RESOURCE INNOVATION INSTITUTE

Efficient Yields
Best practices on energy, water efficiency, and productivity

Greenhouse Optimization - Aligning Your Systems with Your Surroundings

In partnership with

Consumers Energy
Count on Us®

LANSING BWL
Hometown People. Hometown Power.

DTE

March 29, 2022

Agenda

Introduction & Purpose	1:00 pm ET
How CEA Crops Use Air and Moisture	1:10 pm
Benefits of High-Performance Systems for Greenhouses	1:20 pm
Greenhouse Supplemental Lighting Systems	1:35 pm
Greenhouse HVAC Systems	1:45 pm
Optimizing HVAC System Design	1:55 pm
Controls & Automation in Greenhouse Cultivation	2:05 pm
Commissioning Greenhouse Systems	2:20 pm
Benchmarking for CEA Greenhouses	2:25 pm
Greenhouse Efficiency Incentive Programs	2:35 pm
Q&A	2:45 pm

Thank you

MiCIA
MICHIGAN CANNABIS INDUSTRY ASSOCIATION

MEECA
MICHIGAN ENERGY EFFICIENCY CONTRACTORS ASSOCIATION

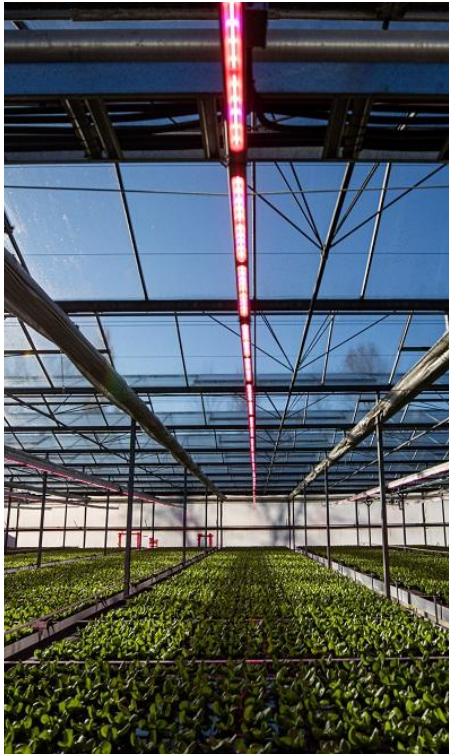
for your collaboration

SECTION 01

INTRODUCTION & PURPOSE

About RII

- Objective, data-driven non-profit
- Founded 2016 in Portland, Oregon
- Expertise in climate policy, utility programs, green building certification, sustainable business, construction & indoor cultivation
- In 2020, received 3-year grant from USDA to develop KPIs, standards & building rating system for CEA



What We Do / Our Mission

We measure, verify & celebrate the world's most efficient agricultural ideas.

Measure

Efficiency & Productivity

- Key Performance Indicators
- Benchmarks
- Baselines

Verify

Best Practices & Standards

- Training
- Policies
- Utility Programs

Celebrate

Leadership Recognition

- Verification
- Case Studies
- Certification

Our Network

Governments
Resource Suppliers
Efficiency Programs
Producers
Supply Chain
Standards

INPUT from industry leaders and partners
RESOURCE INNOVATION INSTITUTE
EDUCATION and advocacy about best practices for growers

RII Technical Advisory Council

Multi-disciplinary body who aggregates knowledge to support producers and other stakeholders with objective and peer-reviewed data and curriculum on benchmarking resource efficiency

- **Guides** development of standards
- **Shapes** tools and resources to support best practices
- **Advocates** for informed policies, incentives and regulations

HVAC - Lighting - Utility - Water
Policy - Data - Controls - Emissions
Facility Design & Construction

ABOUT US

Peer-Reviewed Publications

Best Practices Guides
for Producers

Best Practices Guides
for Governments and Utilities

Industry Reports
on Resource Usage

Today's Speakers

Gretchen Schimelpfenig

RESOURCE INNOVATION INSTITUTE

Dr. Dengke Cai

HAWTHORNE GARDENING CO

Luis Trujillo

hoogendoorn growth management

Rob Hanifin

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Kasey Holland

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Online Application:
lbwl.com/sites/default/files/inline-files/bwl-indoor-agriculture-app.pdf

Michigan Efficiency Programs

Michigan organizations improving energy efficiency in the region with free programs:

- Efficiency programs offer:
  - Technical assistance
  - Energy modeling
  - Financial incentives for efficient technology

- Michigan Saves offers:
  - Financing for energy efficiency projects

Michigan CEA Landscape

Controlled Environment Agriculture (CEA) Crop Categories

- Indoor and greenhouse cultivation)
- Cannabis
  - 906 licenses for 308 companies
  - $511M in sales in 2020
  - Flower, vape, edibles, concentrates, shake/trim, topicals, tinctures)
- Between 2012 and 2017:
- Floriculture
  - **Cut flower** operations doubled
- Vegetables
  - **Tomato** greenhouses increased 53%
- Fungi
  - Mushroom operations increase >400%

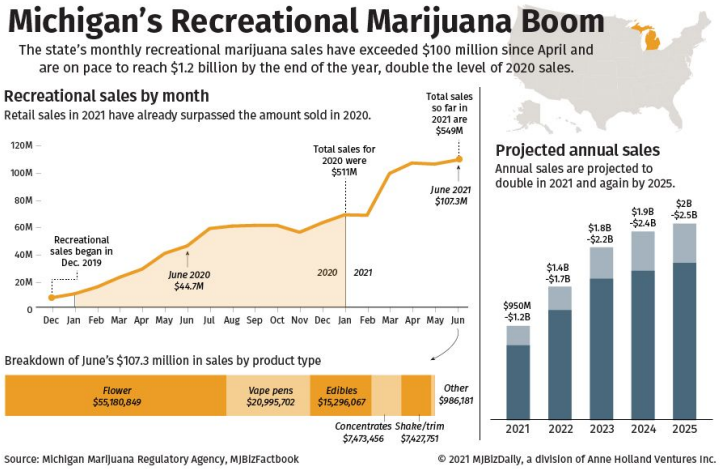


Image credit: MJBizDaily, 2021

Purpose of Today's Workshop

- Help Michigan greenhouse producers improve the efficiency of their operations with lighting, HVAC, and curtain systems
- Convey scientific insights directly to producers and finding the best ways to translate them in the context of a local ecosystem
- Help energy efficiency programs achieve their energy savings and climate goals through knowledge sharing
- Encourage cultivators to take advantage of Michigan efficiency program resources and incentives

Efficient Yields
Best practices on energy, water efficiency, and productivity

Access Your Michigan Virtual Classroom

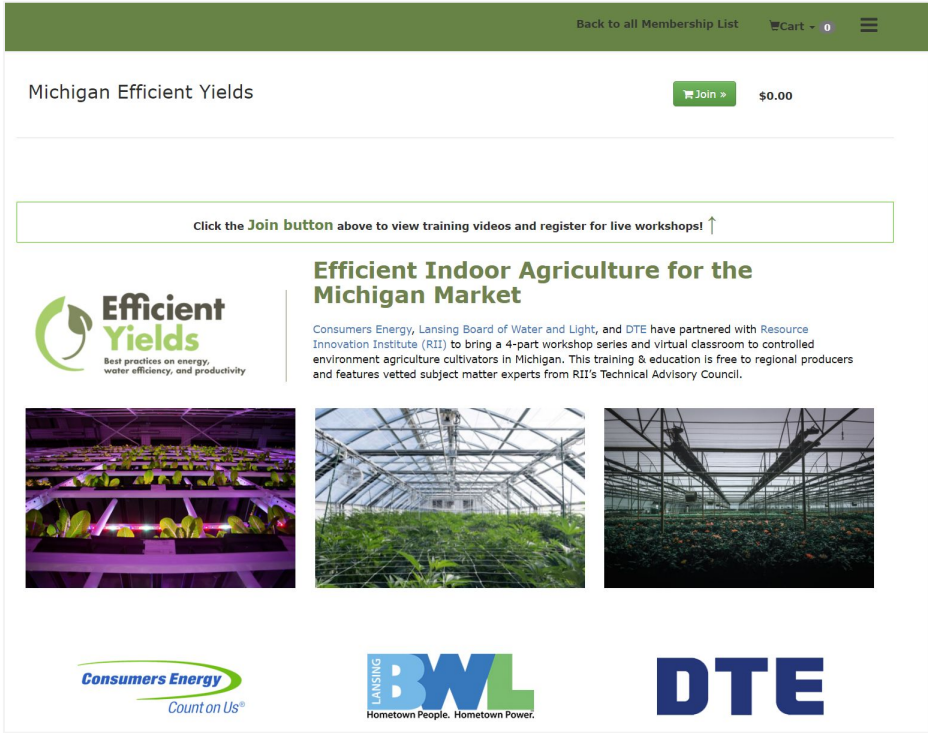
Continue Learning Online

Free guidance on efficient cannabis cultivation

All live workshops are available for on-demand viewing!

- Recordings of live workshops
- Tip Clips
- Downloadable resources
- Consumers Energy, Lansing BWL, and DTE tools

Create an account at
ResourceInnovation.org/Michigan



Stream the Lighting Workshop

Best Practices for Horticultural Lighting

Featuring speakers from Agnetix, TSRgrow, Seinergy, and SixLabs

Learn how LED lighting can influence crop quality and yields, how to inform lighting designs, and how to evaluate lighting solutions

Watch the February workshop on-demand on the RII catalog

Access all classroom content at ResourceInnovation.org/Michigan

Register for the Next Two Workshops

Access the virtual classroom to continue learning

Free guidance on efficient cannabis cultivation

All live workshops are available to stream on-demand!

May 24

- Facility Design & Construction Best Practices for Efficient Indoor Agriculture

June 21

- Controls & Automation Best Practices for Efficient Indoor Agriculture

REGISTER!

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Efficient Yields
Best practices on energy, water efficiency, and productivity

FACILITY DESIGN & CONSTRUCTION FOR EFFICIENT INDOOR AGRICULTURE

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May 24, 2022

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Efficient Yields
Best practices on energy, water efficiency, and productivity

CONTROLS & AUTOMATION BEST PRACTICES FOR EFFICIENT INDOOR AGRICULTURE

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June 21, 2022

REGISTER!

SECTION 02

HOW CEA CROPS USE AIR & MOISTURE

Environmental Quality Impacts Crop Growth

Optimize Air Quality

Greenhouse cultivation spaces are affected by:

- Outdoor temperature
- Sunlight
- Supplemental lighting systems
- HVAC systems
- Curtains

Characteristic	Quality	Plants	Fungi
Temperature	Too High	High leaf temperatures, leaf tip burn, wilting, early bolting, root rot, heat stall	Triggers thermophilic microflora, mycelium and spore death
	Too Low	Reduced metabolic rate, reduced yields	Reduced mycelium growth, limited development
Humidity	Too High	Pathogen outbreaks like powdery mildew and Botrytis, leaf tip burn	Insect infestation, condensation on mushrooms, slimy caps, mold
	Too Low	Outer leaf edge burn, foliar diseases	Casing hardening, dehydration, aborted primordia
Airflow	Too High	Reduced transpiration (closed stomata), desiccation	Scaly mushrooms
	Too Low	Mold growth, diseases	Thin stalks, open mushrooms, reduced second flush

Key Factor for CEA Crop Production

Vapor Pressure Deficit

Influenced by temperature and relative humidity of cultivation space and the temperature of CEA crops

- VPD of 0.8 - 1.0 ideal for most plants
- Greenhouses can have wide swings in humidity depending on facility construction and HVAC system type
- Environmental controls are key to maintain target VPD range

Figure 2: VPD - The Differential Between Grow Room and Leaf Conditions

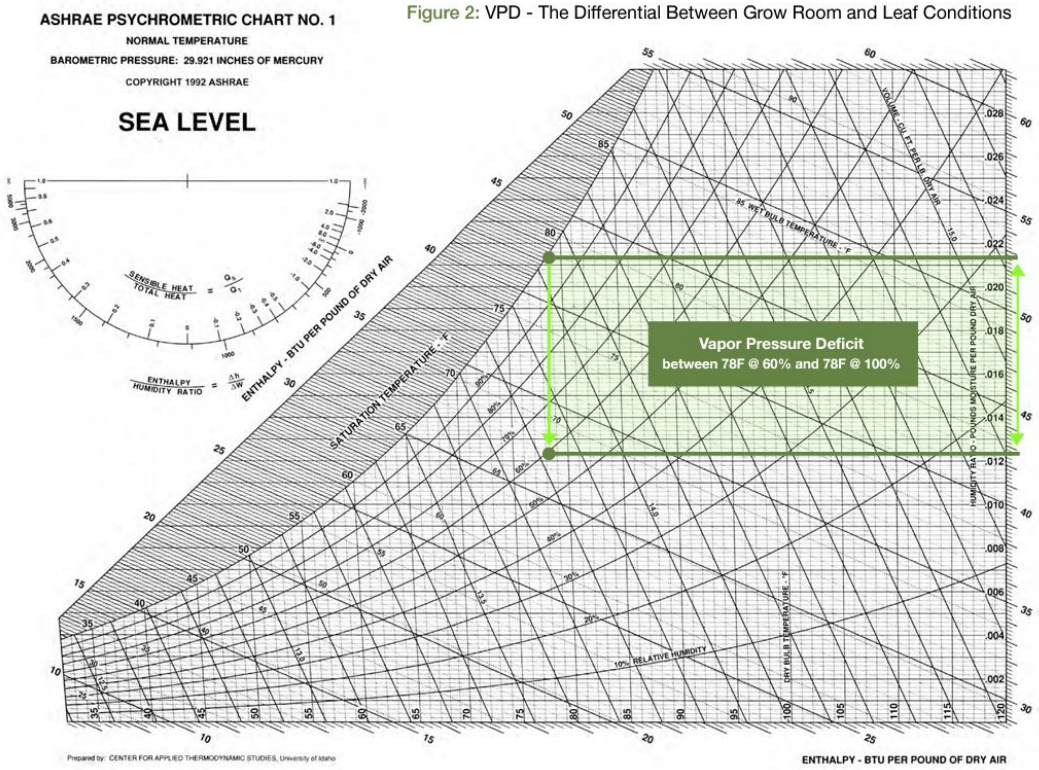


Figure credit: RII, Desert Aire

SECTION 03

BENEFITS OF HIGH PERFORMANCE SYSTEMS

Benefits of High-Performance Greenhouse Systems

Energy and Non-Energy Benefits

Greenhouse systems like coverings, curtains, supplemental lighting, and controls can:

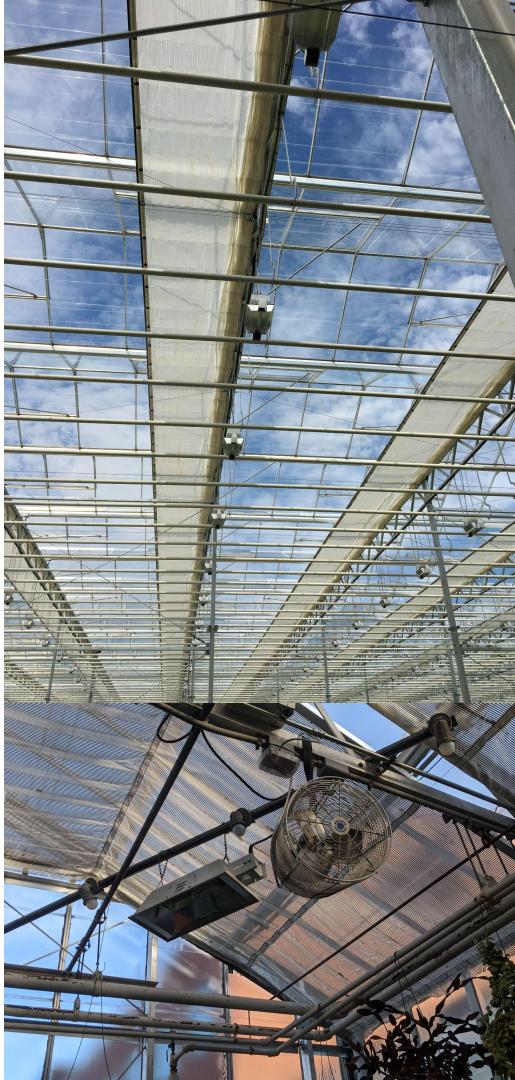
- Optimize crop quality
- Steer crops
- Maximize KPIs
- Ensure resilience

Energy-Saving HVAC Solutions	Energy Savings Potential
Greenhouse Envelope Systems	5 - 50%
LED Horticultural Lighting	30 - 40%
HVAC Systems: • Heating systems • Root zone heating systems • Cooling systems • Variable frequency drives (pumps and fans) • Humidity management equipment • Environmental controls • Airflow controls	20 - 30%
Integrated Controls Systems	15 - 30%

Shade and Thermal Curtains

Climate Curtains or Screens

- Some curtains both shade and insulate, some do one or the other
  - Open-weave (open structure) curtains may not insulate
  - Transparent thermal curtains may not shade
- Climate Screens can:
  - Manage solar radiation
  - Reduce heat loss at night and in colder months
  - Protect plants on sunny and hot days
  - Save energy on both heating and cooling
  - Reduce utility bills
- Manually operated or automatically controlled



Right Climate for Growth

The Right Climate for Growth

A better climate for every crop

Light **Temperature** **Energy**

Optimizing these factors is key to achieving growing goals.

Climate screens allow you to effortlessly control your crops climate, from managing light to temperature, you can enjoy the benefits of complete climate control:

- **Lower energy costs**
- **Less risk of disease**
- **Higher-quality crop**
- **Higher yields**
- **Faster Production**
- **Optimal temperature**

Figure credit: Ludvig Svensson

Different Screens for Different Goals

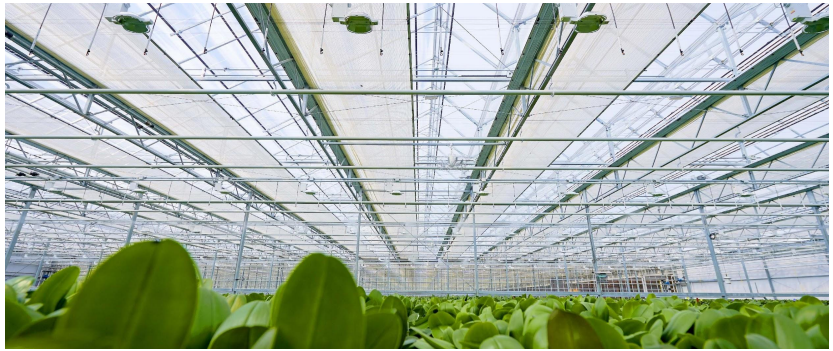


Figure credit: Ludvig Svensson

Diffusion: Even Temperature & Lighting

open

closed

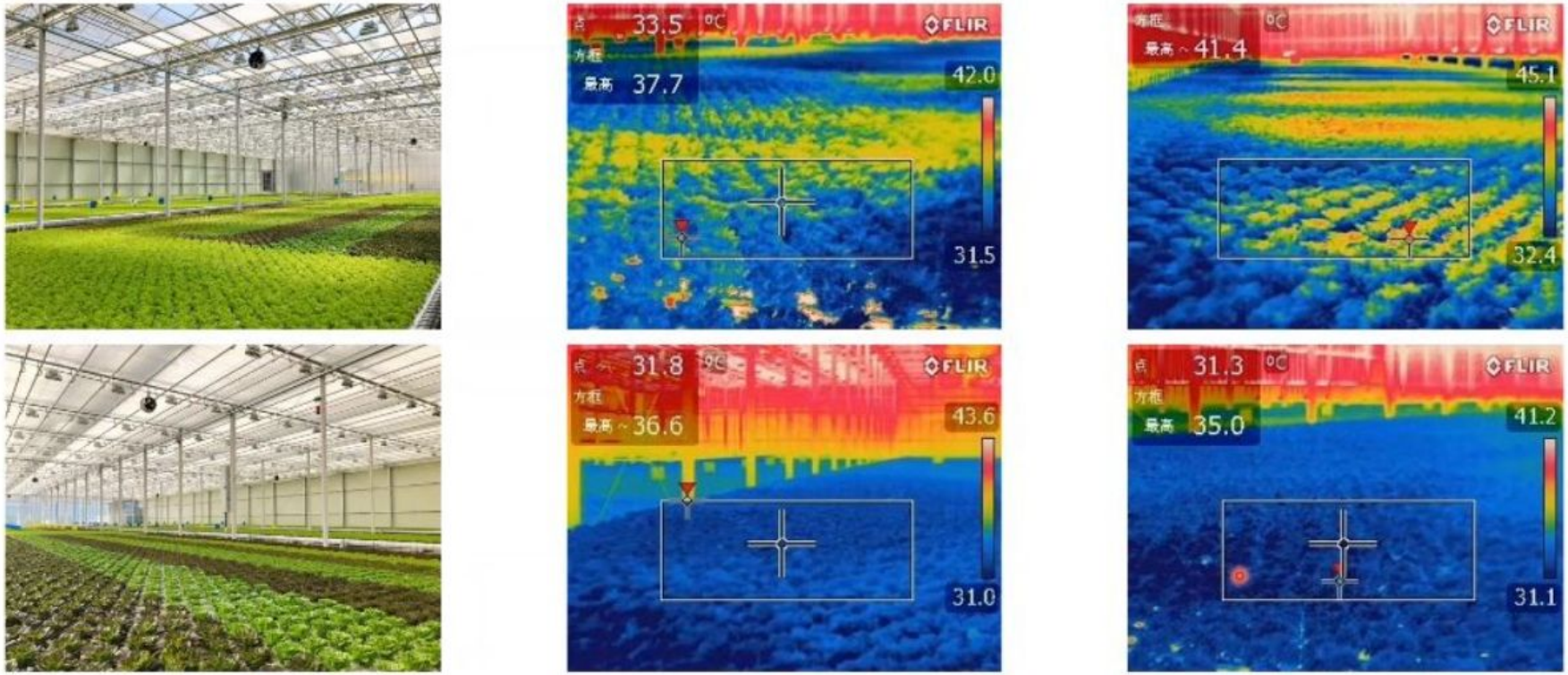


Figure credit: Ludvig Svensson

Other Light Deprivation Considerations

Figure credit: Ludvig Svensson

Rollup Screens & Side Walls

Light Traps

Moisture Management in Screens

- Reduces risk of diseases
  - Powdery mildew
- Gray mold
  - Other fungal diseases
- Helps prevent humidity level extremes and condensation formation on the screen
- Humidity control is vital for CEA during flowering & fruiting

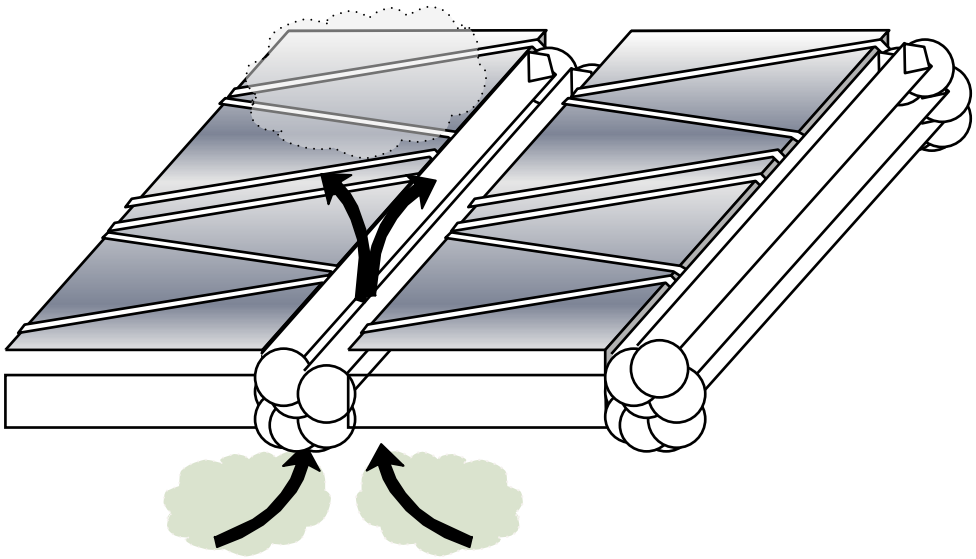


Figure credit: Ludvig Svensson

Michigan Energy Savings from Curtains (Cannabis)

ANNUAL SUMMARY			
Scenario names	No screen	Light Dep Blackout	Dep + Transparent Energy C
Screen 1	-	OBSCURA_10070_FR_WB+E	OBSCURA_10070_FR_WB+E
Screen 2	-	-	LUXOUS_1147_FR_Eco
Screen 3	-	-	-
Vertical 1	-	OBSCURA_10070_R_FR_W	OBSCURA_10070_R_FR_W
Vertical 2	-	-	-
Energy consumpt. (m3 gas)	437 691	251 075	227 892
m3 gas/m²	107.28	61.54	55.86
Energy expenditure	218 845	125 537	113 946
US Dollars/m²	53.6	30.8	27.9
Energy saving (%)	-	43%	48%
Investment	-	57 120	89 760
US Dollars/m²	-	14.00	22.00
Return on investment (year)	-	0.6	0.9

Figure credit: Ludvig Svensson

Michigan Energy Savings from Curtains (Tomatoes)

ANNUAL SUMMARY			
Scenario names	No screen	Light Abatement Blackout	tement + Transparent Energ
Screen 1	-	OBSCURA_9950_FR_W	OBSCURA_9950_FR_W
Screen 2	-	-	LUXOUS_1147_FR_Eco
Screen 3	-	-	-
Vertical 1	-	OBSCURA_10070_R_FR_W	OBSCURA_10070_R_FR_W
Vertical 2	-	-	-
Energy consumpt. (m3 gas)	402 758	291 883	244 948
m3 gas/m²	98.72	71.54	60.04
Energy expenditure	201 379	145 942	122 474
US Dollars/m²	49.4	35.8	30.0
Energy saving (%)	-	28%	39%
Investment	-	48 960	73 440
US Dollars/m²	-	12.00	18.00
Return on investment (year)	-	0.9	0.9

Figure credit: Ludvig Svensson

Blackout Screens: Energy Loss

- Heat, humidity can build up under normal blackout screens increased by:
  - Supplemental lights
  - Pipe temperature
  - Climate
- Common Solution: Gapping Screens
- Common Issues:
  - Difficult to manage
  - Light abatement regulations becoming common
- Solution: Active dehumidification with vertical air movement

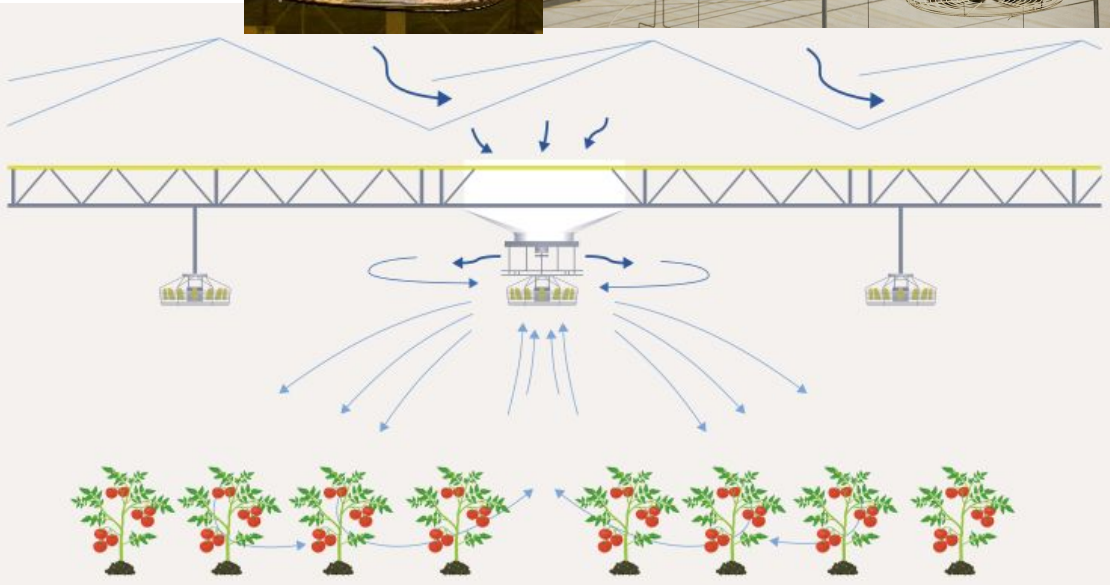
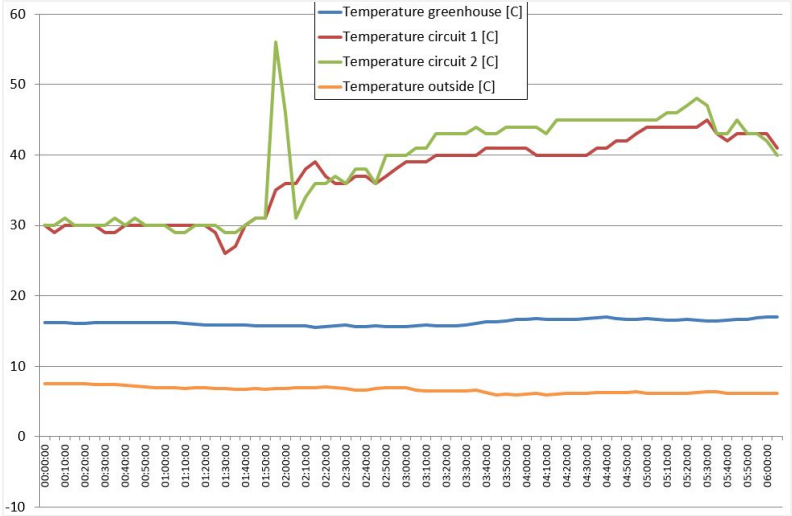
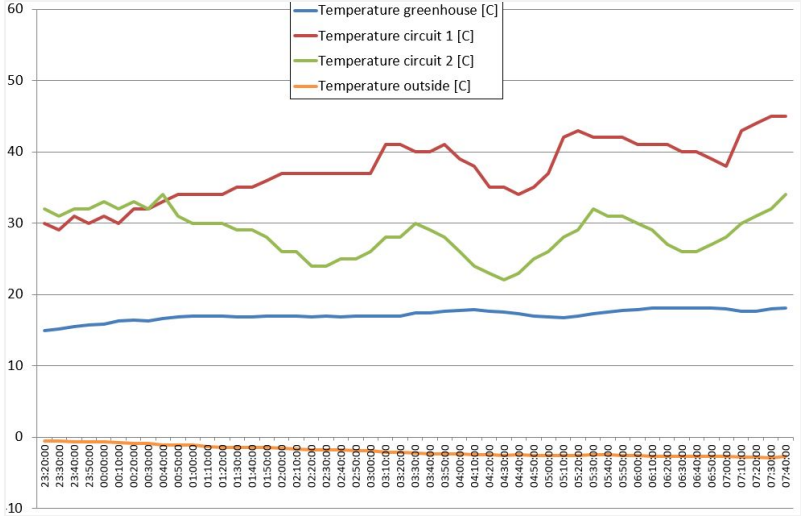


Figure credit: Ludvig Svensson

Vertical Air Movement Energy Savings Potential



Screen in **open** position



Screen in **closed** position

Figure credit: Ludvig Svensson

Envelope/Shade/Thermal Curtains In Cold Climate Field Example

Western Michigan Project

- Hydroponic Lettuce Grower
- Glass venlo with sidewall & roof vents, LEDs
- Phase 1 - aluminized shade & energy curtain (55% shade, 57% energy savings
- Phase 2 - light abatement blackout curtain (99% shade, 50% energy) and diffusion, shade, and energy curtain (20% shade and 47% energy savings)
- Greater energy savings, greater control over climate with multiple curtains
- Variable shading concept

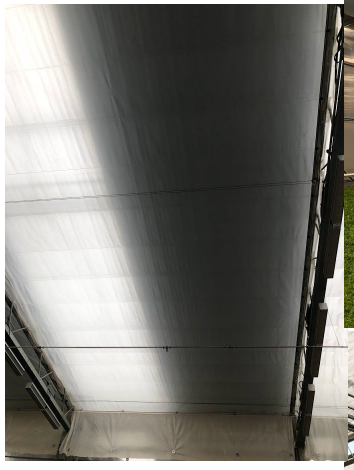


Figure credit: Ludvig Svensson

SECTION 04

GREENHOUSE SUPPLEMENTAL LIGHTING SYSTEMS

Michigan Light Resource

Meeting Greenhouse DLI Targets

Some crops may need supplemental lighting because:

- Available sunlight in winter may not be sufficient to meet target quantity of daily light (daily light integral, DLI)
- Other months of the year, some days may have limited solar resource due to weather
- Greenhouse coverings reduce light transmission from sunlight by up to 50%
- Certain stages of plant growth need more light than sunlight can provide (higher PPFD)

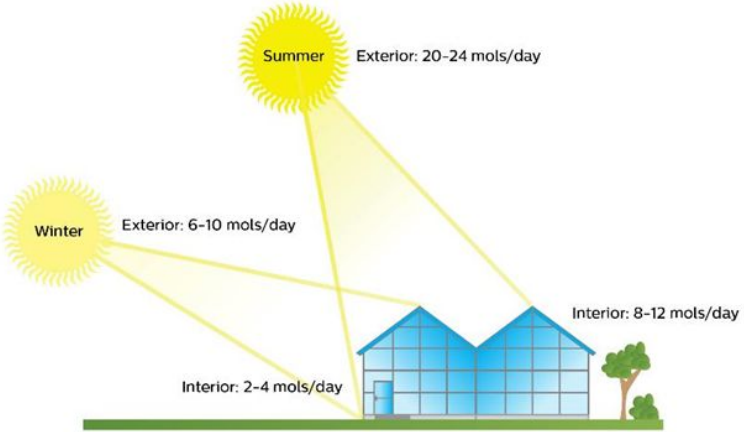
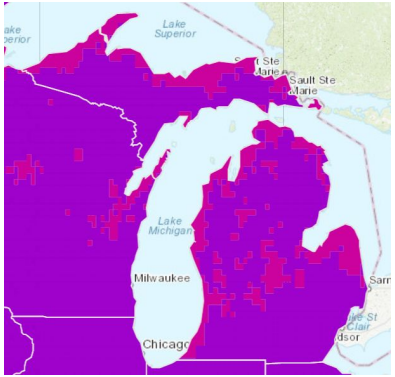


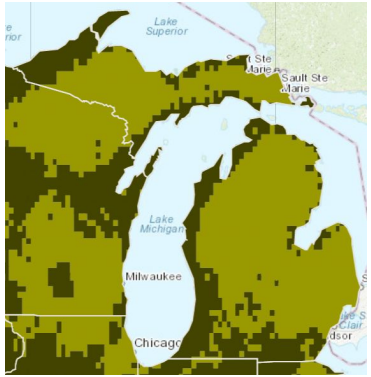
Figure credit: Signify

Michigan Solar Resource Across the Year



January,
5 - 15 mols/ m^2 day

April,
30 - 40 mols/ m^2 day



July,
30 - 45 mols/ m^2 day

October,
15 - 20 mols/ m^2 day

Figure credit: Clemson University

Supplemental Lighting Beam Angles & Light Distribution

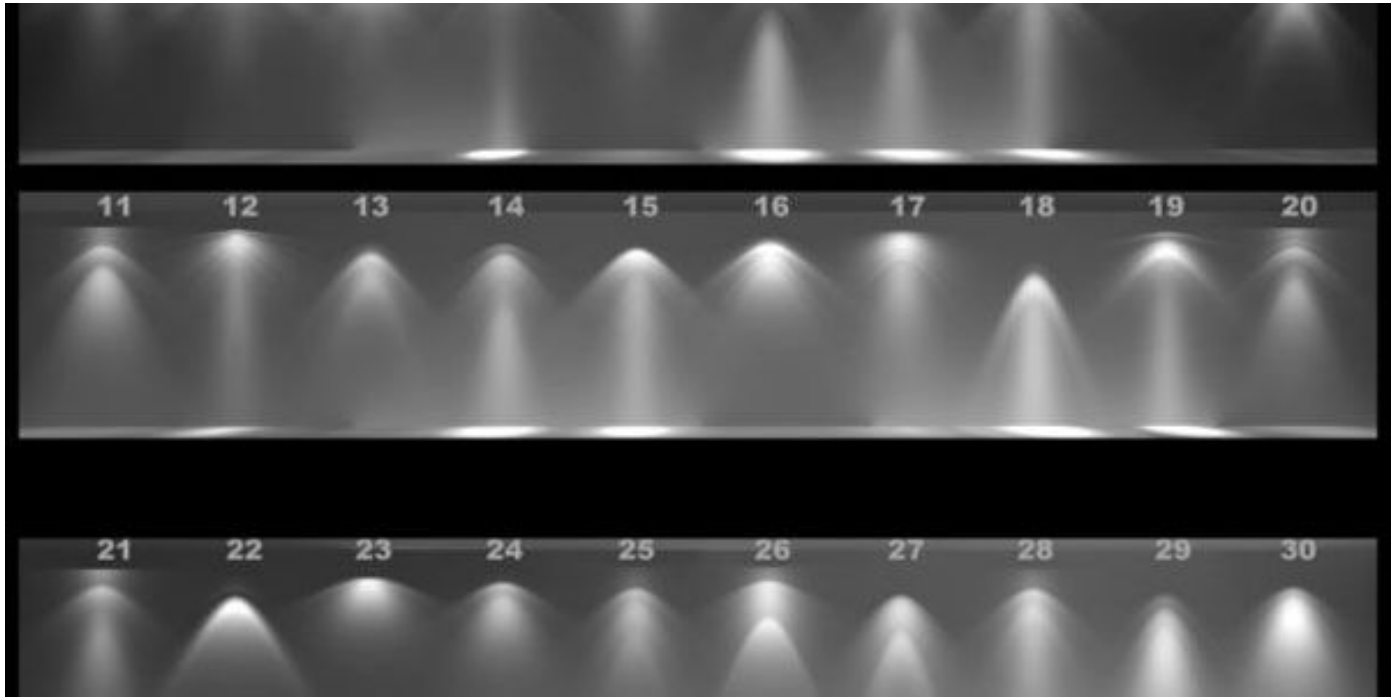
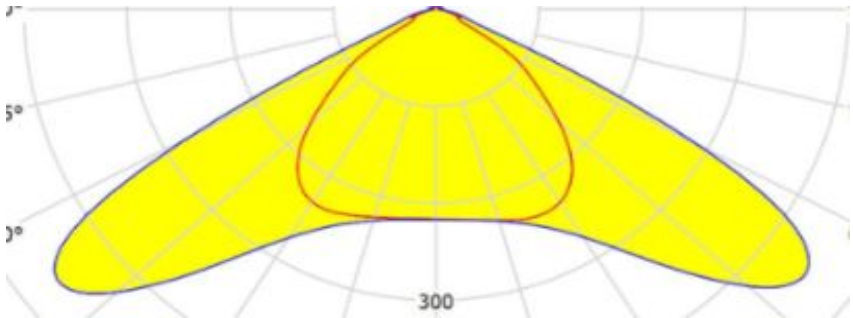


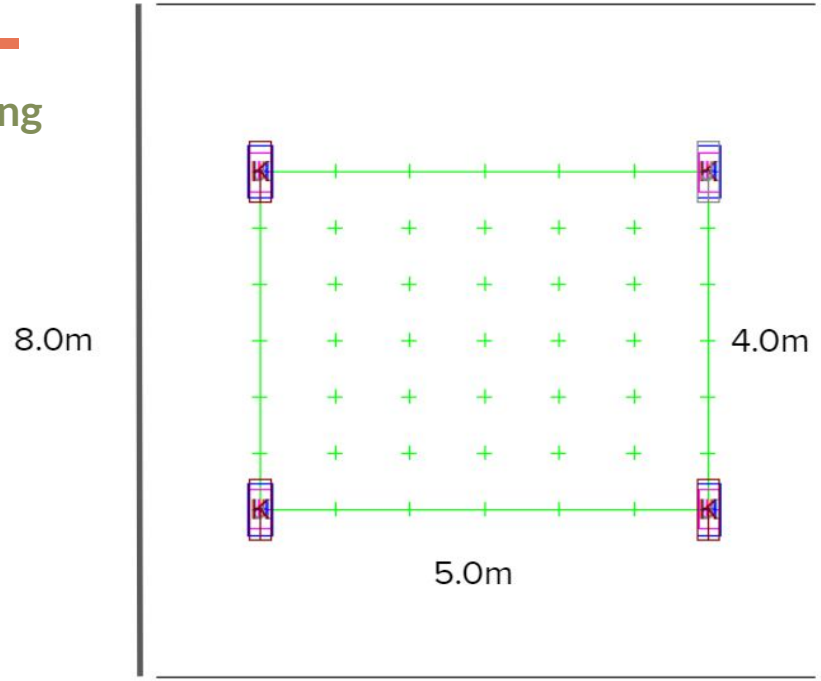
Figure credit: Hawthorne Gardening

Ideal Greenhouse Lighting Distribution

Optimize Distribution for Greenhouse Lighting

- 125 degrees





Calculation Square = 4x5m

Figure credit: Hawthorne Gardening

Choosing Toplighting Solutions

Toplighting for Plant Growth and Development

- Select appropriate PPFD & Spectrum as supplement light to sunlight
- Intensity & spectrum uniformities are key for healthy and consistent growth
- Choose efficient lighting solutions for energy saving and grid health:
  - PPE & Power Factor - as high as possible
- Consider mounting and ease of electrician install:
  - Review Weight - as close to HID DE
  - Wiring for power and controller - less possible

Spectrum		R95B5	R90G5B5
Optics		MD125	MD125
Input voltage		200-400V	200-400V
Output	+/-5%	2700 µmol/s	2650 µmol/s
PF Efficiency	+/-3%	3,6 µmol/J	3,5 µmol/J
Input Power at 100%	+/-5%	760W	760W
	Tolerance		

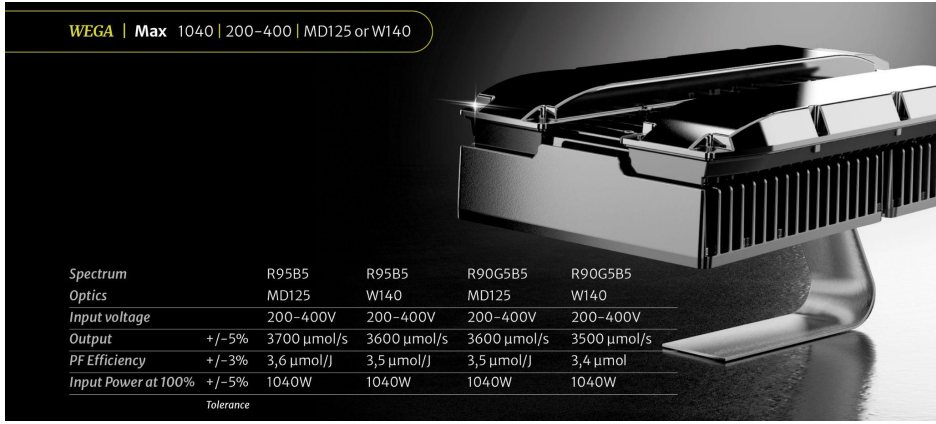
Figure credit: Hawthorne Gardening

Choosing Energy Efficient Greenhouse Lighting

Maximize Efficiency and Optimize Distribution

Reference Criteria for you to Pick a Light:

- PPE
  - 3.6 umol/J possible with LED technology
- Spectrum
  - B5G5R90 popular spectrum
- Distribution
  - 125 °batwing - Most Uniform Optics
- Weight:
  - 11.5 Kg for a 1040 W light - Same as 1000 W DE



Spectrum		R95B5	R95B5	R90G5B5	R90G5B5
Optics		MD125	W140	MD125	W140
Input voltage		200-400V	200-400V	200-400V	200-400V
Output	+/-5%	3700 µmol/s	3600 µmol/s	3600 µmol/s	3500 µmol/s
PF Efficiency	+/-3%	3,6 µmol/J	3,5 µmol/J	3,5 µmol/J	3,4 µmol
Input Power at 100%	+/-5%	1040W	1040W	1040W	1040W
	Tolerance				

Spectrum Selection for Greenhouse Applications

Spectral Treatments for Different CEA Crops

Balance red:blue ratio (R:B)

Narrow band LEDs produce photons in certain wavelengths like red and blue

- For example, 95:5 (95Red 5Blue) works great for tomatoes
- Savings about 40% energy
- For other crops, full spectrum lighting may be needed
- Other crops may find far-red light useful
- Lighting choices should be tailored to your crop, its growth stage, environmental conditions, and other factors such as the need for white light for staff to observe crop appearance

Many studies done and still ongoing at lighting manufacturers, academic research laboratories, and cultivator facilities.

Review Certified Equipment

Use DesignLights Consortium Qualified Products List (QPL)

- Visit https://qpl.designlights.org/horticulture
- DLC is a non-profit that makes tools to accelerate energy efficiency in lighting
  - Stakeholder input and Industry Standards are critical
- All QPL listed products require
  - Horticultural Lighting Safety Certification (UL 8800)
  - 5 year warranty for complete LED fixtures and 3 years for LED lamps
  - Component lifetime requirements (36,000 - 50,000 hours)
  - Representative testing to industry standards

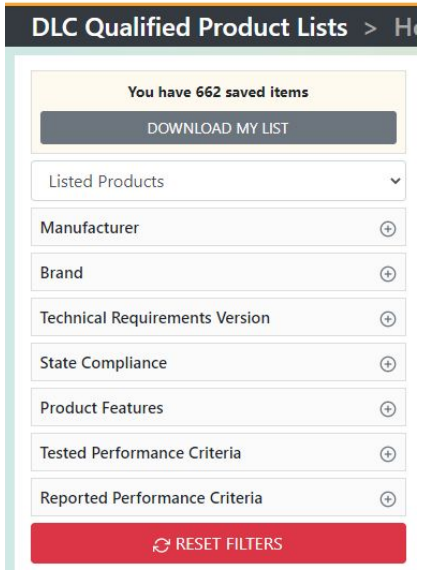


Image credit: DesignLights Consortium Horticultural QPL, accessed March 2022

Review Certified Equipment

Use DesignLights Consortium QPL

- Visit https://qpl.designlights.org/horticulture
- Filter by PPE
  - Choose a minimum and maximum PPE
  - Understand that fixtures with high PPE may be more expensive
  - 3.6 - 3.8 umol/J is the upper bound for fixtures in for attractive grower ROI and may have high amounts of red diodes
- State Compliance filter for businesses operating in states with minimum PPE requirements (MA, IL, soon to be CA)

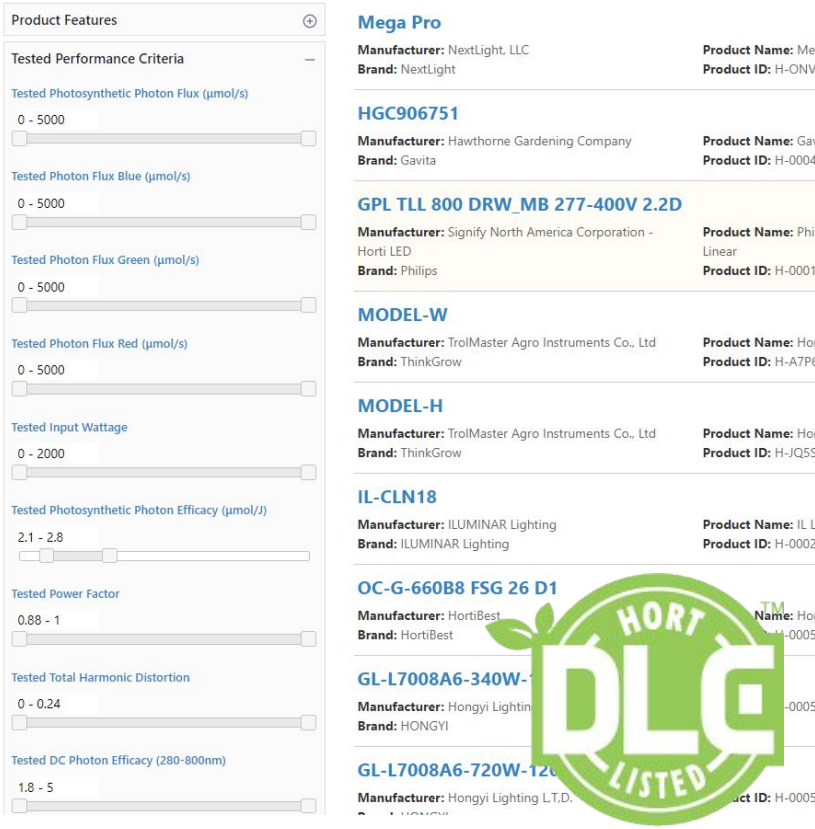


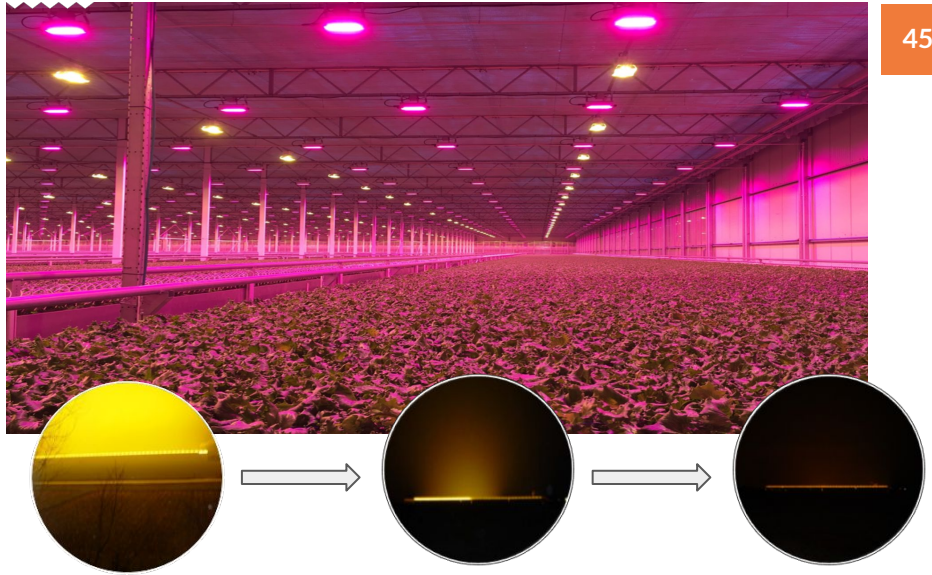
Image credit: DesignLights Consortium Horticultural QPL, accessed February 2022

Light Abatement Solutions

Preserve Dark Skies

Concept:Blackout Screen for keeping light in the greenhouse

- Single layer
- Reflective
- Increases light intensity on crop
- 99% reduction in light emission
- Effective with both HPS and LED
- Compliance with regulations
- Doubles as energy screen



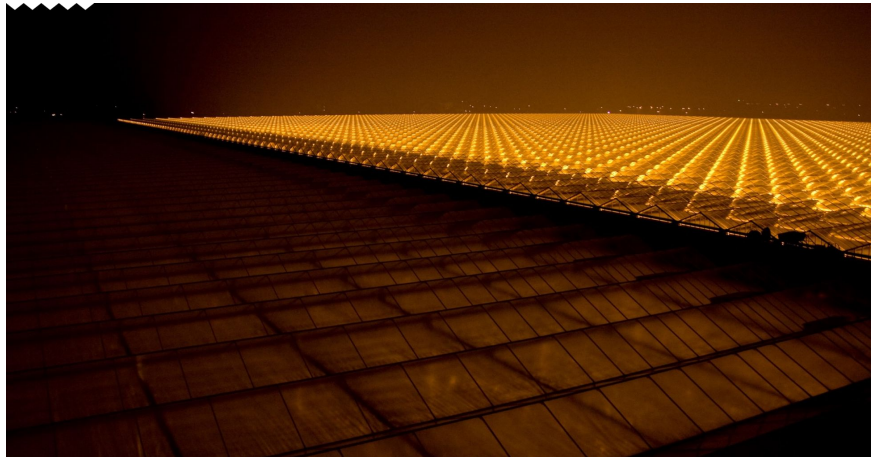


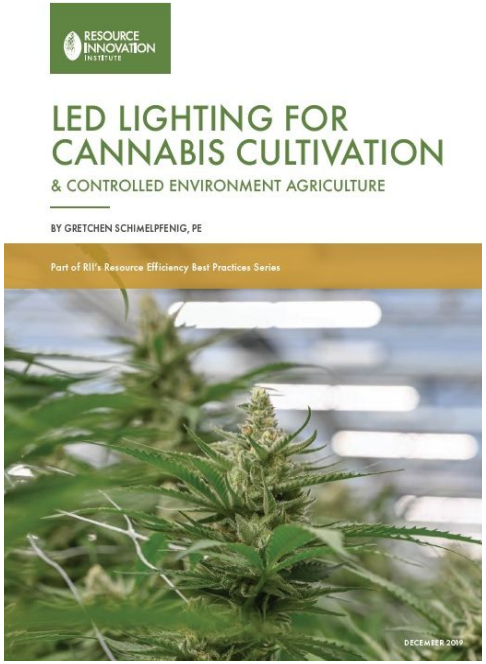
Figure credit: Ludvig Svensson

Cannabis Lighting Best Practices Guide

Brand-agnostic information for producers

Free peer-reviewed guidance on horticultural lighting

- Speak the language relevant to lighting systems in horticultural applications
- Understand types of lighting systems optimizing horticultural environments
- Review manufacturer's literature to evaluate your purchasing options and select horticultural lighting equipment
- Install and operating successful LED lighting solutions in alignment with business models
- Use data from lighting systems to improve productivity and efficiency
- Demonstrate energy savings for utility energy efficiency incentive programs



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SECTION 05

GREENHOUSE HVAC SYSTEMS

Greenhouse Envelope: Evaporative Cooling

Evaporative Cooling

- Wetted fill media provides cooling
- Fans may be utilized to induce air
- Recommend annual cleaning
- Fill media replacement every 8 years
- Manually operated or automated

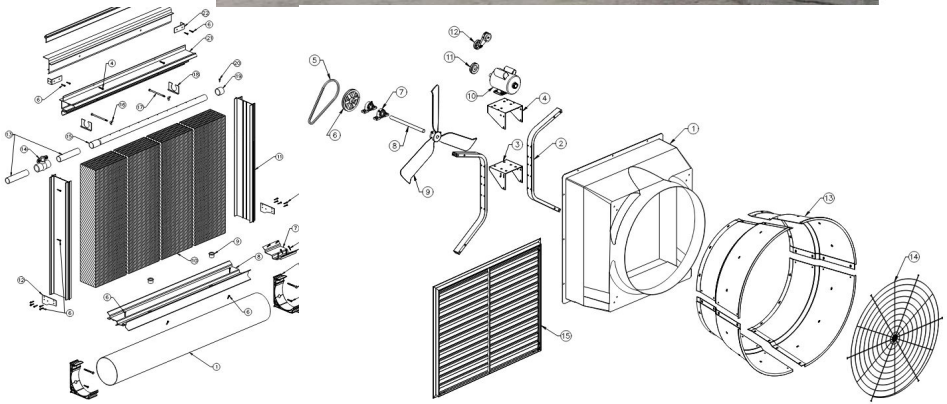


Figure credit: Hoogendoorn, NBDS

Fans

Horizontal Air Flow

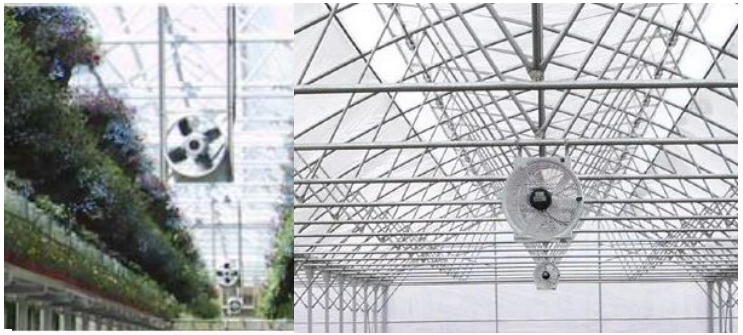
- Arranged end to end (discharge to intake)

Sidewall

- Arranged with and without padwall

Gable

- Remove heat “trapped” above shades



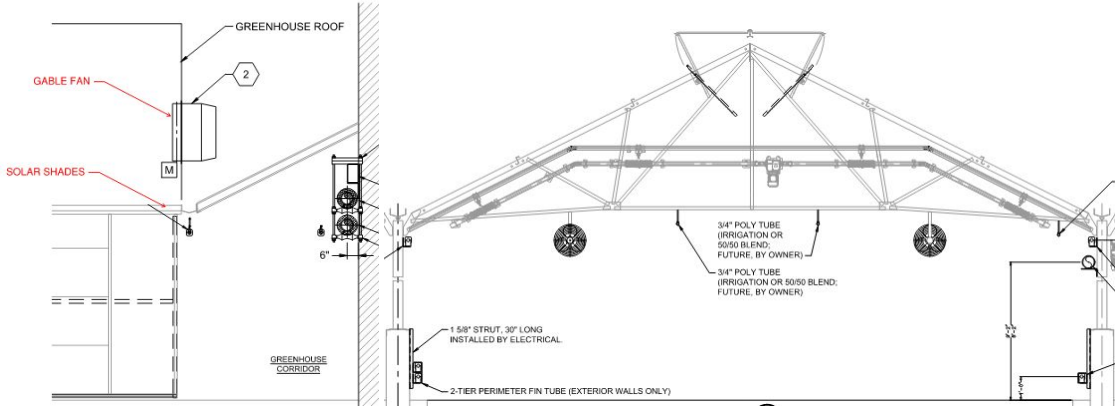


Figure credit: Hoogendoorn, NBDS

Closed and Semi-Closed Greenhouse Heating and Cooling

Tubes

- Made from fabric or polytube
- Distributed under canopy or overhead

Cooling

- Direct expansion or chilled water

Heating

- Typically heating hot water or possibly waste heat

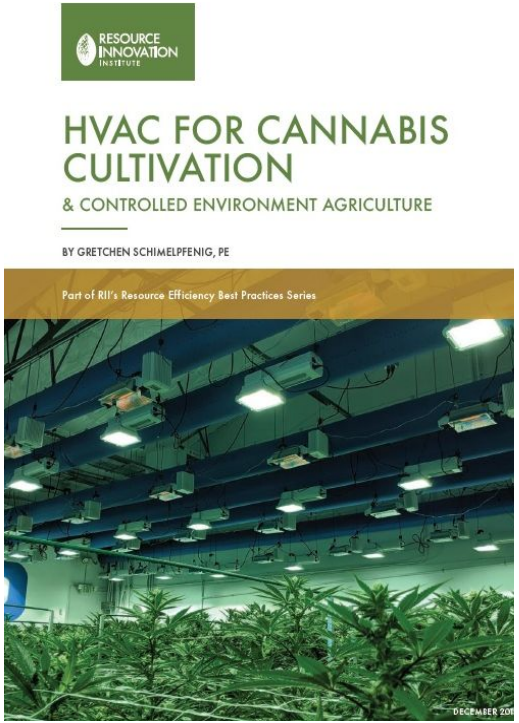
Figure credit: Hoogendoorn - NDBS

Cannabis HVAC Best Practices Guide

Brand-agnostic information for producers

Free peer-reviewed guidance on HVAC for cannabis cultivation

- Speak the language relevant to HVAC in horticultural applications
- Understand types of HVAC systems optimizing horticultural environments
- Review manufacturer's literature to evaluate your purchasing options and select horticultural HVAC equipment
- Install and operating successful HVAC solutions in alignment with business models
- Use data from HVAC systems to improve productivity and efficiency
- Demonstrate energy savings for utility energy efficiency incentive programs



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SECTION 06

OPTIMIZING HVAC SYSTEM DESIGN

Factors Influencing HVAC Loads

Driving HVAC Capacity, CapEx, and OpEx

Lighting system choice and target VPD affect HVAC system size

- Bigger HVAC systems have higher capital costs
- Oversized HVAC systems cost more to run

IMPACT OF TARGET ENVIRONMENTAL CONDITIONS AND LIGHT SOURCE ON THE REQUIRED CAPACITY OF HVAC EQUIPMENT TO OFFSET HEAT LOADS

TARGET INDOOR ENVIRONMENTAL CONDITIONS					LIGHTING SYSTEM WATTS PER SQUARE FOOT		
Various Scenarios	Dry Bulb Temperature (F)	Relative Humidity (%)	Dew Point Temperature (F)	Vapor Pressure Differential (kPa)	LED LPD=35 (W/sq ft)	Hybrid LED/HID LPD=45 (W/sq ft)	HID LPD=60 (W/sq ft)
Scenario 1	80	60%	65	1.40	100%	125%	150%
Scenario 2	75	55%	64	1.33	138%	145%	163%
Scenario 3	70	50%	51	1.25	188%	188%	188%
Scenario 4	65	50%	46	1.05	225%	225%	225%

Figure credit: RII, Cannabis Business Times

Efficient Greenhouse Systems

Equipment Operating in harmony

Latent Loads

- Plants
- Padwall
- Fertigation
- Infiltration (Conduction and Pressurization)

Sensible Loads

- Solar / Supplemental Lighting
- Infiltration (Conduction and Pressurization)

Enrichment

- CO_2

Efficient Greenhouse Systems

Equipment Operating in Harmony

Total Utility Consumption

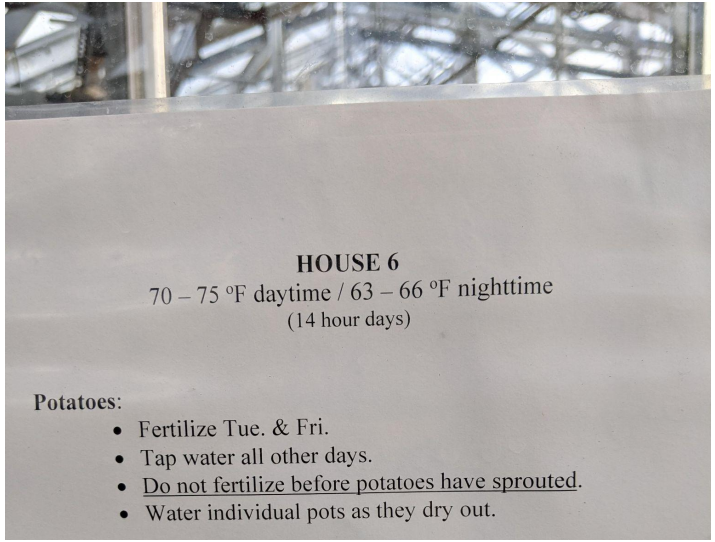
- Develop total carbon footprint of farm
  - Water
  - Electric
  - Gas
  - Sewer

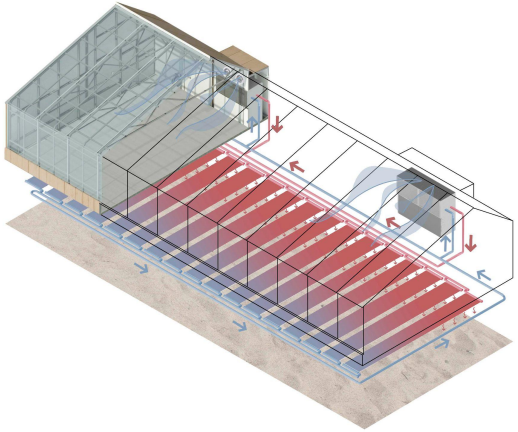
Facility operation

- Target your yields while controlling the environment to minimize environmental and operational cost

Efficient Greenhouse Systems

Equipment Operating in Harmony





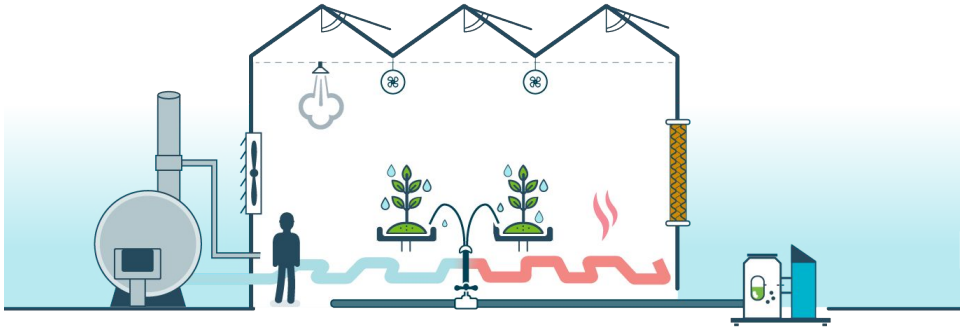


Figure credit: Gretchen Schimelpfenig, University of Vermont, Ceres Greenhouse Solutions, Priva

Efficient Greenhouse Systems

Equipment Operating in Harmony

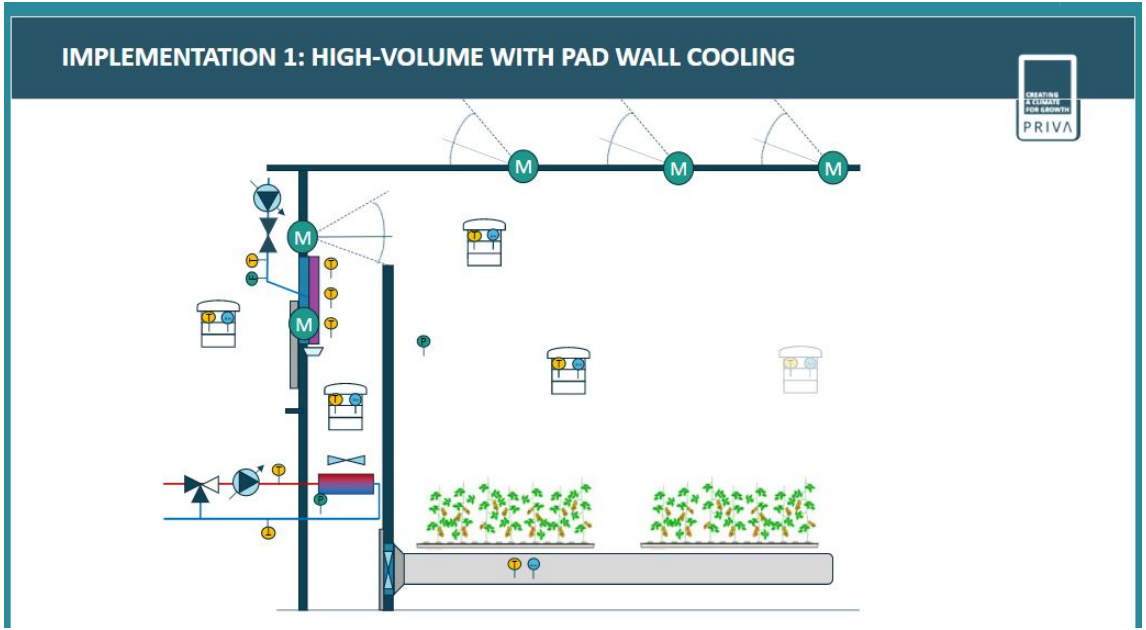


Figure credit: Priva

Efficient Greenhouse Systems

Equipment Operating in Harmony

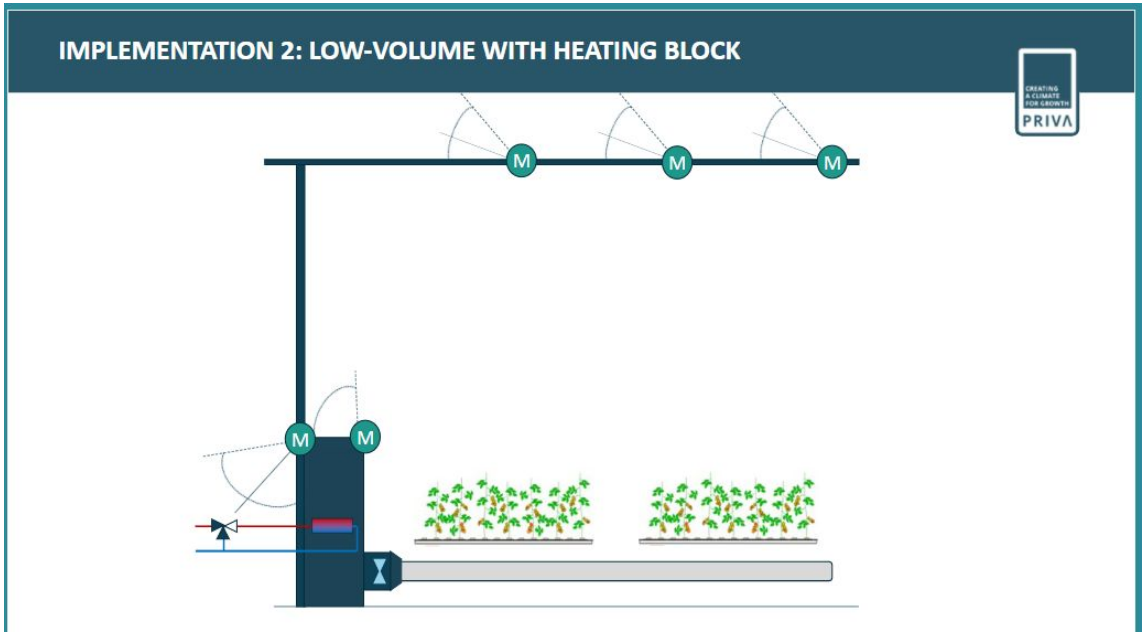


Figure credit: Priva

Efficient Greenhouse Systems

Equipment Operating in Harmony

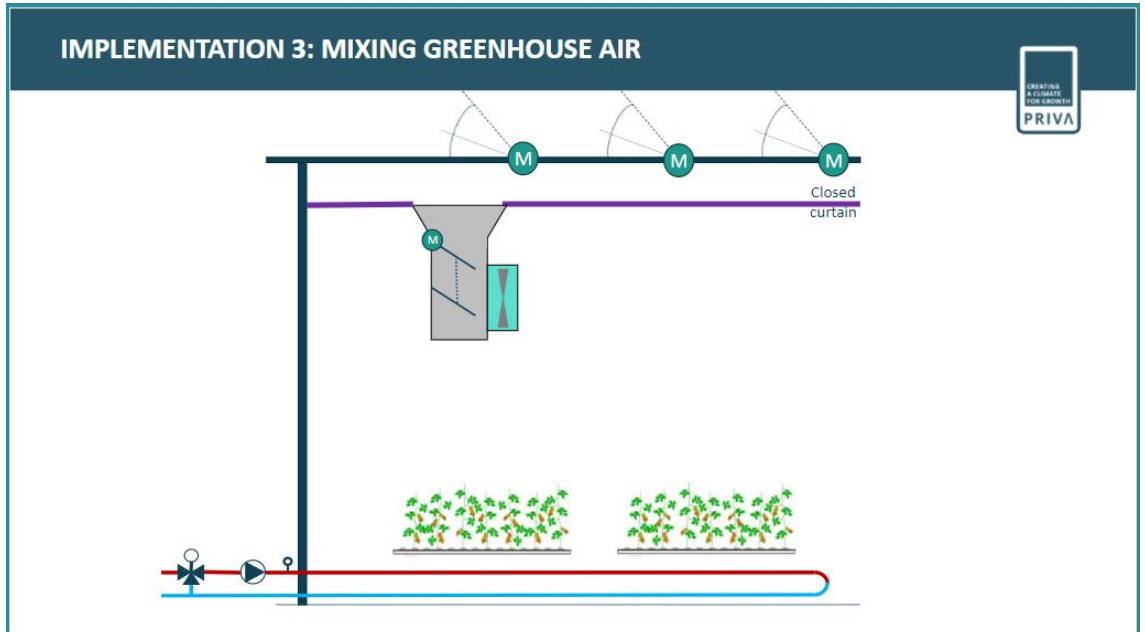


Figure credit: Priva

SECTION 07

CONTROLS & AUTOMATION

Lighting Controls Value Proposition

Dial in the number one nutrient for plants

Provide with granularity:

- Proper light levels
- Optimal spectra for cultivars
- Preferred photoperiod by stage of development
- Desired DLI to empower plant growth

Provide plants with the exact intensity and quantity of light while minimizing energy consumption and lowering bills

Figure credit: Consumers Energy, Signify

HVAC Controls: Value Proposition

Optimize environmental conditions for plants

- Proper temperature (space, relative & leaf), humidity, airflow, CO2 levels
- Optimal plant growth, control mold, mildew and other pests
- ROI plus visibility of data to create a more stable operation

Reduce operating costs while maximizing efficiency and productivity

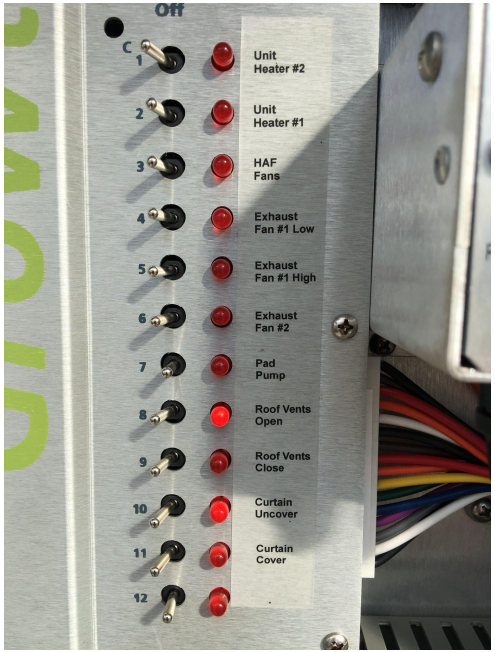


Figure credit: Rob Eddy

Data-Driven Growing

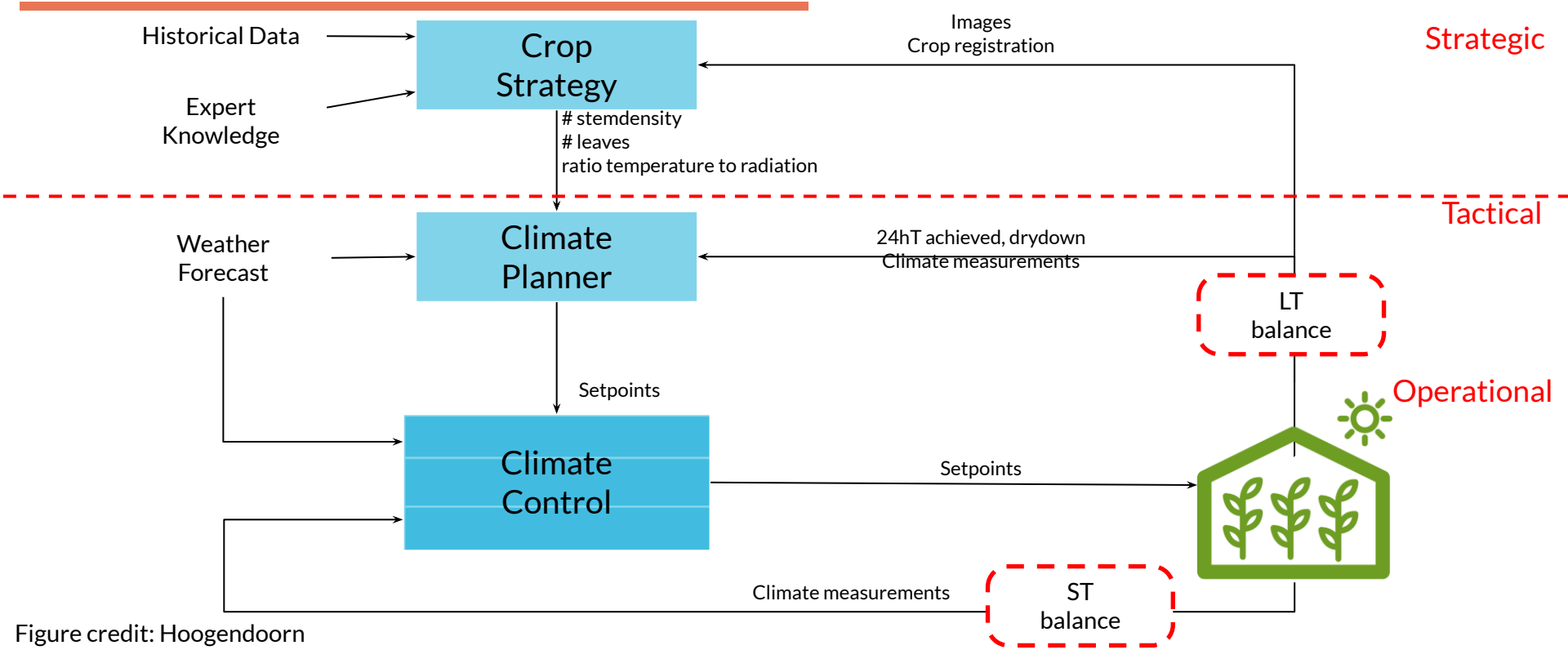


Figure credit: Hoogendoorn

Shade Curtains to Maintain DLI Targets

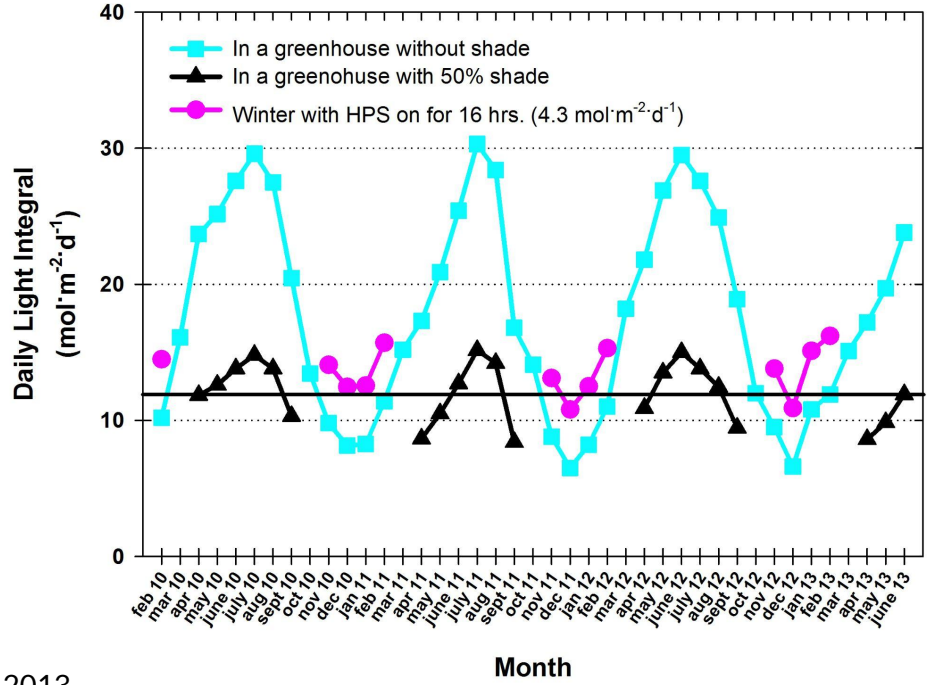
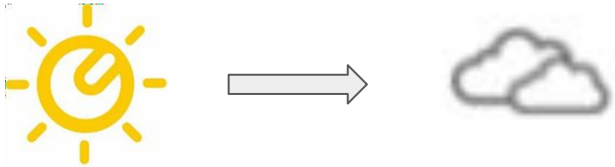
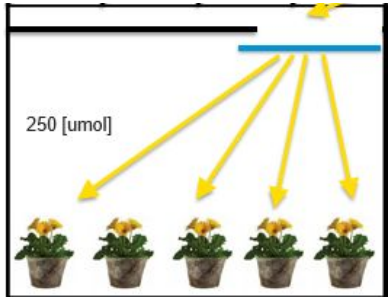


Figure credit: R.G. Lopez, 2013

Two-Curtain Controls: Variable Shading for Better Climate

Light Diffusion screen + 2nd screen to create variable shading to ensure consistent sunlight to crop, and with even light spread





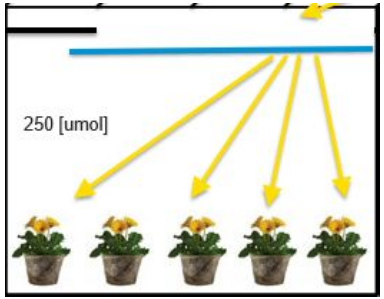
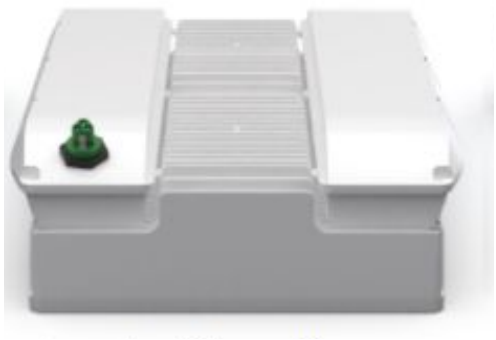


Figure credit: Ludvig Svensson

Increase Fabric Longevity with Programming

Figure credit: Gretchen Schimelpfenig

Greenhouse LED Lighting Field Test

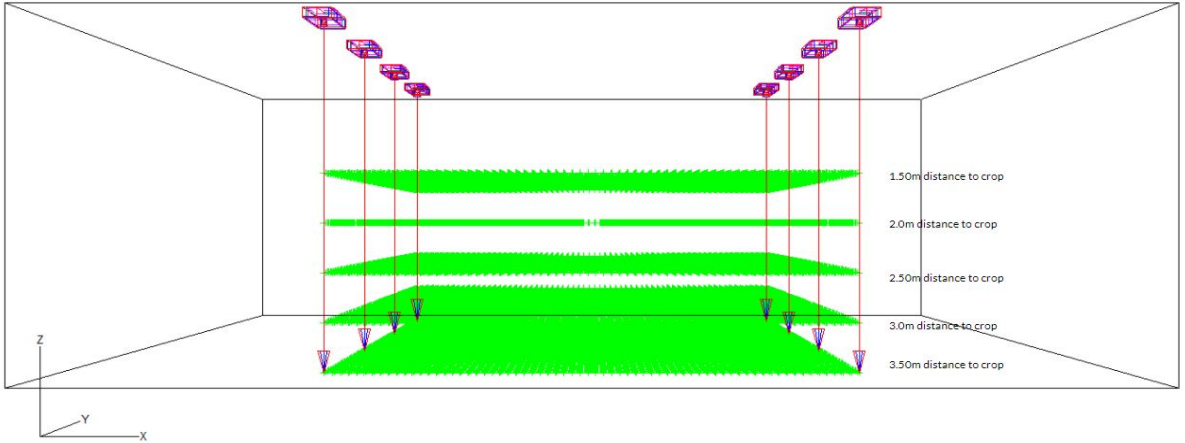


Standard size - (2) pcs in 8m Truss
5m post distance

Hawthorne Agrolux WEGA
760 W

Figure credit: Hawthorne Gardening

Greenhouse Lighting Modeling

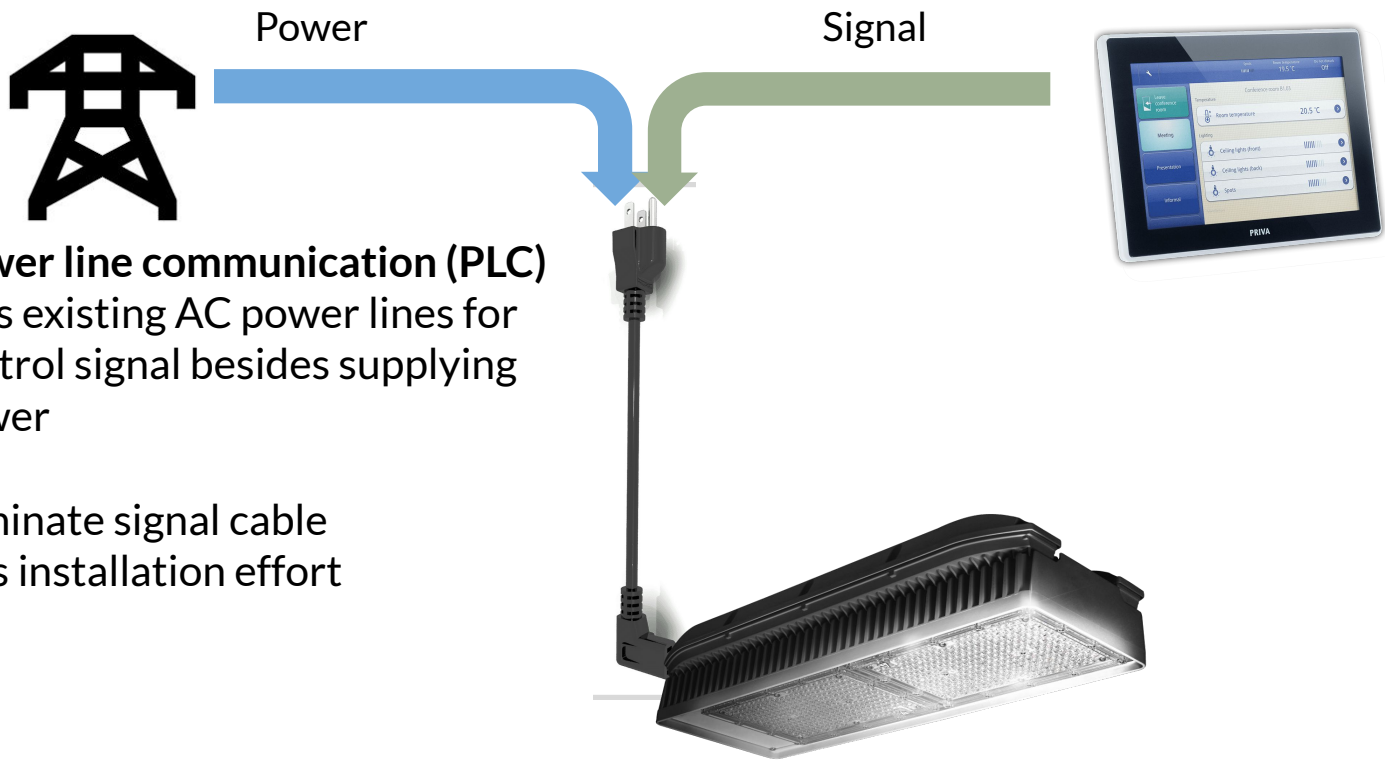


Calculation	Switching Mode	Type	Unit	Ave	Min	Max	Min/Ave	Min/Max	Result
WEGA: 3.0m: 100%	1	ppfd	µmol	174	165	187	0.95	0.88	Direct
WEGA: 2.0m: 100%	1	ppfd	µmol	179	136	210	0.76	0.65	Direct

- >170 umol/s m^2 average PPFD
- >90% uniformity at 3 m hanging height between fixture and crop top
- >70% uniformity at 2 m hanging height between fixture and crop top

Figure credit: Hawthorne Gardening

PLC Controls



Power line communication (PLC) uses existing AC power lines for control signal besides supplying power

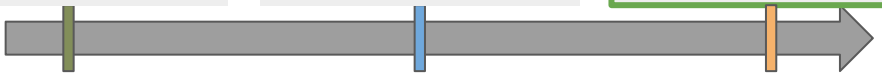
Eliminate signal cable
Less installation effort

Figure credit: Hawthorne Gardening

Greenhouse Controllability

- **Power line communication (PLC)** uses existing AC power lines for signal communication besides supply power
- **Benefit**: eliminate signal cable and lower installation cost

	Very low frequency ~100Hz	Narrowband 10 kHz – 100 kHz	Wideband ~1 MHz
Est.	Before 2000	Early 2000	~2010
Feature	Very limited data rate	High packet loss	High data rate
Application	Electric substation	Power meter reading	Networking



Frequency

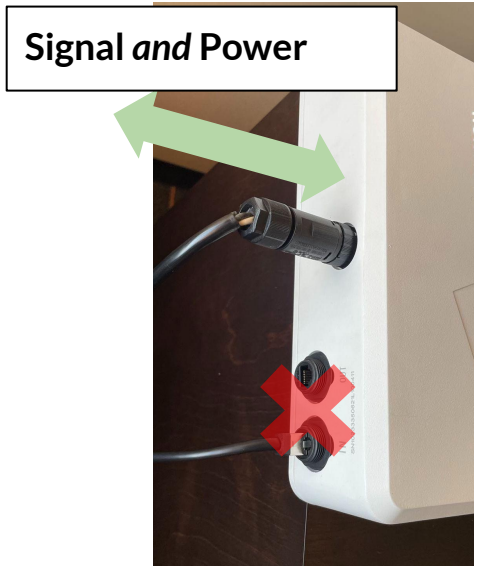
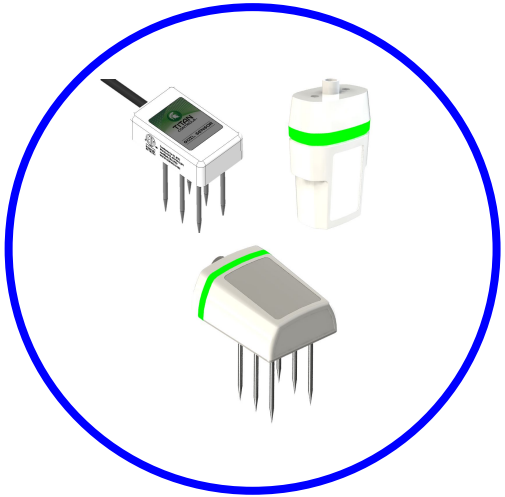


Figure credit: Hawthorne Gardening

Data-Driven Greenhouses



Future Data Characteristics

- Accurate
- Repeatable
- Scalable

Impact on Growers

- Machine Learning
- Artificial Intelligence
- Lower Operating Expense

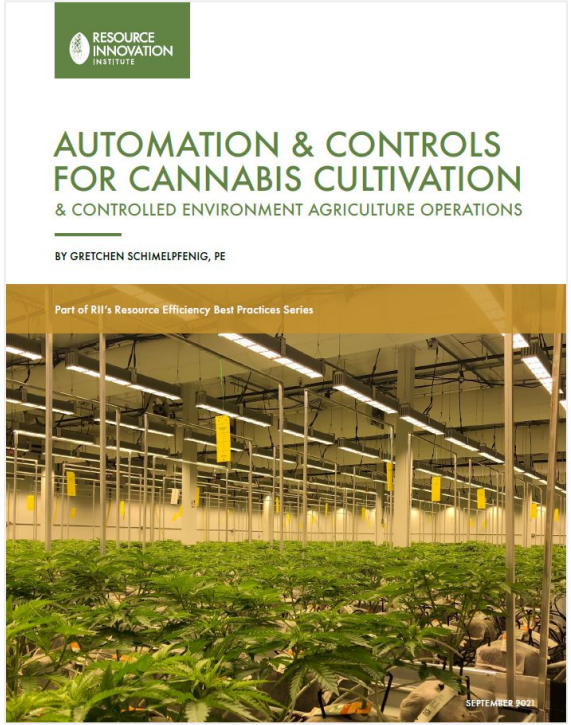
Figure credit: Hawthorne Gardening

Cannabis Controls Best Practices Guide

Brand-agnostic information for producers

Free guidance on lighting, HVAC, and water controls

- Speak the language relevant to controlling and automating environmental control systems in horticultural applications
- Understand types of control systems optimizing horticultural environments
- Plan for integrated controls approaches in greenhouses and indoor operations
- Install and operating successful controls solutions in alignment with business models
- Use data from control systems to improve productivity and efficiency
- Demonstrate energy savings for utility energy efficiency incentive programs



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SECTION 08

COMMISSIONING CEA HVAC SYSTEMS

Validate System Sequences of Operation

Performance Testing for Equipment

Controls systems dashboards help teams verify HVAC, lighting, and curtain components react to satisfy targets for:

- Light intensity
- Temperature
- Relative humidity

Commissioning is crucial to check that systems stage together properly

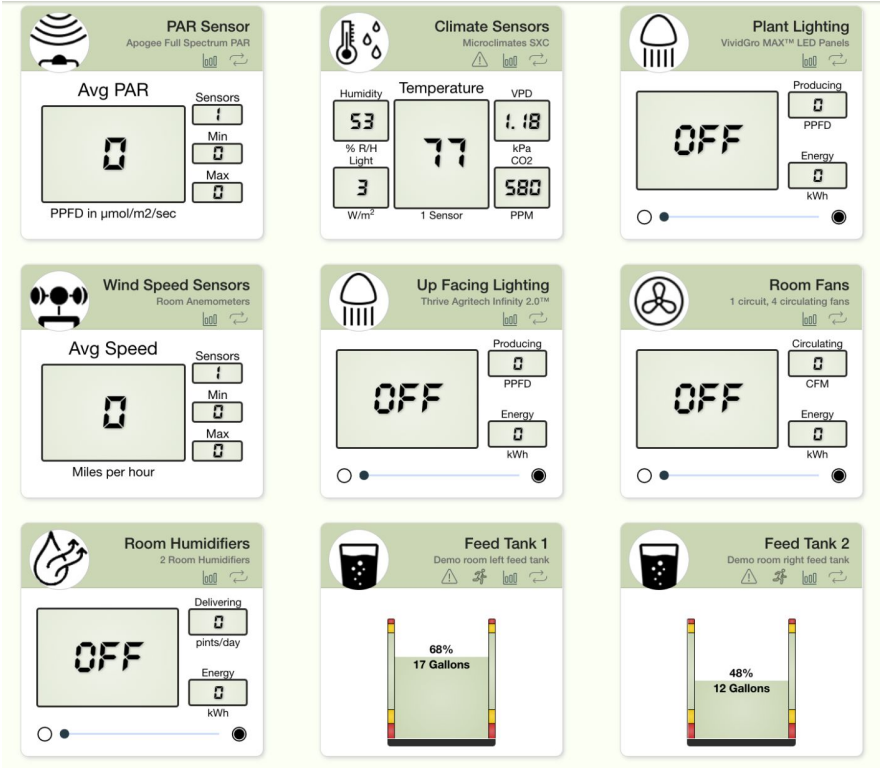


Figure credit: Microclimates

Using Data: Trending History

Back up stored data regularly

- Hundreds of sensors measuring various conditions and collecting data at regular intervals to track historical trends
- A typical control system can generate tens of thousands of data points from a cultivation facility every single day
- Determine how long you want to store your historical logs of trends

Save multiple years of data for year-over-year comparisons

Figure 5: Dashboard of Trended Facility Data

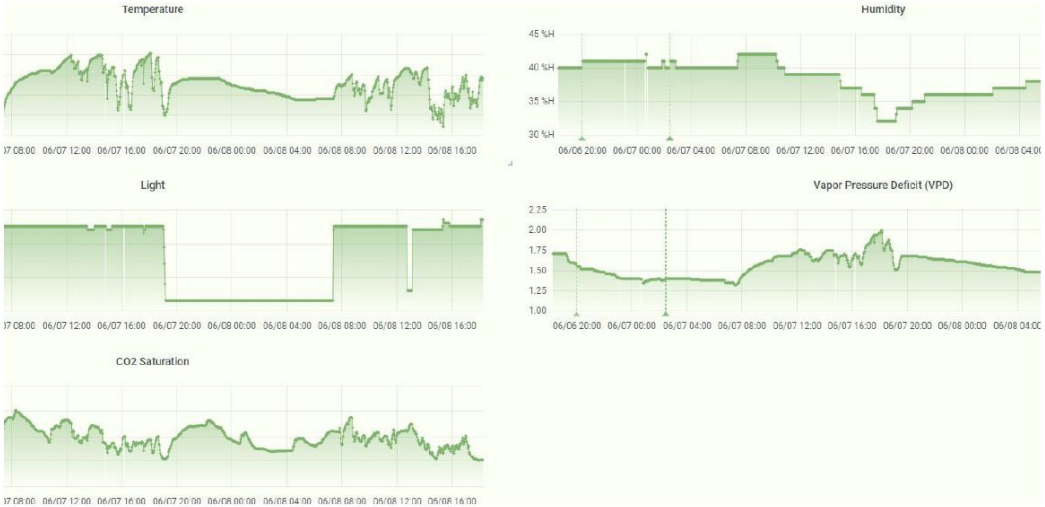


Figure credit: Microclimates

HVAC Controls Trends: VPD Controls

Validate actual conditions are within target ranges

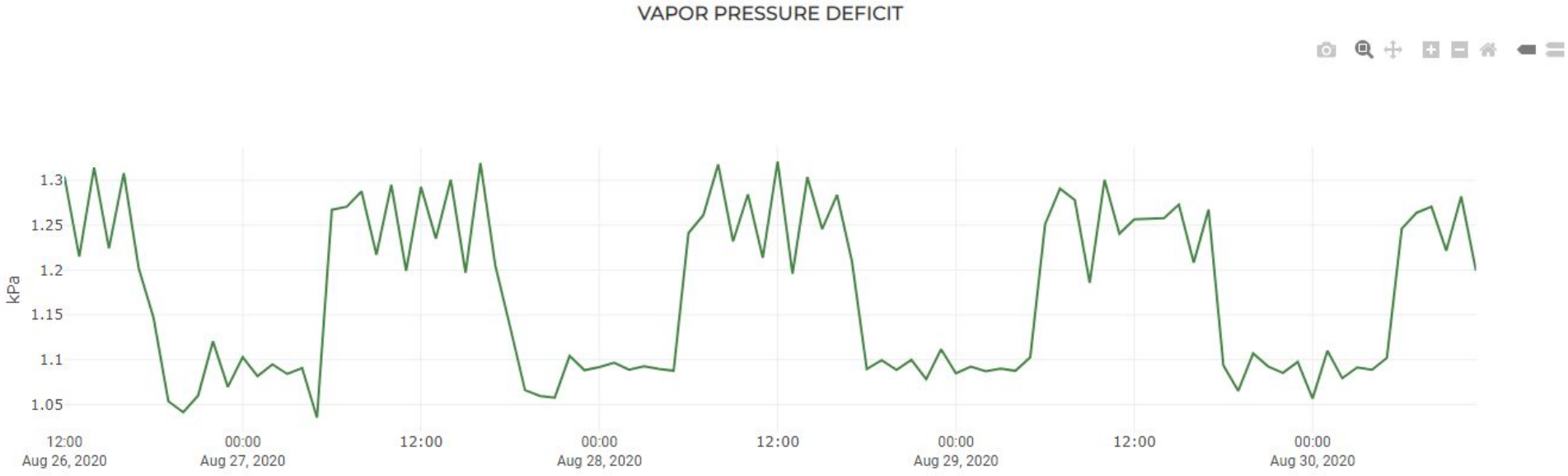


Figure credit: Inspire Transpiration Solutions

SECTION 09

BENCHMARKING HVAC SYSTEM KPIS

Document Baselines

Capture Market Practices and Performance

Benchmark your production environments to create baselines for resource efficiency:

- Energy
- Water
- Emissions

Understand how your facility performs compared to your key performance targets

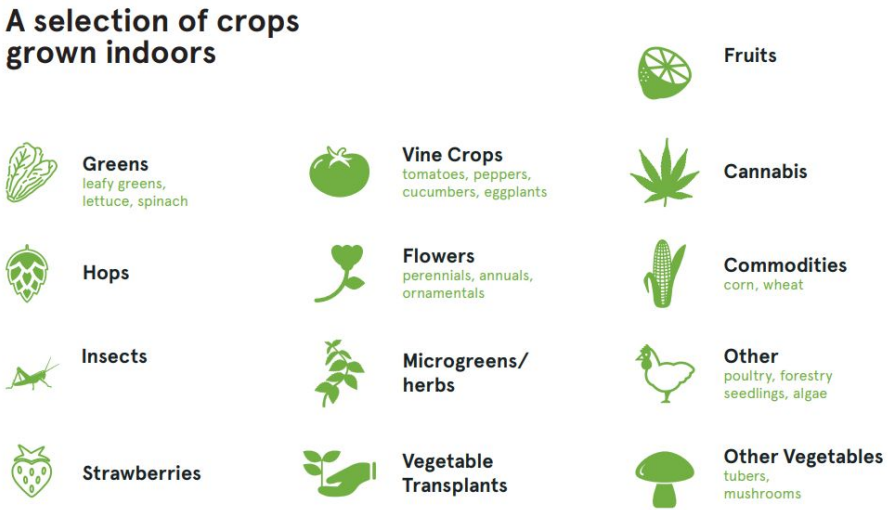


Figure credit: Rhode Island Department of Environmental Management

Targets for Data Driven Growing

Optimize environmental conditions for plants

- Energy efficiency:
  - Light usage optimization (PAR)
  - Cooling / Heating (HVAC) optimization
  - Energy consumption prediction and planning
- Water efficiency
  - “Ideal” irrigation strategy
  - Water balance
- Nutrients efficiency
  - Balance
  - Prediction models : quality and quantity
- CO2 efficiency

Use Data from Automated Integrated Control Systems

Indoor Farm

Control Room

Autonomous growing

Data Driven Growing

Actuators

Measurements

Decision Support System, Predictions

Data Analysis
Artificial Intelligence

Domain Knowledge
Experience

Figure credit: Hoogendoorn, Plant Empowerment

Facility Performance Snapshots

Key Performance Indicators for CEA

Quantify performance of CEA facilities using specialized key performance indicators for:

- Efficiency
- Productivity

Understand how system operation affects facility lighting, HVAC, and energy KPIs

- kWh/day → annual facility energy use

Observe changes in canopy productivity

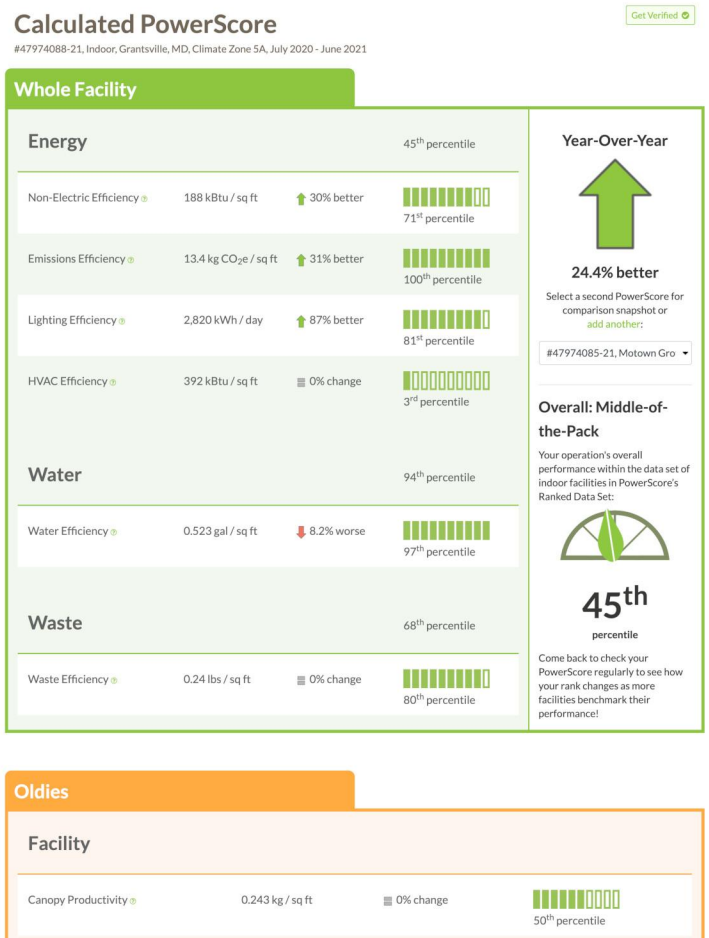


Figure credit: RII, PowerScore

Benchmarking Lighting System KPIs

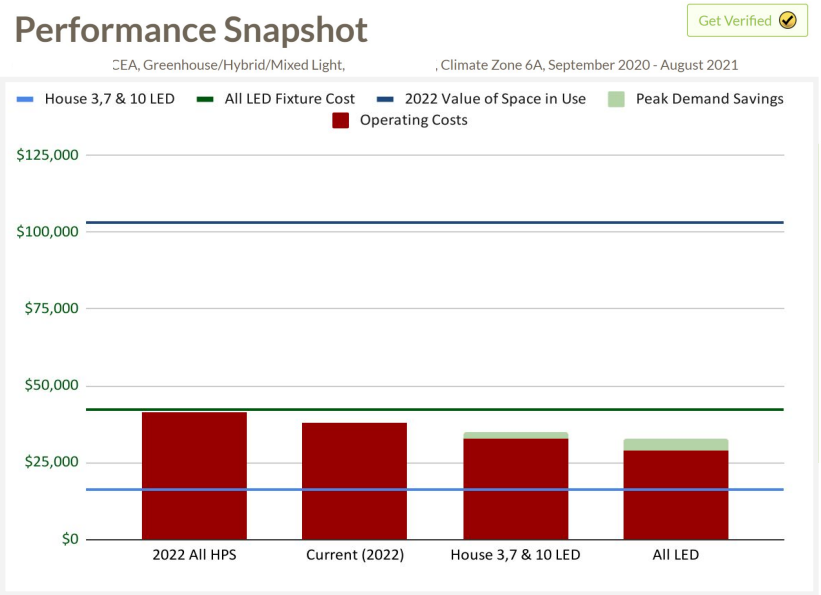
Staged Installation of Supplemental Lighting

Greenhouse adding more lighting to fully utilize bench area, added a mix of HID and LED fixtures in 2021, modeling two future LED scenarios

Installing LEDs saved electricity and avoided peak demand while increasing value of bench area in use and reducing idle space

Future scenarios further reduce operating costs

Benchmarking allows for payback period calculations



	Idle Space (%)	Value of Space in Use ($)
2021 - 2020 Difference	-3%	7%

SECTION 10

MAXIMIZING EFFICIENCY INCENTIVES

Efficiency Utilities Serving Michigan

Three Regional Utilities with Efficiency Programs

- Utility service territories determine eligibility
- Growers in Michigan can benefit from technical assistance and financial incentives
- Incentives reduce the first cost of high-performance technology

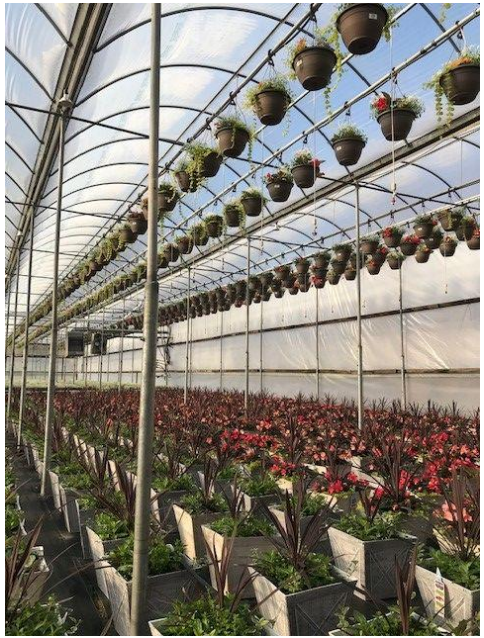
Consumers Energy
Count on Us®

DTE

LANSING BWL
Hometown People. Hometown Power.

...+35 other electric utilities in MI

CEA Efficiency Project Landscape: Greenhouse



Consumers Energy, with their consulting and their rebate program has helped – and will help – our business grow for years to come. - Kari P., Manager, Panse Greenhouses, LLC – Kalamazoo, MI

Consumers Programs for Producers

Consumers Energy
Count on Us®

Energy Efficiency Programs

- Grow in your greenhouses for less and earn rebates when you install:
  - Infrared thermal film
  - Heat curtains
  - In-floor heating
  - Environmental control systems
  - LED grow lights
- Consumers customers can contact Rachel or Tom
  rachel.fredrickson@cmsenergy.com
  tom.gallagher@cmsenergy.com
  - Call: 877-607-0737

Greenhouse Application

Program Offerings for CEA Customers

Energy Efficient Equipment Incentives for Indoor Farms

- $0.70 - $1.00/W reduced for horticultural lighting

AG211a	LED Grow Lights < 6,570 Annual Hours (Retrofit only)	$0.70	Watt Reduced
AG211b	LED Grow Lights ≥ 6,570 Annual Hours (Retrofit only)	$1.00	Watt Reduced
AG211c	LED Grow Lights < 6,570 Annual Hours (New construction only)	$0.70	Watt Installed
AG211d	LED Grow Lights ≥ 6,570 Annual Hours (New construction only)	$1.00	Watt Installed

LC104	Daylight Sensor Controls*	$0.09	Watt Controlled

- $40 - $80/hp VFDs

Other Program Offerings

- Free technical assistance to identify and prioritize energy efficiency projects
- Energy audits and facility walkthroughs for large customers

Consumers Energy customers may qualify for participation. Contact Rachel or Tom for more information!

Program Offerings for CEA Customers

Energy Efficient Equipment Incentives for Greenhouses

Consumers Energy
Count on Us®

ID	Greenhouse (Pre-Notification Required) (Consumers Energy Natural Gas Customers)	Incentive	Unit
AG105	Greenhouse Heat Curtains	$0.25	Square Foot
AG106	Greenhouse Infrared Film Replacing a Single Layer with Double Layer	$0.50	Square Foot
AG107	Greenhouse Infrared Film Replacing a Double Layer with Double Layer	$0.15	Square Foot
AG108	Greenhouse Environmental Controls	$0.30	Square Foot
AG109	Greenhouse In-Floor Heating System (Without Heat Curtains)	$0.50	Square Foot
AG110	Greenhouse In-Floor Heating System (With Heat Curtains)	$0.25	Square Foot

HV309	High-Efficiency Unit Heater (at Least 92% Efficient)	$3.99	MBH
HV310	High-Efficiency Unit Heater (at Least 95% Efficient)	$7.91	MBH

AG111a	Circulation, Exhaust or Ventilation Fans	24 Inch to 35 Inch Fan Blade Diameter	$30.00	Fan
AG111b		36 Inch to 47 Inch Fan Blade Diameter	$50.00	Fan
AG111c		48 Inch to 72 Inch Fan Blade Diameter	$100.00	Fan

Consumers Greenhouse Customer Incentive Examples

Project Types

- installing greenhouse IR/AC film,
- thermal curtains,
- LED grow lights,
- environmental controls

Energy Saving Results

Lowered energy bill by: $115,000
Rebate amount: $125,000
Electric savings: 876,304 kWh
Natural gas savings: 2,353 Mcf

Energy Saving Results

Lowered energy bill by: $2,994
Rebate amount: $16,000
Electric savings: 1,616 kWh
Natural gas savings: 1,067 Mcf

Consumers Greenhouse Customer Incentive Examples

Project Types

- installing greenhouse IR/AC film,
- thermal curtains,
- LED grow lights,
- environmental controls

Energy Saving Results

Lowered energy bill by: $6,232
Rebate amount: $13,000
Electric savings: 3,232 kWh
Natural gas savings: 1,299 Mcf

Energy Saving Results

Lowered energy bill by: $8,307
Rebate amount: $25,000
Natural gas savings: 1,846 Mcf

Program Offerings for CEA Customers

Energy Efficient Equipment Incentives for Greenhouses

- Greenhouse Environmental Controls- $50/1,000 sq. ft
- Heat Curtains- $.05/sq. Ft
- Infrared Film- $.05/sq.ft
- LED Lighting- incentives vary
- Hydronic heating-$ .14 or $.08/sq ft. depending on thermal curtains
- Circulation exhaust fans
- Vfds on pumps and fans
- …and more

Contact Jeff for more information! Jeff.Linkimer@dnv.com

https://www.dtebizrebates.com/

DTE Program Growth

DTE

2019

1 paid project
$99,330 paid
1.986 million kWh saved

2020

9 paid projects
$744,000 paid
15 million kWh saved

2021

103 paid projects
$4,730,000 paid
81.5 million kWh saved

Greenhouse gas emissions avoided since 2019 equivalent to removing 15,197 passenger cars.

DTE Greenhouse Projects

5 greenhouse projects in 2021

- LED Lighting (prescriptive)
- LED Lighting (custom)
- VFD's on Hot Water Pumps
- Exterior Lighting
- HVAC Reduction

Incentives:
$110,863

Energy Savings:
2.17 million kWh per year

DTE

Program Offerings for the Lansing BWL Customers

2022 Energy Efficient Equipment Incentives for Indoor Farms

New Construction Lighting Incentives	
LED Grow Light	$0.25 - $0.40/Watt installed
Retrofit Lighting Incentives	
LED Grow Light	$0.30 - $0.45/Watt reduced
LED Cannabis Grow Light	$0.30-$0.60/Watt reduced
New Construction & Retrofit	
HVAC Load Reduction due to LED conversion	$0.10/Watt reduced
Dehumidification of Indoor Grow Facilities	$1.75/Pint/Day
Incentive Caps	
$50,000 per meter; $250,000 per customer	

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Hometown People. Hometown Power.

2022 Custom Incentive

2022 Custom Incentive	
All Custom Energy Savings Measures	$.07/kWh Saved

Contact Erikka Byrge for more information! ebyrge@slipstreaminc.org

Website: https://www.lbwl.com/customers/save-money-energy/indoor-agriculture-program

Hometown Energy Savers Greenhouse Savings

Energy Efficient Equipment Incentives for Greenhouses

Energy savings measures incentivized: VFD Controls on process pumps/fans Refrigerated storage optimization	
Estimated annual electric energy savings	176,504 kWh
Estimated peak savings	9.4 kW
Cash incentive awarded	$12,002
Estimated annual cost savings	$22,945

LANSING BWL
Hometown People. Hometown Power.

Hometown Energy Savers Greenhouse Savings

Energy Efficient Equipment Incentives for Greenhouses

Energy savings measures incentivized: Geothermal heating/refrigeration Geothermal in-floor heat for seed germination	
Estimated annual electric energy savings	184,838 kWh
Cash incentive awarded	$12,939
Estimated annual cost savings	$24,029

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Hometown Energy Savers Greenhouse Savings

Energy Efficient Equipment Incentives for Greenhouses

Energy savings measures incentivized: LED Grow Lighting	
Estimated annual electric energy savings	1,176,949 kWh
Estimated peak savings	229.7 kW
Project cost	$502,800
Cash incentive awarded	$50,000
Estimated annual cost savings	$153,003
Simple payback	3.0 years

LANSING BWL
Hometown People. Hometown Power.

Michigan Saves

Statewide program

- Offering below-market rates for energy efficiency financing
  - $5,000 - $5,000,000 project size
  - 60 month terms but can go longer
  - One page financing application for equipment finance agreement
  - UCC filing on equipment only
  - Special 0% financing through DTE and CE
- Contractors
  - Quick and easy application to become an Authorized Contractor
  - 75% Pre-funding for Contractors
  - Low contractor fee (1.99%)

Contact Todd O'Grady at 248-701-3058

Visit MichiganSaves.org to learn more

Q & A

CONTACT US

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