TITLE 24, PART 6 2028 CODE CYCLE

Greenhouse Envelope Alternative

Codes and Standards Enhancement (CASE) Team Comment Letter

Lydia Miner
March 5, 2026

CALIFORNIA ENERGY CODES & STANDARDS
A STATEWIDE UTILITY PROGRAM

Proposal Description

- Code Change Proposal
- Benefits
- Background Information

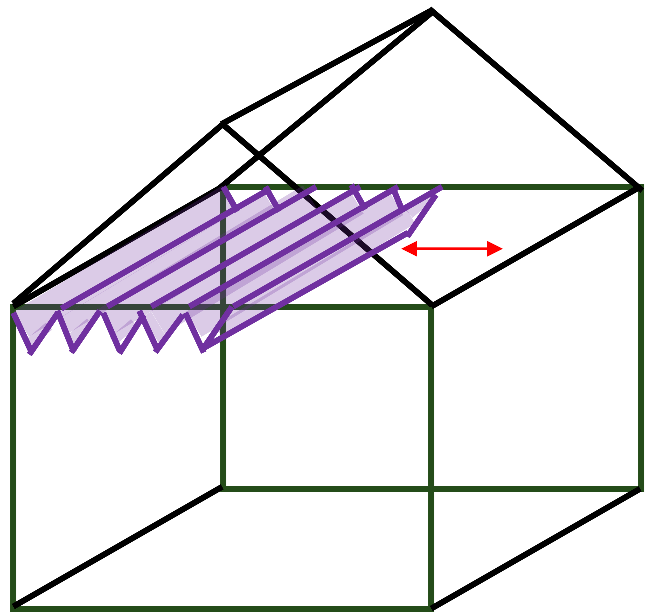
Conditioned Greenhouse Envelope Requirements

- **Conditioned greenhouse** is a greenhouse that is provided with wood heating or mechanical heating that has a capacity exceeding 10 Btu/hr-ft², or mechanical cooling that has a capacity exceeding 5 Btu/hr-ft².
- A **greenhouse** has a **skylight ratio of 50 percent or greater**.
- A **new conditioned greenhouse** or **a greenhouse being converted to a conditioned greenhouse** or **additions to a conditioned greenhouse** shall meet the requirements.
- Current energy code **mandatory** requirement is that all **non-opaque envelopes of conditioned greenhouses** shall have **two layers of glazing** separated be either air or gas.

Greenhouse Type	Code Reference	Glazing Requirement	U-Factor (Opaque Assembly)
Conditioned (heated/cooled)	T24 Part 6, 120.6(h)(4)	Two or more layers separated by either air or gas fill. These could be two layers of glass or double layer plastic products. (estimated U factor of 0.7)	Per 120.7
Unconditioned	T24 Part 6, 120.6(h)(4)	Exempt	Exempt

Proposed Code Change

- Proposed change would create an additional option for the current mandatory requirement for non-opaque envelopes on new conditioned greenhouses.
- Create a new a compliance path for conditioned greenhouses with single-glazed glass envelopes that have curtains meeting the following criteria:
  - **Curtain properties** (emissivity, permeability, and/or U-factor).
  - **Controls** that automate operation of the curtain.
  - **Gaps** between curtain and walls shall be sealed.
  - Structural or mechanical **penetrations** through the curtain plane shall be flashed or sealed with flexible gaskets.
- Specific requirements for curtain properties, controls, gaps, and penetrations will be specified so the alternative compliance path is **energy equivalent to current code requirements**.
- Replace "wood heating" with "biomass heating" in the definition of Conditioned Greenhouse.



Example of gutter-to-gutter curtain installed below attic

Background Information: Greenhouse Heat Loss

- **Radiative Heat Loss:** At night, plants and interior surfaces emit long-wave infrared radiation.
    - **Plastic Glazing** is transparent to long-wave radiation.
    - **Single-Pane Glass Glazing** absorbs and re-radiates long-wave radiation.
    - **Double-Pane Glass Glazing** reduces re-radiation; with a low emissivity coating can reflect most of the radiative heat.
    - **Curtains** with aluminized strips or threads can reflect 66-83% of radiative heat[1].
- **Convective/Conductive Heat Loss:** heat lost through the glazing.
    - **Single-Pane Glazing** has high thermal transmittance (U ~1.1 to 1.2 $BTU/h \cdot ft^2 \cdot °F$) where heat moves rapidly through the solid glass[2].
    - **Double-Pane Glazing** about half the thermal transmittance (U ~ 0.5 to 0.7 $BTU/h \cdot ft^2 \cdot °F$) by using the trapped air/gas gap as an insulator[2].
    - The air space between a **curtain** and the glass provides insulation.

Sources:
1. Geelen, P.A.M., Voogt, J.O., & van Weel, P.A. (2018). Plant Empowerment: The Basic Principles.
2. Bartok, J. W., Jr. (2001). Energy conservation for commercial greenhouses (Revised ed., NRAES-3). Natural Resource, Agriculture, and Engineering Service.

Market and Technical Considerations

- Current Conditions and Trends
- Potential Barriers and Solutions
- Technical feasibility

Background: Greenhouse Curtain Classification

Manufacturers group their products in families:

- **Energy Screens/Thermal Curtains:** Marketed specifically for heat retention. These are “closed-structure” textiles designed to be deployed only at night.
  - Marketed with a “Energy Savings Percentage”
- **Shade Screens:** Designed for daytime use to manage solar heat gain and Photosynthetically Active Radiation (PAR).
  - Marketed with a “Shade Percentage”
- **Dual Purpose (Shade & Energy):** High-performance screens designed for both daytime cooling and nighttime heat retention.
  - Marketed as having “High Solar Reflectance” and “High Thermal Resistance”
- **Blackout/Light Abatement Curtains:** Used for photoperiod control
  - Marketed based on “Opacity”

Any curtain type that meets requirements can be used for the compliance option.

Poll

Which curtain types are most commonly used for energy savings in California?

Rank the following options from 1 (most commonly used) to 5 (least commonly used).

Use each rank only once.

a) Energy Screens/Thermal Curtains
b) Shade Screens
c) Dual Purpose (shade and thermal)
d) Both a Thermal Curtain and a Shade Screen
e) Blackout
f) Not sure

Testing Standards and Certifications

The statewide CASE Team is considering requirements for rating greenhouse thermal curtains with the method used by **AERC (Attachment Energy Rating Council):** https://aercenergyrating.org/

Property	AERC Document	Test Standard Reference	Role in Greenhouse Context
Emissivity	1.1	ASTM E408 / E434	Quantifies the "Low-E" benefit of aluminized curtains.
Air Permeability	1.1 / 1.2	ASTM E283 / D737	Validates the curtain's ability to stop convective loops.
U-factor	1 / 1.2	ASTM C1199	Measures the total "insulating" value of the curtain assembly.

AERC 1 https://aercenergyrating.org/wp-content/uploads/2023/02/AERC-1_Revision-8_final.pdf

AERC 1.1 https://aercenergyrating.org/wp-content/uploads/2023/02/AERC-1.1-Revision-5.pdf

AERC 1.2 https://aercenergyrating.org/wp-content/uploads/2023/02/AERC-1.2_Revision-2_Final.pdf

Poll

How do you test U-factor of a greenhouse thermal curtain?

a) Tests in a laboratory environment
b) Tests at research greenhouses
c) Tests at commercial greenhouses
d) U-factor of thermal curtains is not tested
e) Not Sure

Select all that apply

Poll

What types of test methods do you use to test your greenhouse thermal curtains for emissivity, permeability, and U-factor?

a) International standards
b) ASTM standards
c) Internal (proprietary) test procedures
d) Other
e) Do not test emissivity, permeability, or U-factor of thermal curtains
f) Not sure

Select all that apply

Thermal Curtain Installation

- **Installation practices** are key for thermal performance of curtains.
- Unsealed gaps between curtain edges and outer walls allow warm air to rise and escape, creating a **chimney effect** that pulls cold air into the growing space.
- **Leading edges and transitions** must be sealed tightly to outer walls to block upward airflow.
  - Foam rubber or gaskets, magnetic or hook-and-loop (Velcro) closures, inflatable pockets
- **Curtain sides** should be tightly controlled to prevent air bypass.
  - Track mounting systems, overlapping flaps, brush seals
- **Structural obstructions** (posts, irrigation lines, electrical conduits) require flexible sealing solutions.
  - Pockets and boots, flexible brushes, plastic films or skirts

Poll

Given the research indicating that the “chimney effect” from edge gaps can negate significant amounts of the energy savings from thermal curtains, how do you prioritize gap sealing in your designs or greenhouses?

a) This is a design priority
b) The is an optional secondary detail
c) Edge sealing is not considered
d) Depends on the facility
e) Not sure

Select one

Automated Control Requirements

To qualify, the system cannot be manually operated. The system must be automatically controlled by at least one of the following:

- Schedule with astronomical clock,
- Basic sensor-based control (ex. thermostats, light intensity, etc.), or
- Advanced and integrated control (ex. using multiple sensors).

Note: if “burping” strategies are used to relieve humidity, they must be programmed (e.g., via humidity or vapor pressure deficit (VPD) sensors, or advanced integrated control); do not rely on manual overrides for routine burping.

Propose a simple acceptance test, performed by a field technician, to confirm automatic operation.

Considering a requirement that **manual overrides** must automatically reset to “Energy Mode” after a fixed duration.

Poll

Which types of curtain controls are most commonly used in California greenhouses?

a) Manual control
b) Scheduled control
c) Basic sensor-based control (ex. thermostats)
d) Advanced and integrated control (ex. climate computers)
e) Other
f) Not sure

Select one

Curtain Durability and Maintenance Considerations

- Single-pane glass allows high levels of UV radiation to reach the curtain.
  - UV stabilization can extend the lifetime of the curtain and improve durability of energy savings.
- Chemicals used for pest control and fertilization can oxidize aluminum coatings or embrittle plastics.
- An automated curtain may cycle hundreds of times per year. Mechanical failure will lead to loss of the energy benefit.
  - Motors should be rated for the load of the curtain assembly.
- Over time cables can stretch and drive tubes can shift, leading to uneven closure of curtains.
  - Tensioning spring systems or rigid push pull drives can minimize need for re-alignment.

Considering a requirement for a **10 year or longer Warranty Certificate** for both **curtains and controls.**

Poll

What are the warranty-lengths of longer-lasting thermal curtains for greenhouses and their automated controls?

a) 10 years or longer for both curtains and controls
b) 10 years or longer for curtains but 5 years for controls
c) 10 years or longer for controls, but 5 years for curtains
d) 5 years for both curtains and controls
e) Other (please enter information in chat)
f) Not sure

Select one

Poll

What is the average interval between greenhouse curtain fabric replacement in California greenhouses?

a) 5 years or fewer
b) 5-10 years
c) 10-15 years
d) 15-20 years
e) 20-25 years
f) More than 25 years
g) Not sure

Select one

Poll

How long after curtain hardware or motors stop working are they typically replaced?

a) Immediately
b) Within a month
c) Within a year
d) Multiple years
e) Not sure

Select one

Per Unit Energy and Cost Impacts

Methodology and Assumptions

- Energy and Energy Cost Savings
- Incremental Costs

Energy and Energy Cost Savings Methodology

- Using parameters from an existing Prototypical Greenhouse Energy Model used in 2022 Title 24 and for International Energy Conservation Code (IECC).
  - Greenhouse size: 32ft by 250 ft, and 16 ft high
  - Dirt floor
  - Fixed setpoints: 75°F day and 72°F night
  - Heating-only greenhouse (gas furnace, 80% efficiency)
- Model California Climate Zones 1-16
- Baseline: Double layer envelope
- Measure Case:
  - Single layer glass envelope and thermal curtain at night with schedule-based controls
  - Curtain degradation and curtain replacement rate (to be determined)
- Model Outputs:
  - Gas use (for greenhouse heating)
  - Electricity use (including electricity use by the thermal curtain motors)
  - 30-year long-term system cost (LSC)

Compliance Verification

- Key Aspects of Compliance Verification
- Barriers and Solutions

Key Aspects of Compliance Verification

Updates to Covered Process Compliance Form NRCC-PRC-E

- Document compliance path selection: double glazing or single-pane glass with curtain.
- If thermal curtain path is selected, document required thermal curtain parameters, edge sealing strategies, and controls.

Updates to Covered Process Installation form NRCI-PRC-E

- Allow building inspectors to confirm curtain installation and control strategies are compliant.
- Document make/model of thermal curtains and controls installed.
- Confirm that manufacturer warranty certificate meets warranty length requirement.

Acceptance Test Protocol (Field Verification)

- Ensure the automatic operation of curtains.
- Performed by field technicians at the time of installation.
- Confirm response to scheduled time, lighting conditions, or other parameter.
- Add a new NRCA-PRC form.

Specific enforcement details will depend on the final code implementation.

Poll

What else should we know? Are there market or technical barriers or solutions we should consider?

Open ended response

We want to hear from you!

Lydia Miner
West Monroe
lminer@westmonroe.com

Amy Droitcour
West Monroe
adroitcour@westmonroe.com

Please copy: info@title24stakeholders.com

More information on
CEC's 2028 proceeding website.