Indoor Agriculture Energy Savings Deep Dive #3: CONTROLS

November 19, 2020

Presented by:

RESOURCE INNOVATION INSTITUTE

In cooperation with:

UMass Amherst

Organized by:

MAEEP
Massachusetts Energy Efficiency Partnership
nationalgrid EVERSOURCE

Agenda

Welcome, introductions & purpose	1:00 pm
Automation & controls strategies for new construction & retrofits	1:10 pm
HVACD controls	1:20 pm
Lighting controls	1:25 pm
Integration and automation of systems & processes	1:30 pm
Planning for flexible demand management	1:50 pm

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@RIInstitute

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We advance resource efficiency to cultivate a better cannabis future

Energy | Water | Waste | Carbon Emissions

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Objective | Non-profit | Data-driven

Strategic Direction

Extension of services to CEA

USDA (NRCS-CIG) funding
Market characterization
Resource benchmarking
Best practices

Additional energy measures

Automation & Controls
Design & Construction

Water recirculation

Best practices

We bring stakeholders together to:

Measure and report resource efficiency

- Benchmarks
- Baselines

Inform governments, utilities & industry

- Best practices & standards
- Policies
- Programs

Validate cultivation approaches

- Technologies
- Techniques

Trusted by Programs, Cultivators, Supply Chain, & Governments

Technical Advisory Council

Multi-disciplinary body facilitated by RII to aggregate knowledge and data to support cultivators, governments, utilities, standards bodies and other stakeholders with objective, peer-reviewed information on cultivation resource use and quantification of performance

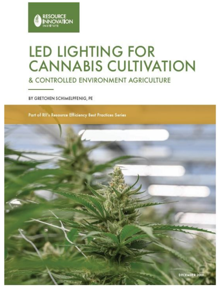
1. Provides guidance on development of standards
2. Shapes tools and resources to support best practices
3. Informs advocacy on policies, incentives and regulations

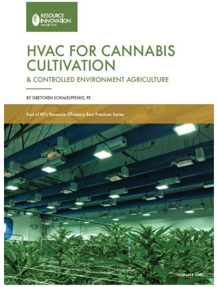


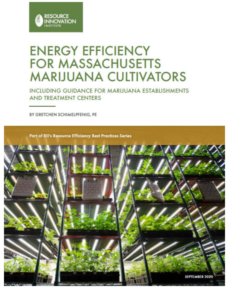
Technical Advisory Council Working Groups

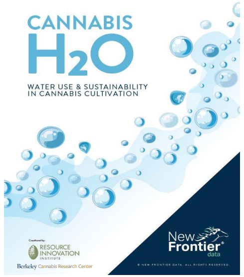
2019	Q1 2020	Q2 - Q4 2020	2021
Lighting	Utility	Water	*Design & Construction*
	HVAC	Massachusetts	*Carbon Emissions*
		Policy	
		Data	
		Controls	

IAES'20
Indoor Agriculture Energy Solutions









Best Practices Guides

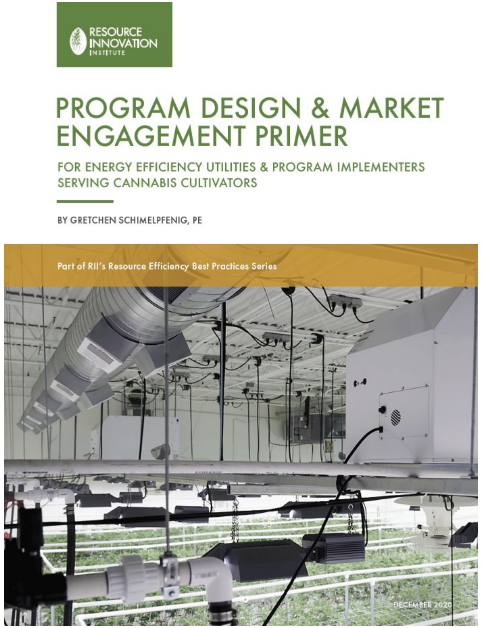
- **60+ contributors & peer reviewers**, including cultivators, architects, engineers, manufacturers
- Defines key terms
- Recommends KPIs
- Meets all growers where they are
- State-specific guidance for Massachusetts

Free downloads at ***ResourceInnovation.org/Resources***

Support for utilities and implementers

- **Educational curriculum**
  Cultivators, utility staff, trade allies
- **Utility Working Group**
- **Best practices guidance**
  Peer-reviewed, brand-agnostic
- **Grower outreach**
  Marketing toolkit
- **Project planning & verification platform**
  M&V guidelines
  PowerScore for portfolios

Efficient yields
CULTIVATION WORKSHOPS
Best practices on energy. Grower led. No sales pitches.



Cannabis PowerScore

Benchmark operational efficiency with Cannabis PowerScore

Competitive

- **KPIs** benchmark facility resource efficiency:
  - Energy: **kBtu/sq ft**
    grams / kBtu
  - Water: **gallons / sq ft**
    grams /gallon
- **Ranks** competitive position relative to other facilities

Trusted

- Used by **300+ cultivators & facilities**
- Metrics **peer-reviewed** by Technical Advisory Council
- **Specified by governments** including Massachusetts

Confidential

- Maintained by a **non-profit**
- **Confidential** survey
- **Protected** individual farm data
- **Free** to cultivators

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PowerScore Performance Benchmarks

KPIs

Energy Efficiency

Facility	3,130 kBtu / sq ft		40th percentile
Electric Facility	976 kBtu / sq ft		37th percentile
Non-Electric Facility			
Production			
Electric Production			
Non-Electric Production			
Lighting Efficiency			
HVAC Efficiency			

Water Efficiency

Water Facility

Water Productivity

Waste Efficiency

Waste Efficiency

Overall: Middle-of-the-Pack

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

Facility Ranking

Learning Objectives

You will leave today understanding:

- **The varying types of HVACD, lighting, and controls systems used for industrial cannabis production processes**
- **Comparing and contrasting energy and non-energy benefits of controls systems**
- **Various kinds of lighting controls and capabilities**
- **Controls to enable flexible demand management in cannabis cultivation operations**

Program Information

If you are a supply chain professional working with cultivators...

Partner with Mass Save program administrators for cannabis client projects

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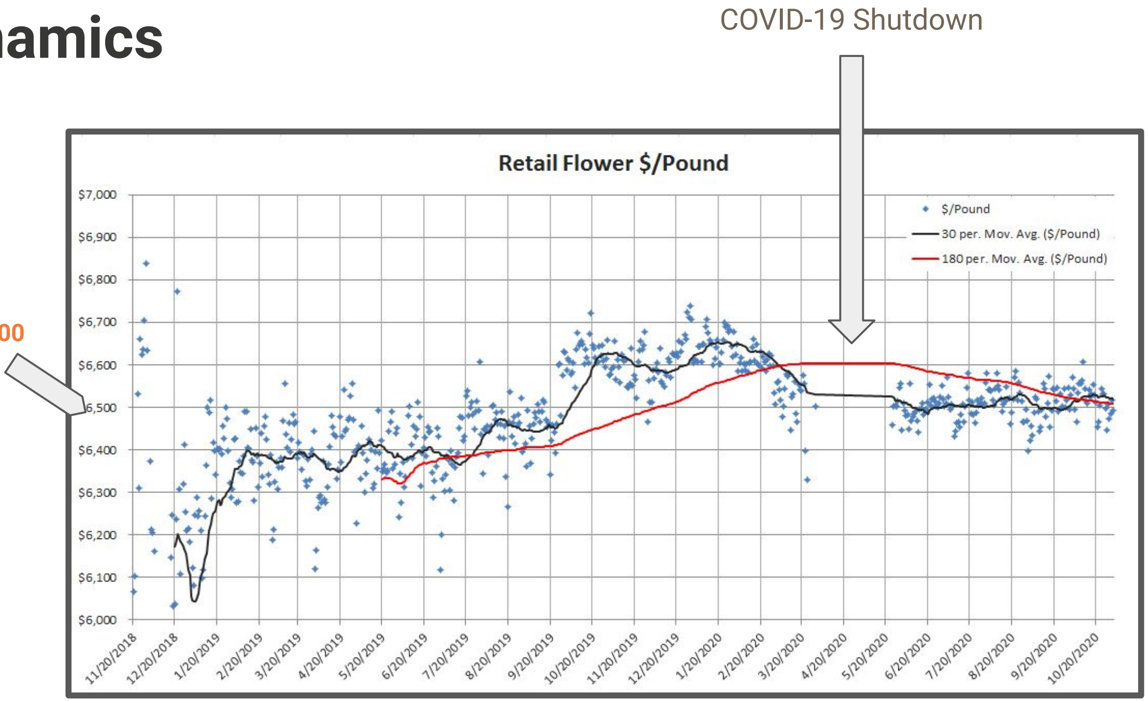
How can automation and controls be considered for new and existing cultivation operations?

Opportunity for Automation & Controls in Indoor Agriculture

- There are so many opportunities for automation and controls for precision ag for high value crops
  - For many ag organizations their process is their intellectual property
  - More controls will be required as precision ag becomes similar to manufacturing and **margins are squeezed by lower wholesale prices**

MA Cannabis Market Dynamics

- Two basic models in commercial indoor ag: maximize output or maximize efficiency
- The cannabis industry currently is in ‘maximize output’ especially in MA where the wholesale price per lb is extremely high



Massachusetts Adult-Use Retail Cannabis Flower Prices -
Chart Credit: Ed Watson / Mainley Productions from Public CCC Data

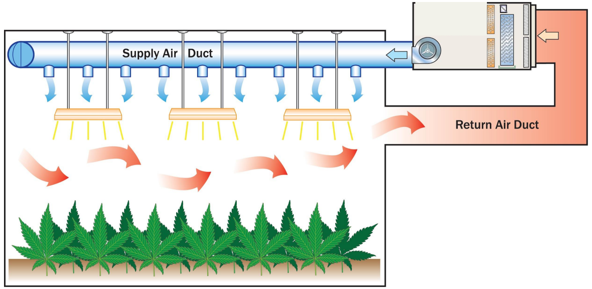
How MA Cannabis Producers See Productivity

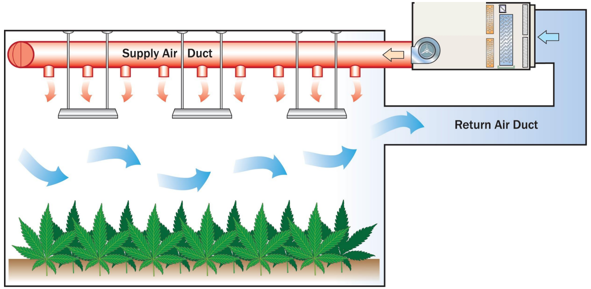
- Productivity KPIs:
  - Grams per sf per year of canopy
  - Cost of production per pound of flower
    - Productivity per unit of energy

In a cannabis cultivation, what are we controlling?

- **HVAC-D:** RH %, temperature, airflow, CO_2 ppm
- **Lighting:** intensity, photoperiod, transitions
- **Water:** treatment (temp, TDS, pH) , fertigation (pH, EC)

Sensing & monitoring equipment provides feedback loops for controls





Producers' Control Systems

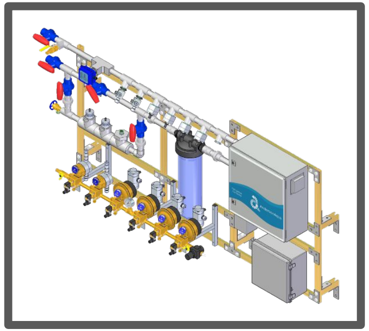
Size of Facility

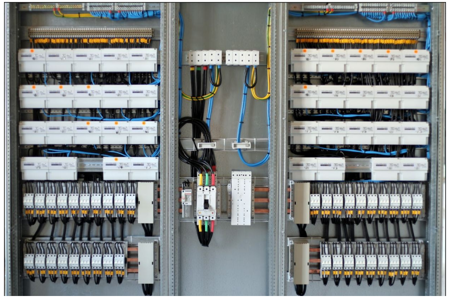
Tier 0 | Tier 1 | Tier 2 | Tier 3+

Basic room control, hand mixed nutrients, other systems ad-hoc and not connected

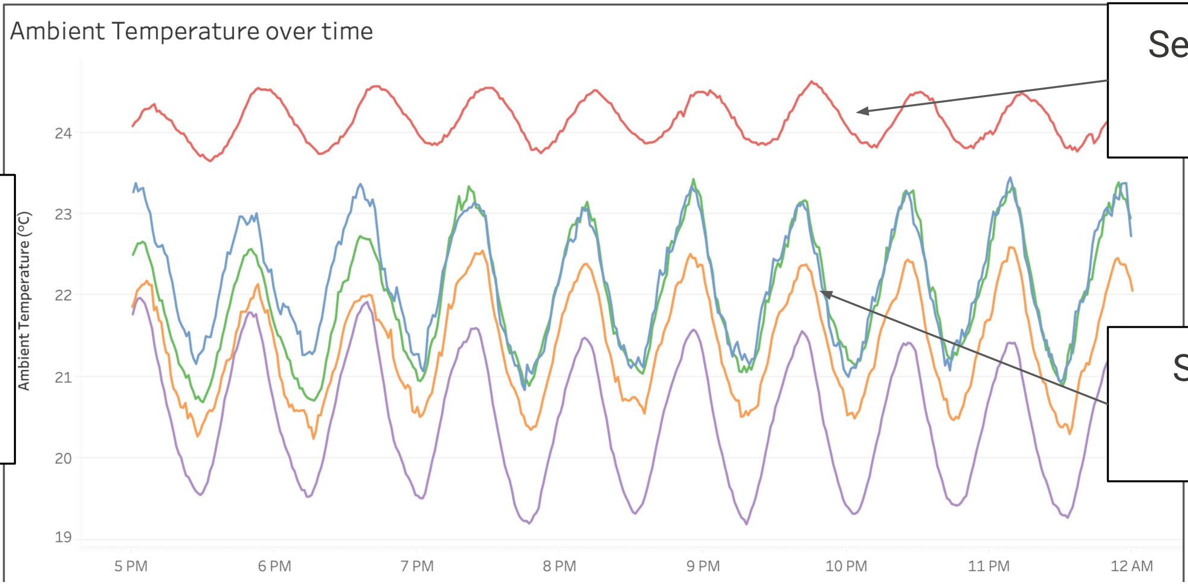
Room by room control, some automation, centralization achieved manually by operator

Fully centralized and automated





Full System Effect Illustration: Control is only as good as the sensor placement



Sensor placed near thermostat

Sensors at plant levels

~2-4 C temperature difference between thermostat and plant levels. Suggest to relocate thermostat to location more indicative of plant conditions

Takeaway: Systems need to be designed and deployed with full system view of how it will be operated. This is hard!

How can HVACD controls be used to save energy and increase productivity in cultivation operations?

Target Environmental Conditions & Equipment Sizing

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%

Learn more about loads and target environmental conditions in RII's Cannabis Business Times editorial ***A 'COY' Approach to HVAC***

Massachusetts Example Sizing & Target Setpoints

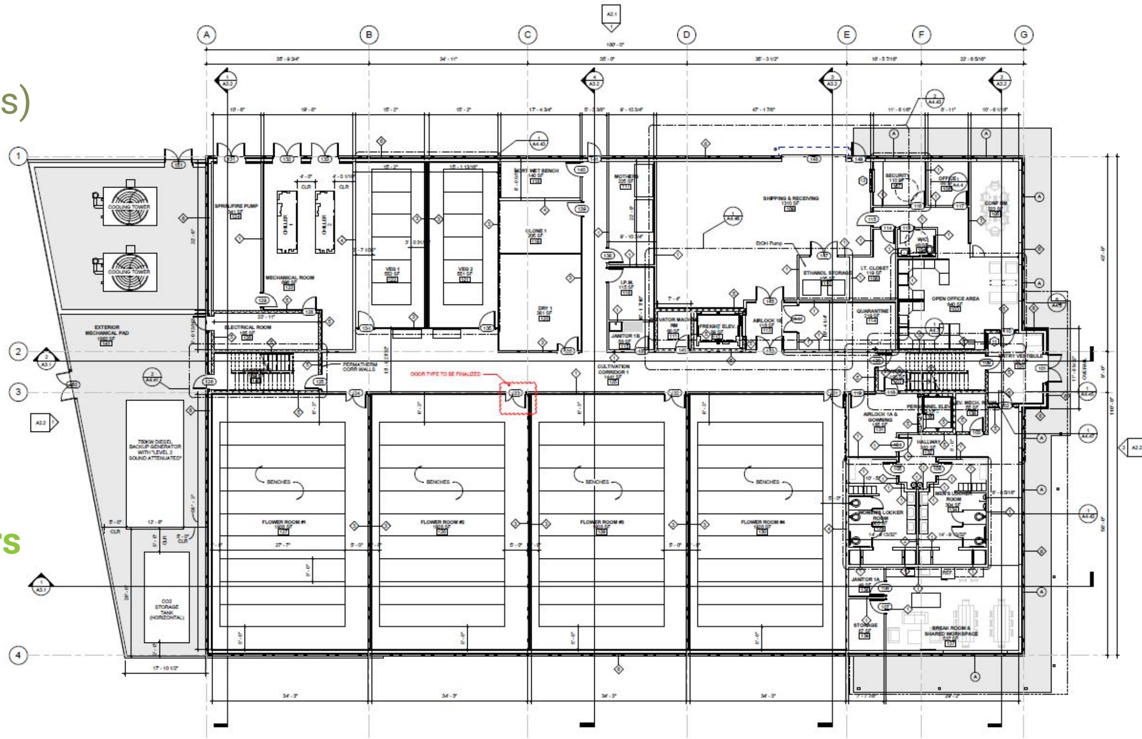
Cultivation and Manufacturing Facility in MA

40,000 GSF/ 16,000 CSF in horticulture
- 12,000sf flower canopy (1-tier benches)

(616)x 630W LED lights (77) per room
35.00 W/CSF (aka HLPD)

Dry Bulb & RH
Day: 80 F +/- 3 F @ 50% RH +/-5%
Night: 72 F +/- 3 F @ 45% RH +/- 5%

Chilled Water / 4-pipe to Modular ERUs
Ventilation: +500 CFM, MERV 11, HEPA
Cooling Load: **400 Tons (2) gas-fired chillers**
Electrical Load: 2,000 Amps 480V 3-phase



ANDERSON PORTER DESIGN

Target Environmental Conditions at Same VPD

Example

Target VPD 1.4 kPa

Targets for HID lighting:

76F / 50% RH

Targets for LED lighting:

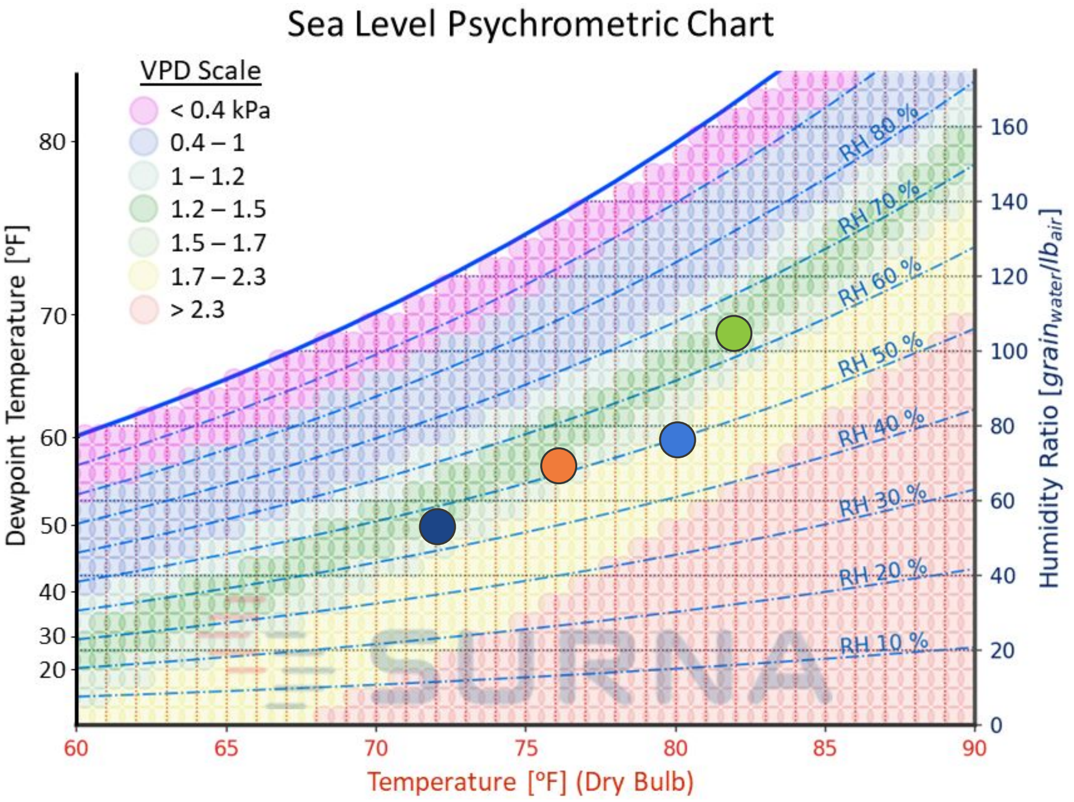
82F / 65% RH

MA example's LED targets:

Target VPDs 1.4 - 1.7 kPa

80F / 50% RH

72F / 45% RH



Target Environmental Conditions Impact HVAC

T [F]	RH [%]	VPD [kPa]	Dewpoint [F]	Change in Air Handling Requirements	Change in BTU/Compressor Requirements
82	64	1.34	68.6	-35-50%	-20-40%
80	62	1.33	65.8	-30-45%	-15-35%
78	59	1.34	62.6	-25-35%	-10-25%
75	55	1.33	57.8	Reference Condition	Reference Condition
72	50	1.34	52.4	+50-90%	+30-50%
70	47	1.33	48.9	+150-250%	+90-130%

Calculations performed at sea level and assume room fully loaded with transpiring plants. Air handling and compressor BTU percentages are estimates and can vary significantly by equipment selections.

Measuring Productivity Impacts of Controls

1. Record target environmental conditions in SOPs
2. Monitor actual environmental conditions
3. Benchmark productivity under existing SOPs
4. Replace or install new controls infrastructure and update SOPs
5. Monitor actual environmental conditions
6. Benchmark productivity continuously
7. Use strategic energy management approaches to understand energy savings using baseline productivity and benchmarking trends

Building Automation System Example #1

- 46,000 square foot building in Plymouth
- Structure built in 1969 and retrofitted in 2017
- Indoor cannabis cultivation operation uses 25,000 square feet of the space
- **Six grow rooms**
- 6,440 square feet of flowering canopy
- Two to three tiers of vertical racking
- Air handling units (AHUs) without economizer

Building Automation System Example #1

- Air handling units (AHUs); one AHU serves each grow room
- Separate units used for drying and trimming areas
- AHUs are connected to a central heating and cooling plant served by two 800 MBH condensing boilers and a high performance 200-ton natural-gas-driven chiller with heat recovery
- **Building automation system to monitor operations and control air handling units, rooftop units, chilled water, boiler, pumps, fans, and CO_2 systems**

Building Automation System Example #1

- Controls system is crucial to ensuring energy savings of HVACD measures
- Controls system can be used to calculate interactive HVAC savings based on actual operation of LED grow lights

ECM #	Description of Energy Conservation Measure (ECM)	Annual Utility Bill Savings			Max Peak Demand Reduction kW	Incremental Cost $	Payback Period Years
		Electric kWh	Gas therms	Cost Savings $			
1	*LED Grow Lights*	*382,642*	*7,358*	***$57,028***	*82.6*	*$206,375*	**3.6**
2	*Exhaust Fans with EC Motors*	*1,251*		***$163***	*0.5*	*$1,350*	**8.3**
3	*Gas-Driven Chiller with Heat Recovery*	*286,674*	*-18,199*	***$19,251***	*49.3*	*$97,240*	**5.1**
4	*Condensing Boilers*		*1,565*	***$1,549***		*$20,018*	**12.9**
5	*VFDs on HWS & CW Pumps*	*16,114*		***$2,095***	*2.7*	*$7,093*	**3.4**

How can lighting controls be used to save energy and increase productivity in cultivation operations?

Dimming Controls for Controlled Environment Agriculture

- Is dimming desirable for the application?
  - Cannabis and non-cannabis crops
  - Diminishing returns
  - Photoacclimation
    - PPFD matching veg and flower, then ramp up day by day
  - Sunrise/sunset
    - Modulate light levels at start and end of day
    - Reduces peak loads on HVACD equipment by ramping up and down relative humidity

Daylight Integral (DLI) Definition

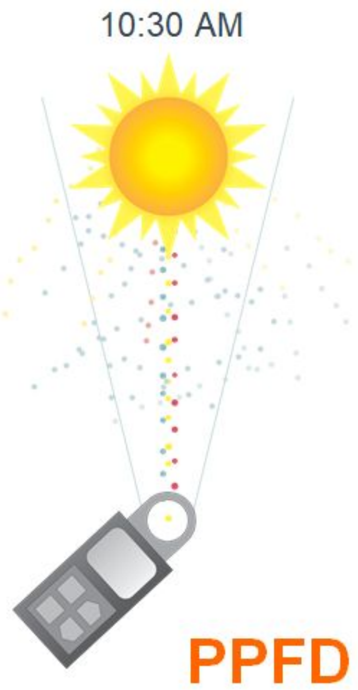
The total number of photons of PAR accumulated over one given area, over one 24-hour period.

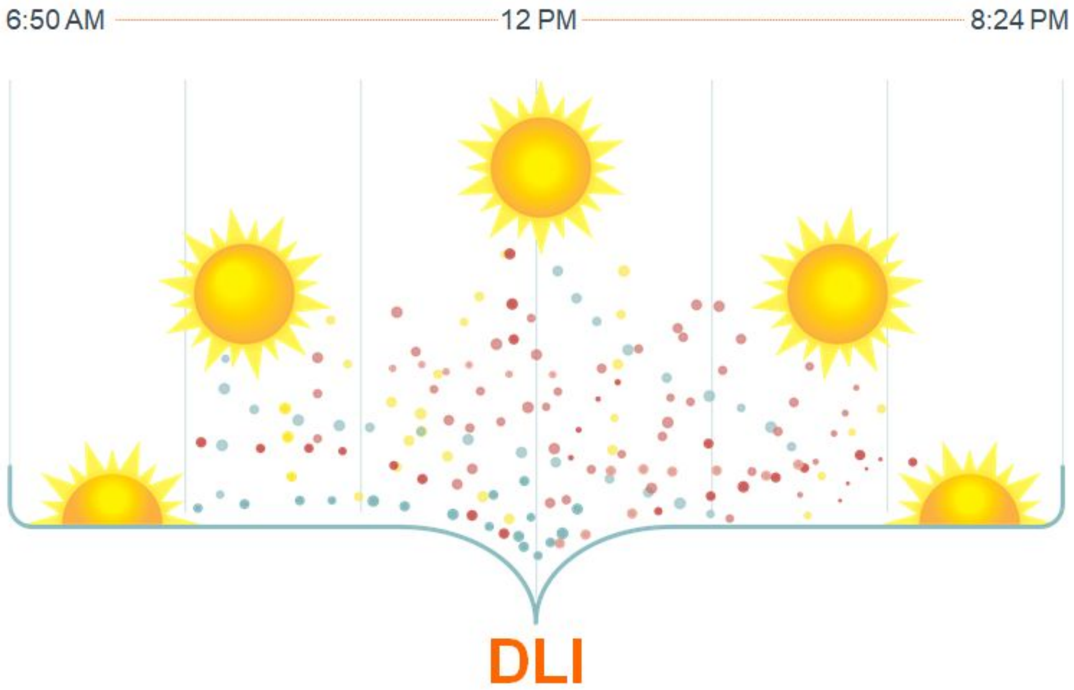
$$\frac{\text{PPFD } (X\ \mu mol/m^2/s) \times 60 \text{ MINUTES/HOUR} \times 60 \text{ SECONDS/MINUTE} \times \text{PHOTOPERIOD (Hours)}}{1{,}000{,}000\ \mu mol/mol}$$

DLC

FLUENCE BY OSRAM

PPFD vs. DLI





DLC

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PHOTOPERIOD CANNABIS

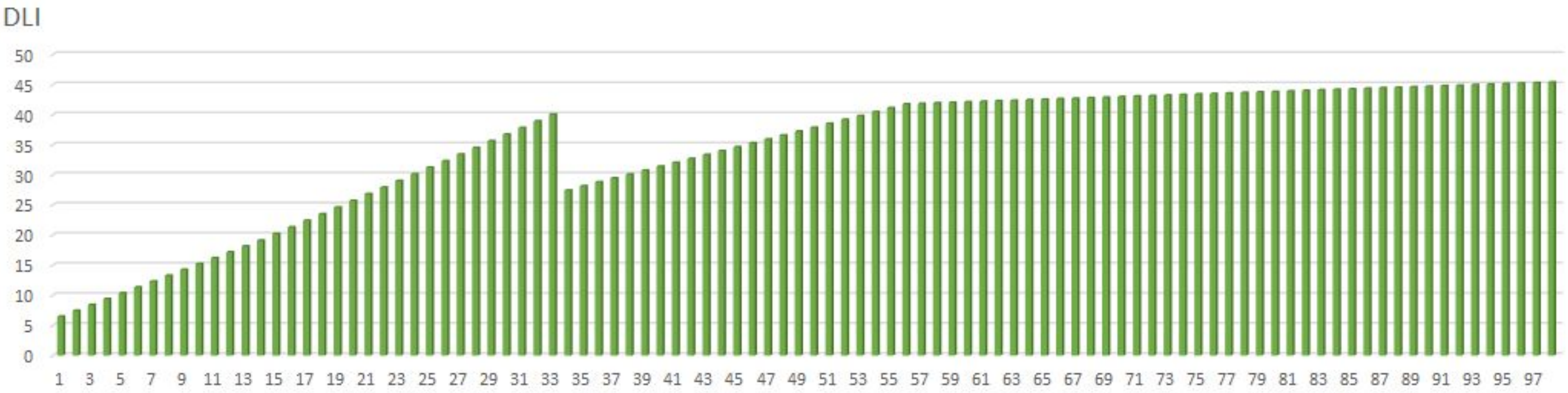
STAGE	Cloning		Vegetative (Bulking)			Acclimation to Bloom (Flowering)						Flowers Maturing		
					Flower initiation begins						Flowers fully formed			Flowers harvested
WK#	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	18 HOUR					12 HOUR								



PHOTOACCLIMATION

Flower initiation begins | Flowers fully formed | Flowers harvested

STAGE	Cloning		Vegetative (Bulking)			Acclimation to Bloom (Flowering)						Flowers Maturing		
WK#	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	18 Hour Photoperiod (Long Day)					12 Hour Photoperiod (Short Day)								
PPFD	80 - ~250/300		~250 – 400/650			650 ---------- 800 ---------- 900-------------950-----------1000--- ?								



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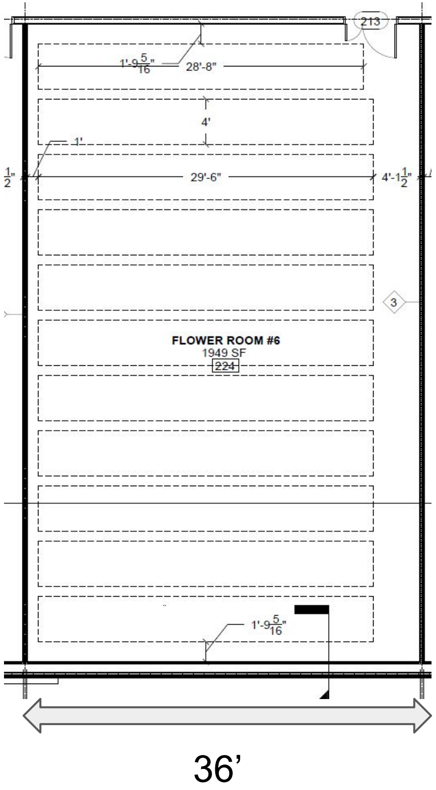
Dimming Controls Considerations

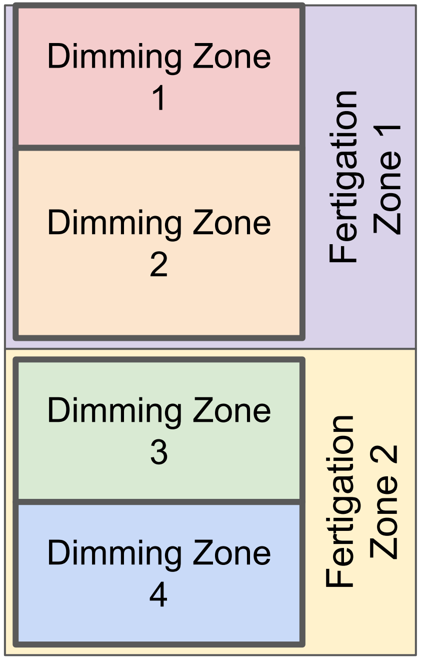
- LED: 0-10V, PWM vs step dimming HID
  - Range of dimming also varies
- Most, but not all, QPL products are dimmable
- Don't make assumptions about spectral tuning
  - Very few products on DLC's QPL are spectrally tunable
- Max distance for multi-product dimming
- Max quantity of fixtures per control product (max source current)

DLC Hort QPL
As of 11/18/20

MA CCC compliant products	164 / 189
Dimmable	144
Non-dimmable	20
Spectrally tunable	5

Massachusetts Lighting Controls Example: Craft / Scale Compromise





- Single level room
- Roll top benches, overhead LED lighting grid
- 1949 sq ft / 1320 canopy sq ft
- ~150 lbs per harvest from this room (~$1M in product)
- 2 irrigation zones per room
- 4 dimming zones
- 4 different plant light X 2 fertigation conditions possible in room concurrently - why?

Target PPFD / DLI

- Target
- Sensing actual light levels
- Recording average light levels
- Feedback loop: is controls system able to respond to sensed/recorded PPFD/DLI?
- Integrated controls matching DLI

Lighting Controls for Mixed Light Applications

- Scheduling with timers
- Dimming capabilities of HID - step dimming, linear dimming
- Warm-up time, hot restrike time
    - May cut it early for day - may not actively turn it up or down, may turn off rows on or off
    - Are growers willing to dim these technologies?
    - Concern about lamp life may prevent growers from more active switching or dimming (already needs frequent replacement)

What to Ask Manufacturers

- Control voltage dimming curve
  - What are the end points and linear function per driver?
- Dimming functionality for spectral tuning
  - Set it maximum
  - Doing it for additional effects
    - Above and beyond yield, don't count on them using it to save energy

Where can project teams access best practices for automation and controls?

Best Practices for Automation and Controls

- Existing resources
  - Lopez, R. and E.S. Runkle. 2017.
    Light Management In Controlled Environments. 180 pp. Meister Media Worldwide, Willoughby, OH.
  - Kozai, T., K. Fujiwara, and E.S. Runkle. 2016.
    LED Lighting for Urban Agriculture. 454 pp. Springer, Singapore.
- RII Best Practices Guide coming in Q3 2021
  - Covering various processes:
    - Lighting, HVACD, Water

How can cultivation facilities use controls to plan for flexible demand management?

Controls for Demand Management

- Controls infrastructure
  - Hardware
    - Load flattening
  - Software
    - Load shifting
- Process for implementation
  - Flexible demand management, demand response

Next Steps

Your Assignment

- Provide feedback via SurveyMonkey
- Attend December 3 workshop on Demand Management

RII Follow-up

Gretchen will:

- Send recording, slide deck and links to shared files from today's workshop
- Provide links to RII resources
- Share information about panelists and their organizations

THANK YOU

Massachusetts Energy Efficiency Partnership

MAEEP
A USDOE Energy Efficiency Partnership

nationalgrid EVERSOURCE

UMass Amherst

Gretchen Schimelpfenig, PE
Technical Director

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Indoor Agriculture Energy Savings Deep Dive #4: DEMAND MANAGEMENT

Thursday, December 3

See you at next month's workshop!

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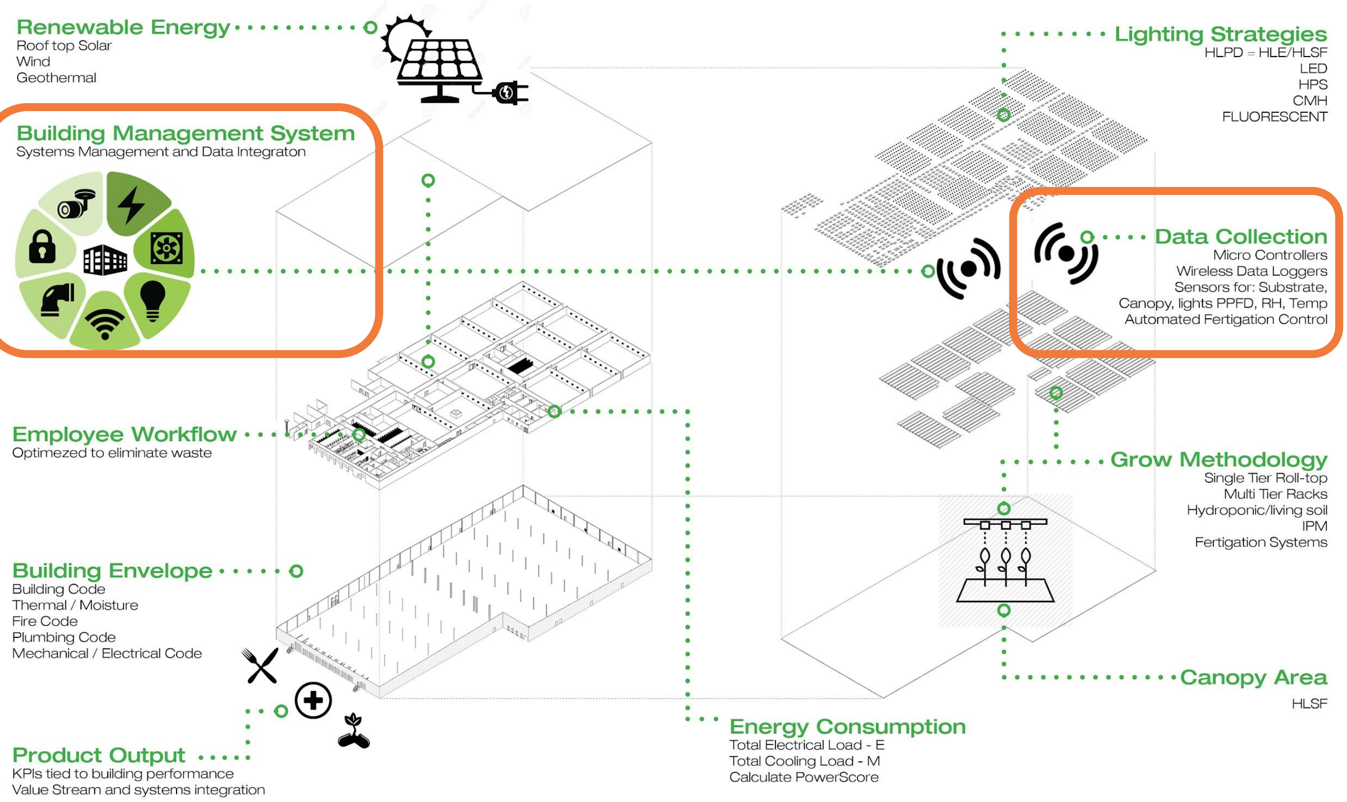
Integrated Design & Operation

- Even if not centralized, systems must be able to monitor and control to maintain all of the room parameters
- Ex: CO_2




SYSTEM - LIGHT DEP CURTAINS
PROCESS - AUTO FERTIGATION SPRAYERS
SYSTEM - ENVIR SENSORS FOR HVAC
PROCESS - MOVING TABLES
SYSTEM - CLOUD ENABLED CONTROL
PROCESS - COMPLIANCE FRID TAGS
SYSTEM - RADIENT HEAT RECYCLE LOOP