



The Critical Role of Building Envelopes and Air Movement in CEA Facilities

October 12, 2023



RESOURCE
INNOVATION
INSTITUTE



SOUTHERN CALIFORNIA
EDISON

An EDISON INTERNATIONAL Company

POLL ALERT!

What kind of facility are you cultivating in?

- Small indoor building
- Warehouse
- Standard, vented greenhouse
- Semi-Sealed, air-conditioned greenhouse
- Container farms or pods
- N/A



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Agenda

Welcome, Introductions and Context

Common Mistakes: Indoor Envelope Design & Construction

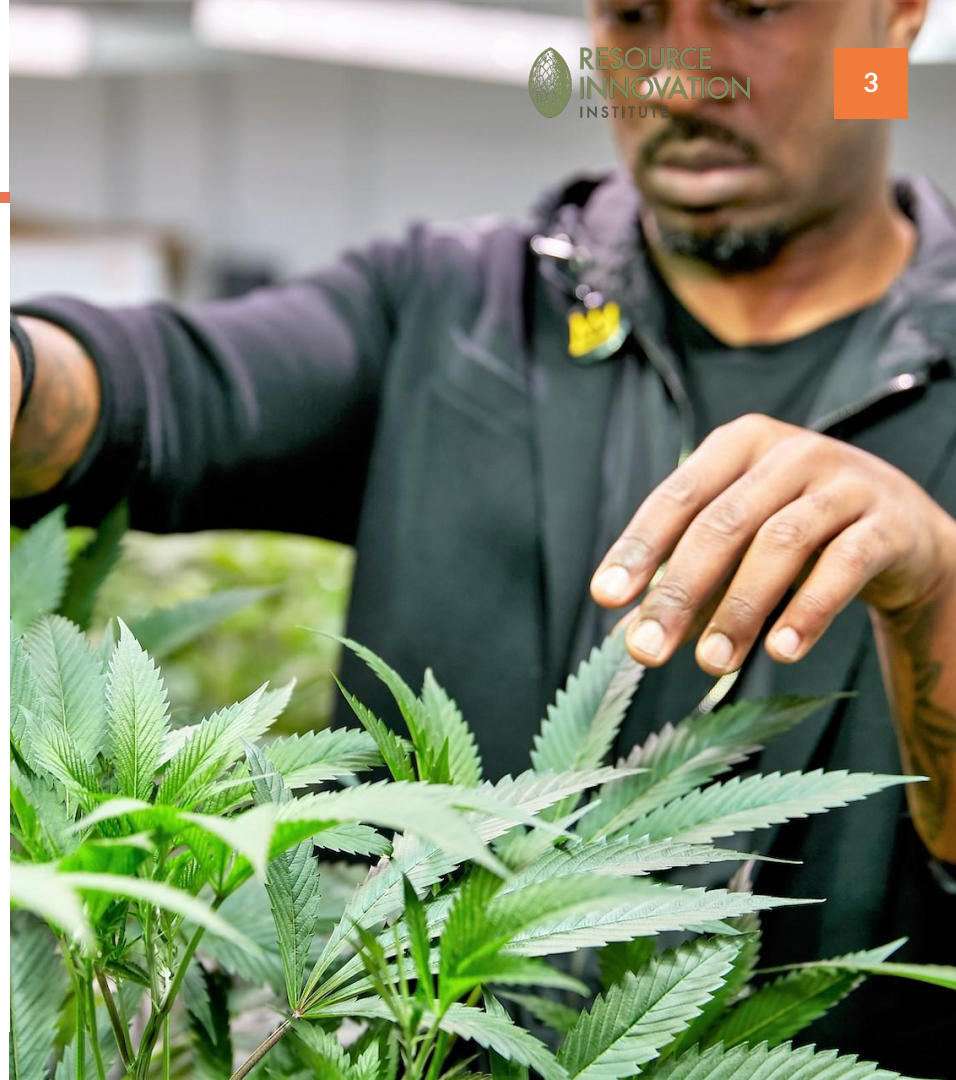
Greenhouse Design Considerations

Common Mistakes: Greenhouse Envelope Design & Construction

Critical Role of Shade & Thermal Curtains

Incentives Overview

Q&A



A person with a beard, wearing a dark jacket and a watch, is shown from the chest up, tending to a large number of green cannabis plants in a grow room. The person's hands are visible, carefully examining the leaves of the plants. The background is slightly blurred, showing more plants and the interior of the grow room.

SECTION 01

INTRODUCTION

Today's Experts



Adrian Giovenco



Matthew Paris



Ton Habraken



Thomas van
Dusseldorp



Caleb Hayhoe



Access Your California Virtual Classroom

Continue Learning Online

Free guidance on efficient cultivation

- Recordings of live workshops
- Tip clips
- Downloadable resources

Create an account at
resourceinnovation.org/California



Product Type

ON DEMAND

California Efficient Yields: Lighting Best Practices for Efficient Controlled Environment Agriculture

Faculty: Kendra Branch | Rob Eddy | Casey Rivero

Duration: 1.5 hours

Format: Audio and Video

Original Program Date: Oct 18, 2022

Price: \$0.00 - Non-Members Rate

[More info »](#)

[Save for Later](#)

[Register](#)



Product Type

ON DEMAND

California Efficient Yields: Facility Design & Construction Best Practices for Efficient Greenhouses and Vertical Farms

Faculty: Brian Anderson | Rob Eddy | Holden Orler | Luis Trujillo

Duration: 2 hours

Format: Audio and Video

Original Program Date: Sep 20, 2022

Price: \$0.00 - Non-Members Rate

[More info »](#)

[Save for Later](#)

[Register](#)

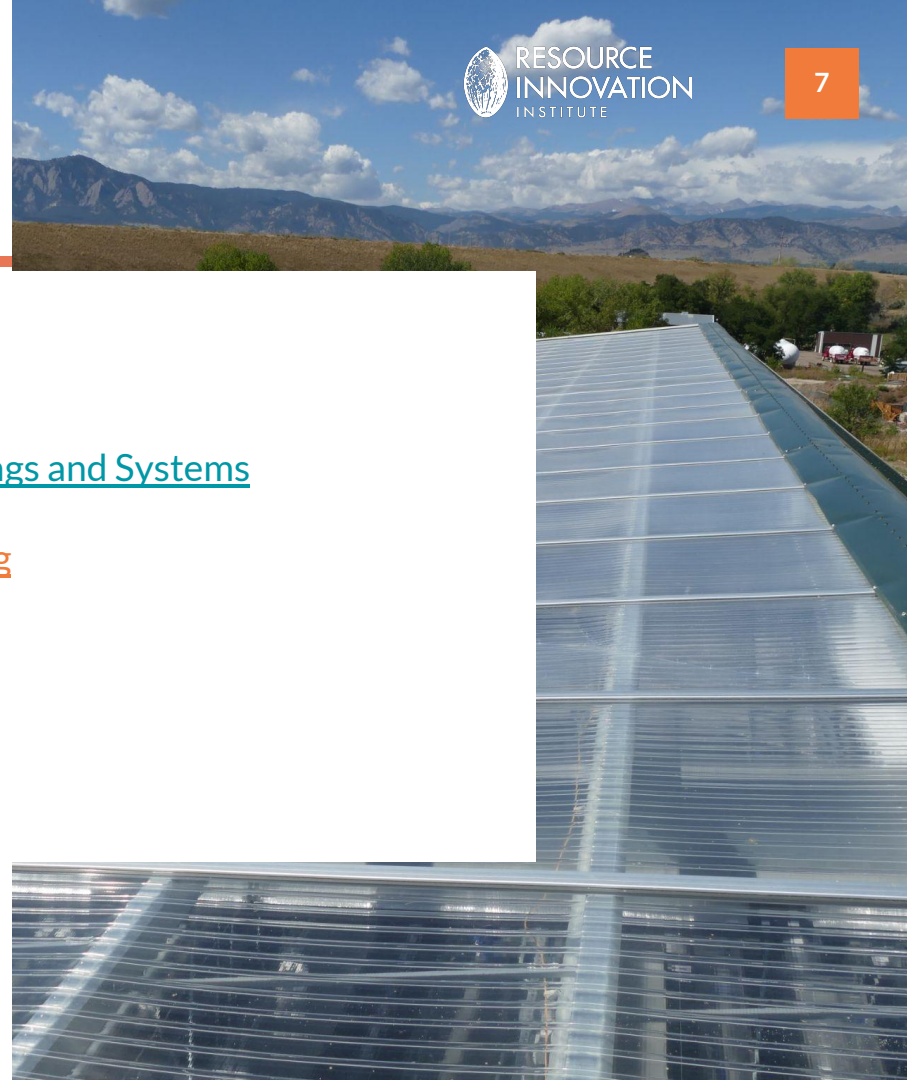
All live workshops are available for on-demand viewing!

Register for Upcoming Workshops

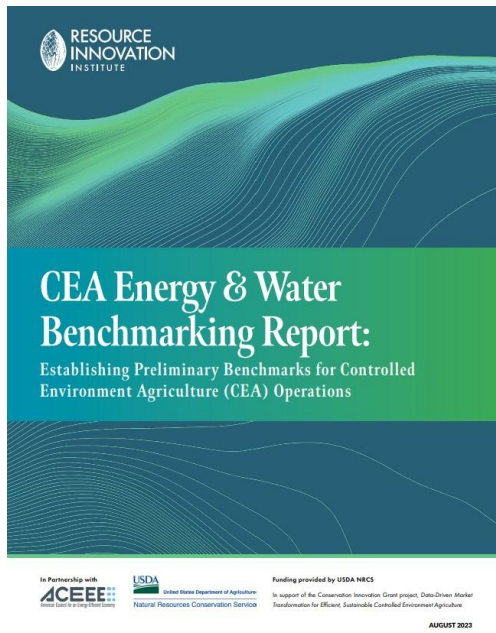
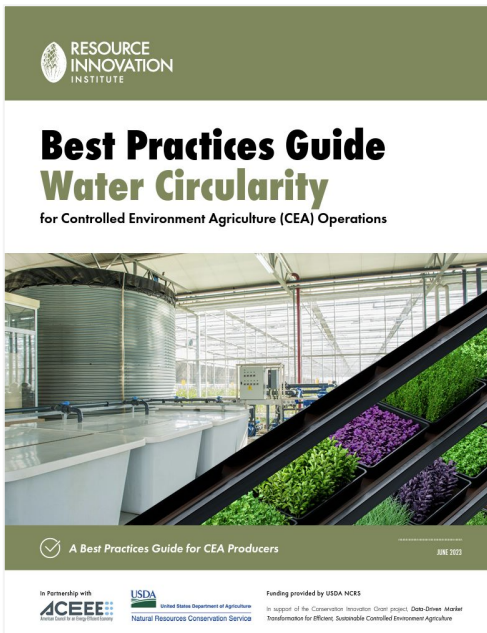
SCE funded Workshops:

October 26 | [Trust But Verify: Commissioning CEA Buildings and Systems](#)

Register and access other free resources on the [RII catalog](#)



CEA Resources



Best Practices Guide Featuring contributions from 15 Working Group member companies

Benchmarking Report Featuring annual resource consumption and productivity of twelve producers growing a variety of crops in greenhouse and indoor facilities across the US.

Access the reports for free on the [RII catalog](#)

Start Collecting Data: Benchmarking

What data should you collect?

- Energy consumption (all fuel types)
- Water consumption
- Water quality
- Production
- Use controls & automation systems to improve data collection (improve understanding of subsystems)

Calculated PowerScore

#47974088-21, Indoor, Grantsville, MD, Climate Zone 5A, July 2020 - June 2021

Get Verified

Whole Facility

Energy

45th percentile

Non-Electric Efficiency 188 kBtu / sq ft 30% better 71st percentile

Emissions Efficiency 13.4 kg CO₂e / sq ft 31% better 100th percentile

Lighting Efficiency 2,820 kWh / day 87% better 81st percentile

HVAC Efficiency 392 kBtu / sq ft 0% change 3rd percentile

Water

94th percentile

Water Efficiency 0.523 gal / sq ft 8.2% worse 97th percentile

Waste

68th percentile

Waste Efficiency 0.24 lbs / sq ft 0% change 80th percentile

Year-Over-Year



24.4% better

Select a second PowerScore for comparison snapshot or [add another](#)

#47974085-21, Motown Gro

Overall: Middle-of-the-Pack

Your operation's overall performance within the data set of indoor facilities in PowerScore's Ranked Data Set:



45th
percentile

Come back to check your PowerScore regularly to see how your rank changes as more facilities benchmark their performance!

Oldies

Facility

Canopy Productivity 0.243 kg / sq ft 0% change 50th percentile

POLL ALERT!

What kind of facility are you cultivating in?

Discuss Results



SECTION 02

Envelope & Air Environment Design Considerations - Indoor

POLL ALERT!

What is the typical size room do you work with?

- $< 500 \text{ ft}^2$
- $500 - 750 \text{ ft}^2$
- $750 - 1,000 \text{ ft}^2$
- $> 1,000 \text{ ft}^2$
- N/A



Critical: Air Tightness & Vapor Barriers

- Sealed Rooms
 - Climate inside room independent of exterior conditions
 - Temp, Relative Humidity, CO2, airborne contaminants
 - Air Tightness
 - Positive Room Pressurization
 - Effects of infiltration or exfiltration
 - Inefficient use of inputs
 - CO2, HVAC/Energy
 - Blower Door Test during Commissioning
- Vapor Barriers
 - Required vapor permeability dependant on building materials & location
 - Prevent wicking of moisture through floor and building surfaces



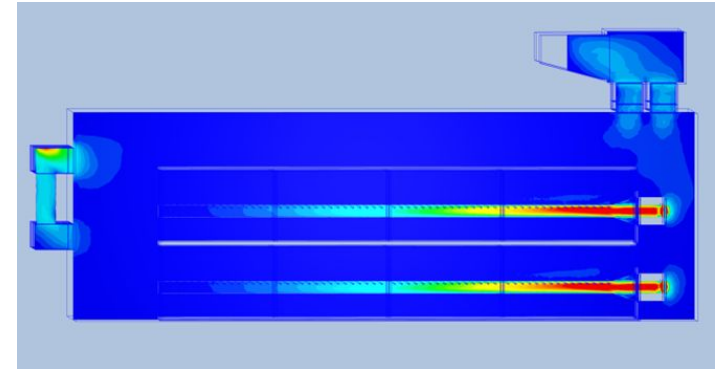
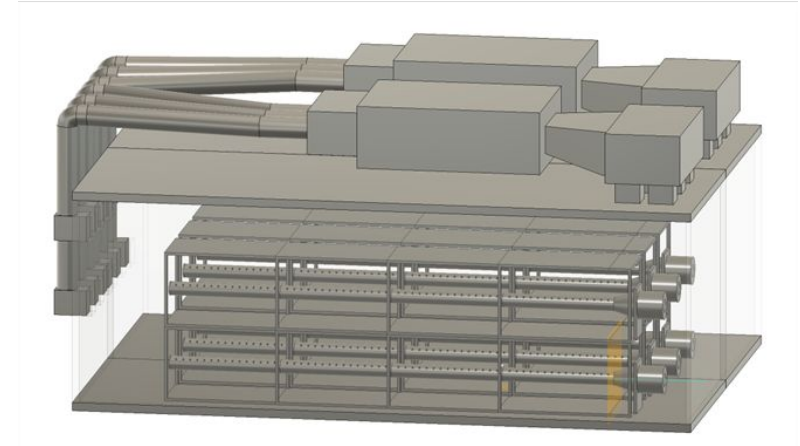
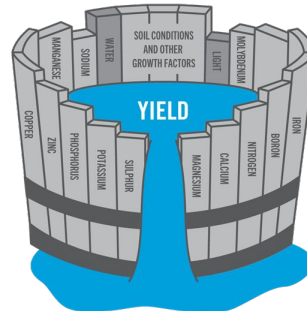
Building Envelope Best Practices

- Materials Selection
 - Metal and polymers
 - Wood & drywall promotes mold, pests & pathogens
- Floors
 - Seal concrete floors
 - Epoxy walls
 - Seal all seams to prevent infiltration/exfiltration
- Culture of Clean
 - Minimize & contain foreign object debris
 - Positively pressurize cultivation & clean rooms
 - Filter and clean all air entering facility
 - Cascade from clean to dirty spaces
- Ventilate Interstitial Spaces



Effective Duct Design

- Integrated HVAC Systems
 - Understand loads & right-size
- Proper Duct Design
 - Law of Minimums applies
- Laminar flow from front to back of room
- Flow through working aisles - not across



Eliminating Microclimates

- Essential to homogenize the cultivation environment
 - Leaf & air temperature
 - Top of canopy vs. sub-canopy
- Minimize pockets of hot / damp air
 - Uniform air distribution
- Sub-Canopy Airflow Systems (SCAS)
 - Deliver cool, conditioned, & CO₂-enriched air directly to stomata on underside of leaves
 - Break up boundary layer in lower part of canopy



The background image shows the interior of a vast greenhouse. The structure is composed of a dense network of metal beams and supports, creating a complex grid-like pattern. The roof is high and appears to be made of a translucent material, allowing natural light to filter through. In the foreground and middle ground, there are numerous rows of seedlings growing in trays. The plants are small and green, with some showing signs of being recently planted. The overall atmosphere is one of a large-scale agricultural operation.

SECTION 03

Greenhouse Design Considerations

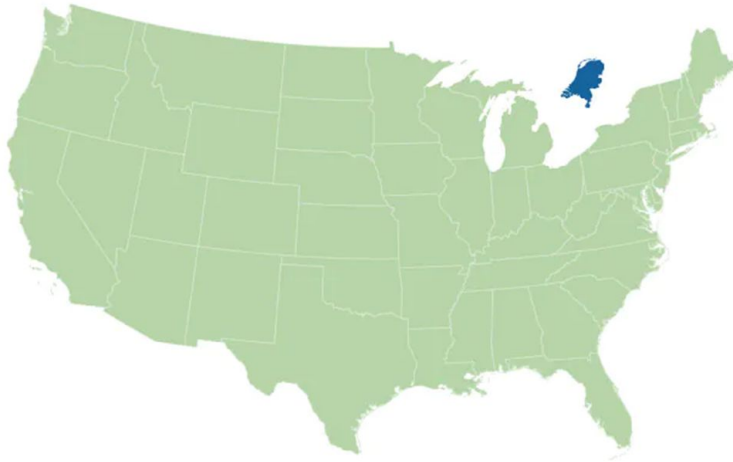
POLL ALERT!

What role do you play in the cultivation space?

- Equipment provider / Vendor
- Owner
- Grower
- Operations Manager
- Consultant / Advisor



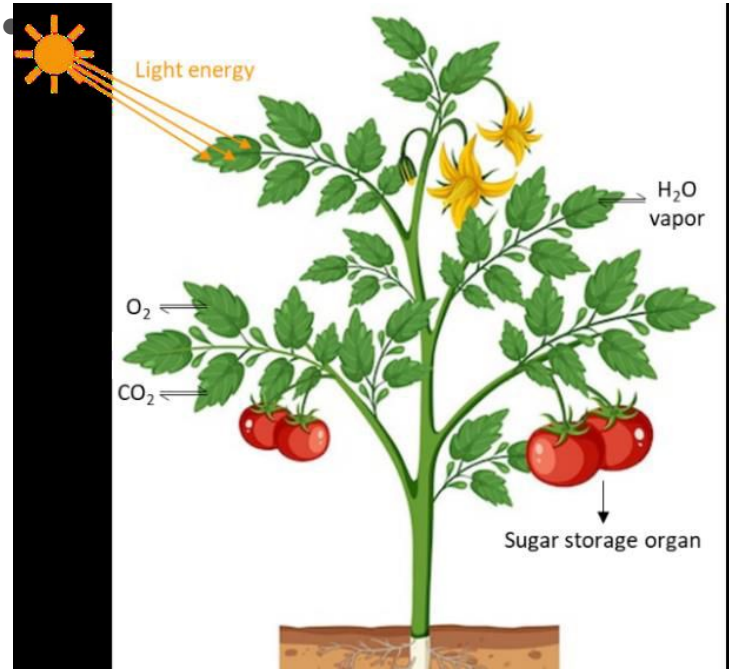
The Netherlands... Where? What?



Geographical	-	237:1
Population	-	19:1
Fresh Produce Export	-	1,5:1

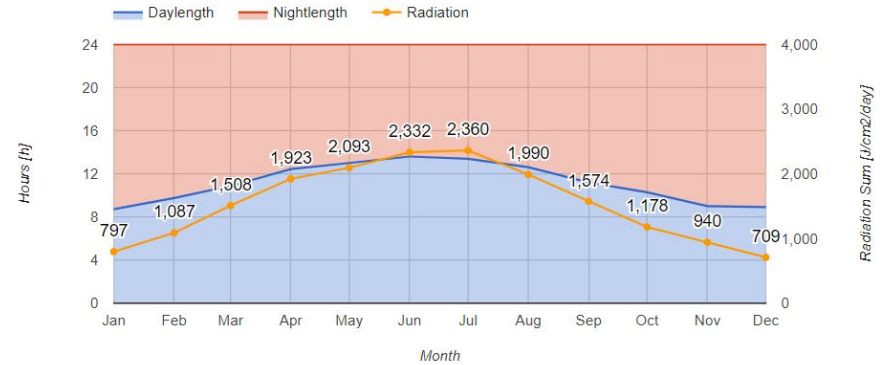
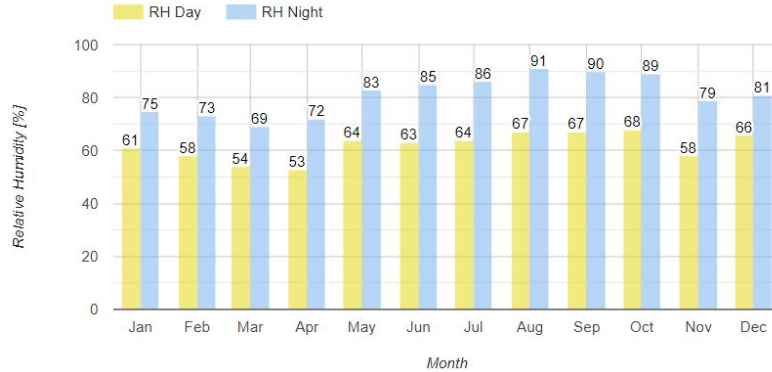
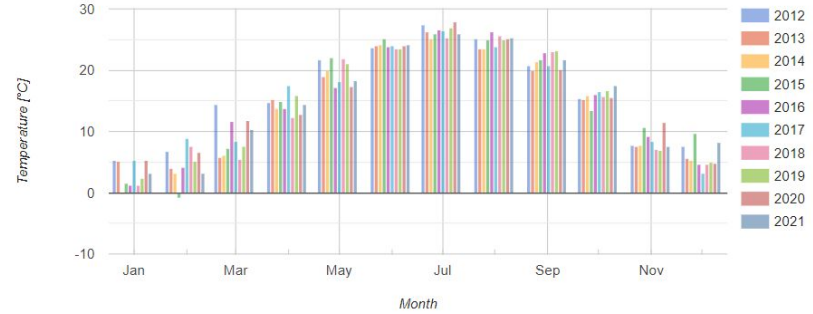
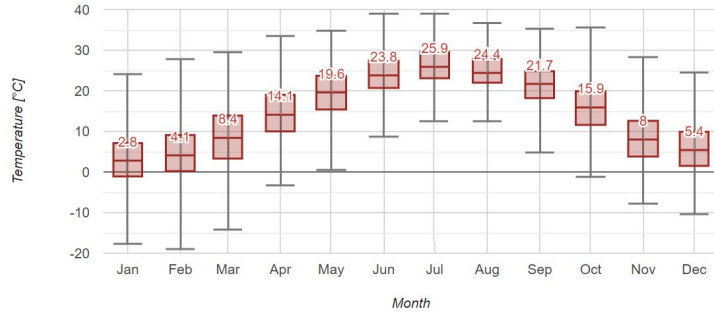


Plant Focus



Ambient Conditions @ Production Location

Weather Summary Box Plot



Apply Technology to Bridge

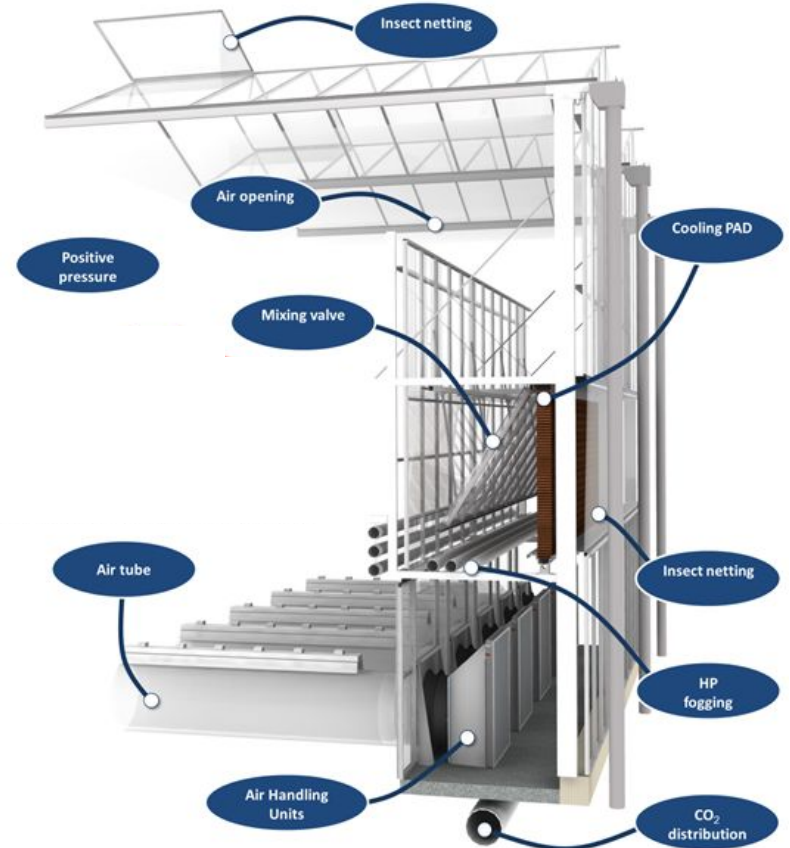


And Even more Technology



Control over Air

- Semi Closed (UltraClima®) - 15 Years
- Active & Controlled Air Flow
- Homogeneous Air Distribution
- Energy Efficiency
- CO₂ Control
- Ideal Crop Climate
- Consistent Quality & Yield
- Year Round Production in Any Climate



Healthy and Sustainable Business Case



SECTION 04

Common Mistakes: Greenhouse Envelope Design & Construction

POLL ALERT!

Do you use any of these textiles in your greenhouse?

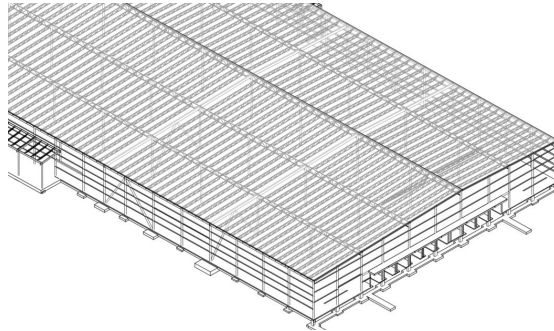
- Shade Curtains
- Combination Shade/Thermal Curtains
- Light-diffusing Shade Curtains
- Photoperiod (Light Dep) Curtains



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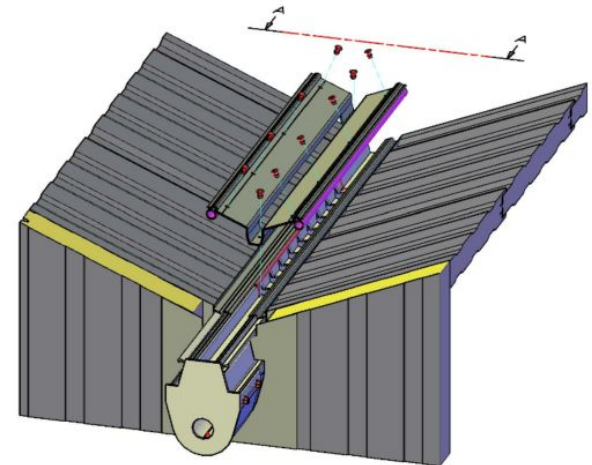
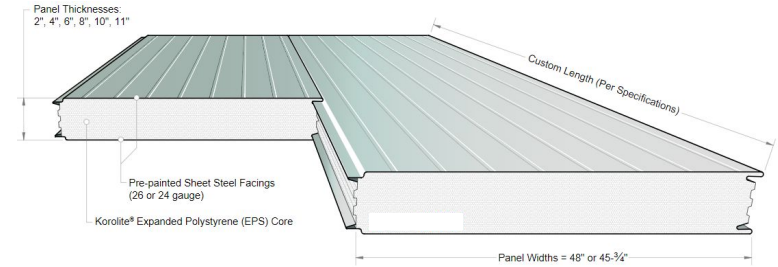
Building Envelope Materials

- Headhouse and Greenhouse Materials
 - PEMB, Venlo
 - Galvanized or Coated Steel
 - Aluminum Extrusions
 - Insulated Metal Panel
 - Glass
- Considerations
 - Roof Height
 - R-Values
 - Waterproofing
 - Dead Load
 - Room Layout



Building Envelopes

- Focus on the End User
 - Size
 - Functionality
- Insulated Metal Panel
 - R-value
 - Non-combustible
 - Strength / Span
 - Waterproofing
 - Rain Collection
- Concrete / Earth
 - Sloping
 - Finish / Coatings



Support Buildings

- Greenhouses are alive! Design Accordingly

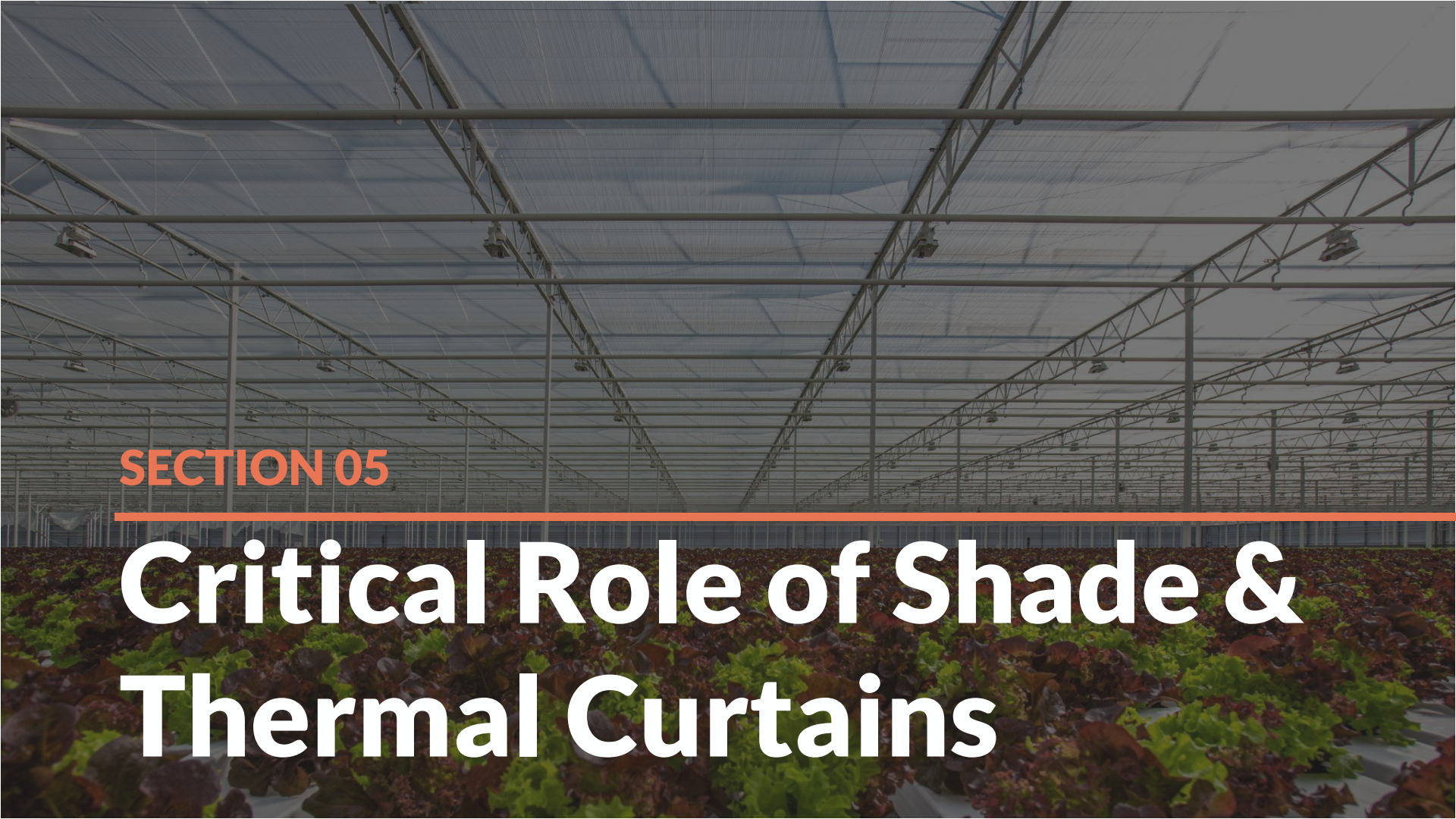


- Consider Food Safety and Washdown
- Harvesting, Processing, Packaging, Irrigation/Fertigation, Storage, Shipping
- RTUs, Refrigeration, Process Piping, Fire Suppression, Water, Lighting

Common Mistakes

- Over/Under Design
- Clear Spans between Joists and Girders
- Humidity and Climate
- Building Color
- Waterproofing / Flashing
- Drainage and Sloping
- Floor Coatings
- Extreme Temperatures in the Greenhouse
- Low Clear Heights
- Undersized Rooms
- Material Selection / Wall Coverings
- Seismic Considerations



A large commercial greenhouse with a complex metal frame and a translucent covering. Rows of plants are visible in the foreground, and the structure extends far into the background.

SECTION 05

Critical Role of Shade & Thermal Curtains

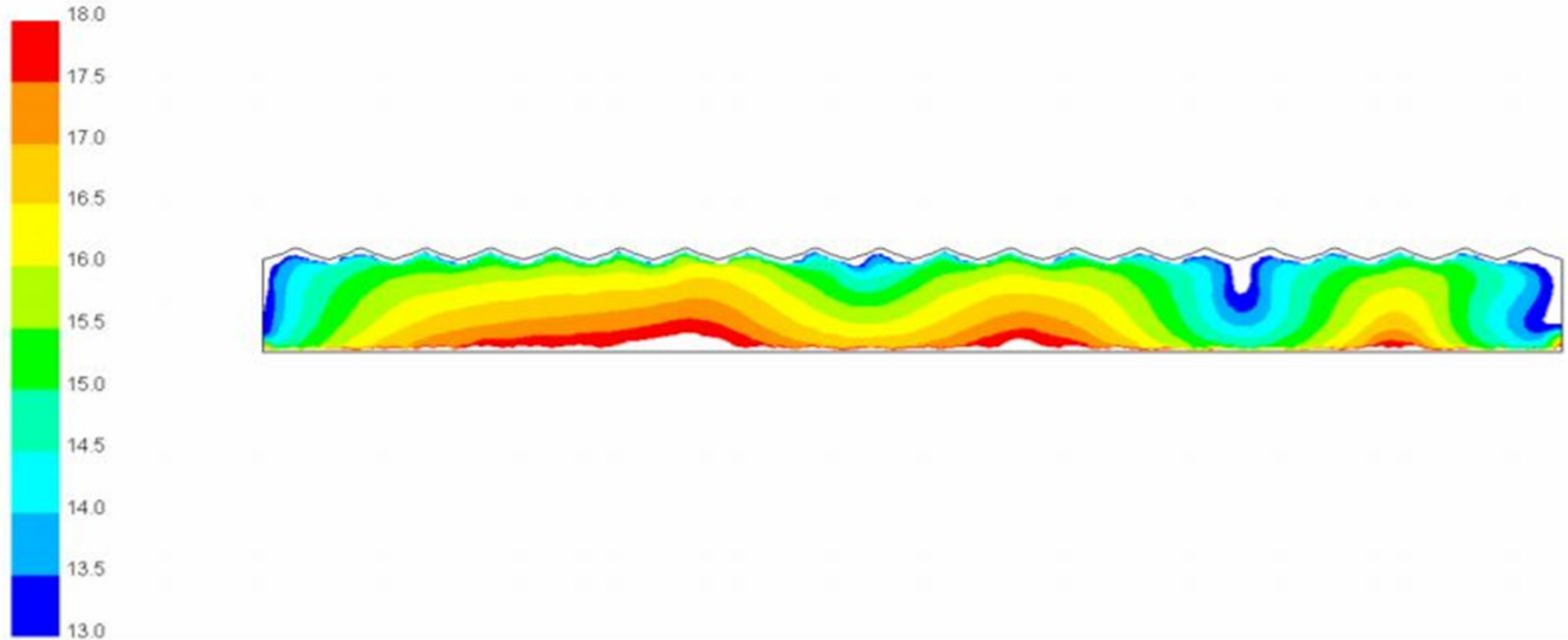
POLL ALERT!

Please select the types of webinars you are interested in.

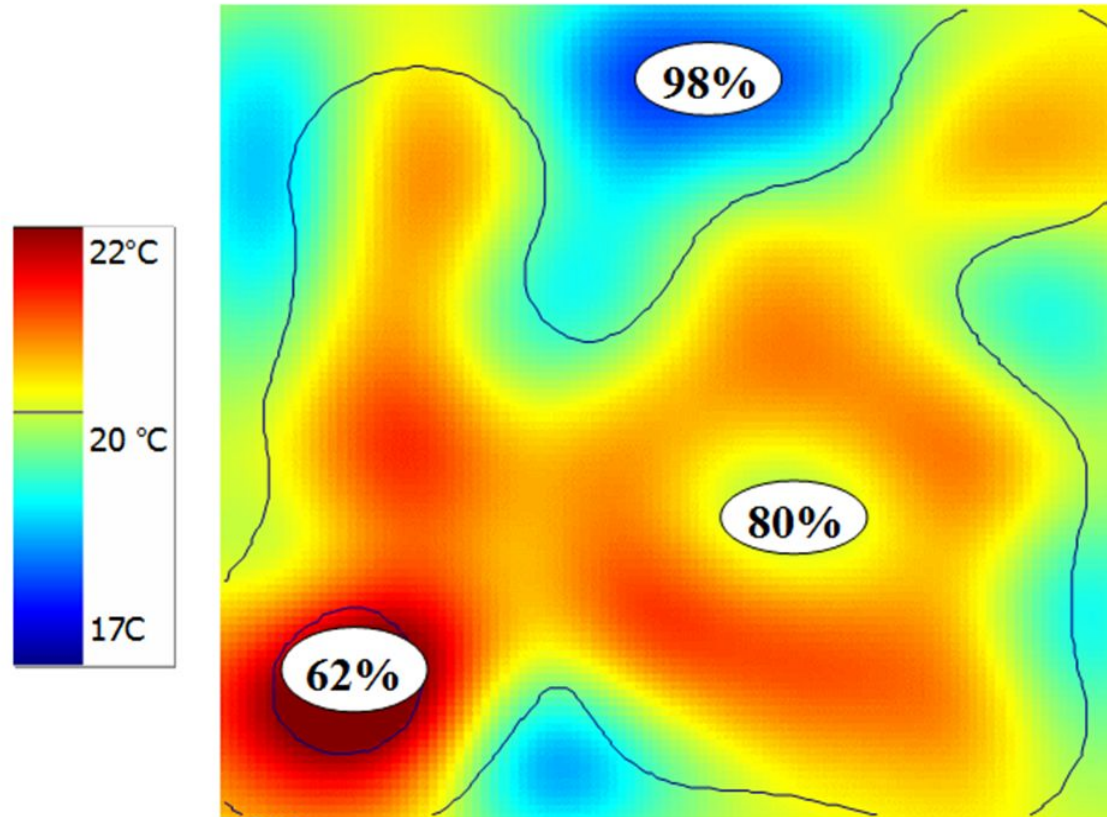
- 30 minute webinars
- 60 minute webinars
- Informal round table on a specific topic
- Multiple topics in one session
- Podcast, no visuals!
- Topic specific webinars



Priority 1: Homogenous greenhouse climate

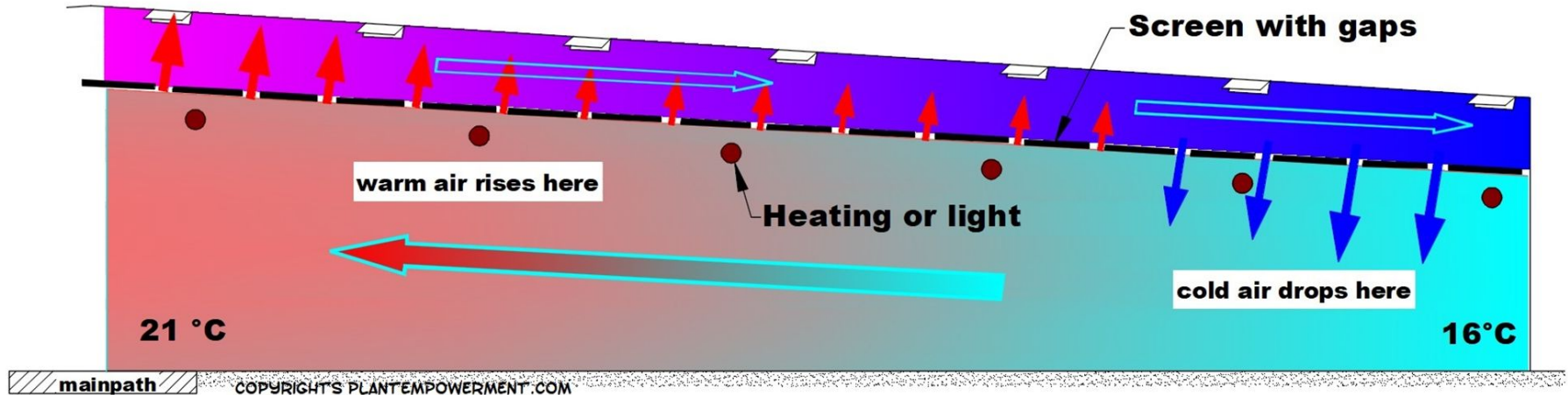


Priority 1: Homogenous greenhouse climate

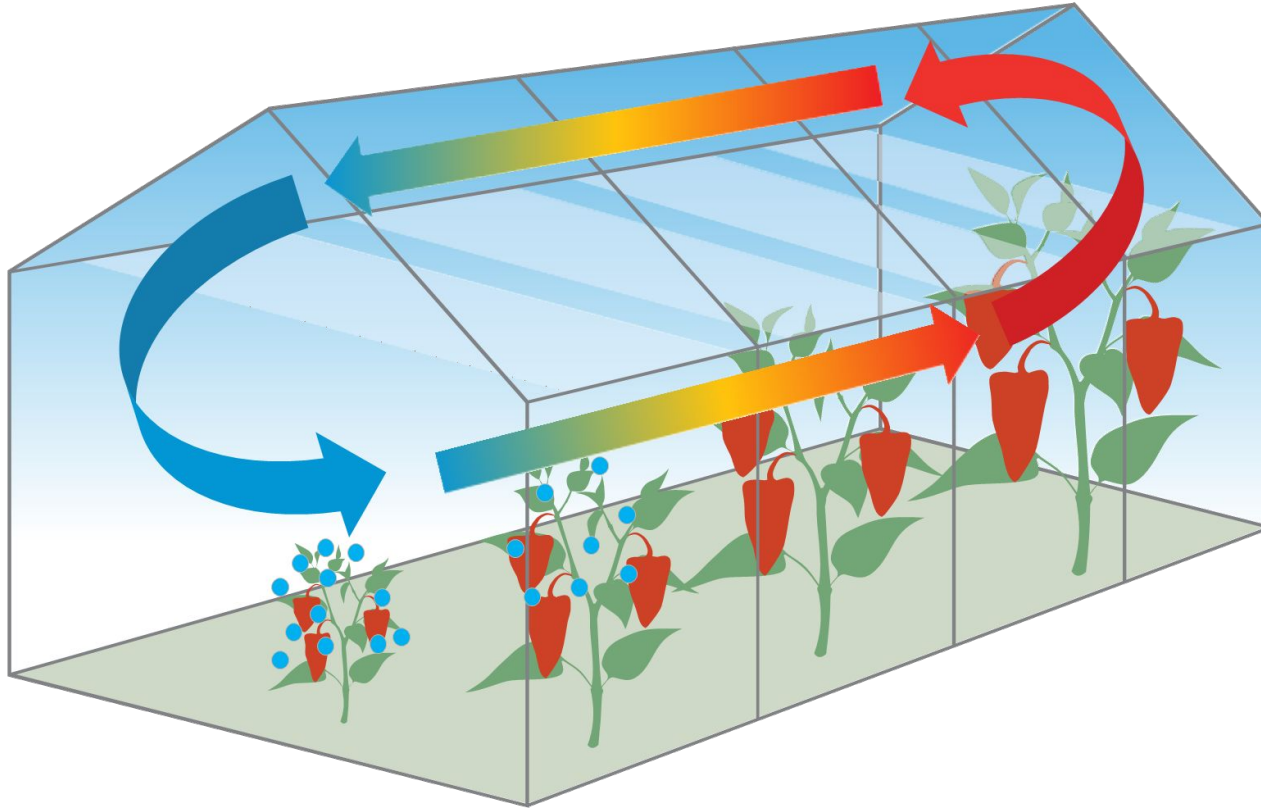


Horizontal temperature differences

Warm air above the screen cools down and travels to the lowest point

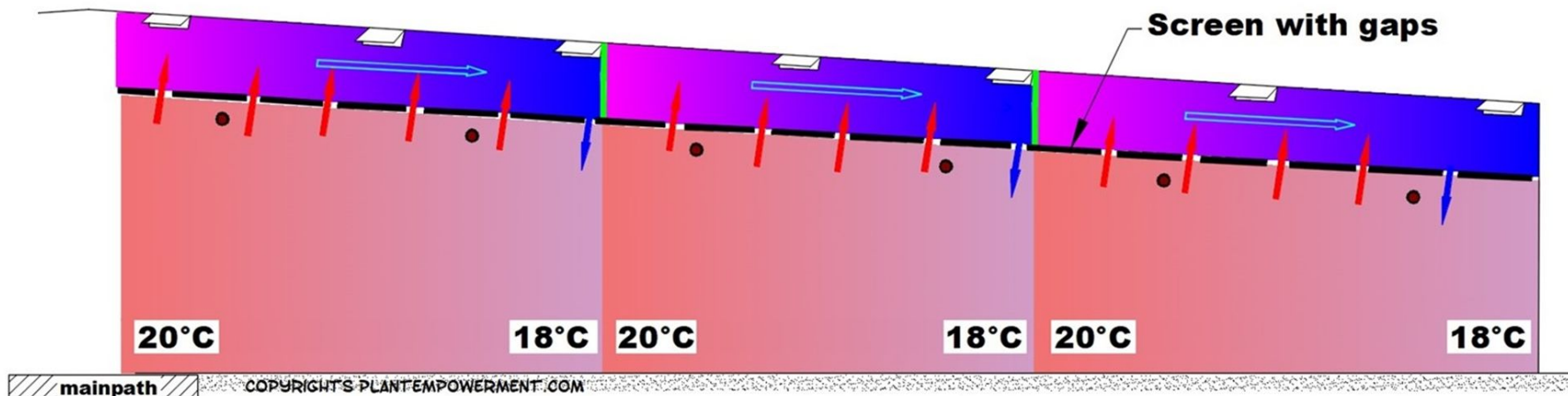


Horizontal temperature differences



Vertical screens

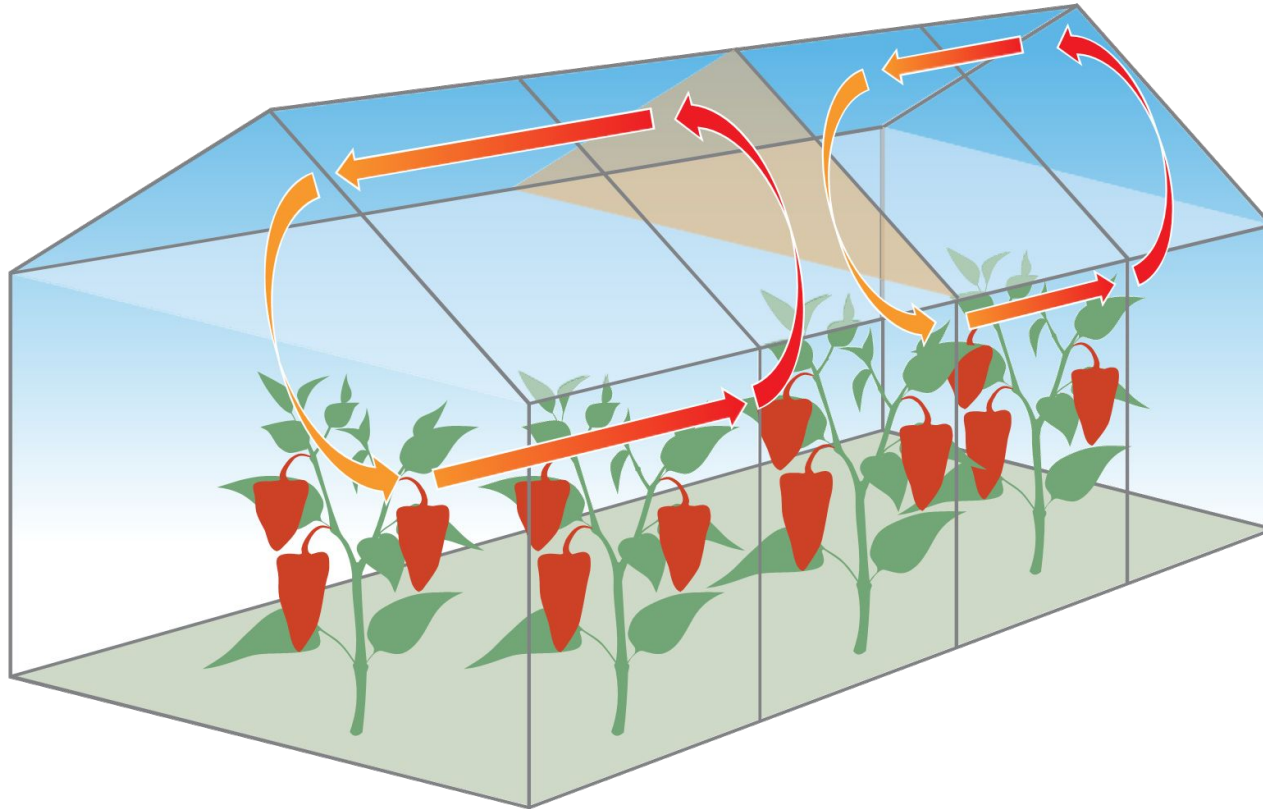
Vertical screens divide the area above the screen in 3 sections



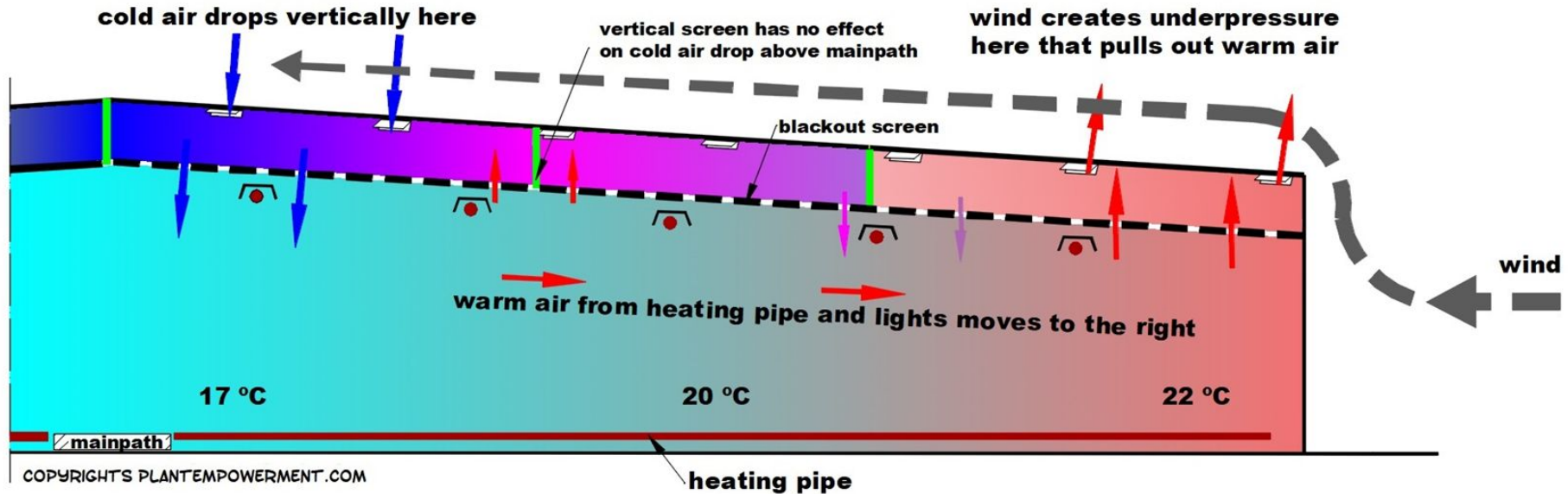
Vertical screens



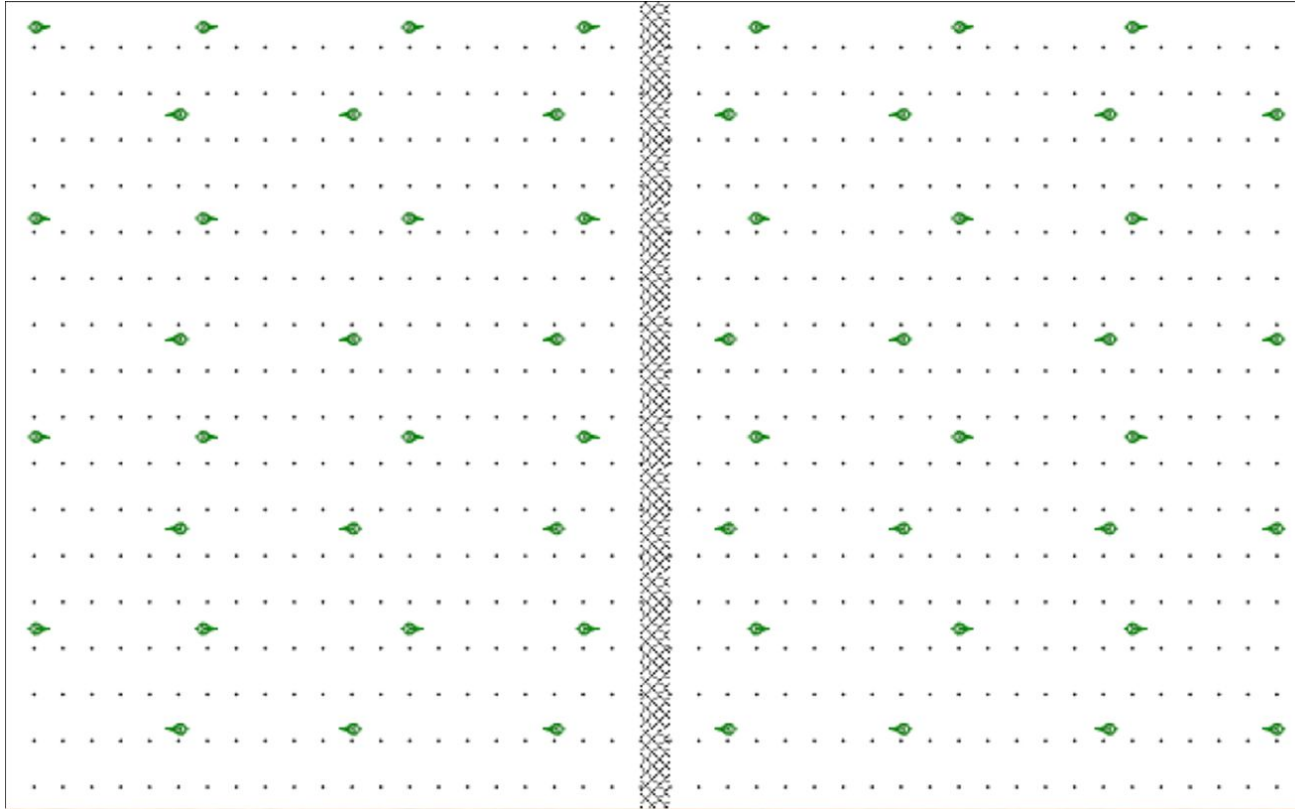
Vertical screens



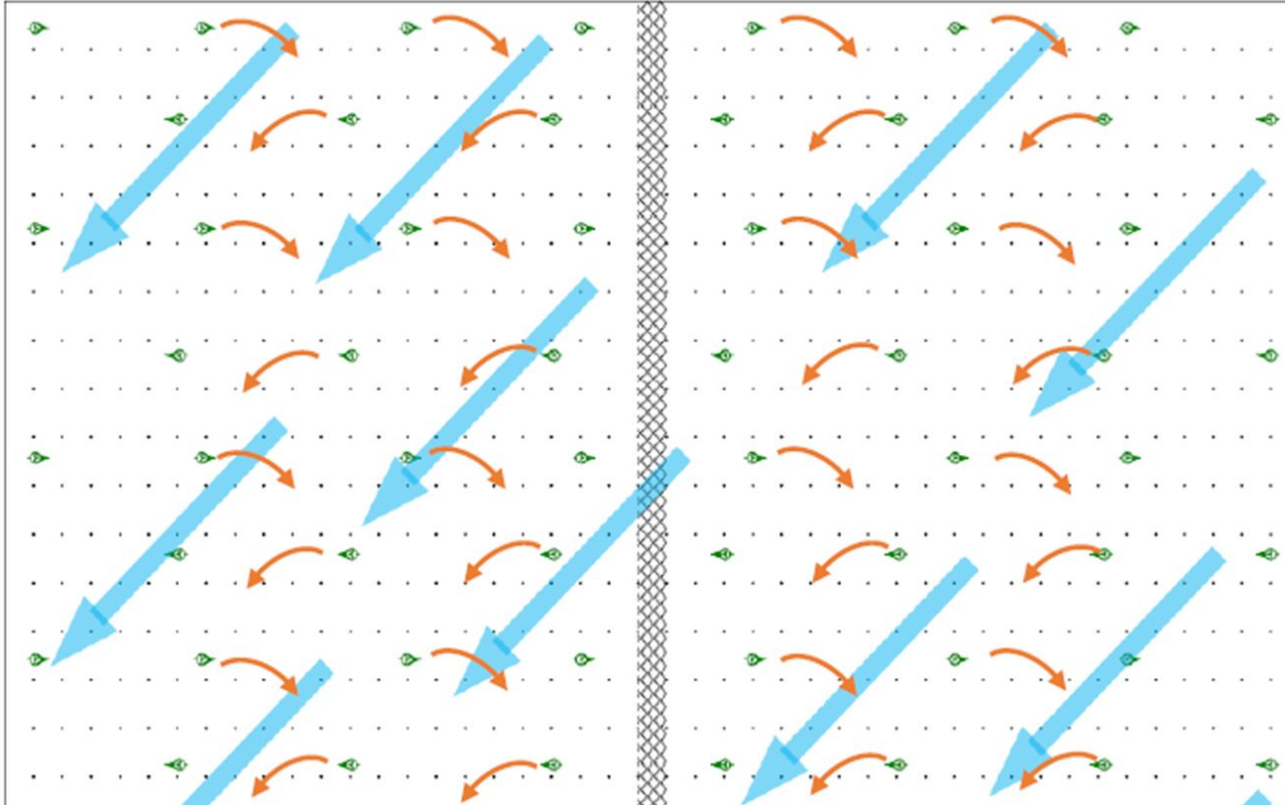
Horizontal temperature differences



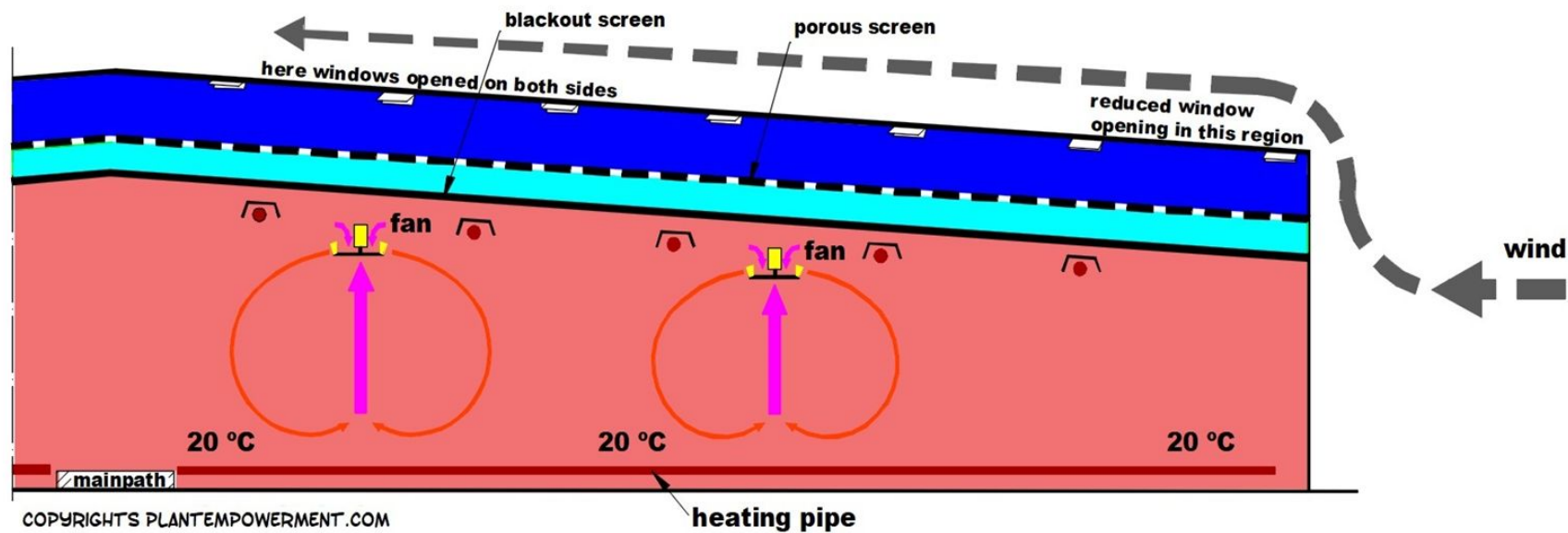
Horizontal Airflow Fans solve the problem?



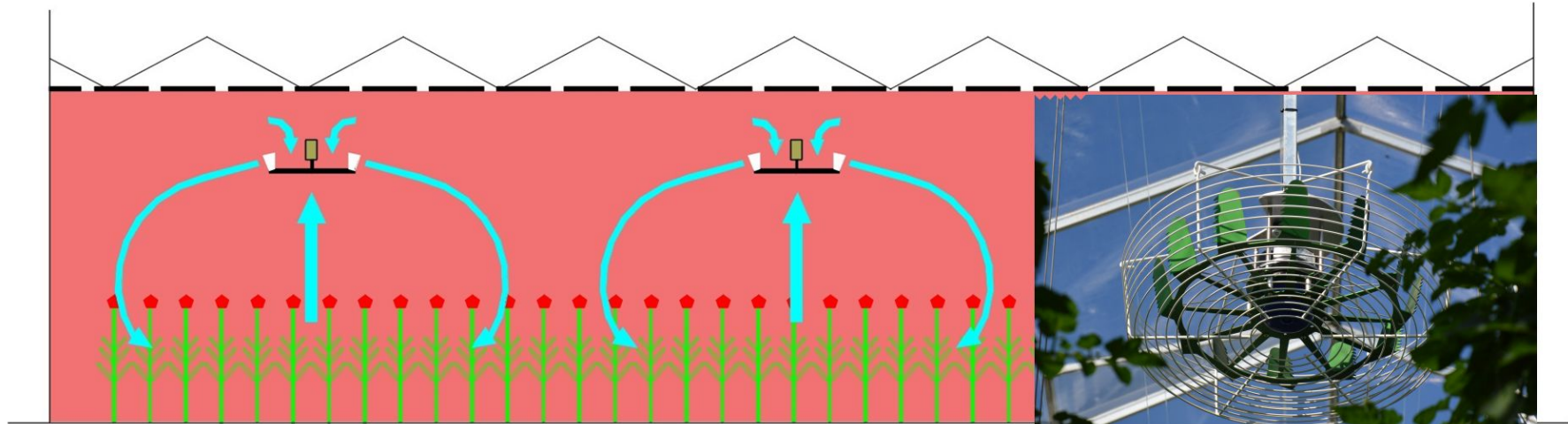
Horizontal Airflow Fans solve the problem?



Stop with screen gaps!

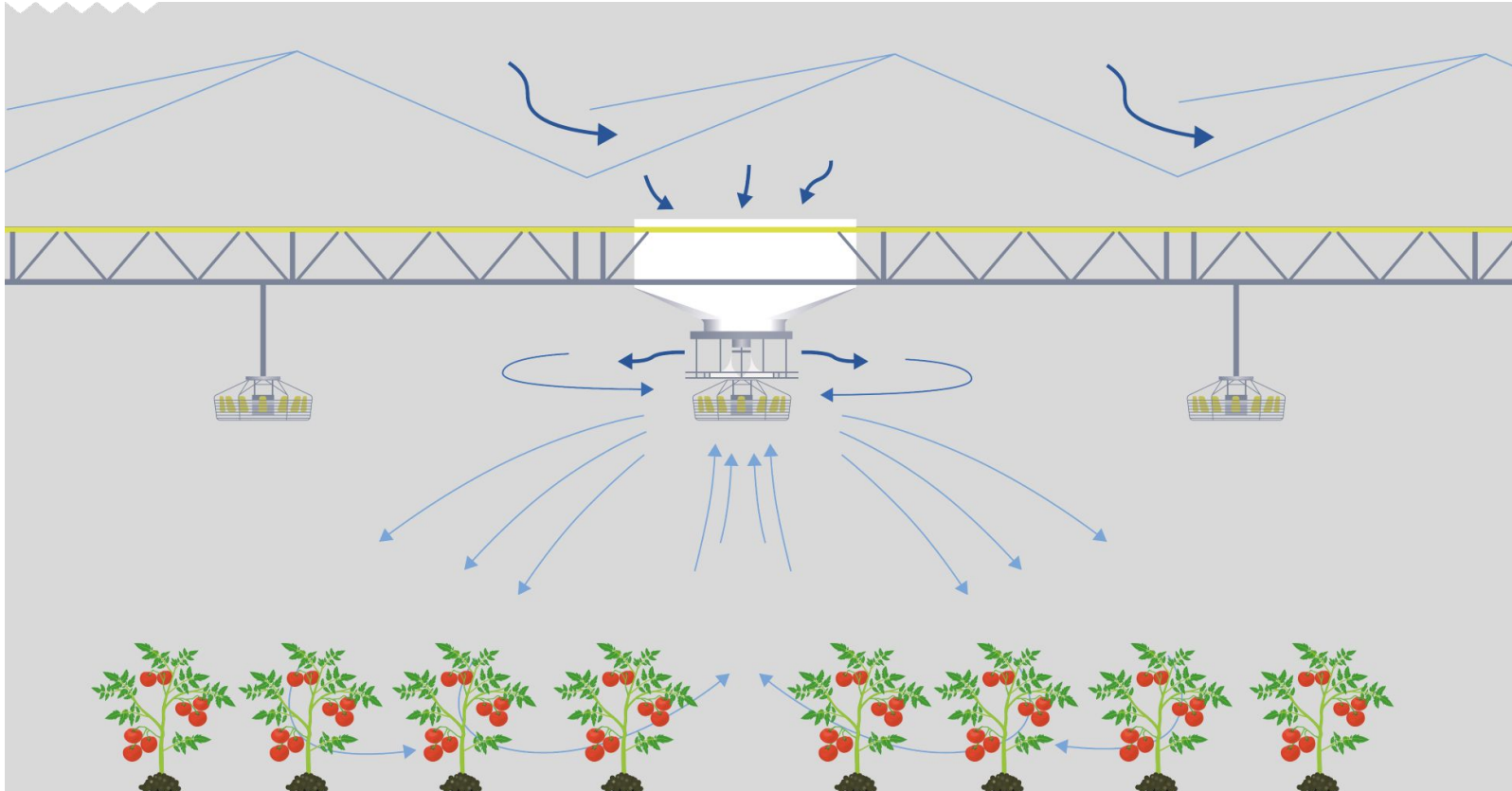


Importance of controlled vertical air movement



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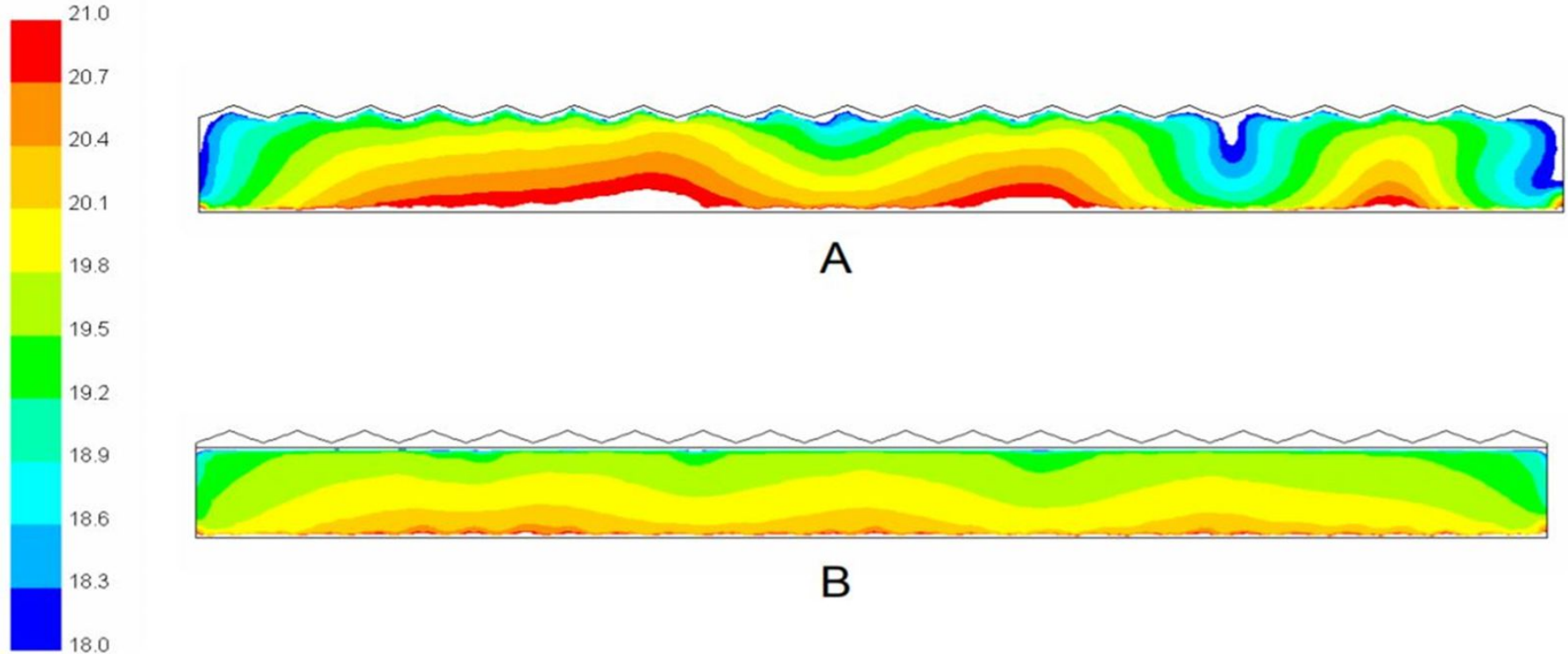
Grow with the Flow!



Grow with the Flow!



Homogenous greenhouse climate



A photograph of a large indoor greenhouse. The ceiling is high with a complex network of white structural beams. Numerous long, rectangular light fixtures are suspended from the ceiling, emitting a warm, orange glow. Several large, white, circular fans are also visible, hanging from the ceiling. In the foreground, rows of green plants are visible, though they are slightly out of focus. The overall atmosphere is industrial and controlled.

SECTION 06

Incentives Overview

Measure and Incentive Details Deemed



Measure	Measure Sizes	Incentive
Glycol Pump VFD	3hp – 25hp	\$1,500 - \$5,000 / unit
High-Low Bay LED Horticultural Lighting	4500 lumens – 65,900 lumens 130 LPW – 150+ LPW	\$30 - \$55 / unit
Efficient Ag Ventilation Fans	24 – 48 inch VSD	\$200 / unit \$195 / hp for VSD
Dust Collection Fan VSD	VFD on 10hp – 150hp motor	\$2,000 - \$15,000 / unit
VFD on Ag Well and Booster Pumps	<75 hp – 600hp	\$75 - \$200 / hp
Enhanced VFD on Ag Well and Booster Pumps	<75 hp – 600hp	\$150 / hp

Measure and Incentive Details Custom + NMEC*



Measure	Measure Examples	Incentive per kWh	Incentive per kW
Lighting	• Lighting controls • Horticulture lighting • Exterior LED lighting • Interior high/low bay LED lighting	\$0.15	\$150
HVAC	• Horticulture HVAC system improvement • HVAC controls and VFDs • HVAC retro-commissioning • Chiller (HVAC) compressor – VFD • Ventilation fan – VFD • Efficient dehumidification system		
Refrigeration	• Refrigeration system insulation • Refrigeration system controls and VFDs • Condenser fan – VFD • Chiller (process) compressor – VFD • Evaporator coil fan – VFD • Efficient refrigeration condensing unit • Oversized air-cooled condenser • Efficient refrigeration compressors		

Measure and Incentive Details Custom + NMEC*



Measure	Measure Examples	Incentive per kWh	Incentive per kW
Irrigation	• Sprinkler/flood to drip irrigation • Distribution uniformity improvement • Irrigation scheduling	\$0.15	\$150
Compressed air	• Compressed air controls • Compressed air system optimization		
Pumping	• Pump controls and VFDs • Pumping system retro-commissioning • Agricultural pumping system upgrades • VFD on Ag well pump serving non-pressurized system (add-on equipment) • VFD on Ag pump serving non-pressurized system • Milk transfer pump – VFD • Vacuum pumps – VFD • Milking vacuum pumps - VFD		
Wastewater	• Wastewater system controls and VFDs • High efficiency blowers • High efficiency pumps • High efficiency aerators • Wastewater treatment management system • Wastewater chemically enhanced primary treatment/sedimentation		

Deemed & DI Water Heating Requirements & Incentives



Customers who located within a Disadvantaged Community (DAC) as defined by CalEnviroScreen 4.0 will receive a higher incentive than customers who are not. Customers who are classified as Hard-to-Reach (HTR) will be offered measures at no-cost.

Measure	Requirements	Standard Deemed Rebate	Increased Rebate for DAC Customers	DI Cost to Customer (for HTR and DAC customers only)
Steam Traps	• ≥ 12 hours of average daily use • Any pipe size	\$150 each	\$300 each	Not eligible
Storage Water Heaters	• 40 Gallon • ≥ 0.64 UEF • Input rating ≤ 75 kBtu/hr	\$20 per rated MBtuh	\$27 per rated MBtuh	No Cost
Storage Water Heaters	• 40 Gallon • ≥ 0.68 UEF • Input rating ≤ 75 kBtu/hr	\$22 per rated MBtuh	\$29 per rated MBtuh	No Cost
Process Boiler	• $\geq 90\%$ CE Hot Water • Must replace standard efficiency process boiler • Input rating $\leq 20,000$ kBtu/hr	\$6 per rated MBtuh	\$10 per rated MBtuh	Not eligible
Process Boiler	• $\geq 85\%$ CE Hot Water • Must replace standard efficiency process boiler • Input rating $\leq 20,000$ kBtu/hr	\$2 per rated MBtuh	\$2.95 per rated MBtuh	Not eligible
Process Boiler	• $\geq 83\%$ CE Steam • Must replace standard efficiency process boiler • Input rating $\leq 20,000$ kBtu/hr	\$3 per rated MBtuh	\$4.35 per rated MBtuh	Not eligible

Deemed & DI Insulation Requirements & Incentives



Customers who located within a Disadvantaged Community (DAC) as defined by CalEnviroScreen 4.0 will receive a higher incentive than customers who are not. Customers who are classified as Hard-to-Reach (HTR) will be offered measures at no-cost.

Measure	Requirements	Standard Deemed Rebate	Increased Rebate for DAC Customers	DI Cost to Customer (for HTR and DAC customers only)
Tank Insulation	1" temperature application 120–170 degrees F solution	\$2.50/ square foot	\$4.00/ square foot	No Cost
Tank Insulation	2" temperature application 170–200 degrees F solution	\$3.25/ square foot	\$6.00/ square foot	No Cost
Fitting Insulation (no steam for DI)	1" minimum insulation thickness <= 1 inch pipe <=15 and >15 PSIG Steam or Hot Water ½" minimum pipe diameter	\$10.00–\$15.00/fitting	\$15.00–\$22.50/fitting	No Cost (Hot Water only)
Fitting Insulation (no steam for DI)	1" minimum insulation thickness > 1 inch pipe <=15 and >15 PSIG Steam or Hot Water	\$14.00–\$40.00/fitting	\$22.00–\$60.00/fitting	No Cost (Hot Water only)
Pipe Insulation (no steam for DI)	- One inch minimum insulation thickness <= 1" inch pipe, <=15 and >15 PSIG Steam, Hot Water, Indoor, and Outdoor – ½" minimum pipe diameter 1 inch – > 4 inch, <=15 and > 15 PSIG Steam, Hot Water, Indoor, and Outdoor	\$2.50/ foot	\$4.00/ foot	No Cost (Hot Water only)

Deemed & DI Greenhouse Requirements & Incentives



Customers who located within a Disadvantaged Community (DAC) as defined by CalEnviroScreen 4.0 will receive a higher incentive than customers who are not. Customers who are classified as Hard-to-Reach (HTR) will be offered measures at no-cost.

Measure	Requirements	Standard Deemed Rebate	Increased Rebate for DAC Customers	DI Cost to Customer (for HTR and DAC customers only)
Greenhouse Heat Curtain – Existing or New Construction	- Natural gas savings rating $\geq 40\%$ - Single layer interior curtain - The heat curtain must have a warranty/product life of five years - The installation must allow the curtain to be automatically or manually moved into place.	\$0.35/ square foot floor area	\$0.50/ square foot floor area	No Cost
Greenhouse Infrared Film - Existing	- Must be infrared, anti-condensate, polyethylene plastic - Minimum thickness of six thousandths of an inch - Cannot be installed on greenhouse walls	\$0.05/ square foot film area	\$0.10 / square foot film area	No Cost
Greenhouse Infrared Film – New Construction	- Must be infrared, anti-condensate, polyethylene plastic - Minimum thickness of six thousandths of an inch - Cannot be installed on greenhouse walls	\$0.02/ square foot film area	\$0.02/ square foot film area	No Cost

Custom Measure Incentives



Measures	Standard Incentive (\$/Therm Savings)	DAC Incentive (\$/Therm Savings)
Boiler System Upgrades	\$2.50	\$3.00
Condensing Unit Heater	\$2.50	\$3.00
Direct Contact Water Heater	\$2.50	\$3.00
Greenhouse Environmental Controls	\$2.50	\$3.00
Greenhouse IR Space Heating	\$2.50	\$3.00
Greenhouse Under-Bench Heating	\$2.50	\$3.00
Heat Recovery, Dehumidification Air Reheat	\$2.50	\$3.00
Process Heat Recovery	\$2.50	\$3.00
Process Pump VFD	\$2.50	\$3.00
Combined Heat and Power	\$2.50	\$3.00
Infrared Heating for Post-Harvest	\$2.50	\$3.00
Greenhouse Envelope Upgrades	\$2.50	\$3.00
Ozone Cleaning and Laundry	\$2.50	\$3.00
Greenhouse Retro commissioning	\$1.25	\$1.25

Measure and Incentive Eligibility



Basic Requirements for All Measures

- Customers must meet [general program eligibility](#) requirements to apply for AgEE Program incentives
- All equipment must be new electric powered equipment
- Qualifying equipment must be purchased and installed between July 5, 2022, and December 31, 2025. The purchase date of the equipment must be within the calendar year that the application is submitted unless indicated otherwise.
- All required efficiencies must exceed Title 20 and 24 standards.

Training and education on broader participation benefits

- Energy savings
- Non-energy benefits (e.g., increased yield, worker safety, animal comfort, etc.)
- Building energy assessments
- Energy benchmarking
- Technical support in selecting the most beneficial measures
- Ongoing guidance regarding measure installation and usage
- Financing assistance through incentives and promotion of on-bill financing
- Provide customers with education on accessing grants such as those from the USDA
- Dedicated outreach for DAC and HTR customers

Program Delivery and Customer Services





Get in touch with us:

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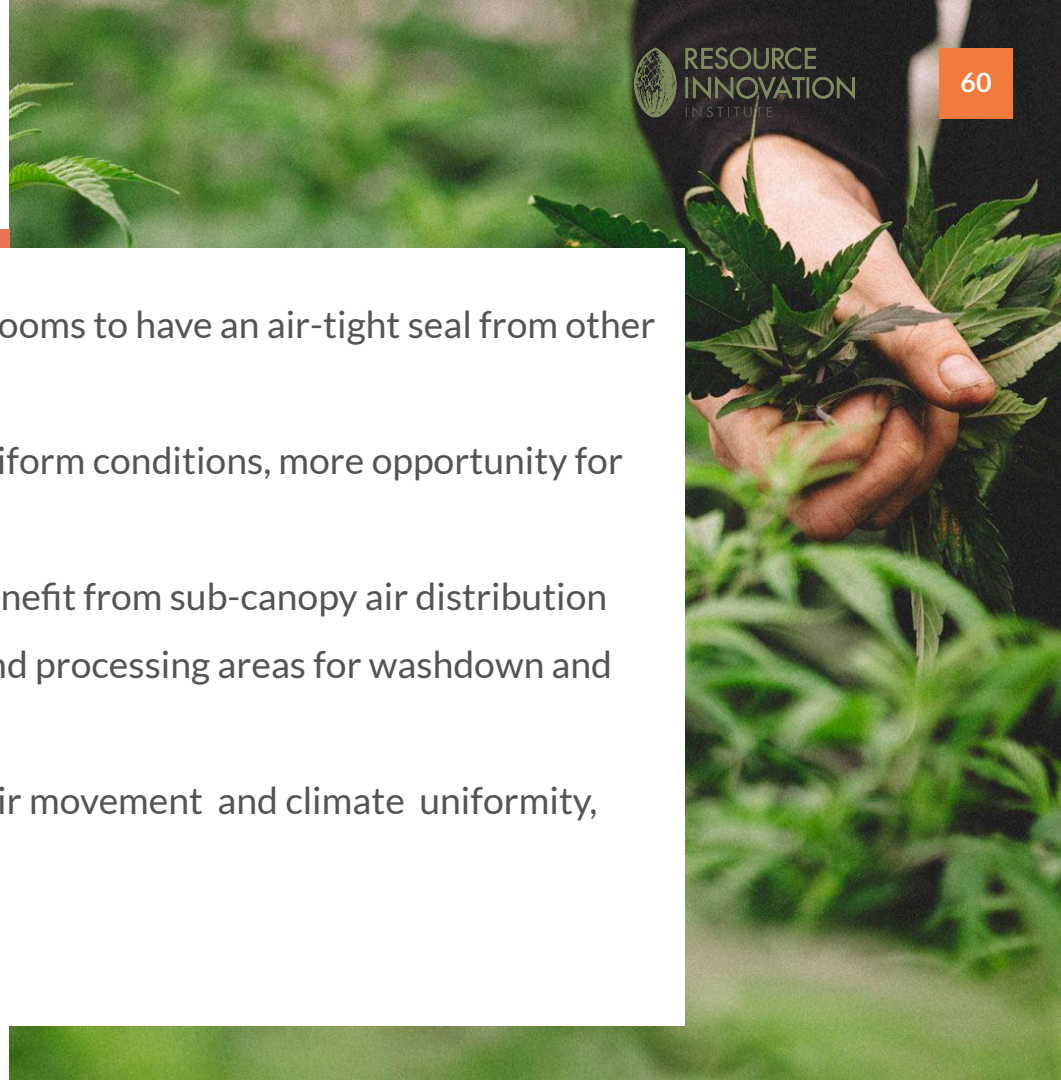
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Actionable Takeaways

- Critically important for indoor farm grow rooms to have an air-tight seal from other areas and from outdoors
- Semi-closed greenhouses provide more uniform conditions, more opportunity for CO2 enrichment, and insect exclusion
- Both indoor farms and greenhouses can benefit from sub-canopy air distribution
- Greenhouses are alive! Design envelope and processing areas for washdown and food safety protocols
- Vertical air flow fans can greatly improve air movement and climate uniformity, above and below curtain layers





Panel Q & A

Today's Experts



Adrian Giovenco



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