy use associated with production.”*

Trends and Observations of Energy Use in the Cannabis Industry. Jesse Remillard, PE, and Nick Collins, PE, ERS. 2017

[https://www.aceee.org/files/proceedings/2017/data/polopoly\\_fs/1.3687880.1501159058/files/server/file/790266/filename/0036\\_0053\\_000046.pdf](https://www.aceee.org/files/proceedings/2017/data/polopoly_fs/1.3687880.1501159058/files/server/file/790266/filename/0036_0053_000046.pdf)

# Background: How Energy is Saved

## **Waste heat recovery when needed, rejection when not needed**

- Standalone dehumidifiers add all dehumidification process heat (condenser and compressor heat exhausted at ~100F) into the grow room, regardless of whether it is needed
- An integrated system reheats the air to the desired temperature and rejects extra heat outdoors, eliminating the need for the cooling system to remove the dehumidifier's waste heat

## **Synchronized and precise control**

- A single control system manages cooling and dehumidification functions in tandem, varying the sensible and latent load removal to match the needs of the grow room
- Variable speed compressors and fans can modulate their output to meet the load rather than short cycling at full power

## **Optimal sizing for the unique demands of cultivation**

- Decoupled systems require more total capacity to meet the latent loads of a grow room and the sensible loads generated by the dehumidifiers

## **Less equipment running**

- Decoupled cooling and dehumidification equipment often operate simultaneously

# Recent Studies Validate Savings and Performance

Year	Study Type	Key Findings	Source
2025	Parallel evaluation study of 10 cannabis flower rooms and 42 grow cycles in four facilities, comparing integrated vs. decoupled HVACD system types	38% lower energy intensity (kWh/ton) for integrated vs. decoupled HVACD	unpublished
2023	Model of three HVACD system types for industrial cannabis flower room: 1. Mini split (23.5 IEER) + dehumidifiers 2. VRF split (22.0 IEER) + dehumidifiers 3. Integrated HVACD (18.2 IEER)	Integrated HVACD System used 14% less energy than system 1 and 16% less than system 2	<a href="#">Cultivation HVACD System Comparison Study</a>
2022	Review of technologies that can support energy savings in indoor farms and greenhouse including HVACD integrated controls	20-30% energy savings potential for high-performance HVAC solutions	<a href="#">Best Practices Guide HVAC for CEA Operations</a>
2019	Case study of cannabis facility in Portland, Oregon that upgraded from code minimum decoupled to integrated HVACD	44% HVACD energy savings	<a href="#">Non-Lighting EE in Indoor Cannabis Growing</a>
2018	Two case studies of cannabis facilities in Portland, Oregon that upgraded lighting and switched from decoupled to integrated HVACD	50-55% HVACD energy savings for integrated vs. decoupled	<a href="#">Indoor Cannabis Growing – Taming the Wild West</a>
2018	Review of HVAC for cannabis	20-40% savings in tonnage by using energy recovery	<a href="#">HVAC for Cannabis Cultivation &amp; CEA</a>
2018	Case study of a grower in Oregon who made high-efficiency HVAC (3-coil ground-mounted RTUs, variable speed drive, HGRH coil, advanced controls) and lighting	30% savings in annual energy usage	

## 2. Proposal Description

- Proposed clarifications and updated definitions
- Proposed updates to mandatory requirements
- Proposed updates to prescriptive requirements



# Proposed Code Change: Code Clarifications

**Who it applies to:** All CEH facilities. New construction, additions, and major alterations.

## Creates/Clarifies Code Language and Definitions

- Exclude Indoor Controlled Environment Horticulture Space from Conditioned Space definition to recognize that the primary purpose of space is for an agricultural process (plant growth—not human occupancy)
- Creates new definition for "CEH Space Conditioning System"
- Introduces "Plant Canopy Area" as trigger
- Revise ventilation requirements for CO<sub>2</sub>-enriched spaces to align with fire code

**Update compliance software to model indoor CEH space conditioning systems and set standard design**

See [Title24stakeholders.com](https://title24stakeholders.com) for CASE Report, proposal description, justification, draft code language, and requested data

# Plant Canopy Area, Facility Size, and Total Capacity

For determining canopy or cultivation area at indoor cannabis cultivation sites there are three main factors to consider:\*

1. The room or rooms where plants will be grown
2. The trays and/or tables upon which the plants will be grown
3. An identifiable boundary in the form of trellising, trays, shelves, etc. that will serve to demarcate the canopy of the cultivation area



Walkway Workspace



Graphic illustrating canopy area calculations for indoor cannabis farms. Source: Sonoma County Law Library

Example of Facilities with Single-Level Flower Rooms with Decoupled HVAC and Dehumidification			
Flower Room Canopy Area (sq. ft.)	≈ Approximate Flower Room Area (sq. ft.)	≈ Approximate Total Facility Footprint (sq. ft.)	≈ Approximate Total Cooling & Dehumidification Capacity for Flower Rooms (Tons)
5,000	6,700	15,000	200
22,000	29,000	66,000	870

\*<https://sonomacountylawlibrary.org/Main%20County%20Site/Administrative%20Support%20%26%20Fiscal%20Services/CAO/Documents/Projects/Cannabis/Determining%20Canopy%20Comprehensive.pdf>

# Proposed Code Change: CEH-Specific Load Calculations and Sizing

**Who it applies to:** Indoor growing facilities above 5,000 square feet of plant canopy area with a high lighting power density (tentatively above 30W/canopy square foot). New construction, additions, and alterations.

## Proposed Mandatory Sizing Requirements:

- Must provide design conditions and equipment conditions for:
  - Lights on / lights off
  - First week, early/mid flower cycle, and late flower cycle
- Sizing calculations must demonstrate that HVAC/D equipment has sufficient cooling, dehumidification, and reheat capacity to meet loads and setpoints for each phase of the grow cycle
  - Load calculation, sizing, and capacity calculations will be covered the Compliance Section

# Proposed Code Change: Heat Recovery and Supplemental Heating

**Who it applies to:** Indoor growing facilities above 5,000 square feet of plant canopy area with a high lighting power density (>30W/canopy square foot). New construction, additions, and alterations

## Proposed Mandatory Requirements:

- **Heat recovery.** Equipment used for dehumidification shall be capable of meeting at least 90% of reheat load with recovered heat
- **Supplemental heating.** If used, electric resistance heating or combustion heating equipment shall:
  - Be sized to meet heating loads that cannot be met with heat recovered from the dehumidification process
  - Be controlled to only operate when heating load exceeds 100% of the available dehumidification process heat

# Proposed Code Change: Controls

**Who it applies to:** Indoor growing facilities above 5,000 square feet of plant canopy area with a high lighting power density (tentatively above 30W/canopy square foot). New construction, additions, and alterations.

## Proposed Mandatory Requirements:

- **Integrated temperature and humidity controls.** Controls for space conditioning equipment shall meet all of the following requirements:
  - One integrated control system shall control both humidity and temperature based on readings from humidity and temperature sensors co-located within the plant canopy
  - Controls shall automatically stage or modulate all space conditioning equipment to meet temperature and humidity setpoint
- **Dehumidification equipment without modulating heat recovery and modulating heat rejection.** If used, dehumidification equipment without modulating heat recovery and modulating heat rejection shall:
  - Be controlled from a central controller that sequences unitary dehumidifiers automatically based on dehumidification load
  - Only be activated during periods when all waste heat can be used in the space or when other space conditioning equipment cannot satisfy 100% of cooling, heating, and dehumidification loads

## Poll

**How widely available are space conditioning controls that meet the following requirements:**

- **use co-located temperature and humidity sensors within the canopy,**
  - **provide integrated control for all types of space conditioning equipment in the room, and**
  - **stage standalone dehumidifiers, if used?**
- 
- a) Available off the shelf from many manufacturers*
  - b) Easy to purchase, but require customization*
  - c) Not readily available*
  - d) Not sure*

# Proposed Code Change: Prescriptive Requirements

**Who it applies to:** Indoor growing facilities above 5,000 square feet of plant canopy area with a high lighting power density (30W/canopy square foot). New construction, additions, and major alterations.

## Proposed Prescriptive Requirements

- Primary space conditioning system capable of providing cooling, dehumidification, and reheat using heat recovered from the dehumidification process
- Primary system sized to meet at least 80% of peak latent and sensible load.
- Primary system and controls capable of:
  - Modulate sensible heat ratio in response to measured space conditions and temperature and humidity setpoints
  - Modulate heat recovery between 0% and 90% of heat of rejection of the primary system, as needed to meet supply air setpoints
  - Modulate supply fan speed in response to measured space conditions and temperature and humidity setpoints

**See [Title24stakeholders.com](https://www.title24stakeholders.com)**  
for Draft CASE Report  
proposal description,  
justification, draft code  
language, and requested data

**Proposal includes option for CEH  
facilities to comply via the  
performance path by modeling  
HVAC/D systems in flower rooms.**

# Proposed Code Changes: Alterations Code Triggers

## **New Space Conditioning requirements would be triggered by:**

- Additions or alterations to indoor CEH facilities that add at least 5000 square feet of plant canopy, and
- Alterations to indoor CEH facilities with at least 5000 square feet of plant canopy that are replacing more than 50% of the total capacity of heating, cooling, and dehumidification systems



# Stakeholder Feedback and Revisions

Updates to proposal since  
September 2025 workshop

# Revisions to Proposal (Presented September 2025)

- September proposal included “review and **revise prescriptive and mandatory requirements for envelope**”
- Stakeholder feedback and sensitivity analysis indicated:
  - Although envelope requirements for non-residential buildings were not developed for indoor farms, they generally align with industry practice
  - Envelope load is such a small portion of overall energy use that updating code requirements would not result in significant savings
- Revised proposal does not include any revisions to existing mandatory or prescriptive envelope requirements

Title 24 2025 NonRes Envelope Requirements				
	Prescriptive U-factor	Mandatory U-factor	R-value equivalent (Prescriptive)	R-value equivalent (Mandatory)
Metal Building Roof/Ceiling:	0.038	0.098	26.3	10.2
Metal-Framed Wall:	0.055	0.151	18.2	6.6
Metal Building Wall:	N/A	0.113	N/A	8.8

## Poll

**How does typical envelope insulation in newly constructed indoor CEH spaces compare to mandatory and prescriptive requirements for metal buildings?**

- a) Meets or exceeds prescriptive requirements*
- b) Somewhere between mandatory and prescriptive*
- c) Does not meet mandatory requirements*
- d) Not sure*

# Revisions to Proposal (Presented September 2025), cont

- September proposal included “review and revise prescriptive and mandatory requirements for **ventilation** to recognize that this is a process space with entirely different loads and schedules”
  - Stakeholder feedback and additional research included:
    - There are no ventilation requirements specifically for CEH spaces in the energy code
    - The logical default space type is Miscellaneous – Other @ 0.15 CFM/sq ft
    - Most designers provide zero ventilation to CO<sub>2</sub>-enriched CEH spaces, and most code officials do not directly enforce ventilation requirements
    - CO<sub>2</sub> enrichment systems are designed to maintain desired levels, adjusting to replace any CO<sub>2</sub> lost through ventilation
    - Other process spaces (freezers and refrigerated spaces) have zero minimum ventilation requirements
    - The California Fire Code requires alarms and ventilation purge @ 1 CFM/sq ft to protect workers in CO<sub>2</sub>-enriched spaces
  - Revised proposal would set minimum ventilation rate for CO<sub>2</sub>-enriched CEH spaces to zero

## Poll

**How are energy code ventilation requirements interpreted and implemented in CO<sub>2</sub>-enriched spaces such as flower rooms?**

- a) *Designed to meet minimum requirement of 0.15 cfm/sq. ft.*
- b) *Designed without continuous ventilation and receive waiver from code officials*
- c) *Designed without ventilation directly to the CEH space – but still meeting total building ventilation rate by increasing ventilation to adjacent spaces in the building*
- d) *Not sure*

# Revisions to Proposal (Presented September 2025), cont

- September proposal included different prescriptive requirements (four-pipe system with heat recovery chiller) for **facilities with over 22,000 square feet of canopy**.
- Stakeholder feedback included:
  - Setting two different prescriptive requirements based on facility size would add complexity
  - Although chilled water systems are very efficient, they can be difficult to maintain and control
  - Liquid desiccant systems offer an efficient solution with the same key attributes as other “integrated” equipment
  - Facilities as large as 70,000 square feet are still being constructed with decoupled designs
  - All types of “integrated” system, including integrated DX, offer improved efficiency vs. a baseline decoupled system
- Revised proposal would allow any “integrated” HVAC/D system to comply prescriptively for any facility over 5,000 square feet of canopy, including:
  - Integrated DX HVAC/D systems with variable SHR and modulating hot gas reheat
  - Four-pipe chilled water with heat recovery chiller
  - Desiccant dehumidification system that uses waste heat for regeneration.

# Revisions to Proposal (Presented September 2025), cont

- September proposal included **modulating heat recovery/rejection [TBD%]**.
- Stakeholder feedback included:
  - Concerns about over-reliance on resistance heating in integrated DX systems due to:
    - Insufficient reheat capacity in some designs,
    - Failure of modulating hot gas reheat valves in some products, and
    - Frequent compressor failure in first-gen integrated DX products.
  - Integrated DX products have improved significantly over the past five+ years.
- Revised proposal includes specific prescriptive requirements to:
  - Modulate recovered heat between 0% and 90%.
  - Developed load calculation and sizing tool to verify heat recovery ratio.

# Revisions to Proposal (Presented September 2025), cont

- September proposal included primary system **sized to [TBD%] of peak latent and sensible load.**
- Stakeholder feedback included:
  - Meeting 100% of sensible and latent load with integrated equipment requires additional capacity and increases cost – especially when targeting cool/dry conditions late in flower cycle
  - Strategic use of standalone dehumidifiers in combination with integrated DX equipment can be a cost-effective, efficient solution
  - Revised proposal includes specific prescriptive requirements for:
    - Sizing the primary integrated system to 80% of peak load, and
    - Using load calculation and sizing tool to verify sizing

# Revisions to Proposal (Presented September 2025), cont

- September proposal included primary mechanical system with **variable sensible heat ratio (SHR) [Range TBD]**.
- Stakeholder and expert feedback included:
  - Variable equipment SHR is a key attribute of integrated systems that can adjust to fluctuations in sensible and latent load
  - Calculations for coil sensible heat ratios should be based on design conditions for different points in each flower cycle
  - Sensible loads can be very high the first week of the flower cycle, requiring equipment to operate at high SHR, and SHRs are typically low during mid and late flower cycles
  - Revised proposal to include specific prescriptive requirements for:
    - Demonstrating that SHR can adjust as needed to meet 6 conditions (day/night in first week of grow cycle, mid-point in grow cycle, and last week of grow cycle)
    - Developed load calculation and sizing tool to verify SHRs

# Revisions to Proposal (Presented September 2025), cont

- September proposal included **prescriptive controls requirements** integrating primary and supplemental equipment.
  - SME and stakeholder feedback included:
    - Controls requirements should apply to both decoupled and integrated equipment
    - Controls requirements should be mandatory
  - Revised proposal:
    - Unifies controls requirements for all types of HVAC/D equipment used in CEH flower rooms



# Break for Q&A

# 3. Model Prototype and Energy Savings

## *Methodology and Assumptions*

- Indoor CEH Facility Prototype
- Energy and Energy Cost Savings



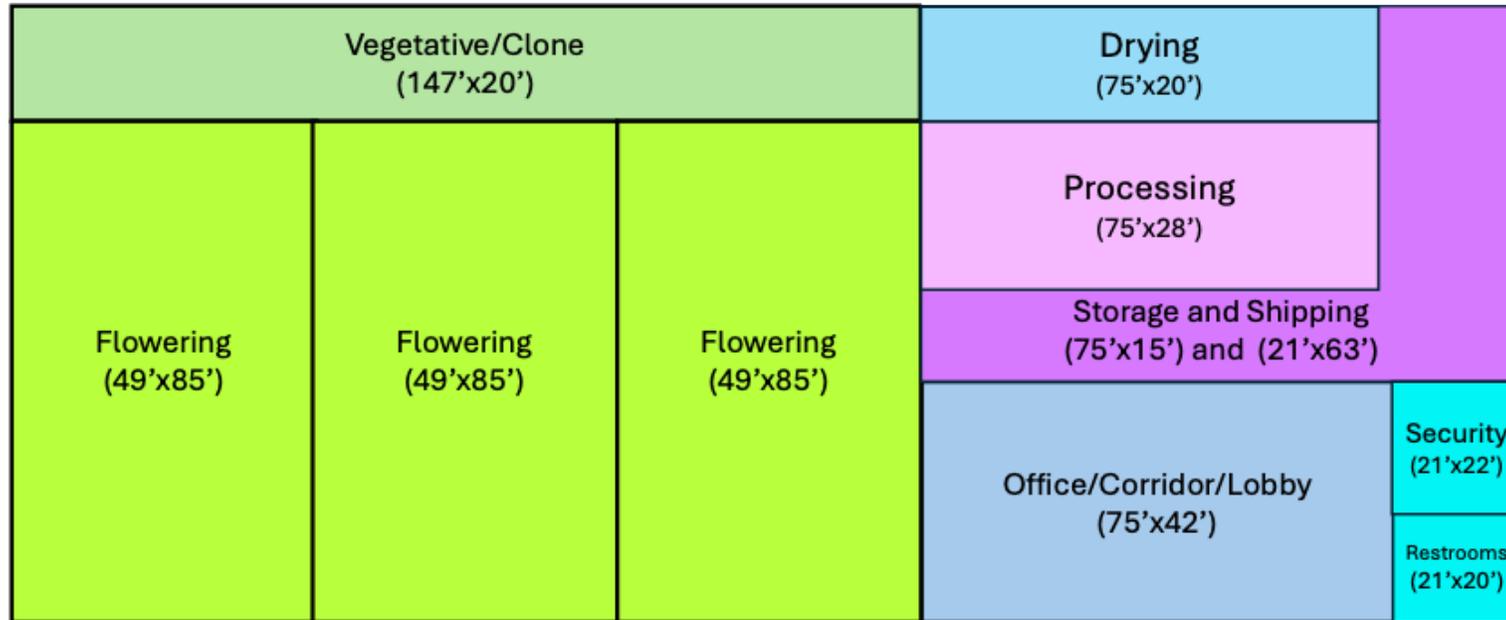
# Energy and Energy Cost Savings Methodology

- California Energy Commission's standard methodology and metrics
- Develop high lighting intensity indoor CEH facility prototype model
- Compare baseline system compliant with *current* code requirements to system compliant with *proposed* prescriptive requirements
  - Baseline: Humidistat-controlled standalone dehumidifiers and thermostat-controlled, single-stage HVAC with supplemental electric resistance heating.
  - Proposed: Variable capacity integrated DX HVAC/D system with modulating hot gas reheat (HGRH), variable sensible heat ratio, integrated temperature and humidity controls, and supplemental electric resistance heating
- Baseline and proposed are the same for all spaces other than the flower rooms

# Updates to CEH Prototype (Presented Dec 2025)

- Revising ventilation rates for non-CEH spaces to align with code
- Revising veg room ventilation rate to align with market practice
- Reviewing early and mid-grow setpoints to increase temperature based on contemporary LED designs
- Reviewing appropriate HVAC specification for non-CEH spaces
- Clarify that dimming only applies to new construction prototype

# Prototype CEH Facility Layout and Attributes



- Three single-zone flower rooms with staggered flower cycle start dates
- 2-tier veg/clone to provide enough plants for the flowering rooms
- Processing area including trimming, curing, and packaging
- 25,515 total square feet; approximately 13,000 total square feet of plant canopy area in all growing spaces

- **Metal building insulation:** R-26 (roof), R-19 (walls)
  - 14' ceiling
  - 4' plenum above ceiling
- **Grow Rooms**
  - **Canopy area:** 70% of room area, single-level
  - **Max Lighting intensity:** 48.5 Watt/sq. ft. canopy
  - **Photosynthetic photon efficacy (PPE):** 2.3  $\mu\text{Mol}/\text{J}$
  - **Photosynthetic photon flux density (PPFD):** 1200  $\mu\text{Mol}/\text{m}^2/\text{s}$  with dimming
  - **Max evapotranspiration latent cooling load:** 80 Btuh/square foot

# Temperature and Humidity Setpoint Assumptions

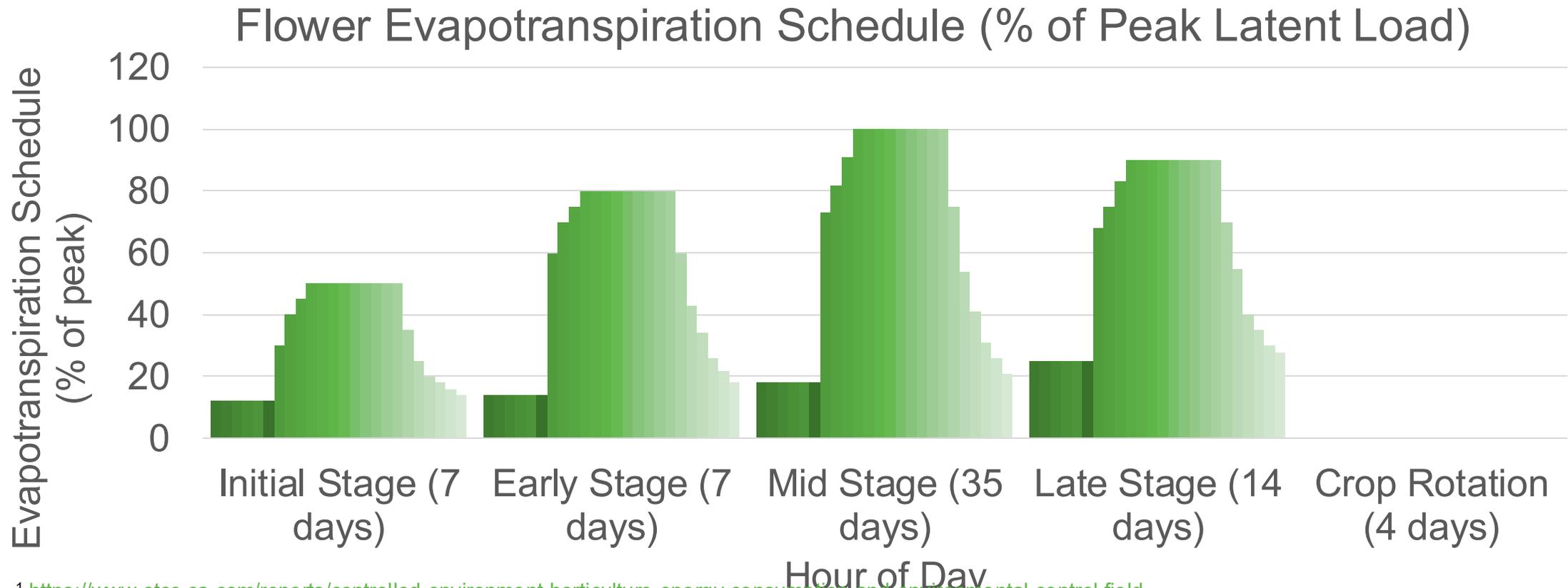
	Heating Setpoint (F)	Heating Setback (F)	Cooling Setpoint (F)	Cooling Setback (F)	Humidity Setpoint (%RH)
<b>Office</b>	70	60	75	80	N/A
<b>Security</b>	70	60	75	80	N/A
<b>Restrooms</b>	70	60	75	80	N/A
<b>Storage and Shipping</b>	60	50	65	70	60%
<b>Processing</b>	65	60	65	70	60%
<b>Horticulture Drying</b>	60	N/A	60	N/A	60%
<b>Horticulture Vegetative</b>	82	N/A	82	N/A	65%

Flower Room	Early (weeks 1-2)	Mid (weeks 3-7)	Late (weeks 8-9)
<b>Lights on</b>	82°F/ 67%RH	79°F/ 57%RH	73°F/ 48%RH
<b>Lights off</b>	79°F/ 65%RH	75°F/ 54%RH	70°F/ 46%RH

- Storage is typically cool & dry to preserve product
- Drying room is not typically occupied
- Horticulture flowering setpoints vary through the grow cycle
- Flower room temperature threshold allows 1°F drift
- Flower room dewpoint threshold allows 2° F drift

# Energy Modeling – CEH Flower Room Prototype

- Hourly latent loads based on field data from PG&E Code Readiness field study<sup>1</sup>
- Latent load shapes for each stage of plant growth throughout the grow cycle



<sup>1</sup> <https://www.etcc-ca.com/reports/controlled-environment-horticulture-energy-consumption-and-environmental-control-field>

# Model Output: Per Unit Energy Savings by Climate Zone

- **Energy savings:** 28 to 42 kWh per year per canopy square foot
- **Electric demand reductions:** about 0.004 kW per canopy square foot across climate zones
- **No natural gas savings** are associated with the proposed measure



First Year Electricity Savings (kWh) per Canopy Square Foot by Climate Zone (CZ)

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
41.8	40.1	41.1	37.3	40.9	39.8	39.2	37.5	36.5	35.6	36.3	38.3	35.6	34.4	28.6	37.4

# Assumptions used to calculate statewide savings

- 32% of CEH square footage is indoor growing facilities (not greenhouse)
- 92% of indoor growing square footage is in facilities growing cannabis
- 87% of statewide indoor cannabis canopy square footage is in facilities with at least 5,000 square feet of canopy
- 47% of the square footage in an indoor cannabis growing facility dedicated to flower rooms
- Canopy square footage in a cannabis flower room is 98% of the room square footage, based on a weighted average of:
  - 60% single-tier at 70% canopy to floor area ratio
  - 40% two-tier with 140% canopy to floor area ratio
- An existing HVAC/D system is fully replaced roughly every 12 years due to changing canopy area or to get more control over environmental conditions
- Integrated systems have roughly 25% market share

## 4. Incremental Cost

- First costs
- Maintenance costs
- Benefit to cost ratios



# Incremental Cost Calculations

- Incremental cost components:
  - First cost - Equipment
  - First cost - Installation
  - Maintenance and replacement costs
- One 2000 square foot cannabis flower room
- 1400 square feet of plant canopy
- Equipment sized by mechanical designer with extensive experience in cannabis facility HVAC/D design

Equipment	Baseline System (Decoupled)	Proposed System (Integrated)
System Type	<ul style="list-style-type: none"> <li>• 10 x 5-ton fixed-capacity DX units</li> <li>• 12 x 710 pint/day dehumidifiers</li> </ul>	<ul style="list-style-type: none"> <li>• 2 x 40-ton integrated DX units</li> </ul>
Total Cooling Capacity	<ul style="list-style-type: none"> <li>• Sensible: 50 tons</li> <li>• Latent* <math>\approx</math> 42 tons</li> <li>• Total Cooling <math>\approx</math> 92 tons</li> </ul>	<ul style="list-style-type: none"> <li>• Integrated sensible and latent cooling</li> <li>• Total Cooling = 80 tons</li> </ul>

# Incremental Cost Calculations: First Costs

Equipment	Baseline System (Decoupled)	Proposed System (Integrated)
System Type	10 x 5-ton DX units 12 x 710 pint/day dehumidifier	2 x 40-ton DX units
Equipment Cost- Warm Climate (CEC CZ 1-15)	10 x \$4,300 = \$43,000 12 x \$9,000 = \$108,000 <b>Total = \$151,000</b>	2 x \$100,000 <b>Total = \$200,000</b>
Equipment Cost – Cold Climate (CEC CZ 16)	10 x \$5,300 = \$53,000 12 x \$9,000 = \$108,000 <b>Total = \$161,000</b>	2 x \$128,000 <b>Total = \$256,000</b>
Installation	<b>= \$332,000</b>	<b>= \$300,000</b>
Total First Costs (CZs 1-15)	<b>= \$483,000</b>	<b>= \$500,000</b>
Total First Costs (CZs 16)	<b>= \$493,000</b>	<b>= \$556,000</b>

- Integrated system based on quotes
- Decoupled costs based on online search
- Additional electrical, ducting, and plumbing increases installed cost of decoupled system
- Low-ambient adds cost to both baseline and proposed
- Incremental first costs:
  - \$17,000 in most CEC Climate Zones
  - \$63,000 in Climate Zone 16

# Incremental Maintenance and Replacement Costs

Baseline				Proposed			
Decoupled HVACD Equipment	Estimated Useful Life (years)	Quantity	Replacement & Installation Cost per Unit (\$)	Integrated HVACD Equipment	Estimated Useful Life (years)	Quantity	Replacement & Installation Cost per Unit (\$)
DX Units	6	10	\$4,300 each DX unit \$2,000 installation	CEH Units <sup>2</sup>	17	2	\$120,000 each DX unit \$20,000 installation
DX Compressors	2	1 x 5-ton compressor per DX unit = 10 total	\$3,500 per compressor	CEH Compressors	6	4 x 10-ton compressors per DX unit = 8 total	\$15,000 per compressor
Dehumidifiers	6	12	\$9,000 per dehumidifier \$1,500 installation	CEH Filters*	0.25	1 per unit = 2 total	\$120 per filter set
DX Filters	0.25	1 per unit = 2 total	\$120 per filter set				
Dehumidifier Filters*	0.25	1 per unit = 12 total	\$50 per filter				

\*Assumes 4 harvests per year and filters changed after each harvest

# Incremental Maintenance and Replacement Costs, cont

Proposed System Costs					Baseline System Costs					Incremental Costs	
Incremental Replacement & Maintenance Costs Year	Integrated Full System (\$)	Integrated Compressor Replacement (\$)	Integrated Filters (\$)	Total Integrated (\$)	Decoupled DX Full System Replacement (\$)	Decoupled DX Compressor Replacement (\$)	Decoupled Dehumidifier Replacement (\$)	Decoupled Filters (\$)	Total Decoupled (\$)	Incremental Cost (\$)	Incremental Cost (\$/canopy sf)
1			\$1,600	\$1,600				\$7,200	\$7,200	(\$5,600)	(\$4.00)
2			\$1,600	\$1,600				\$7,200	\$7,200	(\$5,600)	(\$4.00)
3			\$1,600	\$1,600			\$17,500	\$7,200	\$24,700	(\$23,100)	(\$16.50)
4			\$1,600	\$1,600			\$17,500	\$7,200	\$24,700	(\$23,100)	(\$16.50)
5			\$1,600	\$1,600			\$17,500	\$7,200	\$24,700	(\$23,100)	(\$16.50)
6			\$1,600	\$1,600			\$17,500	\$7,200	\$24,700	(\$23,100)	(\$16.50)
7		\$60,000	\$1,600	\$61,600	\$63,000		\$126,000	\$7,200	\$196,200	(\$134,600)	(\$96.14)
8			\$1,600	\$1,600				\$7,200	\$7,200	(\$5,600)	(\$4.00)
9			\$1,600	\$1,600			\$17,500	\$7,200	\$24,700	(\$23,100)	(\$16.50)
10			\$1,600	\$1,600			\$17,500	\$7,200	\$24,700	(\$23,100)	(\$16.50)
11			\$1,600	\$1,600			\$17,500	\$7,200	\$24,700	(\$23,100)	(\$16.50)
12			\$1,600	\$1,600			\$17,500	\$7,200	\$24,700	(\$23,100)	(\$16.50)
13		\$60,000	\$1,600	\$61,600	\$63,000		\$126,000	\$7,200	\$196,200	(\$134,600)	(\$96.14)
14			\$1,600	\$1,600				\$7,200	\$7,200	(\$5,600)	(\$4.00)
15			\$1,600	\$1,600			\$17,500	\$7,200	\$24,700	(\$23,100)	(\$16.50)
16			\$1,600	\$1,600			\$17,500	\$7,200	\$24,700	(\$23,100)	(\$16.50)
17	\$240,000		\$1,600	\$241,600			\$17,500	\$7,200	\$24,700	\$216,900	\$154.93
18			\$1,600	\$1,600			\$17,500	\$7,200	\$24,700	(\$23,100)	(\$16.50)
19			\$1,600	\$1,600	\$63,000		\$126,000	\$7,200	\$196,200	(\$194,600)	(\$139.00)
20			\$1,600	\$1,600				\$7,200	\$7,200	(\$5,600)	(\$4.00)
21			\$1,600	\$1,600			\$17,500	\$7,200	\$24,700	(\$23,100)	(\$16.50)
22			\$1,600	\$1,600			\$17,500	\$7,200	\$24,700	(\$23,100)	(\$16.50)
23		\$60,000	\$1,600	\$61,600			\$17,500	\$7,200	\$24,700	\$36,900	\$26.36
24			\$1,600	\$1,600			\$17,500	\$7,200	\$24,700	(\$23,100)	(\$16.50)
25			\$1,600	\$1,600	\$63,000		\$126,000	\$7,200	\$196,200	(\$194,600)	(\$139.00)
26			\$1,600	\$1,600				\$7,200	\$7,200	(\$5,600)	(\$4.00)
27			\$1,600	\$1,600			\$17,500	\$7,200	\$24,700	(\$23,100)	(\$16.50)
28			\$1,600	\$1,600			\$17,500	\$7,200	\$24,700	(\$23,100)	(\$16.50)
29		\$60,000	\$1,600	\$61,600			\$17,500	\$7,200	\$24,700	\$36,900	\$26.36
30			\$1,600	\$1,600			\$17,500	\$7,200	\$24,700	(\$23,100)	(\$16.50)
<b>TOTAL</b>				<b>\$528,000</b>					<b>\$1,322,000</b>	<b>(\$794,000)</b>	<b>(\$567)</b>

## Poll

**When conventional RTUs are used for cooling in indoor agriculture flower rooms, what are common replacement intervals for compressors and for the full unit?**

- a) Compressors last three years or longer
- b) Compressors replaced approximately every two years
- c) Compressors replaced every one year or less
- d) Full unit lasts seven years or longer
- e) Full unit replaced every five to seven years
- f) Full unit replaced every five years or fewer
- g) Not sure

*Select all that apply*

# Incremental First Cost: Cultivation HVACD System Comparison Study (2023)

- Study found integrated HVACD systems had lower first costs than decoupled.
- Decoupled components and design were more efficient and more expensive than code-minimum units used in CASE cost analysis.

	<b>System 1 Ductless Splits</b>	<b>System 2 VRF Splits</b>	<b>System 3 Integrated HVACD</b>
<b>Equipment cost</b>	\$171,270	\$162,718	\$159,390
<b>Material</b>	\$10,646	\$43,086	\$25,831
<b>Labor</b>	\$39,124	\$65,240	\$33,477
<b>Subcontractors</b>	\$30,000	\$30,000	\$14,000
<b>Ancillary/Soft Cost</b>	\$65,989	\$85,146	\$56,713
<b>Total HVACD Cost</b>	<b>\$317,029</b>	<b>\$386,190</b>	<b>\$289,411</b>
<b>Cost/ sqft</b>	\$194/ sqft	\$236/ sqft	\$177/sqft

The above costs include electrical for HVACD equipment only and sales tax of 9%. Labor and material costs are from the date of publication.

J. Megerson, B. Anderson, and M. Zartarian, "Cultivation HVACD System Comparison Study," 2023 <https://www.andersonporter.com/blog/hvacd-systems>

## Poll

**Although the cost per ton is higher for integrated systems than decoupled systems, the total tonnage required is less and the installation costs are lower, leading to comparable installed costs, within ~5%.**

**Based on your experience in the market, do you feel this incremental cost estimate is:**

- a) Accurate, consistent with what I see.
- b) The relative equipment sizing does not reflect what I see in the market.
- c) The equipment costs do not reflect what I see in the market.
- d) The installation costs do not reflect what I see in the market.
- e) I am not sufficiently familiar with the market to provide input.

*Multiple answers allowed*

# Benefit to Cost Ratio

- Monetary value of energy savings calculation:
  - Long-term System Cost (LSC) is a time-based valuation metric that quantifies the CEC's projected present value of costs over a 30-year period for California's energy system.
  - Hourly energy savings data in each climate zone are multiplied by CZ-specific hourly LSC values to provide a monetary value for energy savings.
  - LSC savings do not directly correspond to utility bill savings for consumers.
- Benefit to Cost Ratio calculation:
  - Benefits are calculated as the Long-term System Cost (LSC) savings minus the present value of the (negative) incremental maintenance costs.
  - Costs are the incremental first costs.
  - The benefits are divided by the costs to calculate the Benefit to Cost Ratio (BCR).
  - The BCR for this measure ranges between 52 and 60, depending on Climate Zone.

# Benefit to Cost Ratio by Climate Zone

Climate Zone	Benefits LSC Savings + Other PV Savings (2029 PV\$ per canopy square foot)	First Costs Total Incremental PV Costs (Per canopy square foot)	Benefit-to-Cost Ratio
1	\$732.42	\$12.14	60
2	\$720.67	\$12.14	59
3	\$727.62	\$12.14	60
4	\$698.57	\$12.14	58
5	\$725.16	\$12.14	60
6	\$719.26	\$12.14	59
7	\$710.87	\$12.14	59
8	\$695.64	\$12.14	57
9	\$684.98	\$12.14	56
10	\$680.99	\$12.14	56
11	\$687.90	\$12.14	57
12	\$702.70	\$12.14	58
13	\$681.18	\$12.14	56
14	\$676.72	\$12.14	56
15	\$629.53	\$12.14	52
16	\$694.24	\$12.14	57
<b>Weighted Average</b>	<b>\$704.56</b>	<b>\$12.14</b>	<b>58</b>



## 5. Compliance and Verification

- Key Aspects of Compliance Verification
- Barriers and Solutions
- Revisions to Compliance Software

# Mandatory Measures and Prescriptive and Performance Paths

## Mandatory Measures

**Must** always be met, **may** be exceeded

### Option #1



#### Prescriptive Approach

- **Simplest** – all or nothing approach to compliance.
- List of prescriptive requirements can apply to the whole building or system by system.
- New prescriptive requirements for CEH would likely be limited to mechanical system.

**or**

### Option #2



#### Performance Approach

- **Allows flexibility** and building customization.
- Modeling software verifies whether the “Proposed Design” is as good as, or better than, the “Standard Design” (the baseline for performance).
- Tradeoffs would likely be limited to the mechanical system in flower rooms and related equipment and building systems.

Modeled after Energy Code Ace Fact Sheet

# Proposed Compliance Process

Calculate total plant canopy area and horticultural lighting Watts/square foot of canopy

- If less than 5000 canopy square feet or 30 Watts per canopy square foot:
  - Confirm that dehumidification system meets one of the four mandatory requirements in section 120.6 (h)
- If more than 5000 canopy square feet and 30 Watts per canopy square foot:
  - Provide load calculations and system performance information to demonstrate that the system is sized to meet design heating, cooling, and dehumidification loads
  - Verify compliance with mandatory requirements for:
    - Dehumidification process heat recovery
    - Supplement heating sizing
    - Integrated temperature and humidity controls
    - Standalone dehumidification equipment controls
    - Field verification of controls
  - Determine if system meets prescriptive requirements, or must follow the performance path

# Key Aspects of Compliance Verification

- **Updates to NRCC-PRC-E: Load Calculations and Sizing Guide**
  - Document assumptions for each high intensity lighting grow room
  - Document HVAC/D equipment capacity
  - Calculate room loads and sensible heat ratio and compare to documented equipment capacity and sensible heat ratio
- **Update NRCC-PRF-E form** to enable documentation of performance approach
- **Field Verification**
  - Evaluating requirements for verification of controls settings by field technician
- **Updates to Compliance Software**
- **Updates to NRCI-PRC-E**
  - Document key installed equipment specifications

# Facility Design Conditions and Room Details

- A load calculation and sizing tool would be made available to designers and Title 24 consultants to verify sizing calculations and equipment specifications, as needed to complete compliance forms
- The first step is providing ambient outdoor conditions, canopy square feet, and setpoints

Facility Ambient Design Conditions			
ASHRAE WMO Station:			Key
Summer Design (0.4%)	DB (°F)		User Input Value
	MCWB (°F)		Default no value
Winter Design (99%):	DB (°F)		Calculated Value

Facility Room Details							
Fill out the following for each room/CEH Space							
Room Name:	<input type="text"/>					(Can be multiple rooms of	
Canopy Square Feet:	<input type="text"/>					the same size)	
Provide the Design Space Conditions for the four CEH environment operating conditions:							
Daytime Room Conditions (Lights On)	DB (°F) WB (°F)	Week 1 of Grow Cycle		Early/Mid Plant Life		Late Plant Life	
		Day	Night	Day	Night	Day	Night
		<input type="text"/>	<input type="text"/>				

# CEH Room Load Calculation

- The next step is to provide inputs that are used to calculate sensible and latent loads in each of three stages of the flower cycle
- Automated checks will identify parameters that are inconsistent with typical practices
- The Sensible Space Load and Evapotranspiration Load will be automatically calculated

CEH Room Load Calc							
Provide the CEH Environmental Load Requirements for each space at the 6 prescribed conditions:							
		Week 1 of Grow Cycle		Early/Mid Plant Life		Late Plant Life	
		Day	Night	Day	Night	Day	Night
Horticultural Lighting	(kW)						
Motor Heat (Fan Power)	(kW)						
Standalone Dehu Load	(BTU/hr)	-		-			
Envelope Load (Optional)	(BTU/hr)						
Plant Irrigation	(gal/day)						
% of Total Irrigation Transpired	%						
Hours (Day/Night)	(hrs)						
Sensible Space Load	(BTU/hr)	-	-	-	-	-	-
Evapotranspiration Load	(BTU/hr)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

## Poll

### Do CEH HVAC/D designers know all the required inputs for grow room load calculations?

The proposed required inputs for grow room load calculations include: **canopy area** (square feet), **lighting power** (kW), **lighting on time** (hours), and **plant irrigation** (gal/day), for day 1 of the grow cycle, an early/mid grow cycle period, and a late grow cycle period.

- a) Yes, designers have all this information
- b) No, designers have these inputs, but not for all three points in the grow cycle
- c) No, designers have some, but not all of these inputs
- d) No, designers do not have any of this information
- e) Not sure

# Sizing Calculations: Equipment Specifications

- Next step is to describe equipment specifications and capacity at the described conditions
- Automated checks will calculate whether SHR and reheat capacity meet prescriptive requirements
- Capacity needed to perform calculations will be provided by manufacturer and/or mechanical designer, depending on system type

Prescriptive Compliance and Cooling System Operating Performance Information							
Cooling/Integrated System Equipment Specification							
Input the Primary System Performance Information <b>that corresponds to the ambient and CEH space operating conditions and loads above:</b>							
		Week 1 of Grow Cycle		Early/Mid Plant Life		Late Plant Life	
		Day	Night	Day	Night	Day	Night
System Operating Air Flow	(CFM)						
Total Cooling Operating Capacity	(BTU/hr)						
Latent Removal Operating Capacity	(BTU/hr)						
Operating Sensible Heat Ratio		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Reheat Operating Load	(BTU/hr)						
Recovered Heat Operating Capacity	(BTU/hr)						
Source of Recovered heat:		Text or Selection					
Cooling Stages:		#					
Cooling Stage # Type:		Variable or Constant					

## Poll

**Do you any have concerns with providing the required equipment performance at user-specified setpoints for lights on and lights off times in the early grow period and late grow period?**

The proposed required equipment performance parameters include: **air flow** (CFM), **total cooling capacity** (BTU/hr), **latent removal capacity** (BTU/hr), **reheat capacity** (BTU/hr), and **recovered heat capacity** (BTU/hr). These parameters would need to be recorded on the NRCC form for lights on and lights off times at an early grow cycle period and late grow cycle period.

*Open ended response*

# Additional Equipment Specification & Summary

Additional Equipment Specification							
		Week 1 of Grow Cycle		Early/Mid Plant Life		Late Plant Life	
		Day	Night	Day	Night	Day	Night
Quantity of Standalone Dehumidifiers	(#)						
Moisture Removal Capacity (At operating conditions)	(pints/day)						
Standalone Dehumidifier Moisture Removal Efficiency	(L/kWh)						
Standalone Dehumidifier Motor Power	(kW/ea)						
Total Hourly Moisture Removal Capacity	(lbm/hr)	0.00	0.00	0.00	0.00	0.00	0.00
Supplemental Heating Capacity	(BTU/hr)						
Supplemental Heating Capacity		Text or Selection					

Mandatory Sizing Requirements - All System Types							
System Summary (including Standalone and Supplemental Heat)							
		Week 1 of Grow Cycle		Early/Mid Plant Life		Late Plant Life	
		Day	Night	Day	Night	Day	Night
Total System Cooling Capacity	(BTU/hr)	-	-	-	-	-	-
Total Latent Removal Capacity	(BTU/hr)	-	-	-	-	-	-

# Key Aspects of Field Verification

- Due to the challenges with creating latent loads prior to occupancy, functional testing of HVAC/D systems would not be required
- Field verification proposal includes confirming that:
  - Installed space conditioning equipment sensible, latent, reheat, and heating capacity match plan documents
  - The control system is installed and configured to prioritize use of recovered heat over supplemental heating
  - Installed standalone dehumidifier capacity and specifications match plan documents
  - The control system can stage individual dehumidifiers
  - Temperature and humidity sensors are located near the plant canopy

## Poll

**Do you have concerns with a field technician (installer of controls) performing the proposed field verification process?**

# Prescriptive vs. Performance Approach

- If system doesn't comply with prescriptive requirements, applicants can demonstrate compliance using CEC-approved energy modeling software to model the mechanical systems
- The “standard design” energy budget will be calculated based on prescriptive requirements CEH space
- The energy model will use a combination of fixed assumptions and user inputs to calculate the standard design budget
- Proposed designs will be compared to this energy budget
- Decoupled systems using high-efficiency dehumidification and cooling equipment can comply via this pathway

# Proposed Inputs and Assumptions

User-modifiable inputs	Fixed assumptions
Envelope	Lighting schedules
Geometry	Temperature and humidity setpoints and schedules
Plant canopy area	Max evapotranspiration (calculated value)
HVAC/D system type and configuration	Latent load shape/schedule
HVAC/D sizing	
HVAC/D efficiency	
Lighting PPE and PPFD	
Circulation fan efficiency and CFM	
Outdoor air exchange	
Climate zone	

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More information on

[CEC's 2028 proceeding website.](#)

**We want to  
hear from you!**