New Strategies for Energy Reduction in Greenhouses and Indoor Farms

September 14, 2023

RESOURCE INNOVATION INSTITUTE

SOUTHERN CALIFORNIA EDISON
An EDISON INTERNATIONAL Company

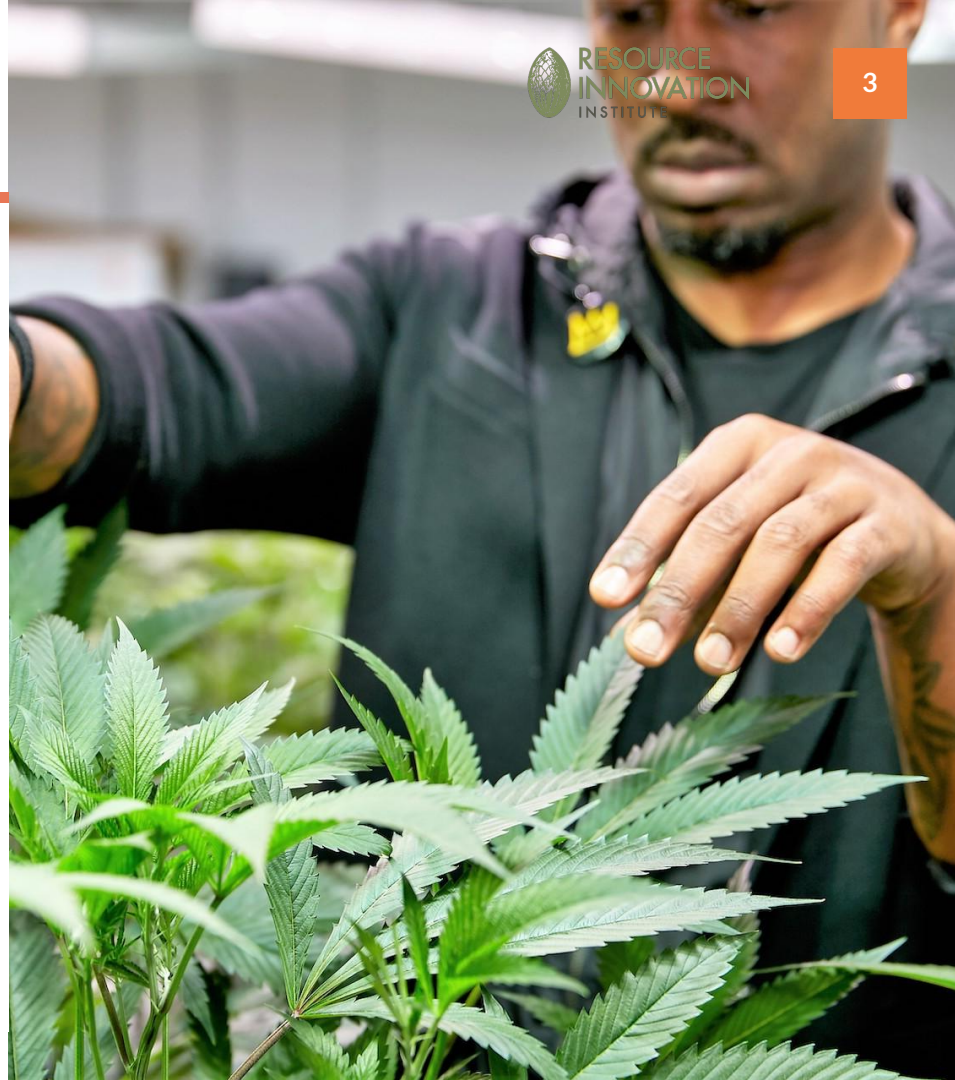
POLL ALERT!

What kind of facility are you cultivating in?

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

Agenda

Welcome, Introductions and Context	1:30 - 1:40
Energy Savings from Building Envelope and CO_2 Enrichment	1:40 - 1:45
Integrated Environmental Controls to Save Energy	1:45 - 2:03
Greenhouse Curtains for Managing Energy Savings and Climate	2:03 - 2:21
Energy and Horticultural Lighting	2:21 - 2:39
Other Energy Savings Practices	2:39 - 2:44
Caleb: ICF Incentives for Energy Savings	2:44 - 2:52
Q&A	2:52 - 3:00



SECTION 01

INTRODUCTION

Today's Experts

Rob Eddy

RESOURCE INNOVATION INSTITUTE

Luis Trujillo

hoogendoorn growth management

Rob Hanifin

Independent Consultant

Mikhail Sagal

TSRgrow™

Caleb Hayhoe

ICF

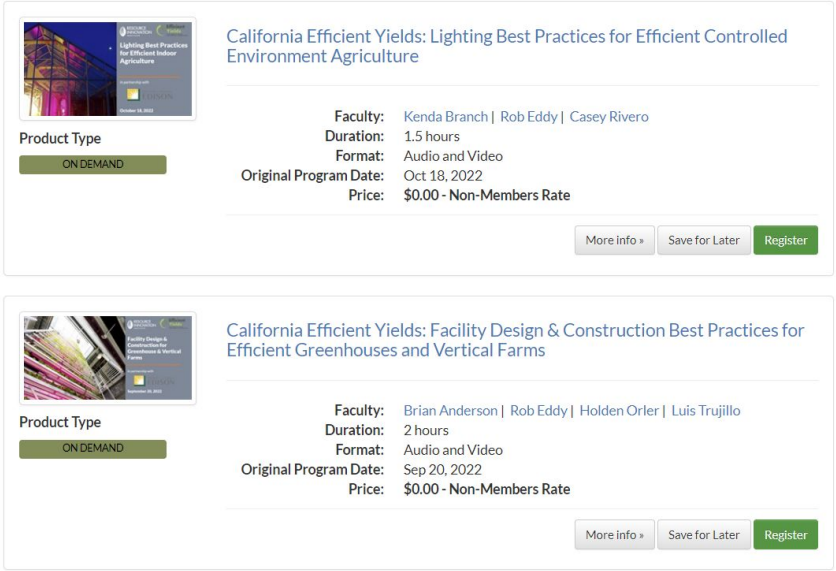
Access Your California Virtual Classroom

Continue Learning Online

Free guidance on efficient cultivation

- Recordings of live workshops
- Tip clips
- Downloadable resources

Create an account at
resourceinnovation.org/California



All live workshops are available for on-demand viewing!

Register for Upcoming Workshops

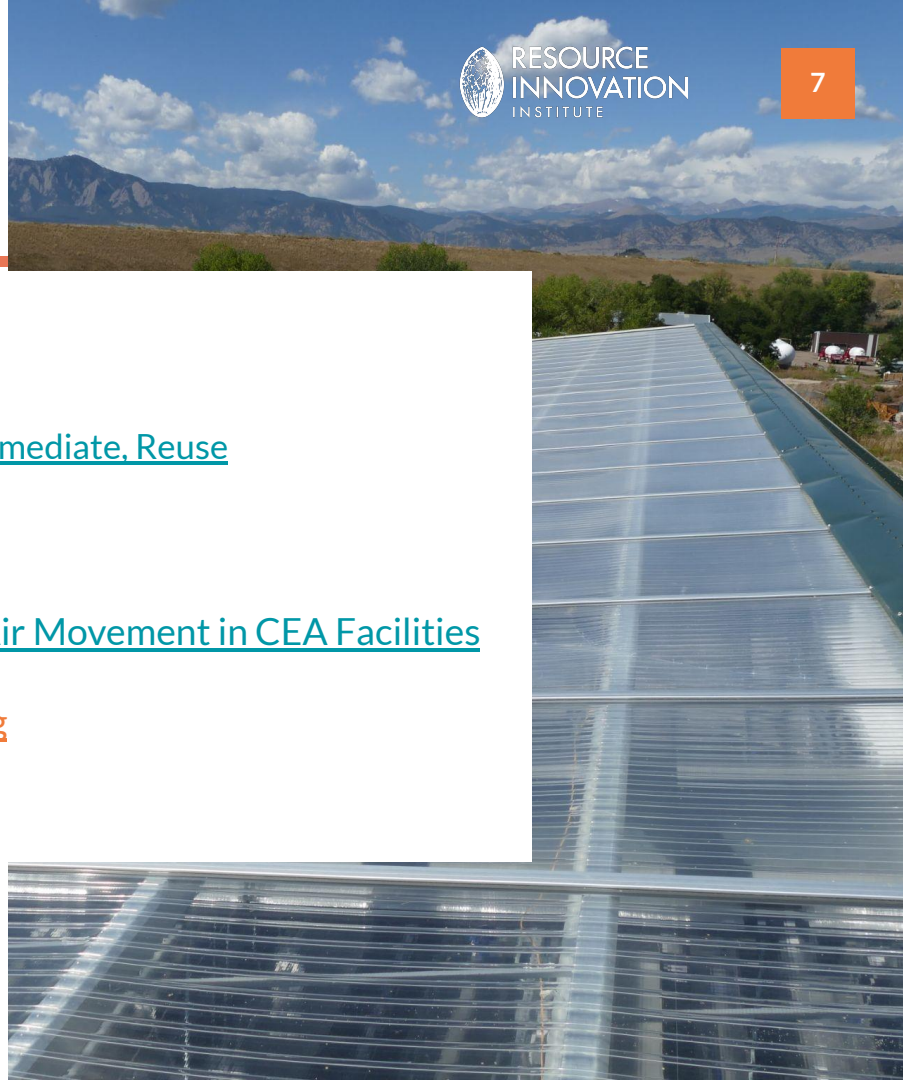
SCE funded Workshops:

September 28 | Water Circularity in CEA Facilities: Reduce, Remediate, Reuse

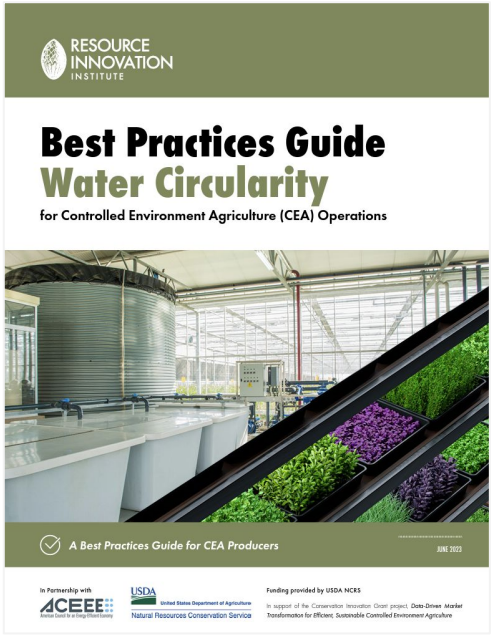
SCE funded Workshops:

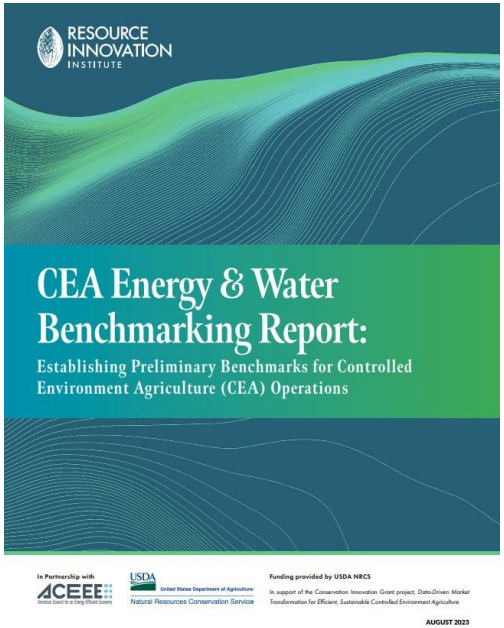
October 12 | The Critical Role of Building Envelopes and Air Movement in CEA Facilities

Register and access other free resources on the RII catalog



CEA Resources





Best Practices Guide Featuring contributions from 15 Working Group member companies

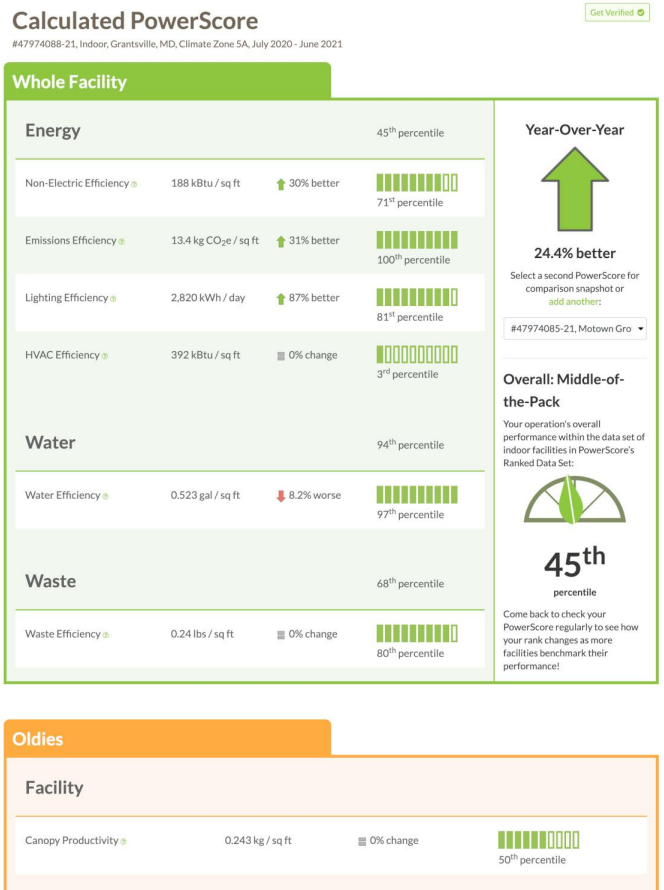
Benchmarking Report Featuring annual resource consumption and productivity of twelve producers growing a variety of crops in greenhouse and indoor facilities across the US.

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)



POLL ALERT!

What kind of facility are you cultivating in?

Discuss Results

SECTION 02

Energy Savings from Building Envelope and CO_2 Enrichment

POLL ALERT!

Should employees with a certification or credential in resource efficiency (energy/water savings) be paid more?

- Yes
- Maybe, I need to know more
- No, that opens up a can of worms
- N/A

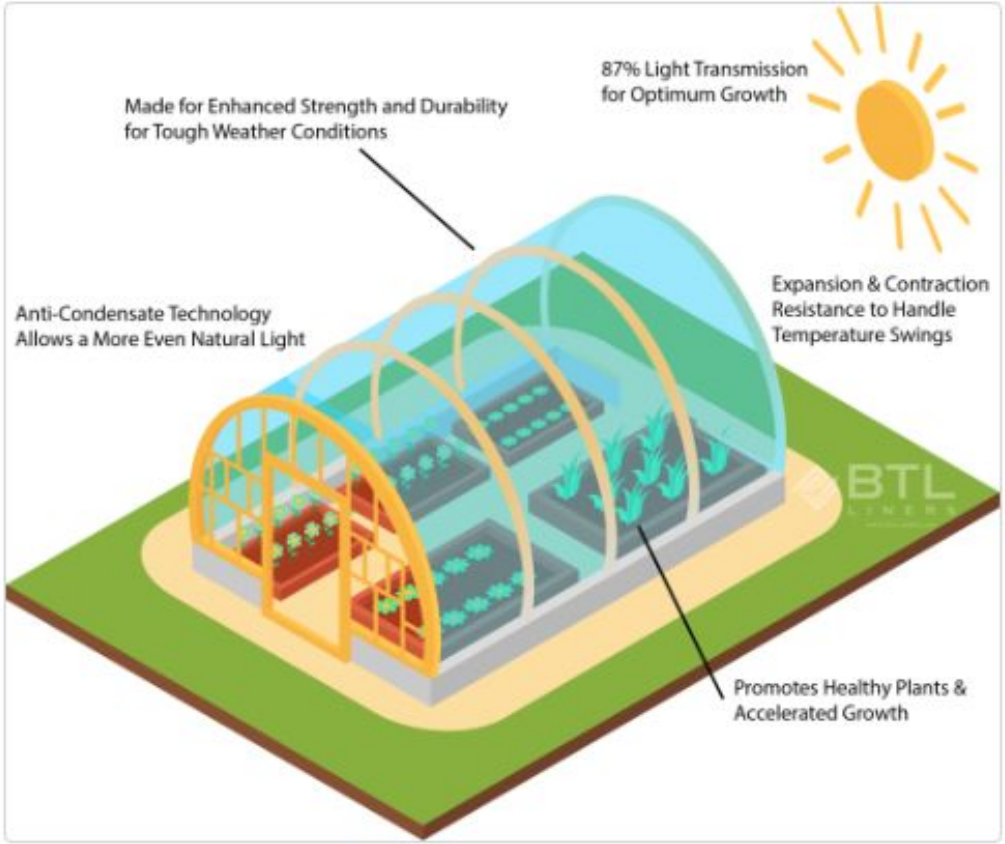
Greenhouse Coverings

Table 6: Common CEA Greenhouse Covering Types

Covering Type[15]	Imperial R-Value (h·ft2·F/Btu)	Imperial U-Factor (Btu/h·ft2·F)	Light Transmission (%)	Cost / Square Foot ($USD/ sq ft)	Useful Life (Years)
Polycarbonate, Five Wall, 25 mm	3.26	0.31	60%	$8.00	10 - 15
Polycarbonate, Triple Wall, 8 mm	2.0	0.50	74 - 78%	$4.00	10 - 15
Double-Pane Storm Windows	2.0	0.50	78%	$6.00	25 - 30
Polyethylene film, Double, with IR	2.0	0.50	78%	$0.25	2 - 4
Polycarbonate, Double Wall, 10 mm	1.89	0.53	80%	$2.50	10 - 15
Acrylic, Double	1.79	0.56	84%	$2.66	15 - 30
Polycarbonate, Double Wall, 8 mm	1.6	0.63	80%	$1.66	10 - 15
Polycarbonate, Double Wall, 6 mm	1.54	0.65	82%	$1.54	10 - 15
Polycarbonate, Double Wall, 4 mm	1.43	0.70	83%	$1.50	10 - 15
Glass, Double Pane	1.43	0.70	75 - 80%	$6.00	25 - 30
Polyethylene film, Double	1.43	0.70	85%	$0.18	2 - 4
Acrylic, Single Wall	0.88	1.13	90%	$2.66	15 - 30
Glass, Single Pane, 3mm	0.95	1.05	88 - 93%	$3.00	25 - 30
Polyethylene film, Single Wall	0.83	1.2	77 - 87%	$0.09	2 - 4
Polycarbonate, Corrugated Single Wall	0.83	1.2	90 - 91%	$1.33	10 - 15

Higher R values (more insulative) typically comes at a cost of light transmission

Location	Current Glazing Materials	Recommended Replacement
Roof Area	Poly, Double	Poly, Double, IR inhibited
Side Walls	Poly, Double	Poly, Double, IR inhibited
End Walls	Poly, Double	Poly, Double, IR inhibited
Est. Energy Savings	162,639,700	Btu
Fuel Savings	1,626	Therm or CCF
Est. Annual Savings	$569	
% Savings	29%	
Greenhouse Gas Reduction	19,029	lbs. CO_2/year



Source: Hortitech Direct

Carbon Dioxide Enrichment

- 800-1200 ppm CO_2 is often used to increase yield
- However, light intensity and temperature need to be elevated
- **CO_2 can be used with low light and cool temps to maintain a *normal* yield *while saving energy***
- This is true for liquid CO_2 systems, but may not be true for CO_2 burners
    - Burners give off heat
    - Burners may release gases that harm plants

POLL ALERT!

Should employees with a certification or credential in resource efficiency (energy/water savings) be paid more?

Discuss Results

SECTION 03

Integrated Environmental Controls to Save Energy

Luis Trujillo - Hoogendoorn USA

KNOWLEDGE CHECK!

IR-inhibiting greenhouse covering can…

- Reduce cooling requirement in warm season
- Increase heating requirement in cold season
- Both

Topics

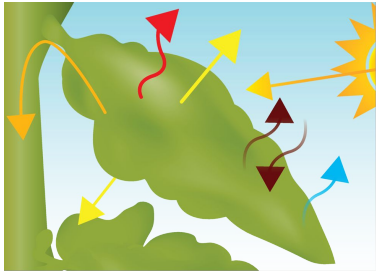
- Discovering the principles
- Applying the principles
- Integration
- Energy efficiency controls plan
- Smart energy controls

Discovering the principles

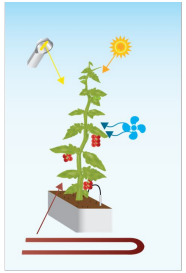
- **First step** : Understanding **what the plants need?** Finding their balance.
- **Energy**, **water** and **assimilates** balance.
- These plant balances are interlinked via the stomata.
- The plant eventually tries to achieve: restoring its three balances as much and as quickly as possible.
- If we want to know if the stomata are closed or

  open, we need to determine the Vapor Pressure

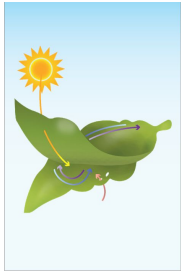
  Difference (VPD) of the plant. Typically VPD should be in the range between 0.3 to 1.5 kPa (kilo Pascal) depending on radiation level for most crops



Energy balance

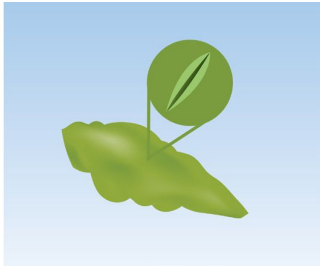


Water balance



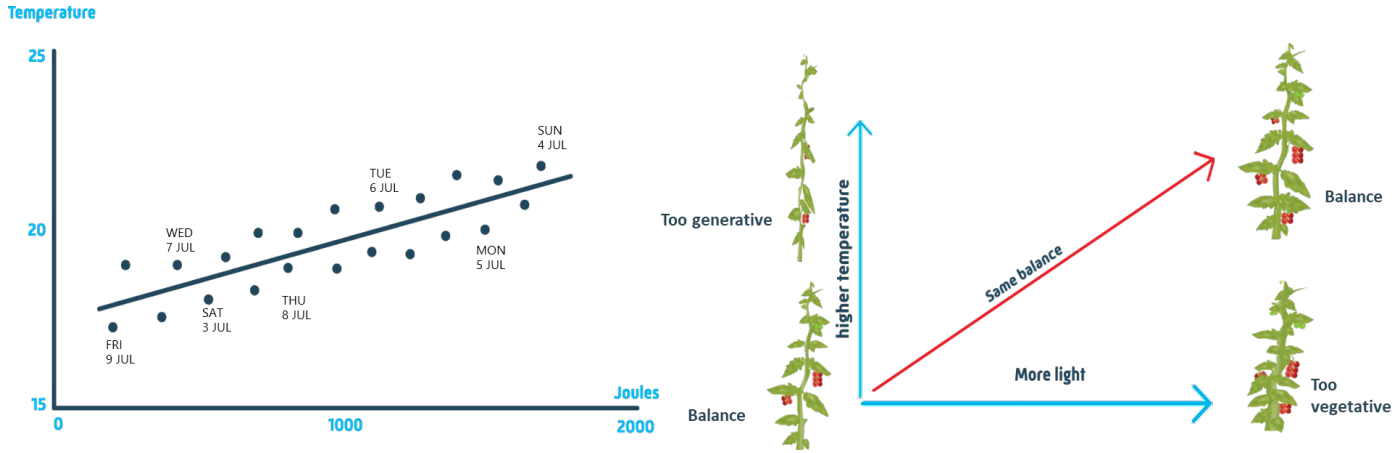
Assimilates balance

Open stomata by low VPD value



Closed stomata by low VPD value

Discovering the principles



Most growers adjust the temperature to the plant development afterwards. If the plant gets too strong then the temperature is increased and if the plant gets too weak the temperature is decreased.

- **Step 1:** Increase the production of assimilates by optimizing the photosynthesis.
- **Step 2:** Use assimilates efficiently for growth of the plant, fruits and flowers.
- **Step 3:** Keep balance between vegetative and generative development. This is accomplished when the average 24h temperature and the amount of PAR sum are in a fixed proportion (RTR).

Applying the principles in greenhouses

Generating reliable data

- Gathering data and making it valuable information.
- Taking information into de decision model
- Using tools to predict using information base but taking in account the actual conditions.
- Long term data can be “tricky” since weather has changed and conditions are not similar

Applying the principles in greenhouses

Making the most of the sun's energy

- Working with RTR -> Light temperature ratio ->
- Growing / applying temperature integration more light-dependently
- Using the higher enthalpy of the greenhouse air to minimize ventilation exhaust
- Harnessing the heat of the day into the night through gradual transitions
- Ventilation line can be moved further from heating line if crop condensation and too rapid greenhouse temperature rise is prevented

Maximise Insulation

- Promote climate homogeneity by avoiding leakage spots
- Screening to prevent heat demand
- Screening to increase plant temperature without additional heat input
- Lower or replace "standard" minimum tube with air movement.
- Maintain evaporation 24/7 and only stimulate extra when necessary

Applying the principles in indoor farms

Making the most of the supplemental light

- Same formula using RTR but based on the available supplemental light and environmental setpoints in the indoor farm (temperature,...)
- Taking in account the air flow
- Calculating and targeting a VPD that is achievable with average temperatures and medium humidity.
- Dimming
- Exploring new spectrum

Integration

Integration with

- Supplemental light
- Irrigation systems
- Air flow
- Specialized sensors
- CO2
- Cooling and heating
- BMS
- Harvesting automation system
- Labor management
- ERP

Via

- Low Voltage
- Modbus
- Tcp/Ip (API)
- BacNet

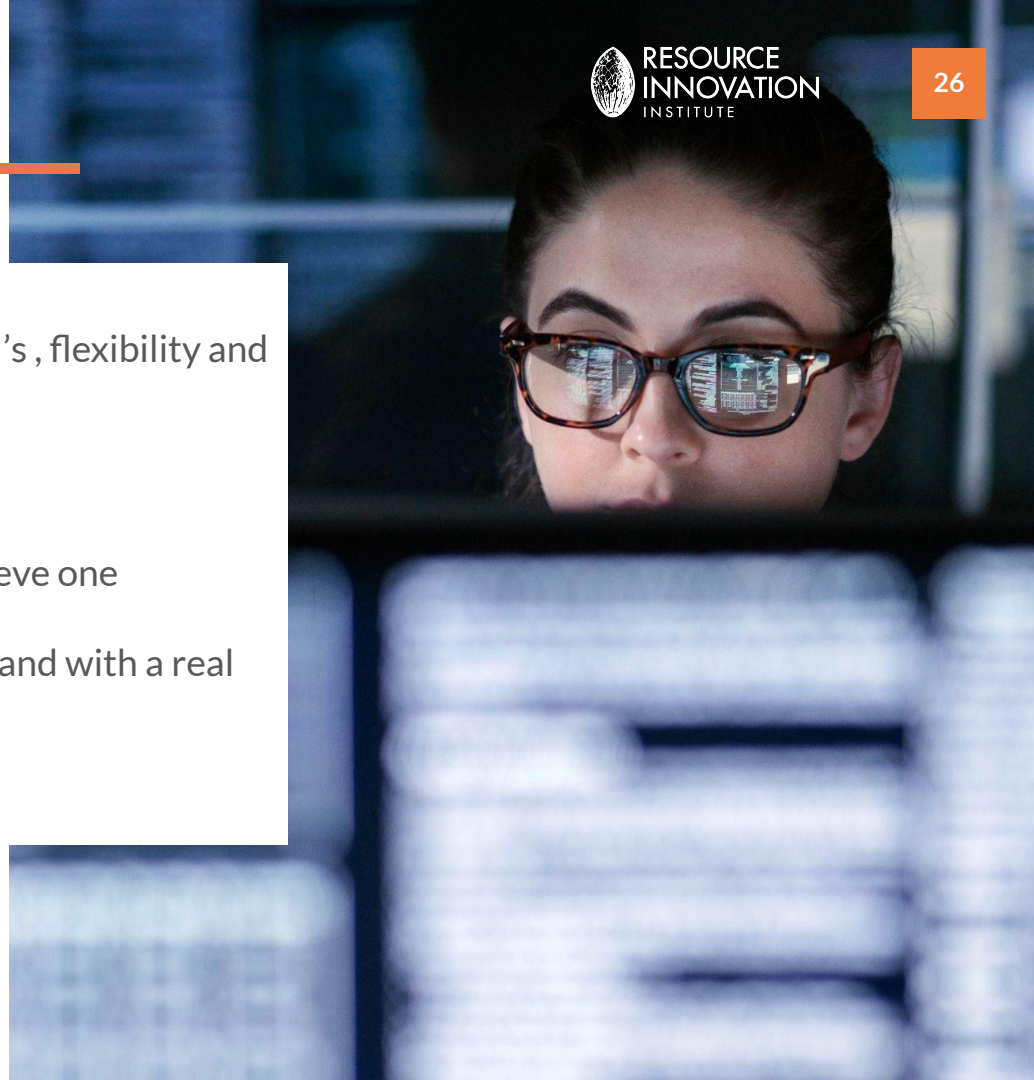
Integration challenges

Decide the appropriate dashboard based on KPI's , flexibility and reliability

Timing and vendor interoperability

Integration **is not an objective** but a tool to achieve one

Information is valuable when it's used correctly and with a real and identified purpose



01

KPI's

Actual energy consumption per block and controls:

Supplemental light, CO2, Heating, Cooling, Air flow, Irrigation,

02

Define

Set energy target KPI's per control and block

03

Implement

Select controls that can achieve targets and produce reliable information to take decisions.

Take in account integration considerations as part of the process

04

Review and fine tune

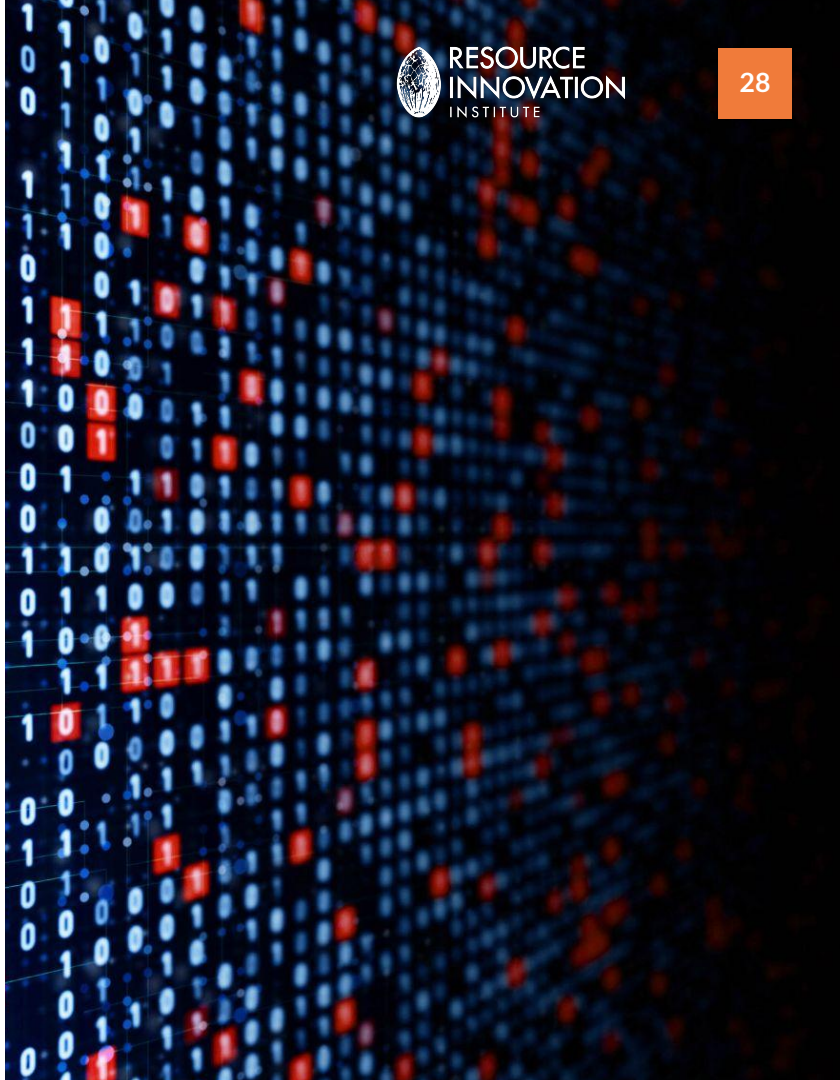
Review KPI's and fine tune controls

Smart energy controls

Artificial intelligence and **intelligent algorithms** applied within controls to support decision making and full operational automation.

Less time trial and error of settings but more **predictive tools t**o build a plan that has its own dynamics and adapts to real weather conditions (*internal and external*). Applies for greenhouses and indoor farms.

Balanced environmental strategies with low energy peaks and yield prediction based on resource efficiency. *What would happen if i use 30% less energy with my yield and my quality ?*



KNOWLEDGE CHECK!
IR-inhibiting greenhouse covering can…

Discuss Results

SECTION 04

Greehouse Curtains for Managing Energy Savings and Climate

Rob Hanifin

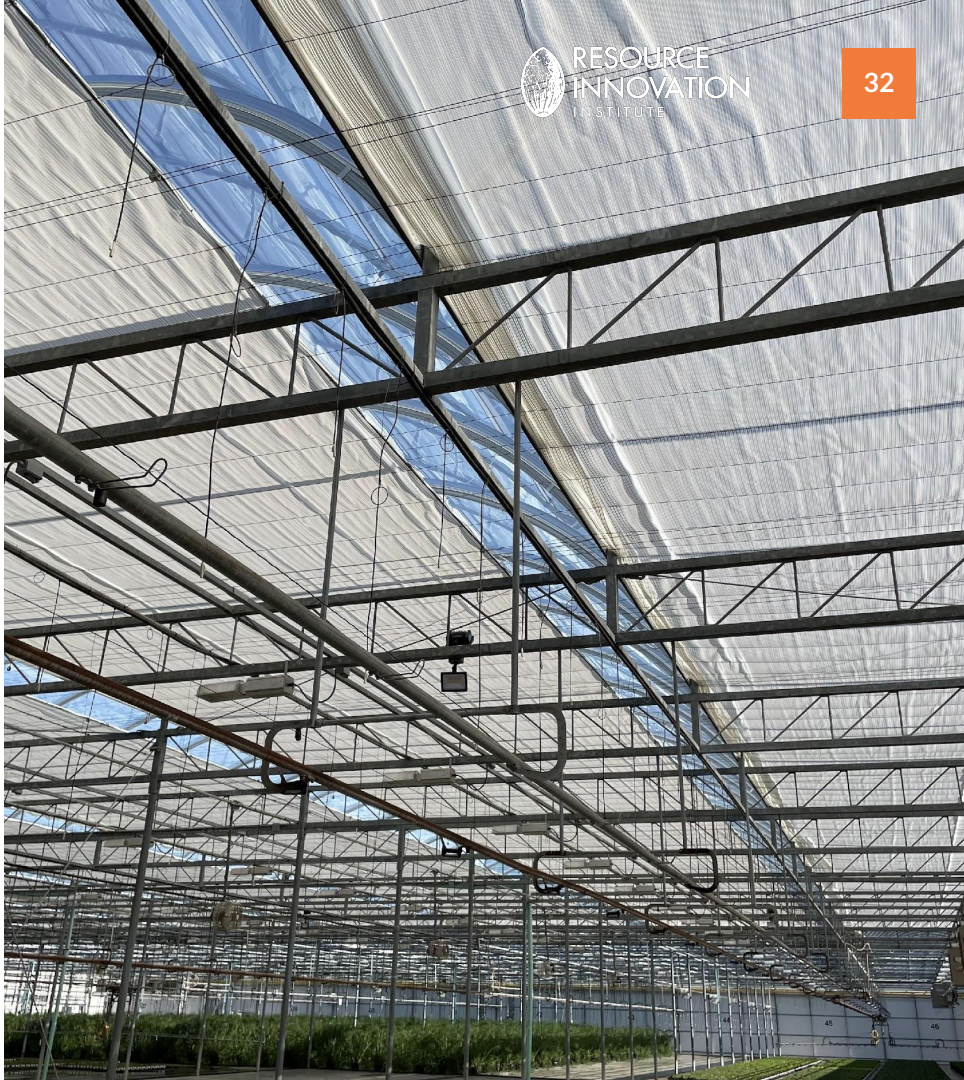
KNOWLEDGE CHECK!

Tracking the Vapor Pressure Deficit (VPD) of a cultivation area can help the grower know if the stomata are open

- True
- False

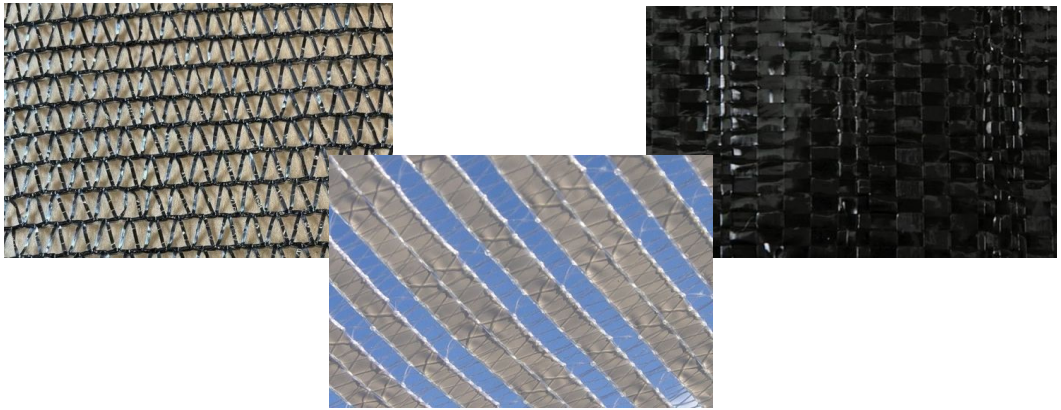
Topics

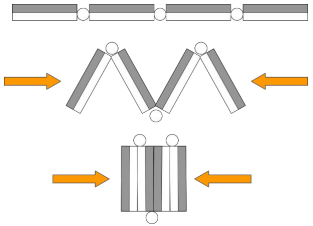
- Greenhouse Curtain Basics
- Managing Climate with Curtains
- Energy Curtains for California
- Diffusion in Curtains
- Use of Multiple Curtains



Greenhouse Curtain Basics

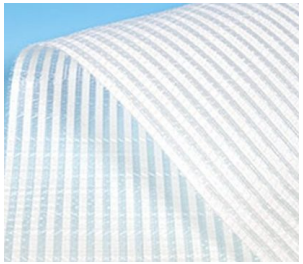
- Greenhouse Climate Screens = Greenhouse Curtains
- First utilized in Europe during the 1970s energy crisis
  - Initially as nighttime “heat blankets” for Dutch glasshouses
  - Today widely applied worldwide
- knitted or woven textiles used for greenhouse climate management
  - Retractable, bundle tightly, typically automated
- Polyester, polyolefin, aluminum, other materials in strips held together with high performance yarns

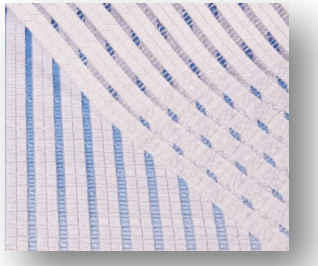


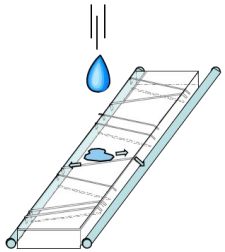


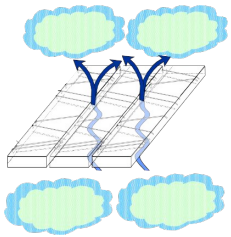
Greenhouse Curtain Basics

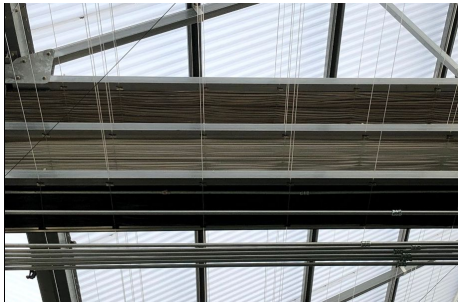
- **Open vs Closed Structure Curtains**
  - Open = gaps in knit or weave, allowing airflow
  - Closed = solid structure
  - Closed structure used for energy-saving screens.
- **Knitted strips determine shade value**
  - Strips can allow no light through or some light through
- **Strips and yarns help control condensation; mitigate humidity**
- **Energy curtains range from transparent to blackout, and every shade level in-between**
  - Lowest shade is 10%, highest 99.9%

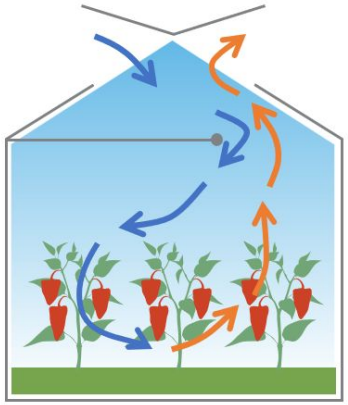




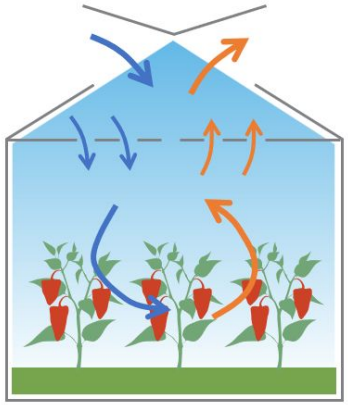








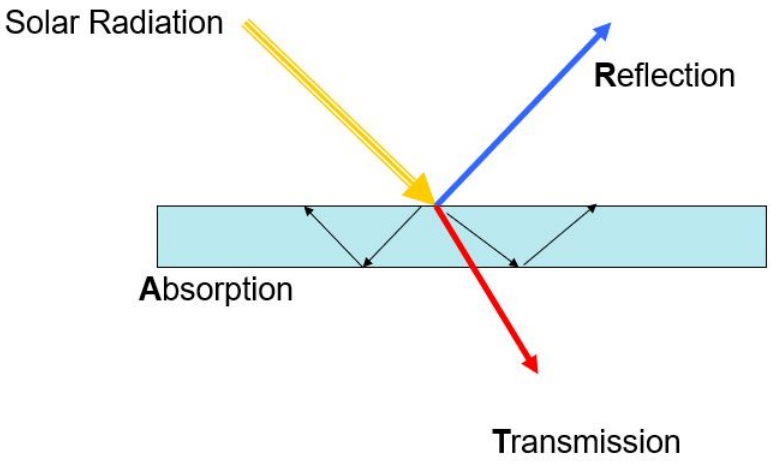
"Closed"



"Open"

Managing Climate

- **Curtains used to help manage greenhouse light, temperature, humidity**
- **Always a function of curtain characteristics + hours of deployment**
  - Shade % = reduction in PAR
  - + number of hours used = reduction in PARSUM or DLI
- **Energy savings of screens achieved by trapping warm greenhouse air underneath and reducing the need for heating fuel to be consumed**
  - Modern energy-saving screens > 40% reduction in energy needed to heat the greenhouse space below them
  - More hours of use = more total energy saved
- **In turn, help to manage the balances, as well as helping keep balance between generative and vegetative growth**



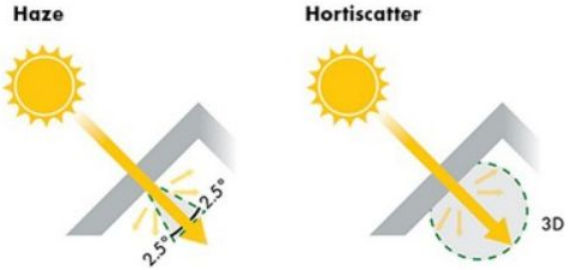
Energy Curtains for California

- **Transparent**
  - high light demanding veggies – year round for energy savings and light shade
  - Other crops – useful for winter use, including daytime
- **Blackout**
  - Photoperiod sensitive crops
  - Light abatement
- **Energy Screens with Shading**
  - Veggies requiring shade, ornamentals, flowers
  - Most useful are screens that include diffusion…

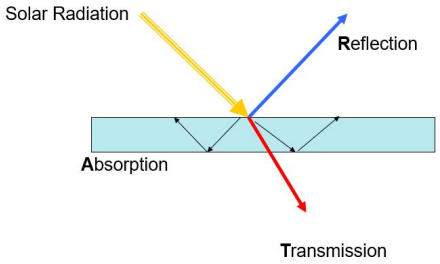
Diffusion in Energy Curtains

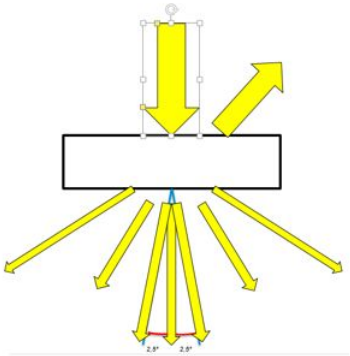
Diffusion in Energy Curtains

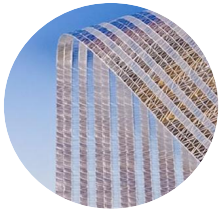
- **Diffusion vs. Haze**
  - concept of Hortiscatter
  - https://www.hortidaily.com/article/9188981/replacing-haze-by-hortiscatter-provides-more-information-about-light-diffusion/
  - Curtains can provide higher hortiscatter than most glazing materials
  - More info: Google search terms WUR; Hortiscatter



- **Diffusive Strips in the curtains**
  - Reflect some radiation
  - Diffuse much of the rest of the light
  - Curtain remains cooler, radiates less heat into greenhouse

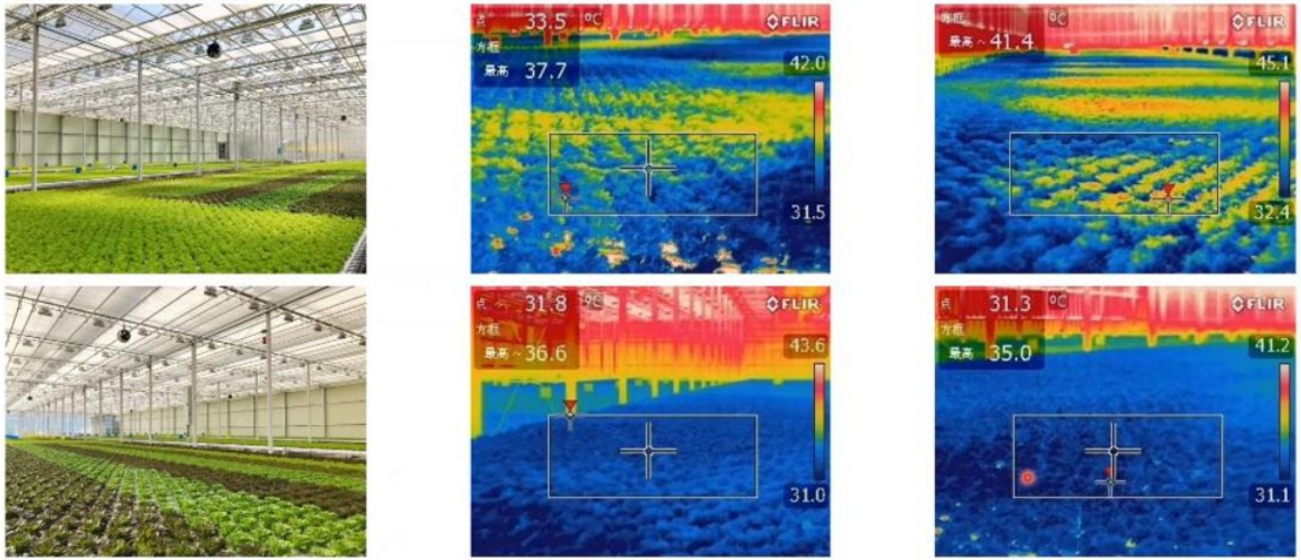






Diffusion in Energy Curtains

Light Diffusion Reduces crop temperature, creates more even crop temperature

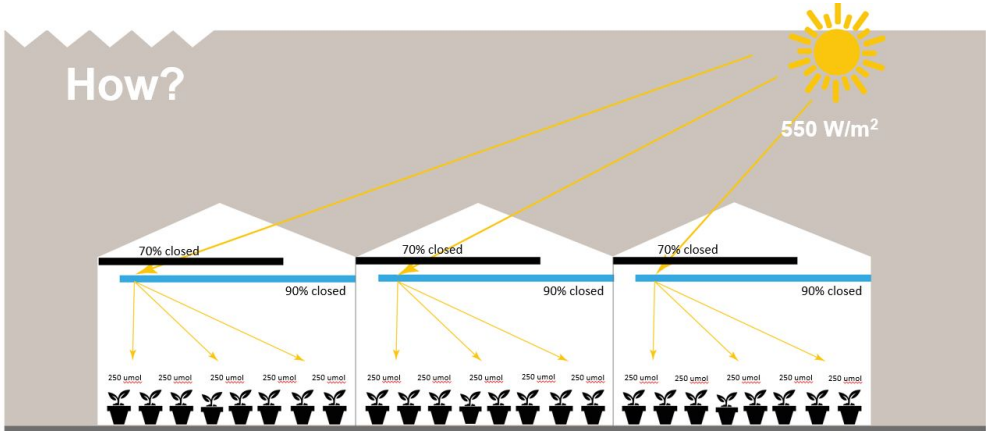


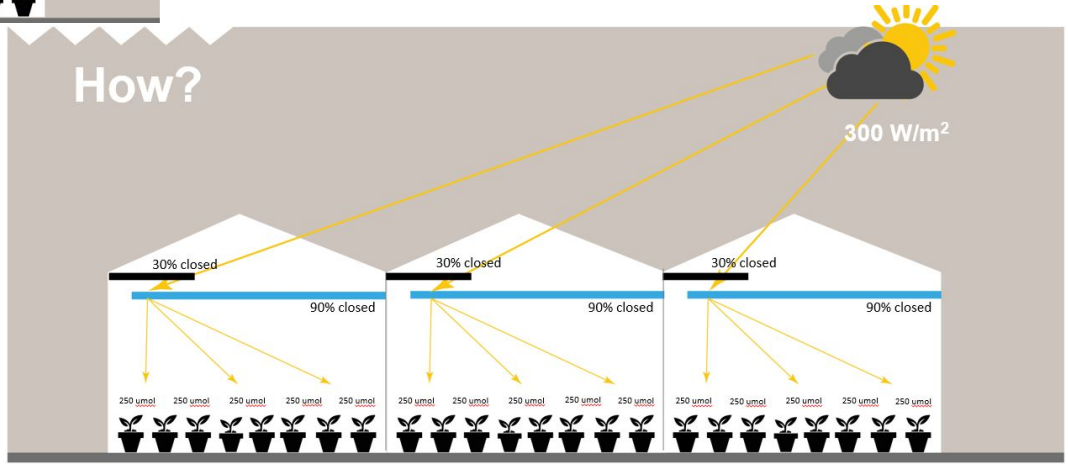
Diffuse energy screen in open and closed positions

svensson

Multiple Energy Curtains – Variable Shading

Multiple Energy Curtains – Variable Shading





Multiple Energy Curtains – Gapping and Airflow

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KNOWLEDGE CHECK!

Tracking the Vapor Pressure Deficit (VPD) of a cultivation area can help the grower know if the stomata are open

Discuss Results

SECTION 05

Energy and Horticultural Lighting

Mikhail Sagal

POLL ALERT!

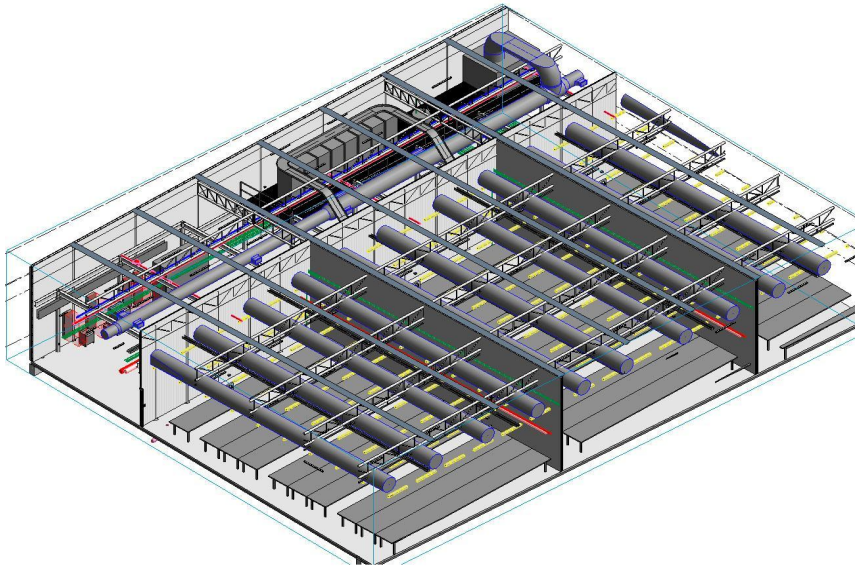
Which of these information sources are you LEAST likely to use?

- Academic journals
- Vendor sales brochures or website
- Trade show demo/discussion
- Industry magazine
- Conference speakers

Energy and Horticulture Lighting

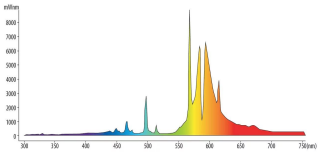
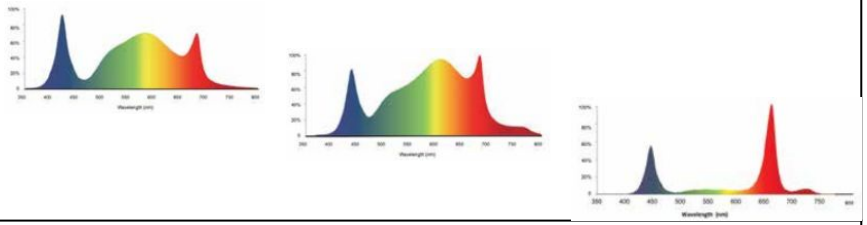
The photon engine of a facility - Lighting

- Critical to successful cultivation
  - supplemental lighting
  - primary lighting
- Lighting uses between 20-40% of energy in farming - How can we reduce!*
- Think about lighting early
- Electric design important - efficiency, grounding and harmonics
- Not all lighting sources are the same!
- Controls make a difference!



*Curtesy Northwest Power and Conservation Council (NPCC

Lighting State of the Art

HID Technology	LED Technology
HID Lighting systems: 1.0 - 1.8 µmol/J	LED Lighting: 1.8 - 3.0 µmol/J
One Spectrum - average yet consistent performance over various crops 	Light recipe examples - specific ratios of LEDs and wavelengths, crop specific challenges 
Limited control Limited optimization	More opportunities for control
Focus only on environment control	Spectrum Recipes important for crops and yield
High Maintenance Costs High Energy Costs	Energy Savings: 40%-60% over HID

Current State of the Art

The Local Driver

- No data or intelligence
- Control wires required
- High Opx - Failure/maintenance
- Maintenance = Contamination
- Harmonics affect power
- Contactors & relay panels
- Hardwired room/large zones
- Extra systems required for BMS and control integration
- Added heat in rooms

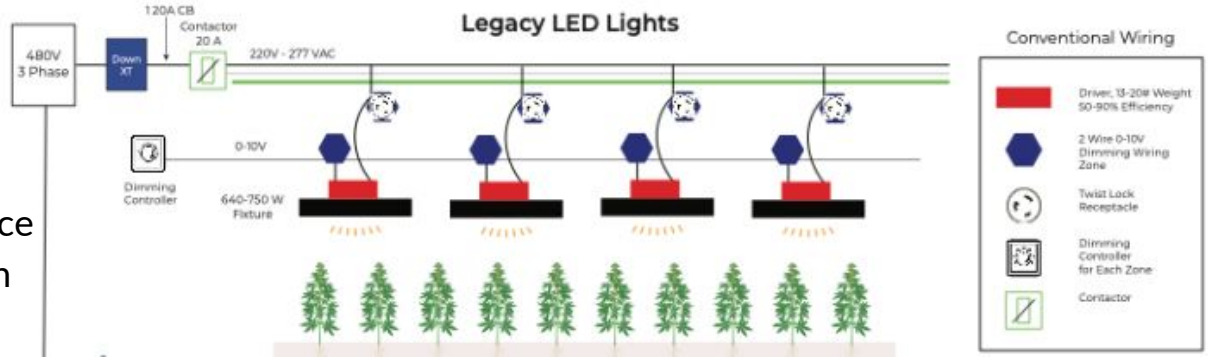
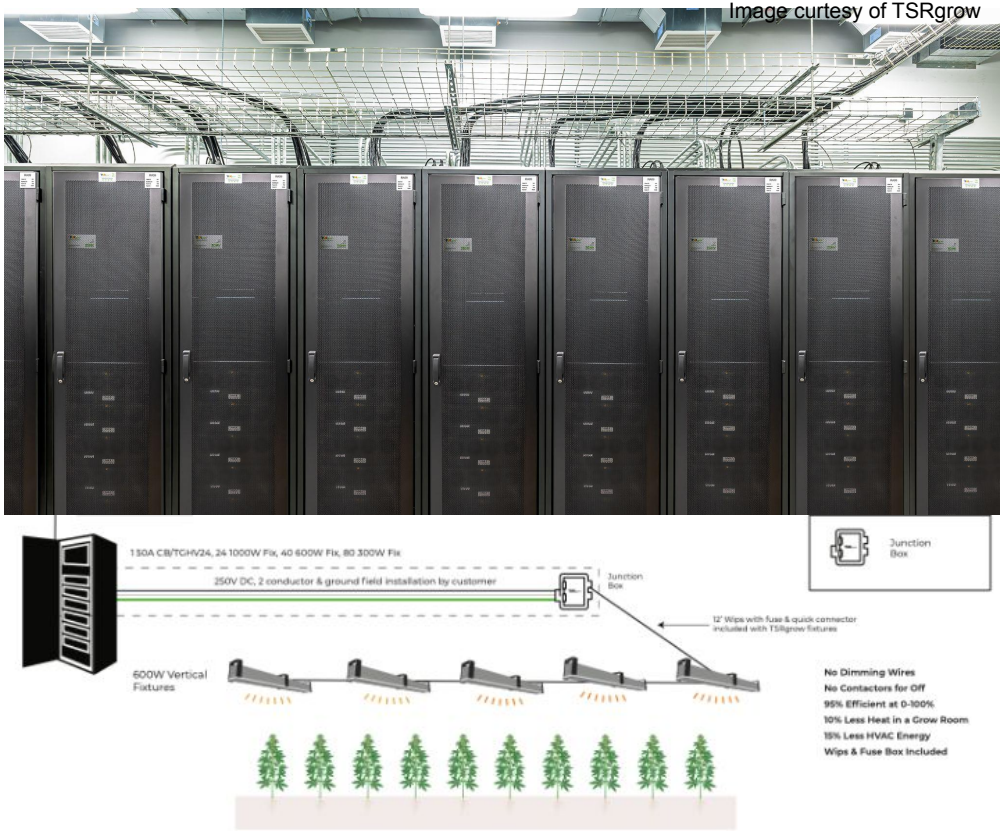


Image courtesy of TSRgrow

The future is now - Ditch the Driver!

Remote Power Solutions

- 10-15% energy savings over local drivers
- Located outside grow areas
- Power/Dimming - Together
- NO Contactors and relay panels
- Highest Efficiency
- BMS Integration
- Supports GMP/GACP
- Crop Steering through lighting
- Maximize yields - minimize OPx
- Up to 50% savings on installation



Ditch the Driver - Greenhouse

Image curtesy of TSRgrow

Ditch the Driver - Indoor Vertical

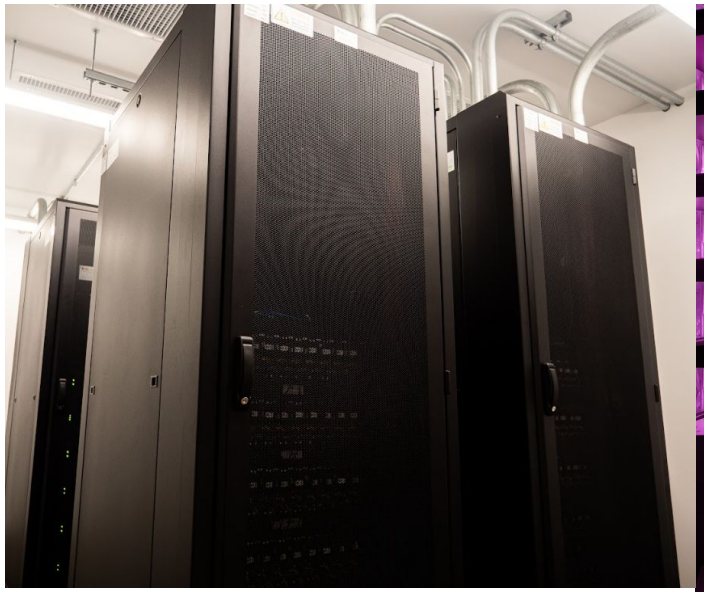


Image courtesy of TSRgrow

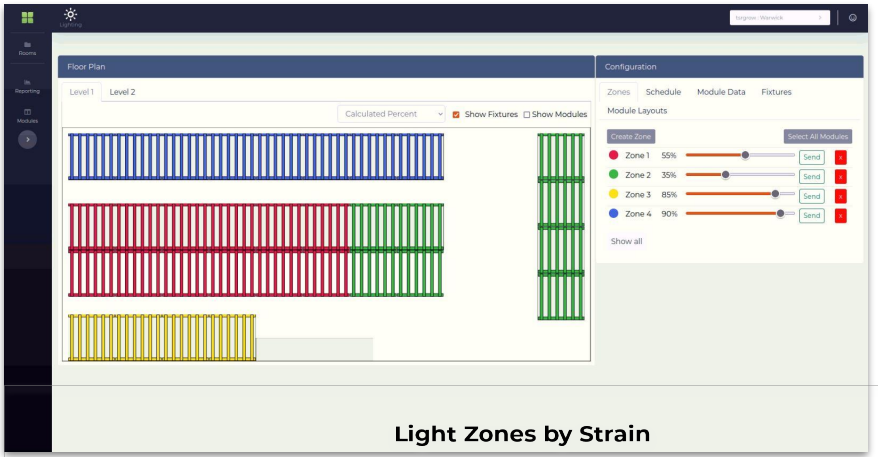
Ditch the Driver - Indoor Single Level

Image curtesy of TSRgrow

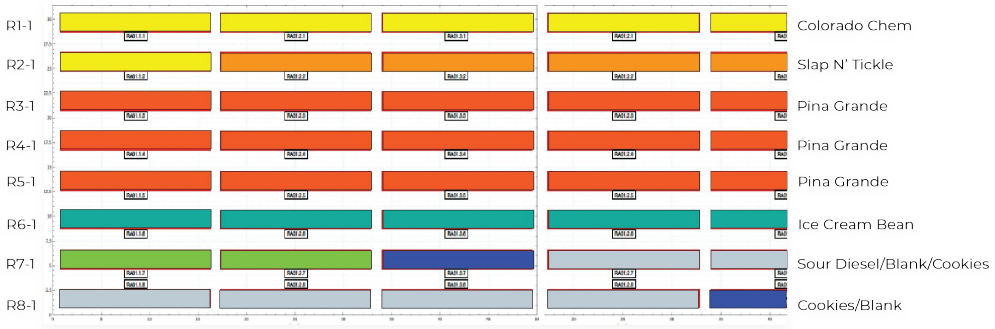
Advantage - Remote Power

REMOTE POWER SERVER FEATURE	REMOTE POWER SERVER BENEFITS
Configurable 0-1000W/Fixture	Light Fixtures can be configured for more power
No 0-10V Dimming Wires	**Power and dimming on the same line**
Outside of Grow Rooms	Reduced heat, eliminates maintenance in grow room, can be located up to 600’ away
No Contactors to turn off fixtures	**$5K-$10K Savings per room**
Dimmable from 0-100%	No need for contactors or relay panels to turn off
Source Power up to 480V	**Reduces electrical infrastructure and cost**
Unlimited Zone Configurations	Strain control - each strain gets exact intensity, optimizing yields.
Demand and Load Shedding	**Lowest Energy Cost, utility friendly**
Temp, Hum, CO2, Vpd, Moisture	Closed loop environment monitoring options
Integrated diagnostics	**Internal monitoring for any drifting or alerts to ensure always on**
Built in recipe creation and crop steering by lighting	Consistent Quality/Strain 10-15% Increased Production over other LED 10-15% Energy Reduction over other LED
Monitoring and reporting	**All data available for GMP, Compliance Tracking, Production and Cost Reporting**

Data Driven Insights



Light Zones by Strain



Crop Steering by TOTAL ZONE CONTROL

"Game Changer" for Commercial Cultivation

Unlimited lighting ZONEs set up by crop

Recipe Profiles for each strain to perfect consistent quality yields at the lowest cost

Refine your TOTALgrow Solution for your competitive edge

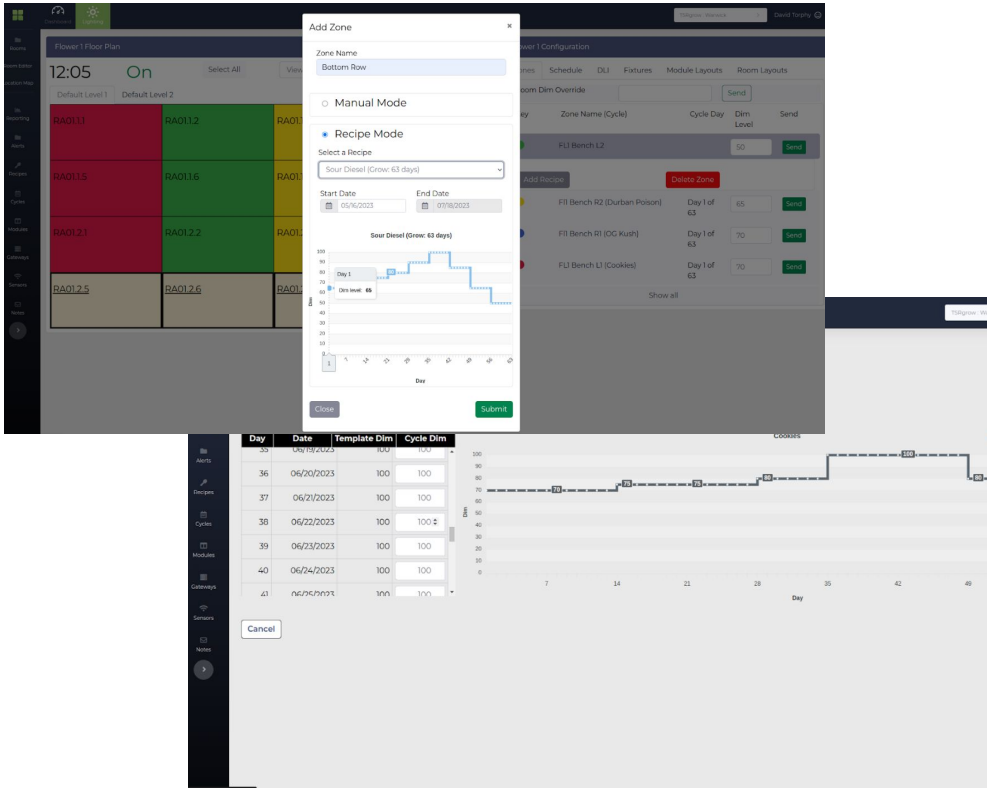
Increase yields and outperform the industry by minimize production

Increase consistent quality yields by 10-15%

Master Recipes

Crop Steering through Lighting

- Master recipes/crop
- Infinite zones
- Closed loop integration to environment, fertigation and HVAC/D, BMS
- KPIs/KPTs
- GMP/GACP
- Consistent Quality, Higher Yields/Strain
- ~15% Energy savings over traditional LED Lighting



Controls Integration

24/7 Monitoring, Reporting, Control

- Data driven efficiency yields crops at lowest energy consumption
- Mapping all of the canopy intensity needs/crop through data monitoring will dial in energy targets
- Data Analytics will make product consistency a standard
- Operators need decision driven information
- Your lowest energy consumption can be planned and then controlled

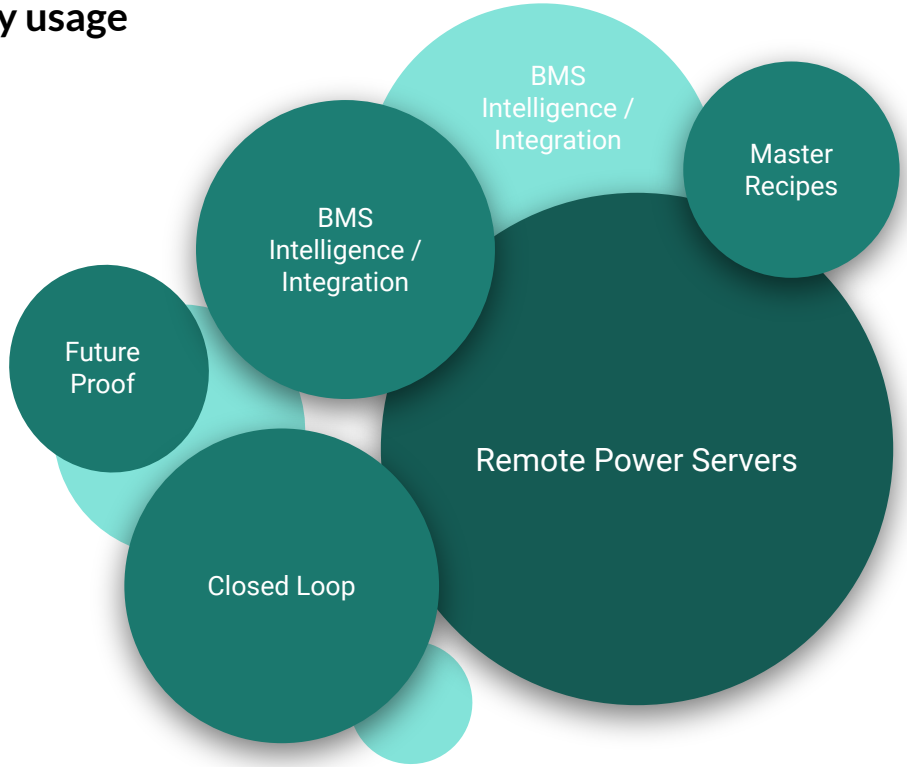
Unparalleled Savings

Savings	Remote Power	Local Driver
All cables, with quick connect and daisy chain from fixture to fixture.		
Fixtures up to 1000W **with remote power servers and enclosures**, full point-to-point installation drawings		
Applications included for **scheduling, Crop Steering, monitoring and control** - meeting all GMP data requirements • Increase Consistent Quality Yields/Strain for 10-15% INCREASED REVENUES		
50% Installation Savings: • No dimming wires needed • No contactor panels needed for turning off lighting • No in grow room driver mounting and wiring • 208V-600V 3-Phase direct to remote power servers • 50% less lighting panels		
Significant Equipment Savings • Fewer fixtures due to 1000W rating • Application Modules for diagnostics, 95% efficiency over 0-100% dimming, Crop Steering, Data Monitoring, Alarm/Alerts for proactive corrective action without crop loss • GMP data tracking, reporting, historical analysis, eliminates in-grow room driver maintenance and cleaning		
24/7 Support, always online monitoring your success		

Energy Reduction Maximized

Remote powered lighting the key to lowest energy usage

- Master recipes/strain
- Infinite zone control
- Crop steering by lighting
- 24/7 Virtual Support and NOC
- Savings:
  - Installation & Maintenance
- Data driven insights
- BMS integration
- Advanced scheduling
- Future proof
- ~15% energy reduction



POLL ALERT!

Which of these information sources are you LEAST likely to use?

Discuss Results

SECTION 06

Other Energy Savings Practices

POLL ALERT!

I have downloaded an RII Best Practices Guide in the last year

- YES
- NO
- NOT SURE

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

Energy - Water Nexus

Can reducing, remediation and recycling water save energy?

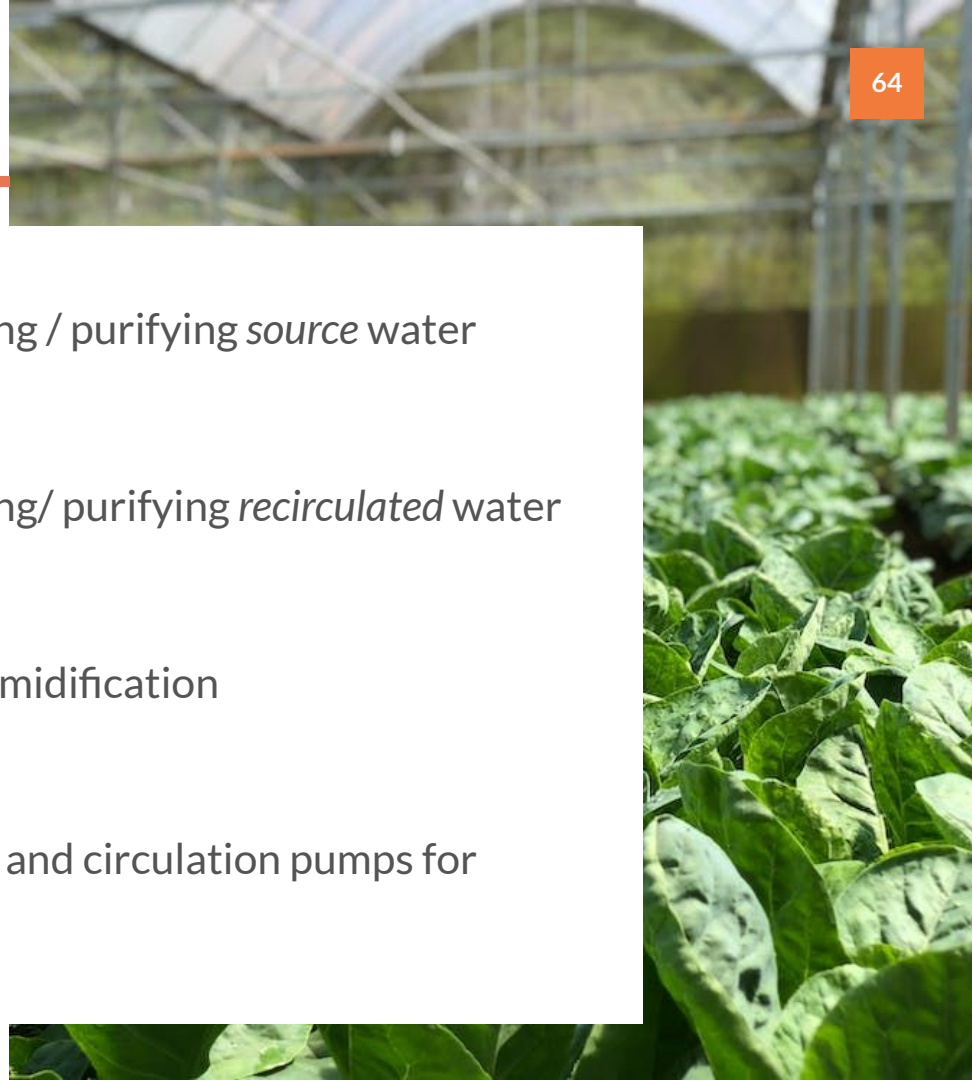
Silver Bullet

Netafim

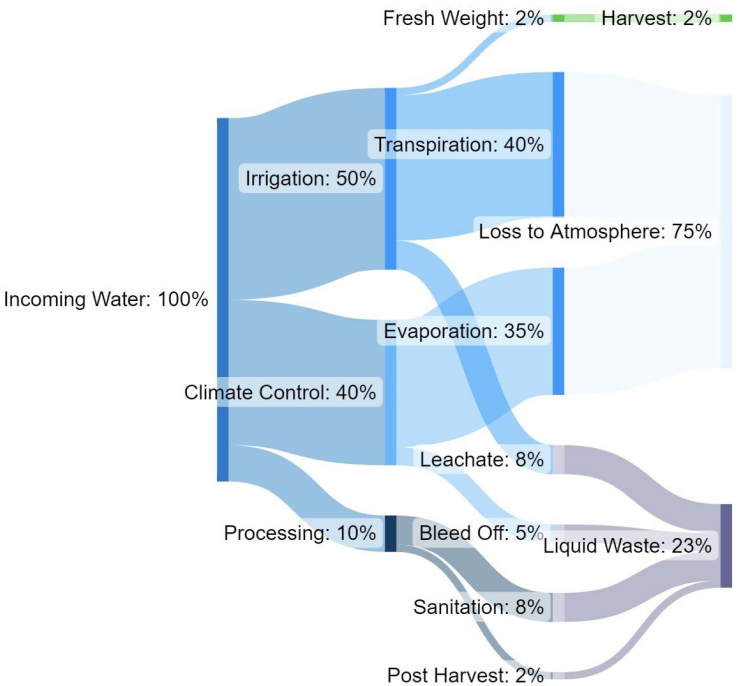
Silver Bullet

Energy - Water Nexus

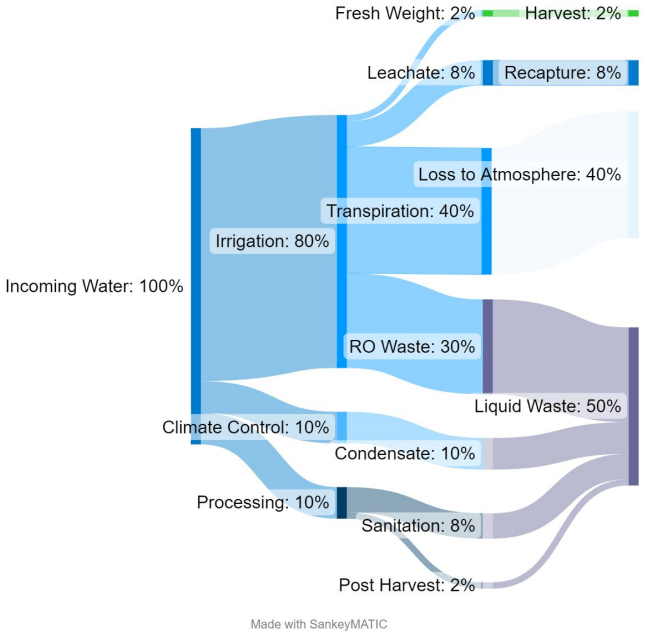
- Reducing irrigation ***waste***
  reduces the energy required for disinfecting / purifying *source* water
- Reducing irrigation ***volume***
  reduces the energy required for disinfecting/ purifying *recirculated* water
- Indoor farm
  reducing irrigation events decreases dehumidification
- Greenhouse
  reducing cooling load reduces exhaust fan and circulation pumps for evaporative pad reservoirs



Fate of Water



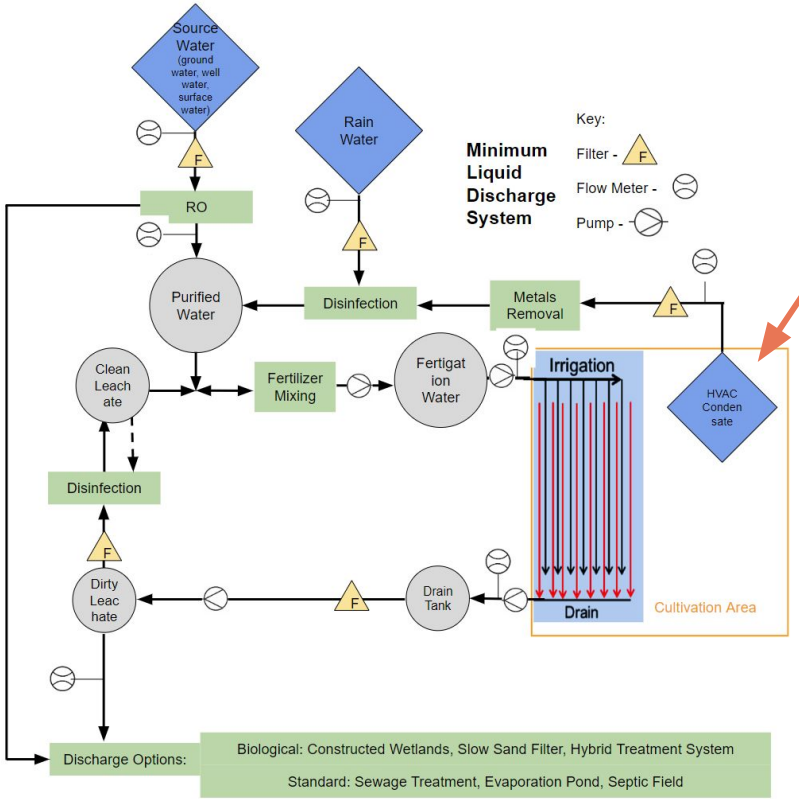
Standard Greenhouse



Standard Indoor Farm (without condensate recapture)

Minimum Liquid Discharge Facility

Recirculating irrigation water has been shown to reduce water consumption by 20%-40% and fertilizer costs by 40%-50%



Research published in 2020 reported **condensate recovery** accounted for 67% of the annual water demand for lettuce in a vertical farm.

Variable Speed Fan Motors

POLL ALERT!

Do you use any of these textiles in your greenhouse?

Discuss Results

SECTION 07

Incentives Overview - ICF

Caleb Hayhoe

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	• >=90% CE Hot Water • Must replace standard efficiency process boiler • Input rating <=20,000 kBtu/hr	$6 per rated MBtuh	$10 per rated MBtuh	Not eligible
Process Boiler	• >=85% CE Hot Water • Must replace standard efficiency process boiler • Input rating <=20,000 kBtu/hr	$2 per rated MBtuh	$2.95 per rated MBtuh	Not eligible
Process Boiler	• >= 83% CE Steam • Must replace standard efficiency process boiler • Input rating <=20,000 kBtu/hr	$3 per rated MBtuh	$4.35 per rated MBtuh	Not eligible

Data Source: California Energy Data and Reporting System Cost-Effectiveness Tool

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)

Data Source: California Energy Data and Reporting System Cost-Effectiveness Tool

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 >=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

Data Source: California Energy Data and Reporting System Cost-Effectiveness Tool

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.

Program Delivery and Customer Services

- 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

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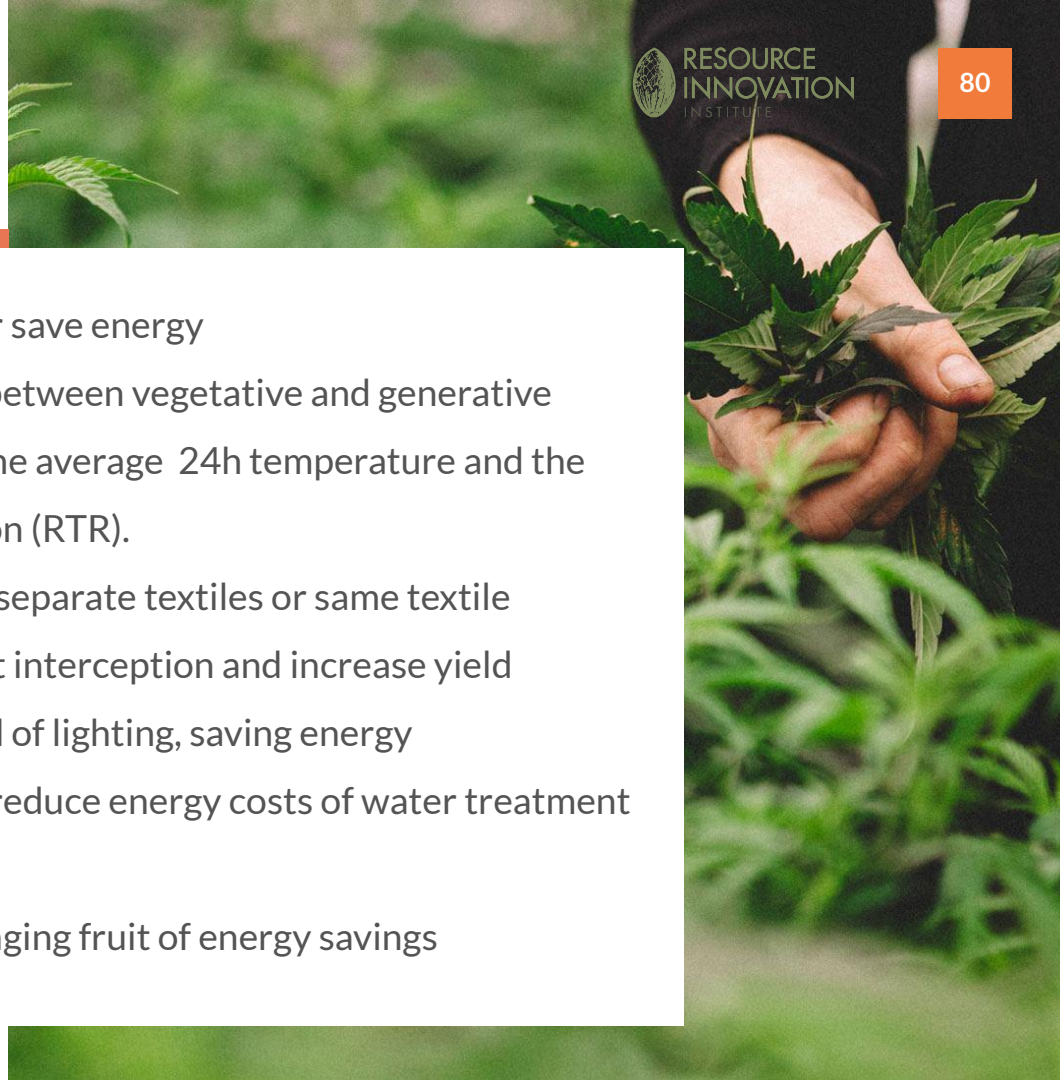
Actionable Takeaways



- CO_2 can be used to either increase yield or save energy
- Advanced controls can help keep balance between vegetative and generative development. This is accomplished when the average 24h temperature and the amount of PAR sum are in a fixed proportion (RTR).
- Energy curtains and shade curtains can be separate textiles or same textile
- Light diffusing shade curtains improve light interception and increase yield
- Fixtures and drivers are no longer required of lighting, saving energy
- Water conservation and recirculation can reduce energy costs of water treatment and remediation
- Variable speed fans and pumps are low hanging fruit of energy savings

Panel Q & A

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