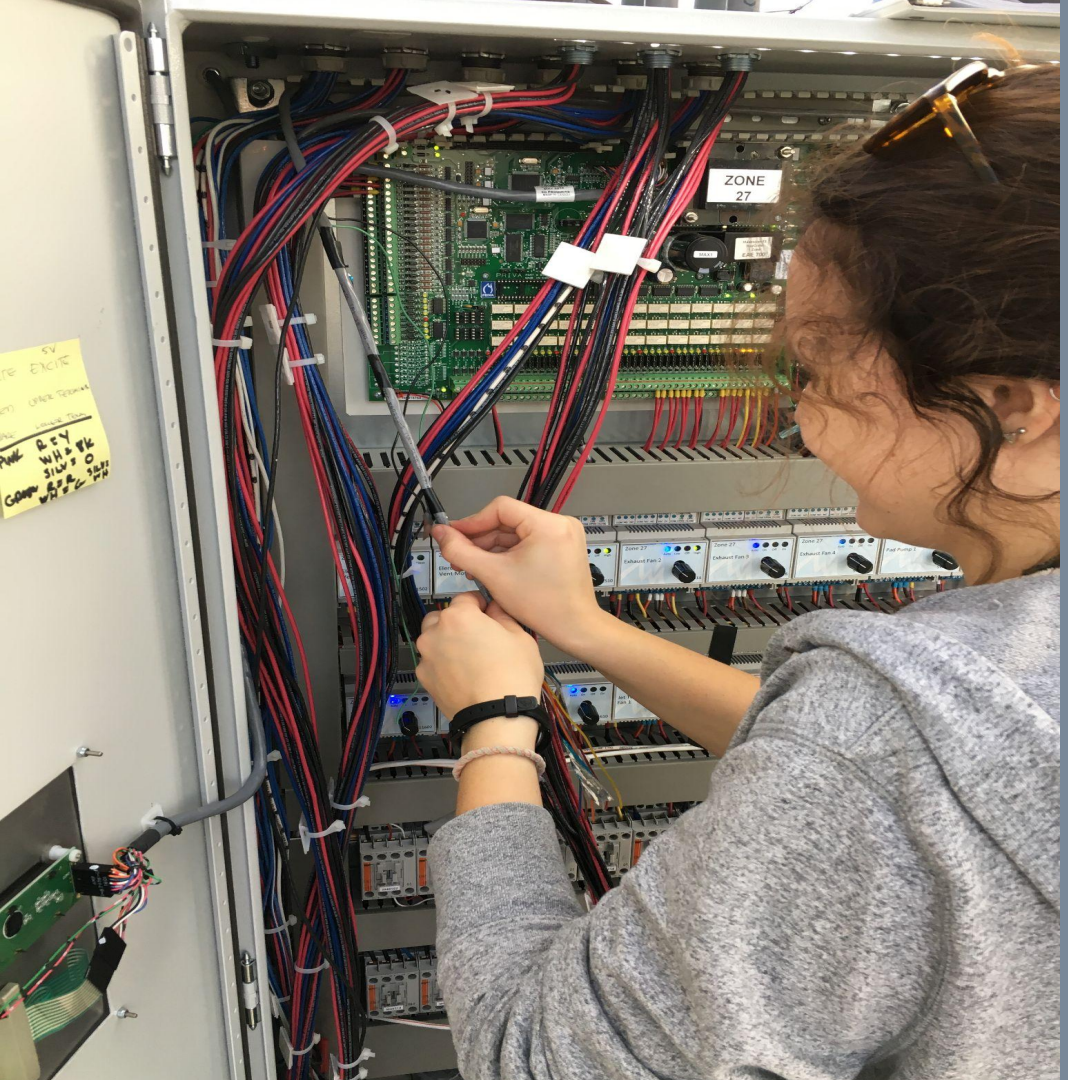

RESOURCE INNOVATION INSTITUTE

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

Controls & Automation Best Practices for Efficient Indoor Agriculture

In partnership with

Consumers Energy
Count on Us®

LANSING BWL
Hometown People. Hometown Power.

DTE

September 29, 2022

Agenda

Introduction & Purpose	1:00 pm ET
How Controls Impact CEA Crops	
Benefits of High-Performance Controls for Indoor Facilities	
CEA Controls Types	
Optimizing Controls System Design	
Best Practices for Advanced Controls & Automation for Indoor Cultivation	
Benchmarking Controls KPIs	
Maximizing Technical Assistance for Controls Projects	
Q&A	2:45 pm

Thank you

MiCIA
MICHIGAN CANNABIS INDUSTRY ASSOCIATION

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MICHIGAN ENERGY EFFICIENCY CONTRACTORS ASSOCIATION

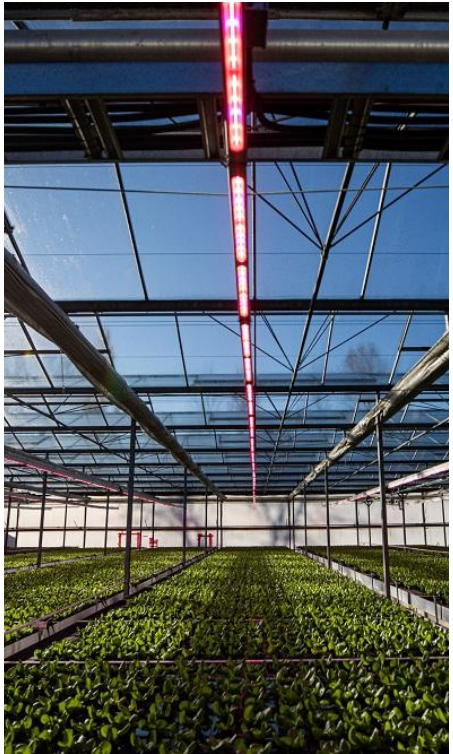
for your collaboration

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

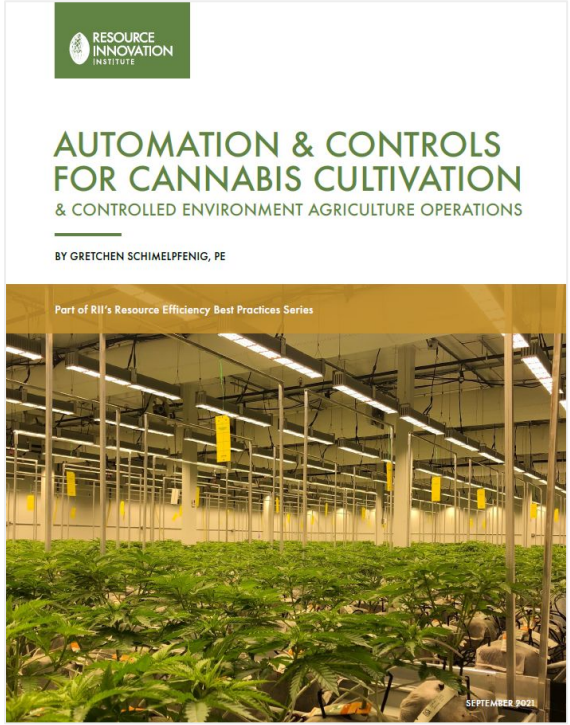
Industry Reports
on Resource Usage

Download the 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



DOWNLOAD NOW

Today's Speakers

Rob Eddy

RESOURCE INNOVATION INSTITUTE

Brian Kammers

DESERT AIRE Est. 1978

Joe Caro

ARCO MURRAY

Brian Debrot

ARGUS CONTROLS

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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%

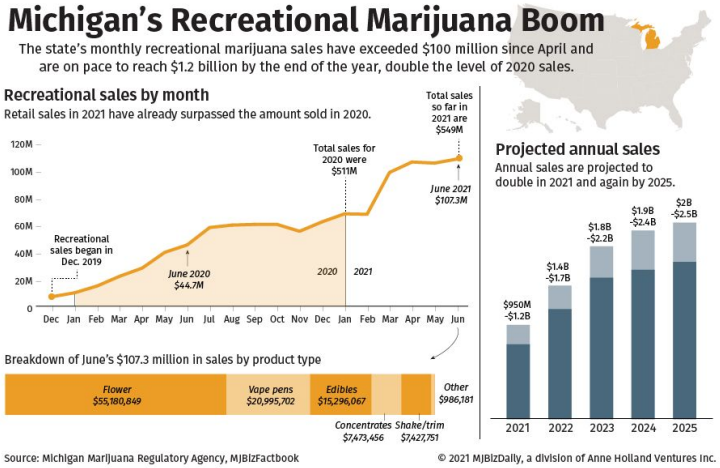


Image credit: MJBizDaily, 2021

Purpose of Today's Workshop

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

- Help Michigan producers improve the efficiency of their operations with lighting, HVAC, and curtain systems
- Convey scientific insights and industry expertise 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

Access Your Michigan Virtual Classroom

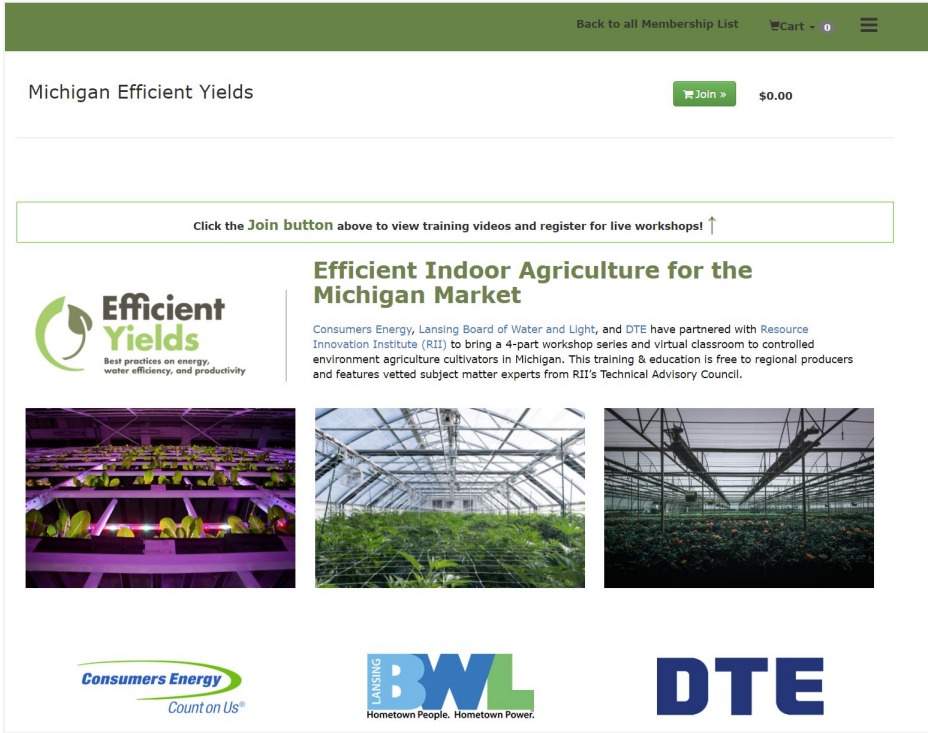
Continue Learning Online

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 Previous Workshops

Greenhouse Optimization- Aligning Your Systems

Featuring speakers from Agnetix, TSRgrow, Seinergy, and SixLabs

Lighting Best Practices for Efficient Indoor Ag

Featuring speakers from Hawthorne Gardening, Hoogendoorn, Ludvig Svensson, and DLC

Watch the workshops on-demand on the RII catalog

Access all classroom content at ResourceInnovation.org/Michigan

Product Type

ON DEMAND

Michigan Efficient Yields: Facility Design & Construction Best Practices for Efficient Indoor Agriculture

Faculty:	Dario Boyce | Johnny Burgoon | Joe Conway | Rob Eddy | Luke Streit
Duration:	2 hours
Format:	Audio and Video
Original Program Date:	Sep 08, 2022
Price:	$0.00 - Non-Members Rate

More info » | Save for Later | Register

Product Type

ON DEMAND

Michigan Efficient Yields: Greenhouse Optimization - Aligning Your Systems with Your Surroundings

Faculty:	Dr. Dengke Cai | Robert Hanifin | Kasey Holland | Luis Trujillo
Duration:	2 hours
Format:	Audio and Video
Original Program Date:	Mar 29, 2022
Price:	$0.00 - Michigan

More info » | Save for Later | Add to Cart »

Product Type

ON DEMAND

Michigan Efficient Yields: Lighting Best Practices for Efficient Indoor Agriculture

Faculty:	Adam Duke | Bob Gunn, CEM | Sanaz Jarolmasjed | Mikhail Sagal
Duration:	2 hours
Format:	Audio and Video
Original Program Date:	Feb 15, 2022
Price:	$0.00 - Non-Members Rate

More info » | Save for Later | Register

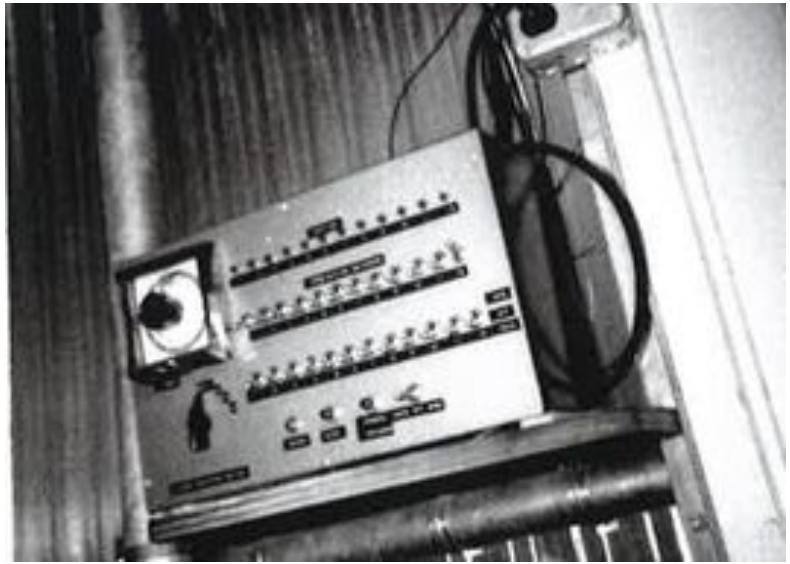
SECTION 03

HOW CONTROLS IMPACT CEA CROPS

plantingdiaries.com

Evolution of Environmental Controls

- Manual
- Thermostats/Humidistats
- Step Controllers with Equipment Integration
- Microprocessor Controls with Feed Forward Logic



Start with the Plant

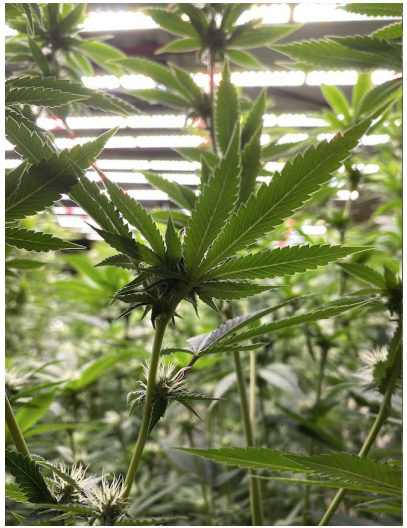
Environmental control for optimal growth

- Automate systems to provide light, climate, airflow, and water to support:
  - High yields
  - Quality biomass

Systems need to be designed and deployed with full system view of how facilities will be operated to keep plants happy

Light:
~40W / canopy square feet (for LED)
12 hours ON

Water:
~500-1000 ml per day



Climate:
78-82 F
55-65% RH
1.2-1.4 kPa VPD

CO2:
~1200-1500 PPM

~ 20 Air Changes Per Hour, MERV 13 Filtration

Figure credit: Zartarian Engineering

Considerations for Greenhouses vs Indoor Farms

Figure credit: Bowery Farming

SECTION 05

BENEFITS OF HIGH PERFORMANCE CONTROLS

Journey to Automation

Increase Productivity & Efficiency

- Continual Improvement to stay competitive
  - Consistent yields
  - Verifiable results

Controls Considerations

- Wired vs wireless control systems
- Sensor placement
- Point of control
- Resolution & accuracy
- Integration
- Maintenance

Lighting Controls: Value Proposition

Dial in the most important variable 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: Grownetics

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

Image credit: The Grove

Controlled Stress Induction: Value Proposition

Secondary Metabolites

- Plant Protection Compounds
- Induced by stress
- Cannabinoids with drought stress
- Flavonoids in tomato with Na stress
- Artemisinin in Wormwood
- Challenge is to not reduce yield!

SECTION 08

CEA CONTROLS TYPES

Fully Integrated Controls

- **Feedback**
  - Reacting to a change
- **Feed forward (integrated)**
  - Acting preemptively and predictively
- **Integration benefits**
  - Reduce wear and tear
  - Improve control
  - Save energy
  - Save water
  - Real time data for troubleshooting

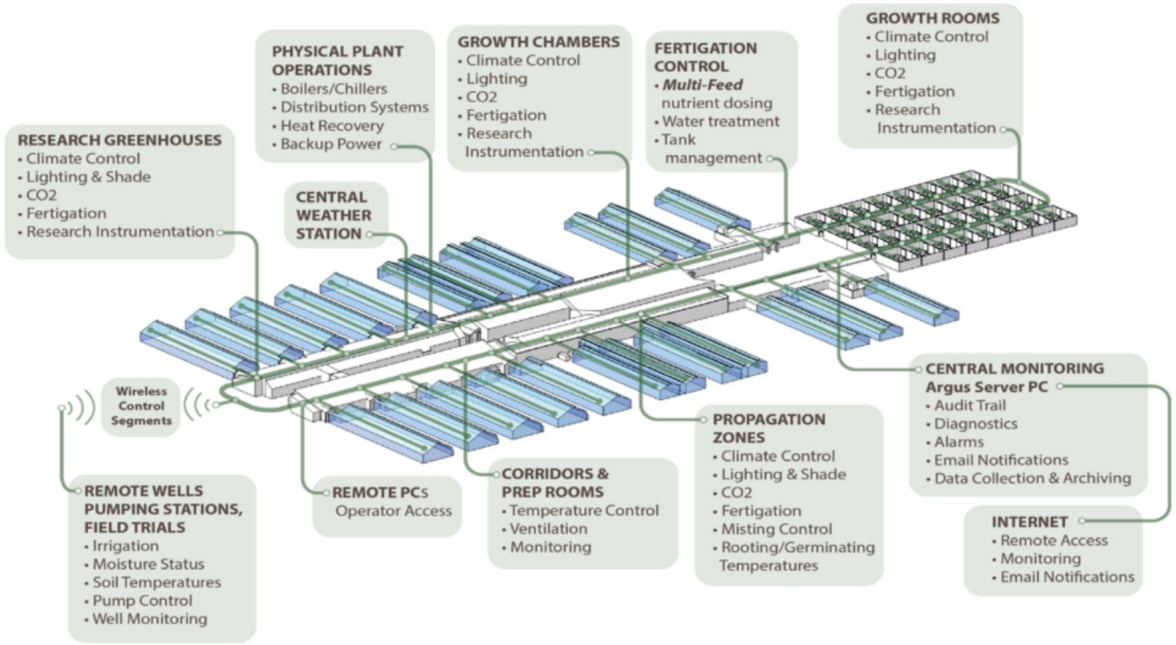


Image credit: Argus Controls

Integrated Controls: Value Proposition

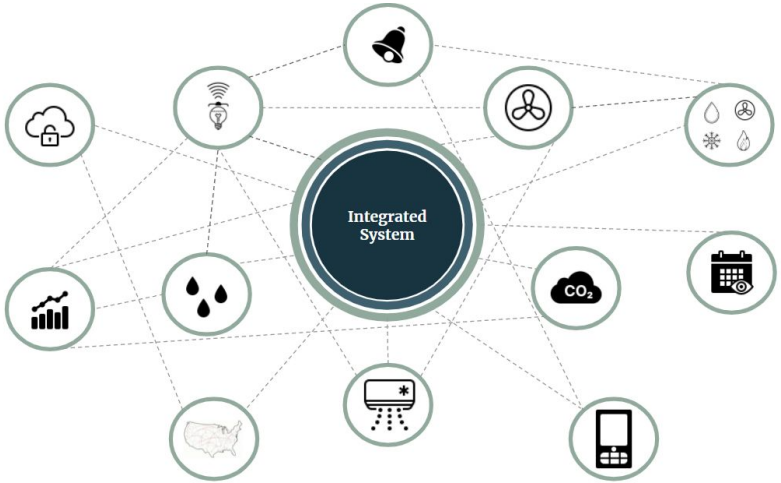
Integration creates consistency across facility systems

Consistent Data

- Cross-system health at a glance - faster resolution
- Consistent dashboards, overlays - spot interactions
- Common data repository - record all data
- Controlled API access - external integrations

Consistent User Experience

- Ease of use - personnel
- Consistent access controls - security
- Common alerting, configuration, annotations - risk



Minimize risk while maximizing security and speed

Figure credit: Microclimates

Feed-Forward Controls for Lighting

Lighting Benefits from Predictive Controls

- Predictive controls and cost-effectiveness
  - Weather
  - Peak demand
  - Shade control integration
  - Photoperiods
  - DLI

Map Your Controls and Responses

  - Zones
  - Dimming
  - Response rates
  - Ambient conditions and interactive effects

Traditional Indoor HVAC Systems

Non-Integrated Systems

- Standalone Dehumidifiers
- Air Conditioning Units
  - RTU's, Splits, VRF, or CW FCU's
- Oscillating Wall Fans

Considerations

- A/C units must overcome heat rejected by dehumidifiers
- Standard commercial HVAC cannot handle unique load profiles
- Difficult to control/integrate; lack of homogeneity

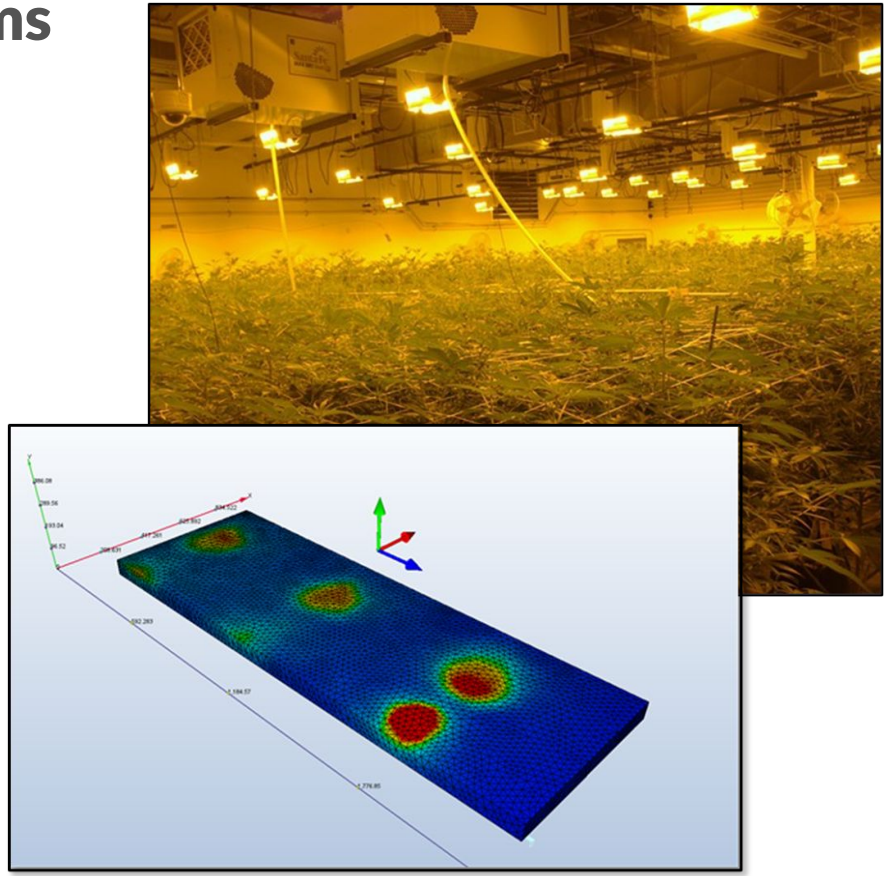


Figure credit: InSpire Transpiration Solutions

High-Performance Indoor HVAC Systems

Integrated Systems

- One system to handle cooling, heating, and dehumidification.
- System types include: DX w/ reheat, desiccants, and CW/HW

Considerations

- Purpose built for indoor horticulture
- Modulating components to match load profiles
- Proper room airflow design for good mixing & homogeneity
- Opportunities for energy efficiency

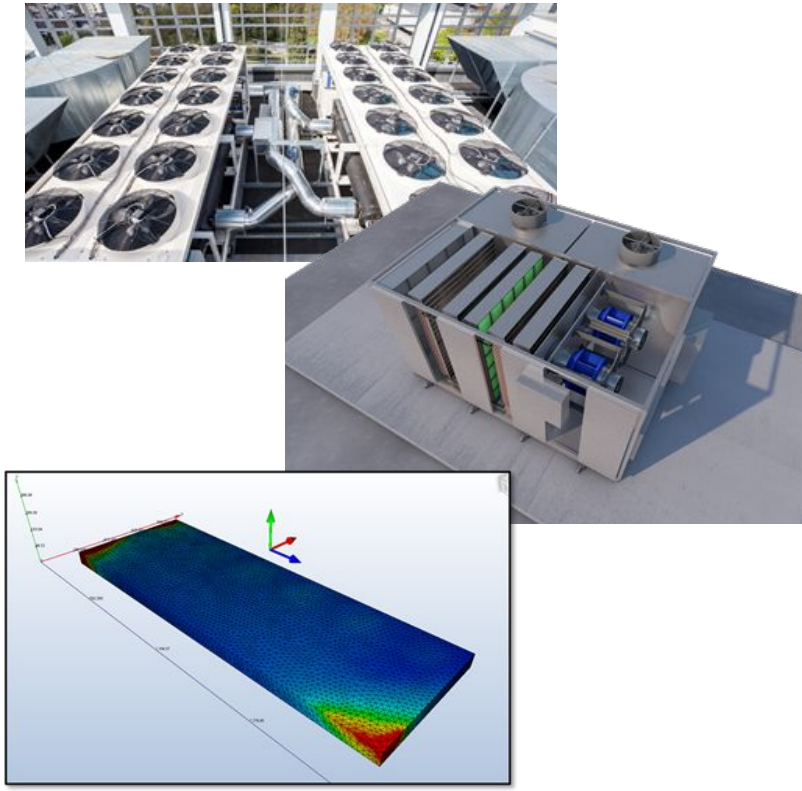


Figure credit: InSpire Transpiration Solutions

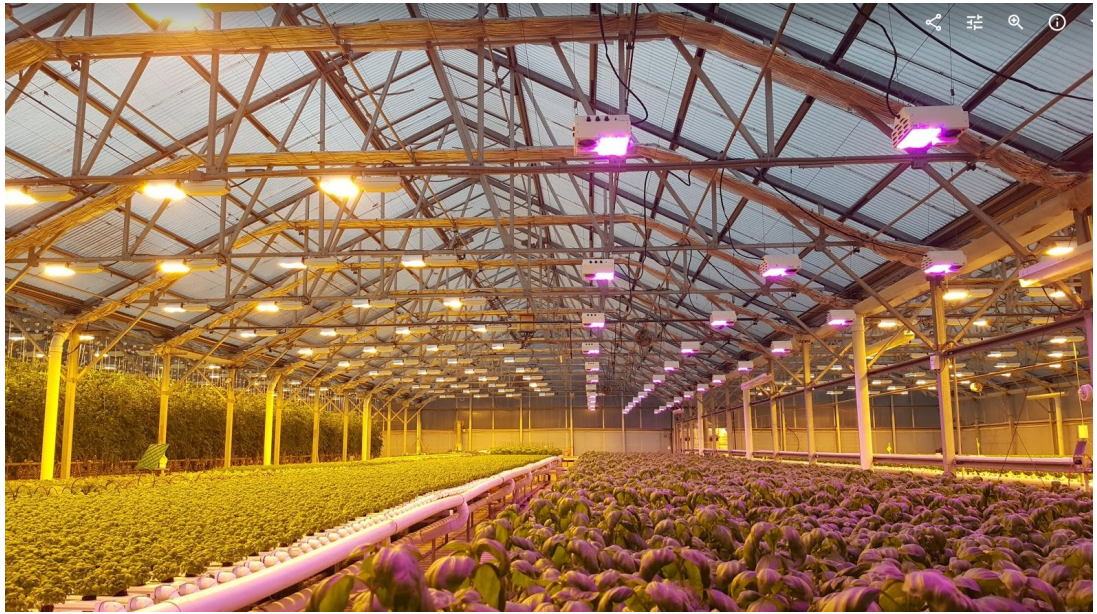
SECTION 03

OPTIMIZING DESIGN OF CONTROLS SYSTEM

Systems to Control: Lighting

Sensors and their integration

- New construction or existing
- Wireless vs. wired
- Determine zones
- Controlling vs monitoring
- Key points to monitor



Lighting Controls Strategies

Scheduling

- Adjust photoperiod

Dimming

- Modulate light intensity by zone of control
  - Daily
  - By stage of plant growth

Spectral Tuning

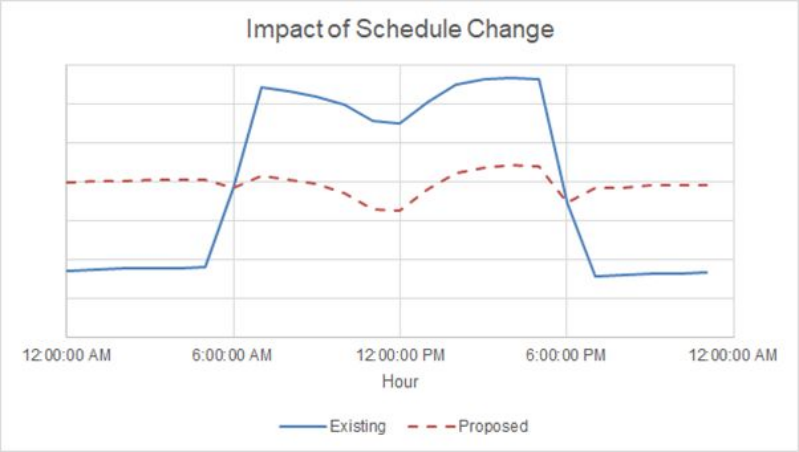
- Modulate photon output from wavelength ranges

Understand energy savings potential of strategies and data needed to validate performance

Table 3: Lighting Controls Parameters Measured by Cannabis Cultivators

Lighting Data Collected[5]	Percentage of Growers Collecting, 2020
Light intensity (PPFD)	55%
Spectral quality	33%

Balanced Flowering Rooms



Credit: Cannabis Business Times (top, figure data source), ERS (bottom)

Designing Lighting Controls Systems

Planning Lighting Controls

- Facility location
- Crop being grown
- Growing seasons
- Cost vs. performance
- Perpetual harvest
- Maximizing production
- Balancing efficiency

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

Figure credit: Solar Therapeutics

Designing Lighting Controls

Power and Light Planning

- Pre-install design, mapping, PPFD
- Configuration vs commissioning
- Post-install verification
- Ties to Rebates (M&V)

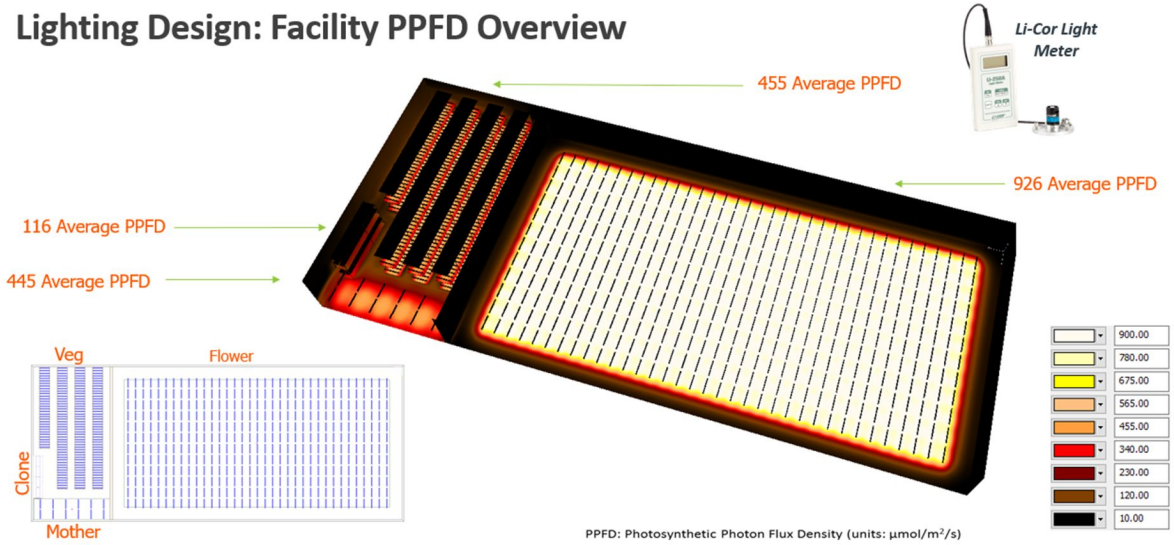


Image credit: Fluence by OSRAM

Spectra Choices

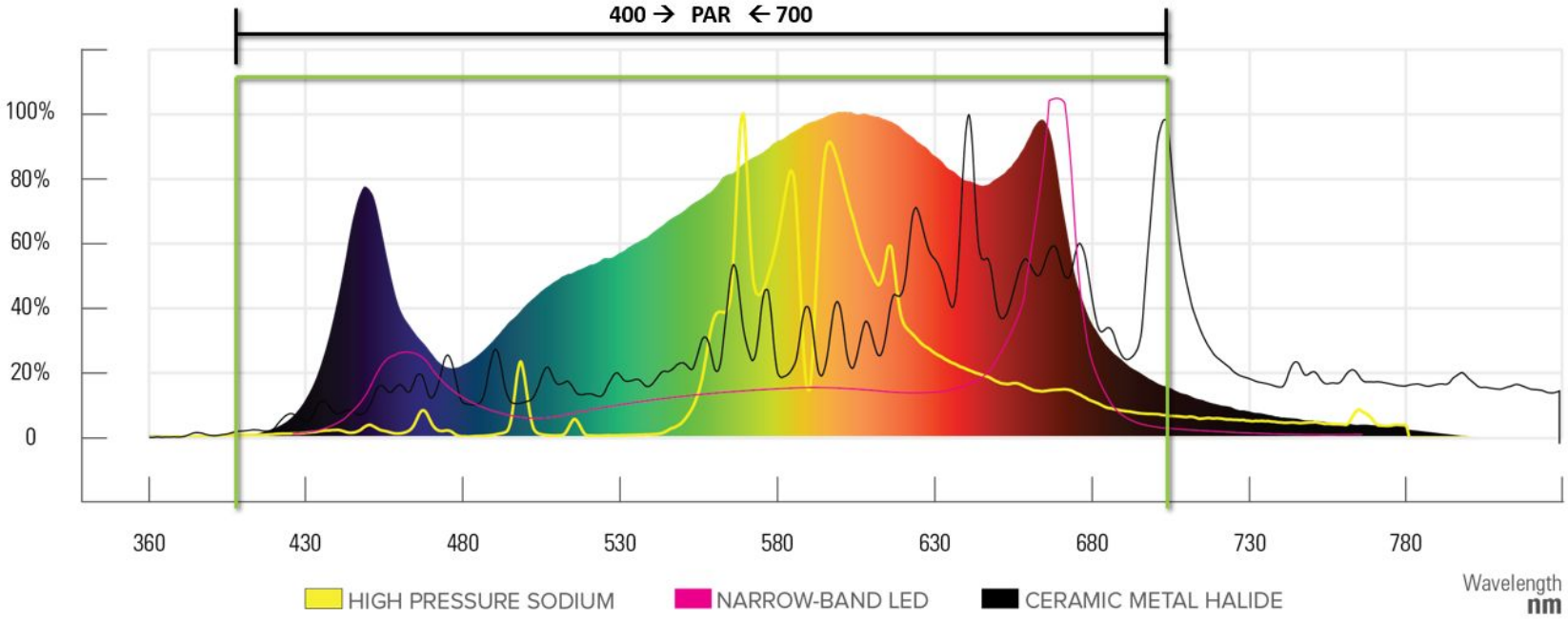


Image credit: Fluence by OSRAM

Commissioning Lighting Controls

Advanced Lighting Systems

- Verification of installation
- Remote monitoring
- ***Integrated startup and commissioning***
- ***Networked interface***
- ***Interactive GUI***
- Reporting and metrics and verification

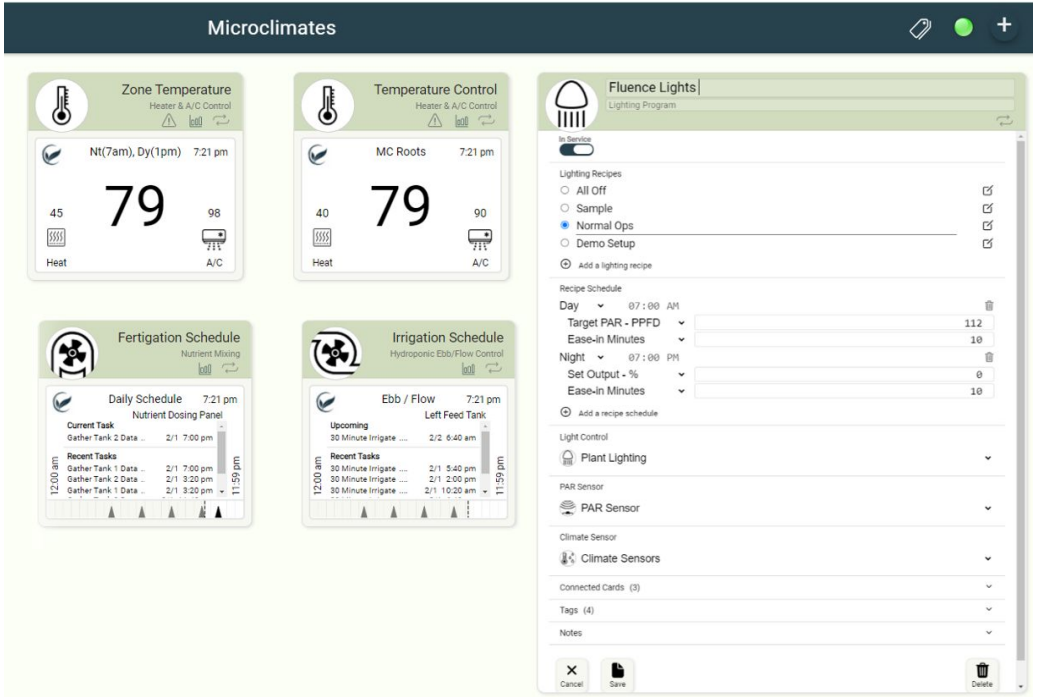


Image credit: Microclimates

HVAC Controls: Interactive Effects

Respond to light and water

- Orchestrate your envelope and HVAC controls to call and respond to daily and seasonal solar variation and your supplemental lighting controls
- When the sun sets, humidity spikes, and control strategies give envelope and HVAC equipment more time to ramp up and respond
- Likewise, plant stage of growth and timing of watering events can demand more of your HVAC system

HVAC equipment should monitor both lighting and irrigation controls activities for faster response times and happier plants

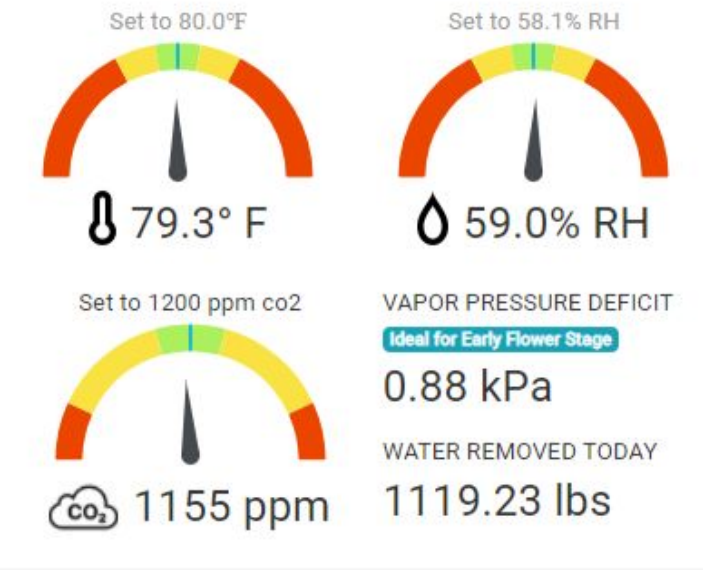
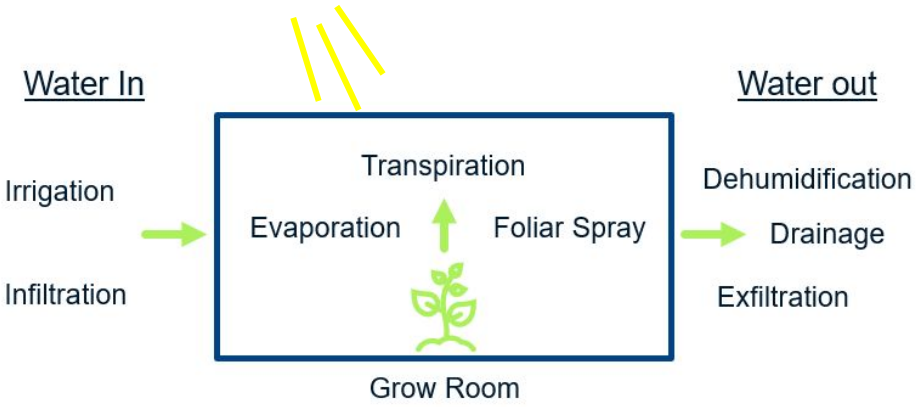


Figure credit: InSpire Transpiration Solutions

HVAC Design: Dynamic Spaces

- Sealed cultivation spaces, generate substantial and dynamic loads
  - Loads shift dramatically during the lights on to off transition periods.
  - Loads change as plants mature and transpiration rates increase



To design and operate efficient HVAC systems, we need to understand what is happening in these spaces throughout the harvest cycle.

Figure credit: InSpire Transpiration Solutions

HVAC Controls Parameters

VPD Controls

- Target ranges vary by stage of plant growth
- Dial in energy-efficient VPD setpoint ranges

Airflow Controls

- Sizing for cultivation can range from 10 to 20 ACH, with some cases as high as 30 - 40 ACH

Understand energy savings potential of strategies and data needed to validate performance

Table 5: Climate and Airflow Controls Parameters Measured by Cannabis Cultivators

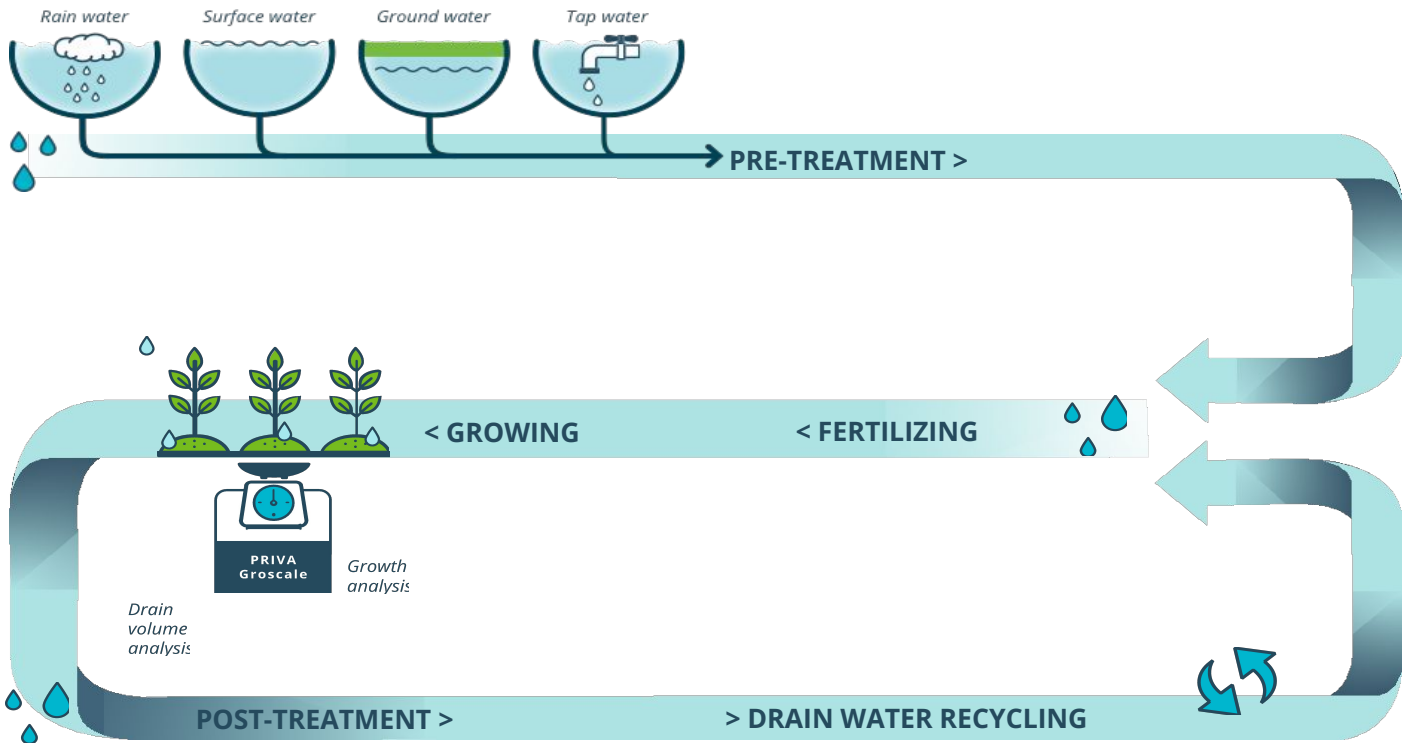
Climate and Airflow Data Collected[7]	Percentage of Growers Collecting, 2020
Space Temperature	85%
Relative humidity	72%
CO2 concentration	66%
Leaf temperature	31%
Air speed	19%

Table 6: VPD Targets for Cannabis Cultivation

Cannabis Growth Stage	Target VPD Range (kPa)
Flower/Bloom/Mother	1.0 - 1.5
Vegetative	0.8 - 1.1
Clone/Seedling	0 - 0.2

Figure data source: Cannabis Business Times

Water Controls: Water Recycling



Credit: Priva

Water Controls: Irrigation Measures

Reduce pumping energy while managing water quality

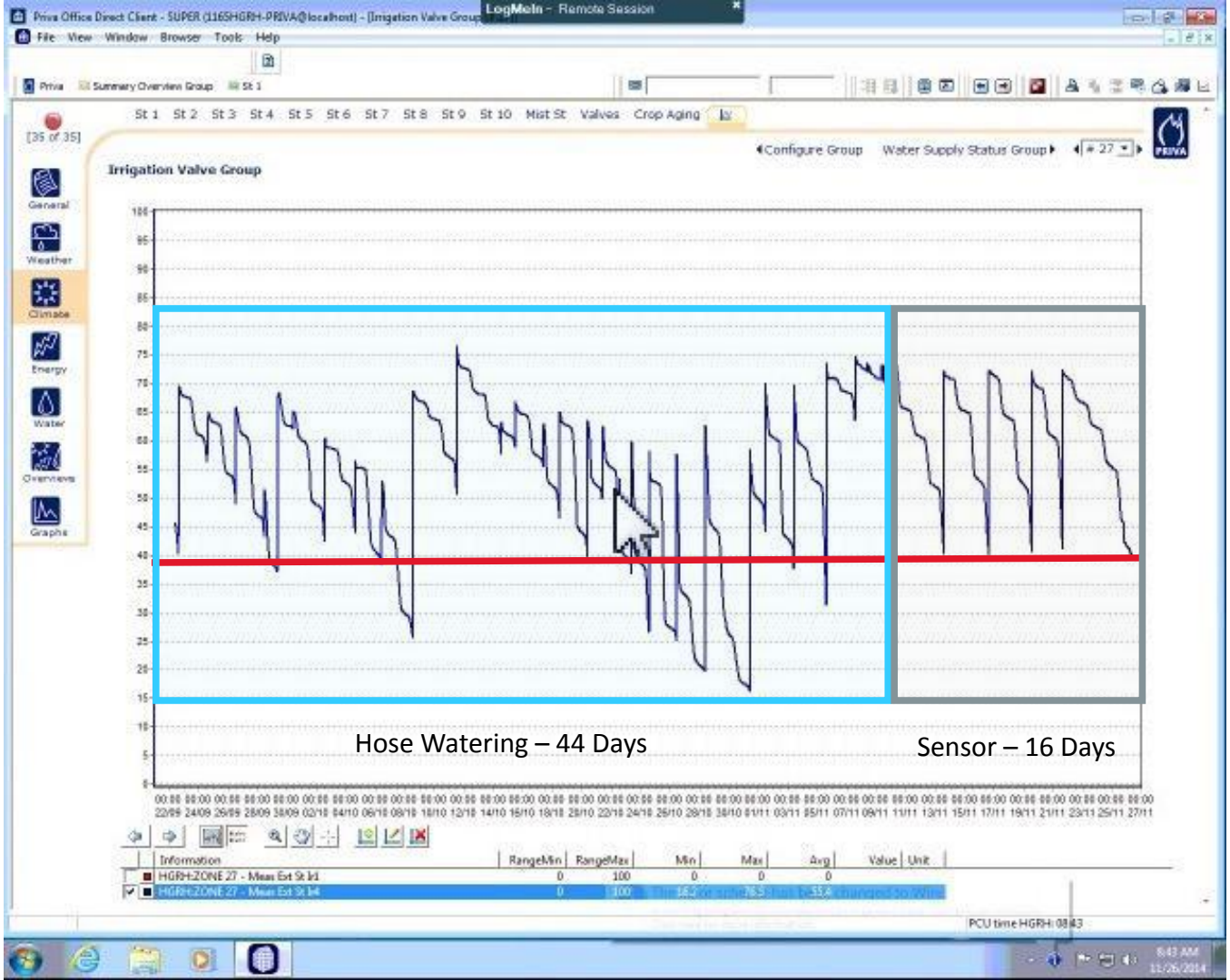
- Choose substrates with lower leach percentage to manage less runoff
  - Lower leach may be achieved with water culture approaches that recirculate irrigated water
- Understand watering and drainage rates
  - Watering events can range from 1 - 20 per day depending on your choice of substrate
- Employ drip irrigation controls

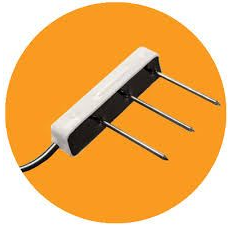
Precise targeting of drip irrigation can reduce water consumption by 30% to 70%, and improve water productivity by 20% to 90%

Table 8: Water Controls Parameters Measured by Cannabis Cultivators

Water Data Collected	Percentage of Growers Collecting, 2020
Nutrient solution pH	76%
Substrate pH	54%
Nutrient solution electrical conductivity (EC)	51%
Media EC	38%
Root zone temperature	21%

Credit: Cannabis Business Times (figure data source)


Irrigation Valve Group
Hose Watering – 44 Days
Sensor – 16 Days



SECTION 03

BEST PRACTICES FOR ADVANCED CONTROLS

Monitoring, Calibration, Commissioning

Monitoring

- You can't manage what you don't measure...but you can't measure what you don't monitor
- Make data to support savings claims

Calibration

- Ensure sensor accuracy so systems respond to actual environmental conditions
- Configure response times to reduce short-cycling

Commissioning

- Functionally test HVAC sequences of operation to ensure persistent energy savings

Figure credit: Gro iQ / InfiSense

Design-Phase Commissioning

Early Engagement to Plan Controls

- Design for annual production
  - All seasons and consistent production
- ***Analyze supplemental lighting needs***
- Understand interactive effects on systems:
  - Power
  - HVAC and humidity management
  - Water
- Plan your controls system ***responses to conditions outside of target ranges***

	Average Daily DLI	Delivered Avg DLI	Required DLI
Month	Hagerstown, MD		
January	14.6	10.22	36.78
February	20.6	14.42	32.58
March	28.7	20.09	26.91
April	35.4	24.78	22.22
May	41.4	28.98	18.02
June	44.1	30.87	16.13
July	43.5	30.45	16.55
August	39.1	27.37	19.63
September	31.2	21.84	25.16
October	23.2	16.24	30.76
November	16.1	11.27	35.73
December	13.2	9.24	37.76

HVAC Controls Trends: Temperature, RH, CO2

Understand how parameters affect environment

- Observe the interaction between control points

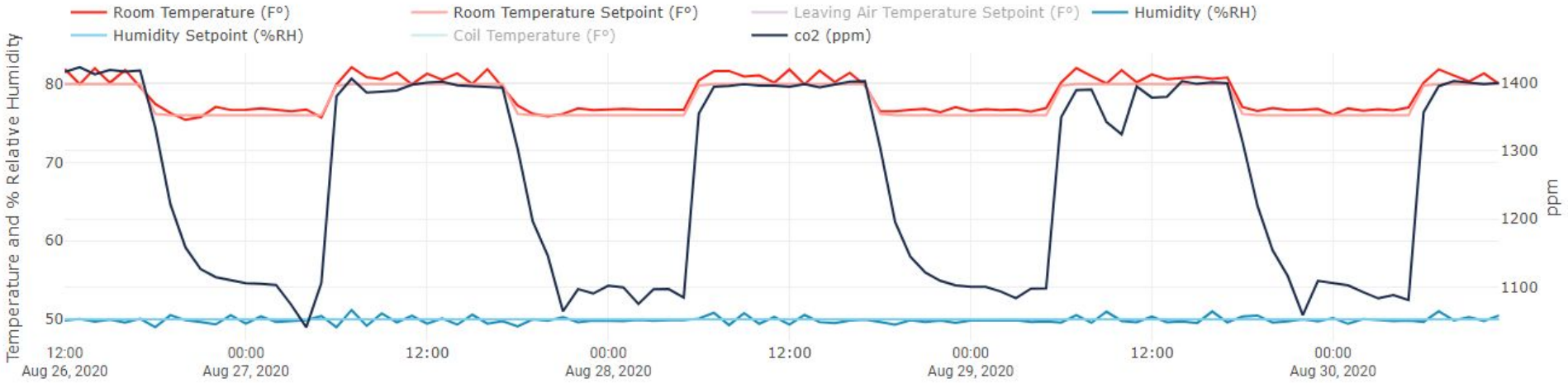


Figure credit: InSpire Transpiration Solutions

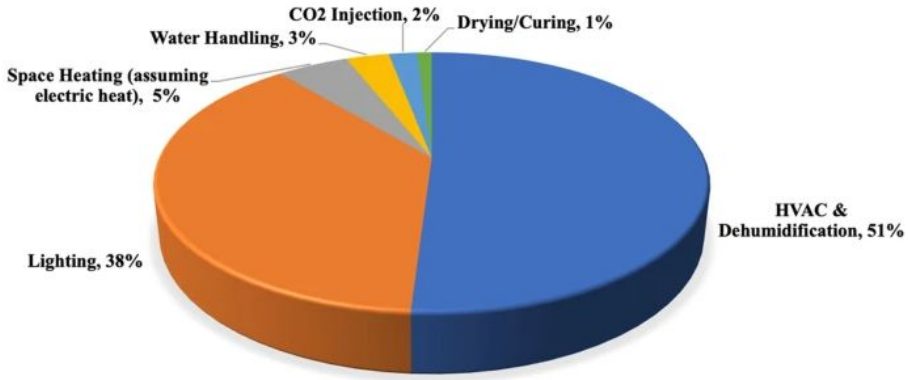
Energy Consumption

-

Electricity Consumption

- Lighting, HVAC and dehumidification
  - 89% of total end-use electricity consumption

Fig. 1



End-use electricity consumption

Figure credit: Journal of Cannabis Research

Carbon Dioxide Enrichment

- For tightly sealed facilities, needed to maintain at least 400ppm for normal Ps, otherwise drops too low
- 800-1200ppm often used for enrichment levels to increase Ps and yield
- Light and temperature need to be elevated to justify enrichment for increasing yield
- However, CO2 can be used with low light and cool temps to maintain a normal Ps rate while saving energy
- Caution: For greenhouses with passive ventilation or cooling, CO2 cannot be used during these periods

SECTION 02

BENCHMARKING CONTROLS 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

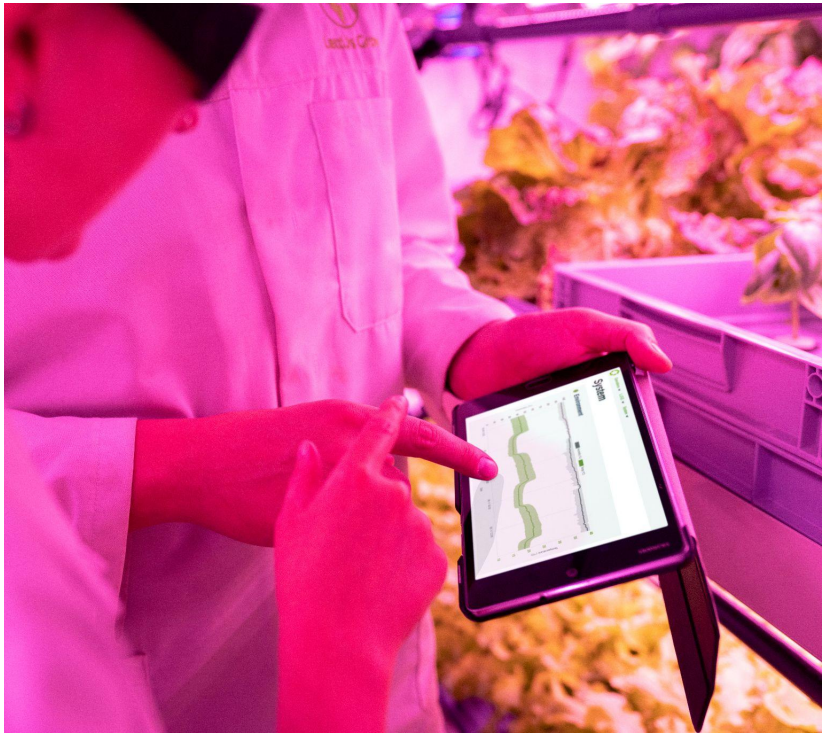


Figure credit: Rhode Island Department of Environmental Management

Facility Performance Snapshots

Key Performance Indicators for CEA

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

- Efficiency (kBtu/ft2 canopy)
- Productivity (kBtu/lb harvest)

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

- kWh/day → annual facility energy use

Observe changes in canopy productivity

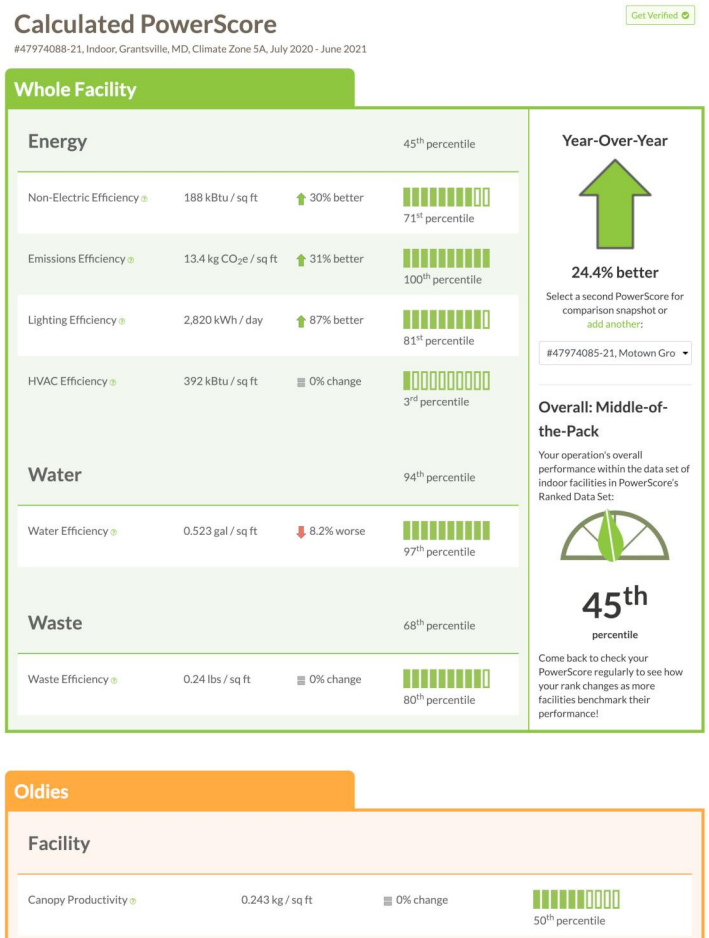


Figure credit: RII, PowerScore

Data Driven Growing = Efficiency

Track and steer cropping inputs impact on yield

- Energy efficiency
- Water efficiency
- Nutrients efficiency
- CO2 efficiency

SECTION 11

MAXIMIZING TECHNICAL ASSISTANCE

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

Consumers Programs for CEA Customers

Consumers Energy
Count on Us®

Energy Efficiency Programs

Grow for less and earn rebates when you install

Indoor Agriculture - Electric Customers

- LED Grows
- Stand-alone dehumidifiers
- HVAC
  - Split systems/ RTUs
  - Mini Splits/ VRFs
  - Chillers

Greenhouses - Natural Gas Customers

- Greenhouse Environmental Controls
- Boilers/ Unit Heaters
- Poly Film/ Shade Curtains

Incentive Application

For more information please call Connor Robertson or Rachel Fredrickson
connor.robertson@cmsenergy.com or rachel.fredrickson@cmsenergy.com Call: 877-607-0737

Program Offerings for CEA Customers

Consumers Energy
Count on Us®

Energy Efficient Equipment Incentives for Indoor Farms
Network Lighting Control (NLC Program)

- Goal:
  - Achieve greater savings in C/I facilities vs. analog lighting controls.
  - Accelerate the adoption of NLC systems across CE territory.
- The NLC segment works with facility managers to improve on facilities:
  - Productivity
  - Safety & security
  - Employee well-being and aesthetics
- *Can save up to 90%* on a facility's general lighting budget*.

For motion information please contact the Consumers Energy's NLCI Program Manager **Aaron Kwiatkowski Aaron.Kwiatkowski@cmsenergy.com**

Consumers Incentive Examples

Indoor Ag NLC - Muskegon Michigan	
Total Square Footage	29,614.00
Annual Hours of Operation	8,760
Baseline kWh/Year (ASHRAE 90.1 2013)	303,519.81
Post kWh/Year	13,673.22
% Saved from Lighting Retrofit	90%
% Saved from implementation of Control System	95%
Total Project Costs	$137,655.20
Total Incentive Received	$68,827.60
Simple Payback Period	**4.32 years**

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Consumers Greenhouse Customer Incentive Examples

Consumers Energy
Count on Us®

Facilities > 100,000 total square feet

Manufacturing/Industrial/Warehouse

$0.18 per kWh saved for one year

Commercial/Retail/School/Hospital

$0.25 per kWh saved for one year

**Energy Reporting via the NLC system mandatory*

Facilities < 100,000 total square feet

Any facility type

$0.25 per kWh saved for one year

**Energy Reporting via the NLC system optional*

Program Offerings for CEA Customers

Energy Efficient Equipment Incentives for CEA

DTE

- Efficient LED lighting
- Stand alone Dehumidifiers
- HVAC units
- **Now offering:** incentives for Energy Modeling! (takes a closer look at environmental controls, management systems, and scheduling)

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 Energy Modeling Project

CASE STUDY:
2022 Energy model customer

- Previously claimed over 14 million kWh in savings over several projects (over $600k in incentive dollars)
- Using modeling software vs. a baseline grow facility and taking into account the environmental and lighting controls, scheduling, irrigation, etc.., we were able to claim an additional 4.7 million kWh and get the customer over $235,000 in supplemental incentives

DTE

Program Offerings for Lansing BWL Customers

2022 Hometown Energy Savers Incentives for Indoor Agriculture

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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Contact Josh or Glenn for more information: jpetersen@slipstreaminc.org; gvoisin@slipstreaminc.org

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

Lansing BWL Hometown Energy Savers

New Construction Grow Facility Completed 2022 - Example 1

Installation of over 200 LED Grow Lights	
Project cost	$202,350
Cash incentive awarded (Capped for 1 Meter)	$50,000
Estimated annual electric savings	262,632 kWh
Estimated annual cost savings	$33,264
Simple payback	4.6 Years

LANSING BWL Hometown People. Hometown Power.

Contact Josh or Glenn for more information: jpetersen@slipstreaminc.org; gvoisin@slipstreaminc.org

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

Lansing BWL Hometown Energy Savers

Grow Facility Addition Completed 2022 - Example 2

Installation of 30 LED Grow Lights and Dehumidifiers	
Project cost	$35,280
Cash incentive awarded	$13,173
Estimated annual electric savings	130,116 kWh
Estimated annual cost savings	$14,000
Simple payback	1.6 Years

LANSING BWL Hometown People. Hometown Power.

Contact Josh or Glenn for more information: jpetersen@slipstreaminc.org; gvoisin@slipstreaminc.org

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

Lansing BWL Hometown Energy Savers

Incentives and Services

Other Incentives Include …

- LED Interior & Exterior Lighting
- Efficient HVAC & Controls
- Refrigeration & Kitchen Equipment
- And More!

Services Include …

- Technical Assistance
- Application Assistance

Contact us early! Pre-approval may be required.

Contact Josh or Glenn for more information: jpetersen@slipstreaminc.org; gvoisin@slipstreaminc.org

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

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

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