DLC℠

CONTROLS SUMMIT ‘24

Integration for the Future

Oct. 15-16 · Milwaukee, WI

Horticultural Controls

Panelists

Kasey Holland

DesignLights Consortium

Mohammed Yousif

Independent Electricity System Operator

Tom Hamilton

Fluence

Eric Noller

Energy Resources Integration

Eric Eisele

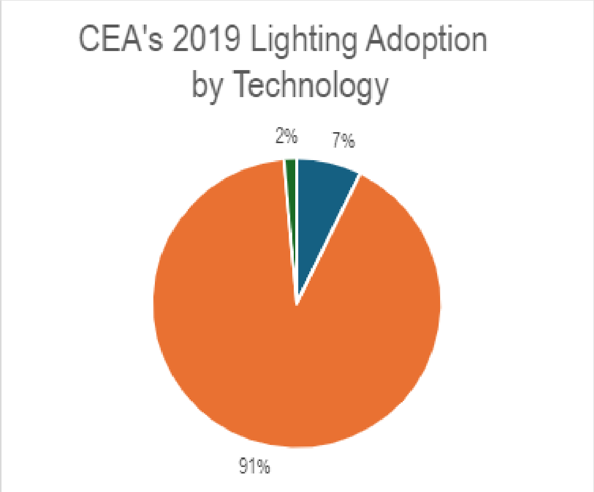
GrowFlux

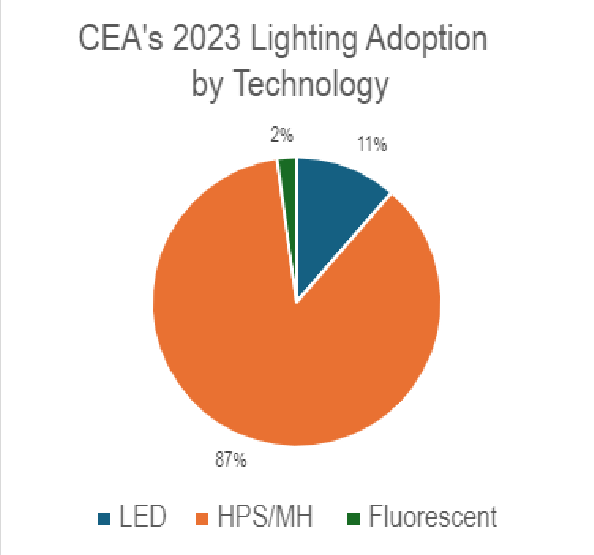
2024 Market Assessment Findings

US CEA Lighting Market trends (2019-2023):

- Total lit grow area up 25%

- Adoption / Technology Mix
  - LED used in an estimated 11% of lit commercial grow spaces
    - up from 10.1 to 19.9 million sq.ft





OCTOBER 16, 2024

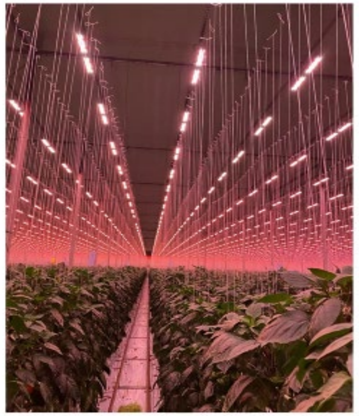
DLC Controls Summit 2024- Horticulture Controls

Mohammed Yousif
Program Advisor – Independent Electricity System Operator (IESO)

ieso Connecting Today. Powering Tomorrow. | SAVE ON ENERGY POWER WHAT'S NEXT

Agenda

1. Save on Energy programs for business
2. Greenhouse sector in Ontario
3. Lighting and controls technologies in Ontario
4. Challenges in adoption and market trends
5. Next Steps



Save on Energy programs for business

- Retrofit Program
- Instant Discounts Program
- Small Business Program
- Strategic Energy Management Program
- Existing Building Commissioning Program
- Energy Performance Program
- Industrial Energy Efficiency Program

Sign up for our quarterly business newsletter at
https://www.saveonenergy.ca/en/Manage-your-subscriptions

Retrofit Program – Incentives for Greenhouses

Incentives are available for

- Horticultural lighting and advanced lighting controls available for greenhouses
- Behind-the-meter solar photovoltaic (PV) generation with battery storage in the Kingsville-Leamington area in the Windsor-Essex region of southwestern Ontario – home to North America's largest concentration of greenhouse vegetable production
    - See Save on Energy for qualifying areas

Horticulture Grow Lights

Horticulture Lighting Incentives:

Horticultural LED Grow Lights – Top Lighting	Incentive
Vegetables/fruits/flowers greenhouse	$200/fixture
Cannabis greenhouse	$125/fixture
Cannabis warehouse	$200/fixture

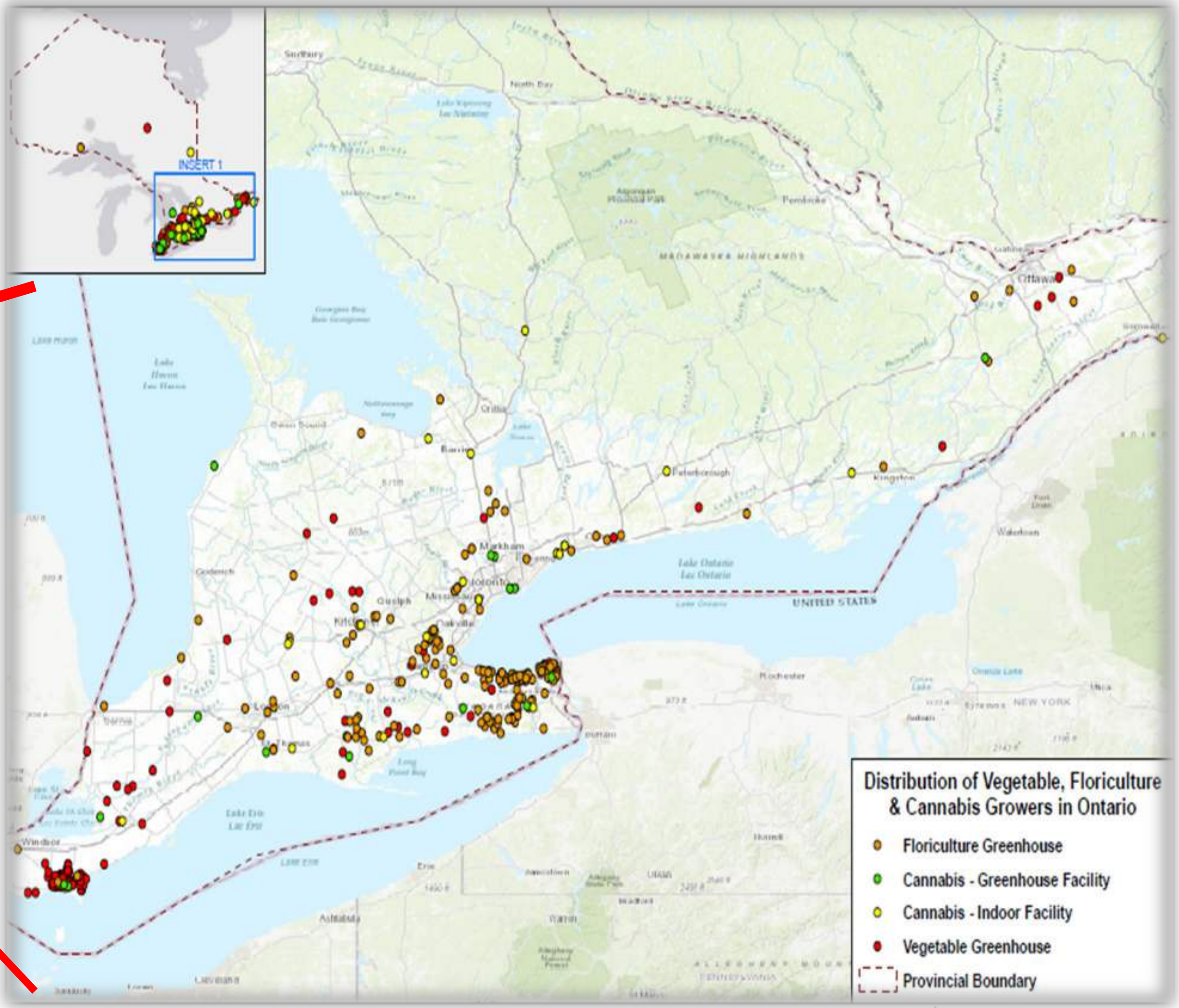
Horticultural LED Grow Lights - Inter-Lighting	Incentive
Within the canopy of the crop	$100/fixture

Horticulture Lighting Controls

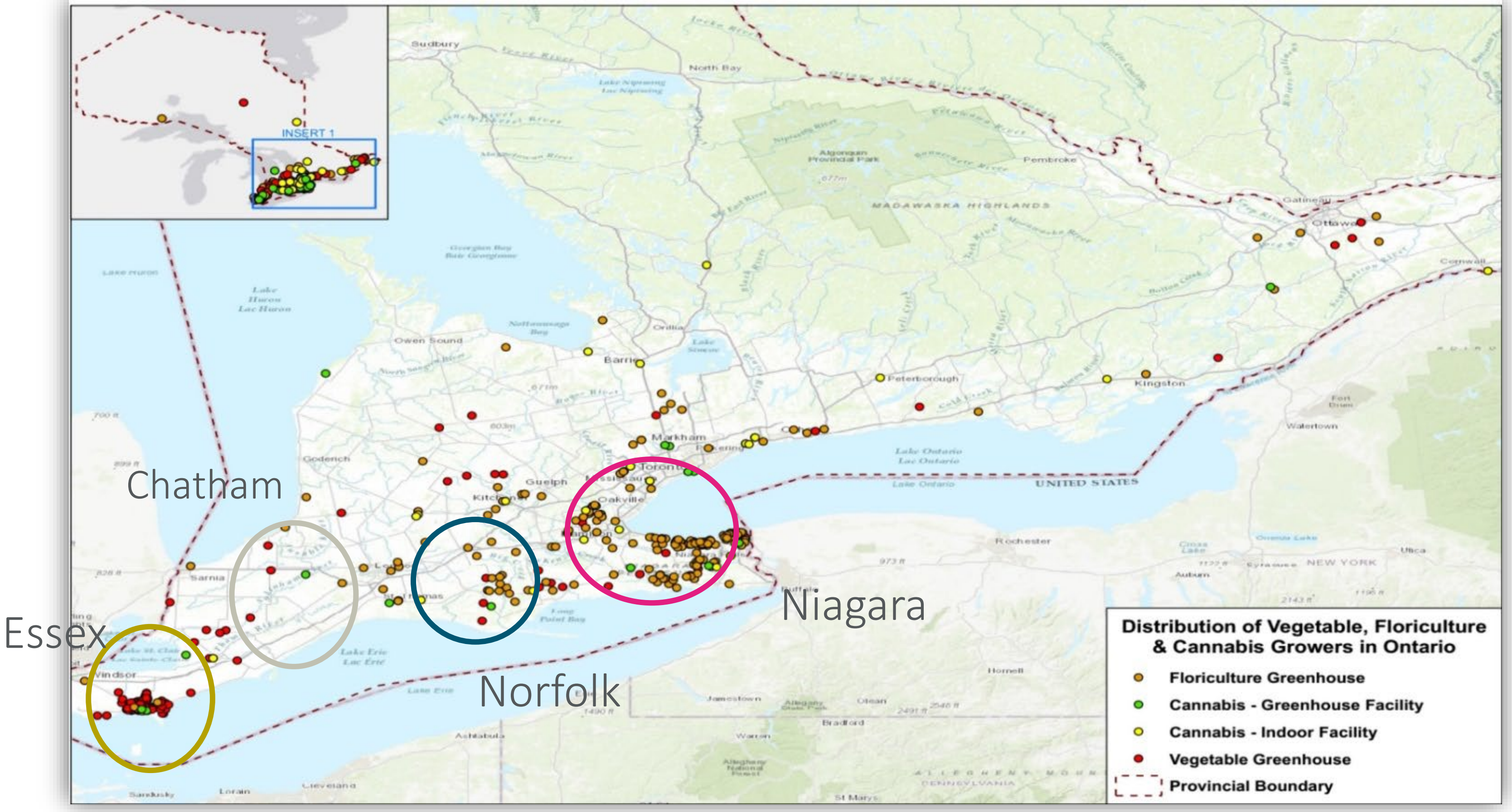
Greenhouse Advanced Lighting Controls	Incentive
The Greenhouse Advanced Lighting Control System must have the following system capabilities: - Continuous Dimming - Control Zoning - Time Scheduling - Use PAR (Photosynthetic Active Radiation) sensors or Broad-Spectrum light sensors - Capable of incorporating weather information - Optional: Capable of reporting (at minimum on lighting runtime).	$0.35/KWh

Documentation confirming the total wattage to be controlled by the DLC system and total area (ft2) of the controlled zone are required.

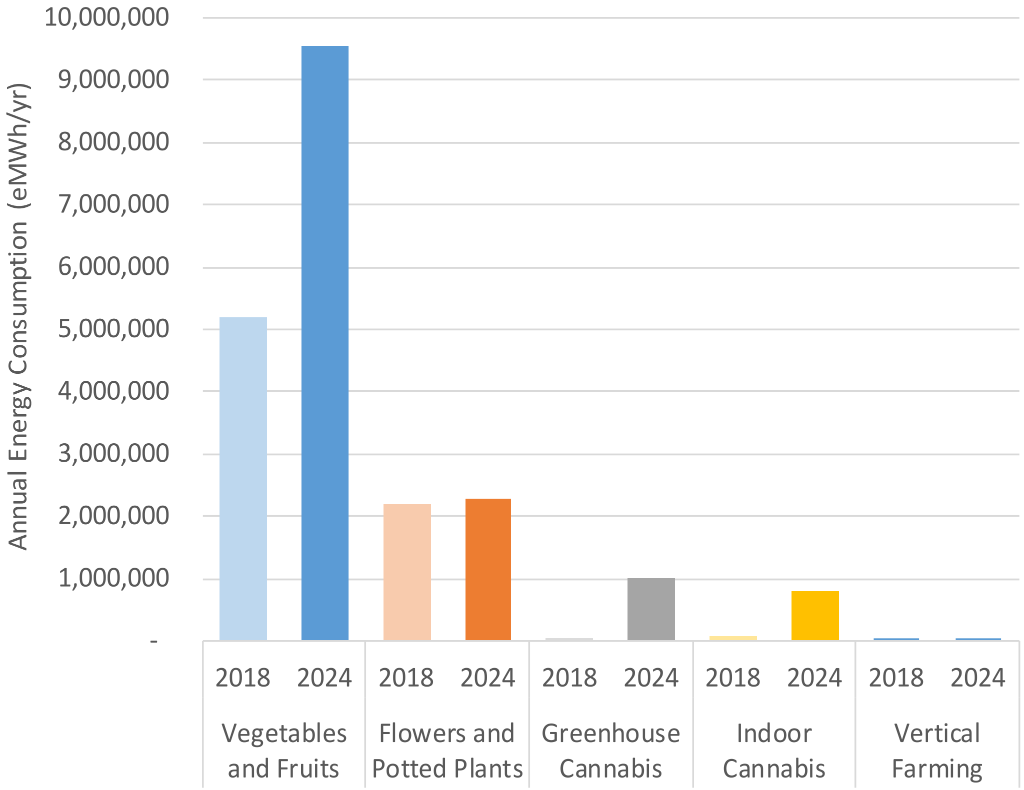
Greenhouse Sector in Ontario



Greenhouse Sector in Ontario



Greenhouse Energy Consumption by sub-sector 2018-2024



Vegetable & Fruit Greenhouses are the largest segment in the sector, both in terms of energy consumption and area.

Current Lighting Technologies in Ontario

Ontario accounts for over 70% of Canada's greenhouse area. Over 4,700 acres of greenhouses. Greenhouse vegetable industry had a revenue of $1.67 billion and the greenhouse floral industry reached $1.05 billion in revenue in 2023.

- **High-Pressure Sodium (HPS)** lighting remains the dominant technology used in Ontario greenhouses. Favored for its broad light spectrum and the additional heat it generates.
- **LED Adoption**: Although LED lighting offers significant energy-saving benefits, its high initial cost and long return on investment (ROI) have slowed widespread adoption.

Current Lighting Controls Technologies in Ontario

- Most growers will already have an **Environmental Control System** for their greenhouses, controlling other equipment, temperature, and CO2 levels within their greenhouse. Lighting is typically included in these systems.
- Systems vary ranging from simple **on and off** capability controls for HPS lighting to more **dynamic smart control** systems.
- HPS lighting remains the most common, the simple on and off capability controls remain the most common system used in Ontario

Challenges in Adoption

Cost Barriers:

- LED systems are approximately four times more expensive than HPS systems.

Knowledge Gaps:

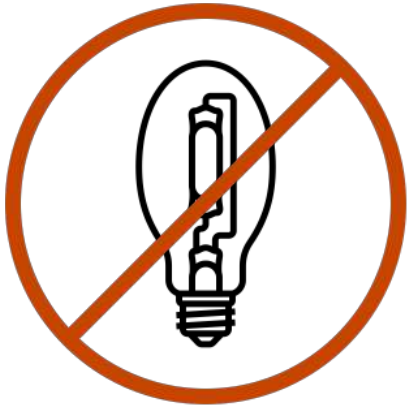
- There is a significant gap in grower knowledge regarding the specific light spectra needed for different crops and how to effectively use more advanced controls.

Electricity Infrastructure:

- Challenge of accessing sufficient electrical capacity.

Market Trends and Future Projections

Gradual Shift to LEDs



Regulatory Impacts

Grid Innovation Fund: Indoor Agriculture Call

Indoor agriculture sector is one of the fastest growing sources of load in Ontario. The targeted call was leveraged to create opportunities for innovation to help alleviate challenges associated with this load growth.

Allegro Acres will demonstrate and accelerate the adoption of the Smart Daily Light Integral and long photoperiod-low intensity lighting control strategies

Great Lakes Greenhouse aims to develop an AI-powered autonomous virtual grower to increase energy efficiency while maintaining or potentially increasing yield.

Univ. of Windsor Powering Greenhouse growth through distributed energy resources

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Next Steps

Expand Research Efforts: Increase research on the specific light spectra and control strategies needed for different crops.

Training Programs: Targeted training programs and workshops to educate growers on the benefits of LED lighting and the use of advanced controls.

Pilot Programs: Collaborate on pilot programs that allow growers to test new technologies.

Revise Incentive Structures: Restructure incentive programs to be more attractive and easier to navigate.

Policy Advocacy for Greenhouse Development: Engage with municipal governments to address regulatory barriers.

Accelerate Infrastructure Development: streamline the process of expanding electrical capacity in key agricultural regions.

Thank you!

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Lighting Controls in Horticulture Applications

Tom Hamilton

FLUENCE HELPING THE WORLD GROW SMARTER

Harnessing Advanced Lighting Controls in Horticulture

About Fluence

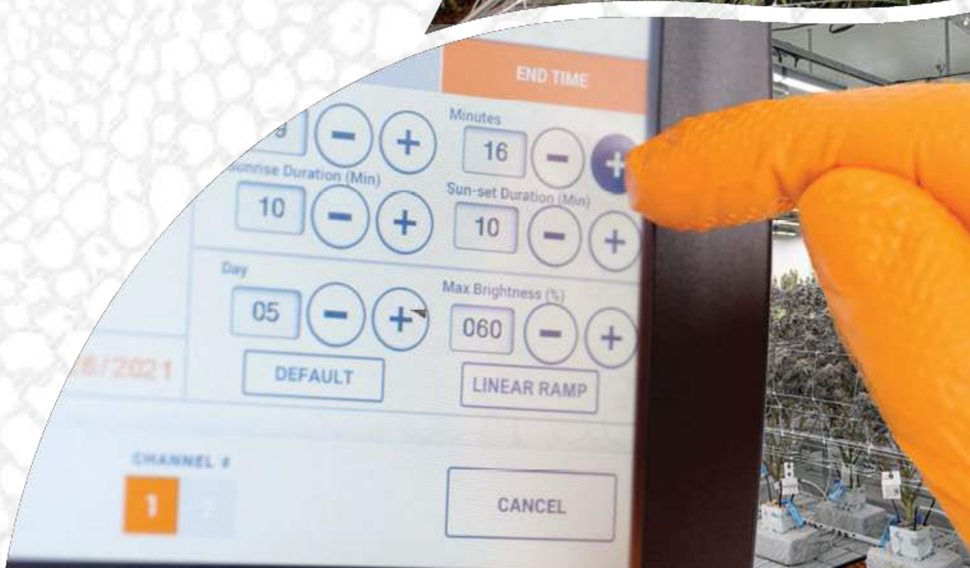
- Lighting & controls manufacturer
- HQ in Austin, TX
- Acquired in 2022 by Signify, the world's leading lighting company
- Over 6 million sq. ft. of cannabis canopy

Energy efficiency in horticultural lighting

- US DOE: 100% conversion to LED represents 34% energy savings annually
- Advanced lighting controls further extend savings

Beyond traditional HPS lighting methods

- Dimming! Luminaire level lighting control!
- Follow the commercial lighting trends



Energy efficiency in horticultural lighting:
https://www.energy.gov/eere/ssl/articles/energy-savings-potential-ssl-horticultural-applications
Overview of horticultural lighting innovations:
https://ag.umass.edu/greenhouse-floriculture/fact-sheets/photoperiod-control-systems-for-greenhouse-crops
https://www.energy.gov/sites/prod/files/2020/07/f76/ssl-agriculture-jun2020.pdf

Tailoring Light Intensity to Plant Development

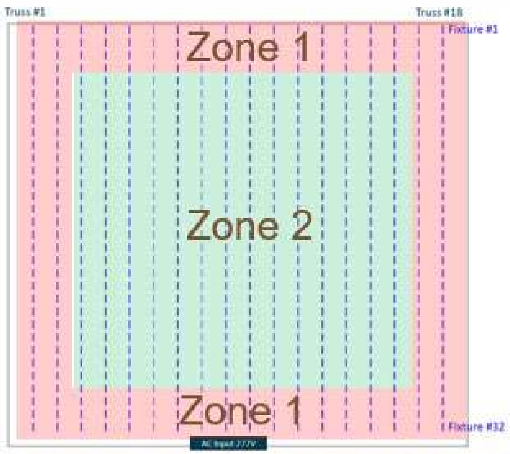
- Adjust lighting levels to match specific growth stages
- Example: Seedlings require less light than mature plants
- Energy Savings realized by application/time intensity programming
- AKA: Task Tuning

Research on adaptive lighting control for greenhouses: https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Publications/Research/Other-Technical-Reports/21-19-Adaptive-Lighting-Controller-Technology-for-Greenhouses.pdf

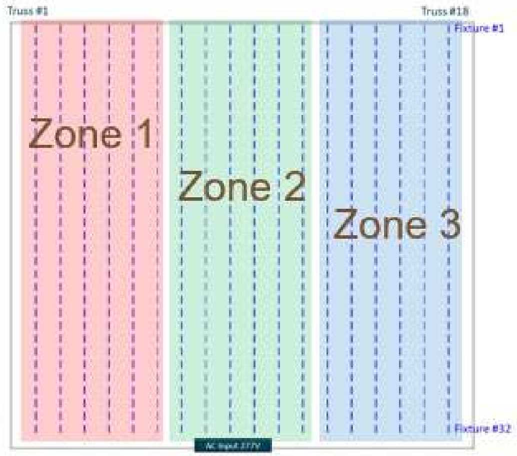
Classified

Customizable Lighting Zones for Optimal Efficiency

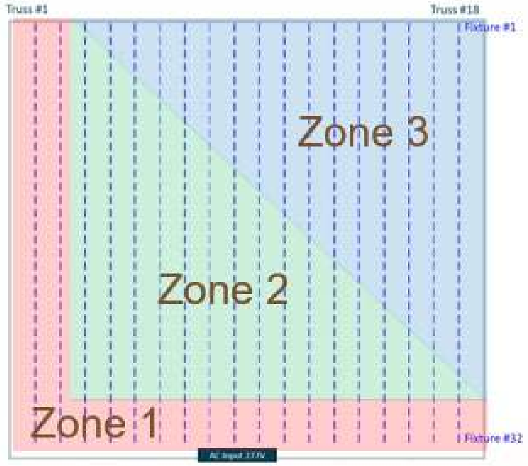
- Create independent lighting zones irrespective of power circuits
- Target specific areas based on crop type or growth phase
- Compensate for irregular shading and shadows
- Balance for light reflection and absorption
- Energy Savings: Avoid over-lighting, focus energy where needed



Perimeter compensation



3 cultivars in rows

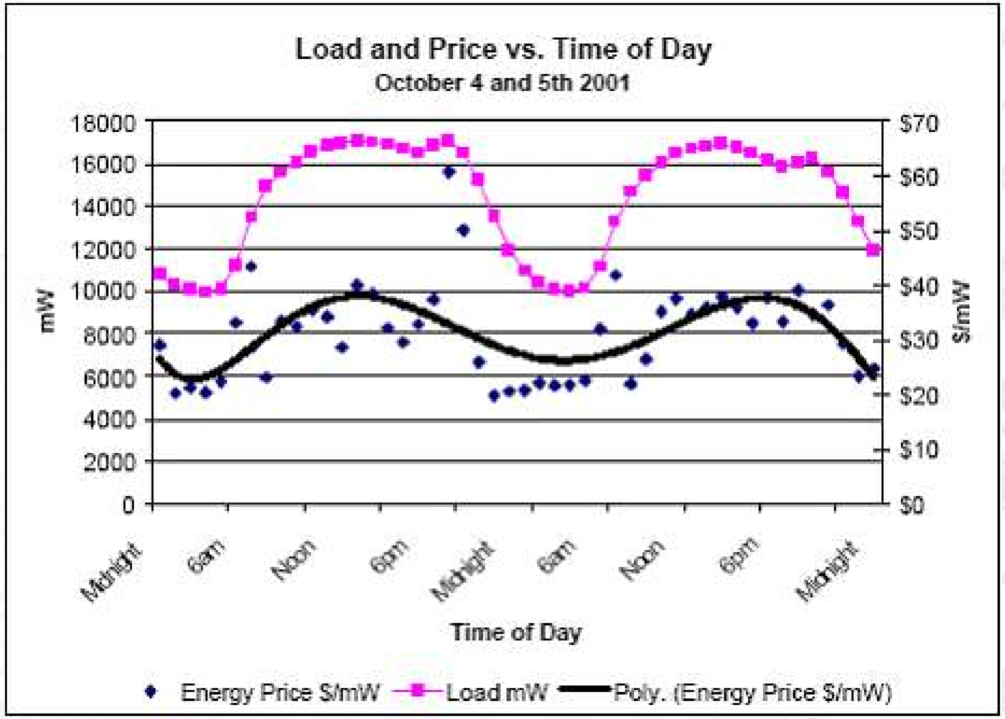


Shading & obstructions

Customizable lighting zones and energy efficiency: https://www.energy.gov/sites/prod/files/2020/07/f76/ssl-agriculture-jun2020.pdf

Aligning Lighting Schedules with Energy Rates

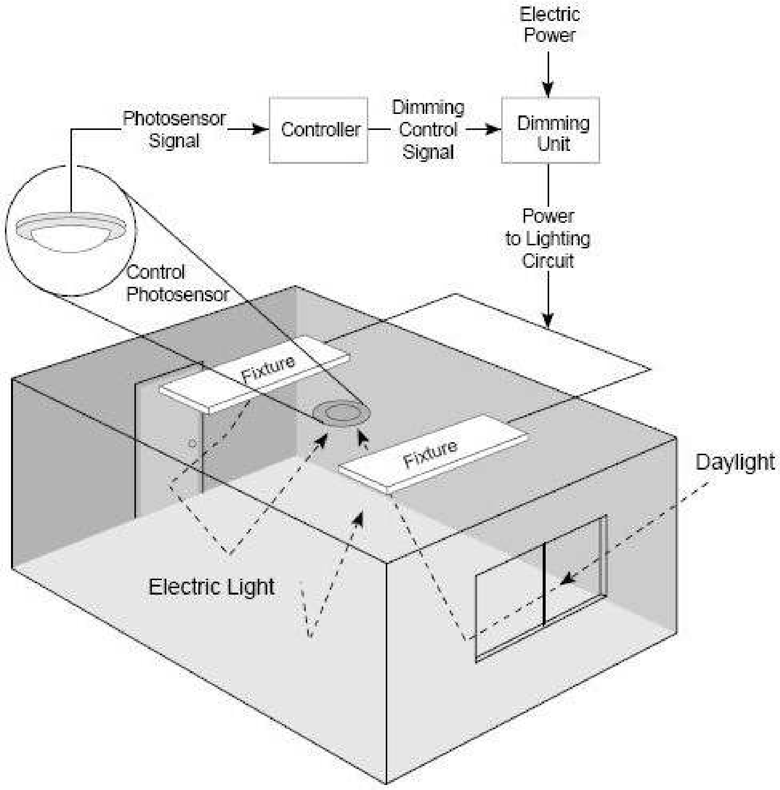
- Schedule intensive lighting during off-peak hours
- Maintain Daily Light Integral (DLI) over time
- Stabilize demand and lower energy costs by utilizing cheaper rates
- Economic demand response techniques



Scheduling lighting and energy consumption patterns: https://www.energy.gov/sites/prod/files/2020/07/f76/ssl-agriculture-jun2020.pdf
https://www.sciencedirect.com/science/article/abs/pii/S0304423820304593

Adapting Lighting to Natural Light Availability

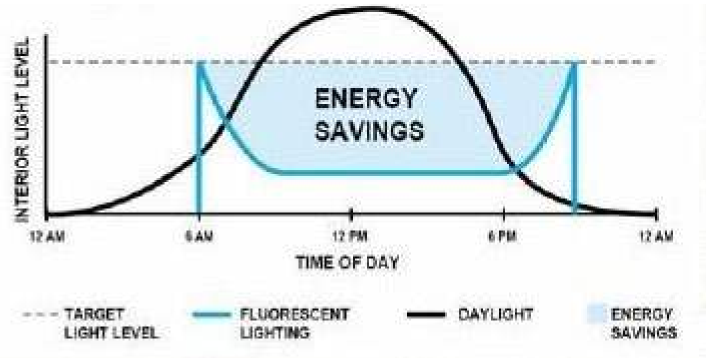
- Use daylight sensors and weather forecasts to anticipate sunlight levels
- Adjust artificial lighting accordingly
- Energy Savings: Reduce lighting when natural light suffices



https://www.automatedbuildings.com/news/aug07/articles/zing/070723051101dilouie.htm

Table 2. Monthly Adaptive Lighting Controller Energy Savings Based on Modeled Baseline

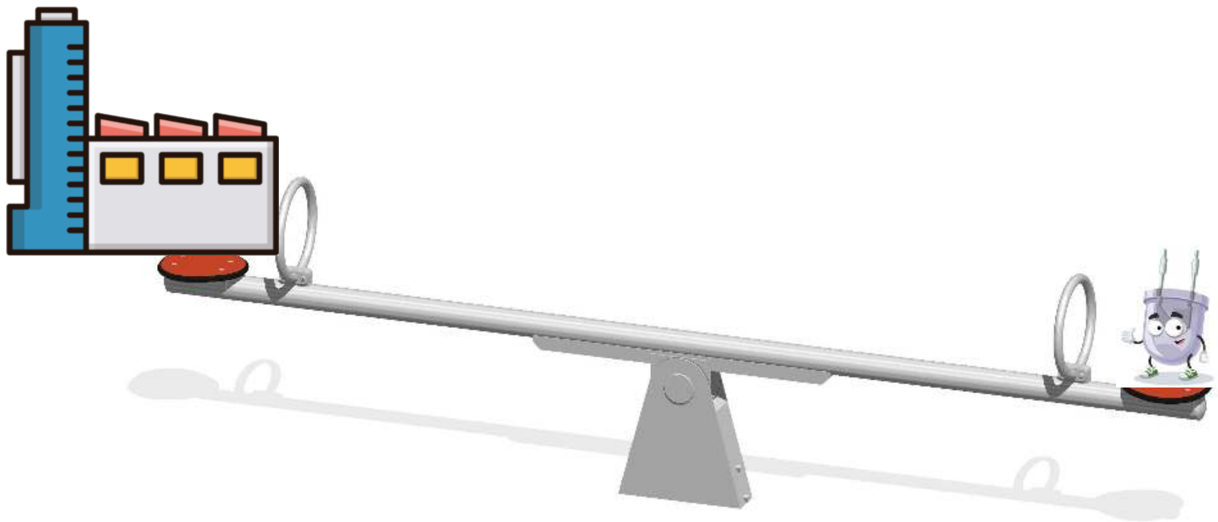
	January	February	March	April	May	September	October	November	December
Energy Savings (%) a	4.40%	14.80%	26.60%	44.60%	52.20%	44.60%	26.60%	14.80%	4.40%
kWh Savings	342	1,074	2,061	3,166	3,784	3,166	2,061	1,074	342
Energy Cost Savings b	$34	$107	$206	$317	$378	$317	$206	$107	$34
Cumulative Cost Savings	$698	$806	$1,012	$1,328	$1,707	$317	$523	$630	$664
Cumulative kWh Savings	6,985	8,058	10,119	13,285	17,068	3,166	5,226	6,300	6,642



Smart greenhouse lighting systems: https://research.uga.edu/news/smart-greenhouses-could-slash-electricity-costs/
https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Publications/Research/Other-Technical-Reports/21-19-Adaptive-Lighting-Controller-Technology-for-Greenhouses.pdf

Collaborating with Energy Providers

- Demand Response: reduce lighting loads during peak demand periods
- Energy Destruction: increase lighting loads to absorb capacity, stabilize grid quickly
- Participate in ancillary demand response programs that pay premiums
- 20ksqft multitier grow-room is ~1MW load



Energy savings potential in horticultural applications: https://www.energy.gov/eere/ssl/articles/energy-savings-potential-ssl-horticultural-applications
https://www.energy.gov/sites/prod/files/2020/07/f76/ssl-agriculture-jun2020.pdf

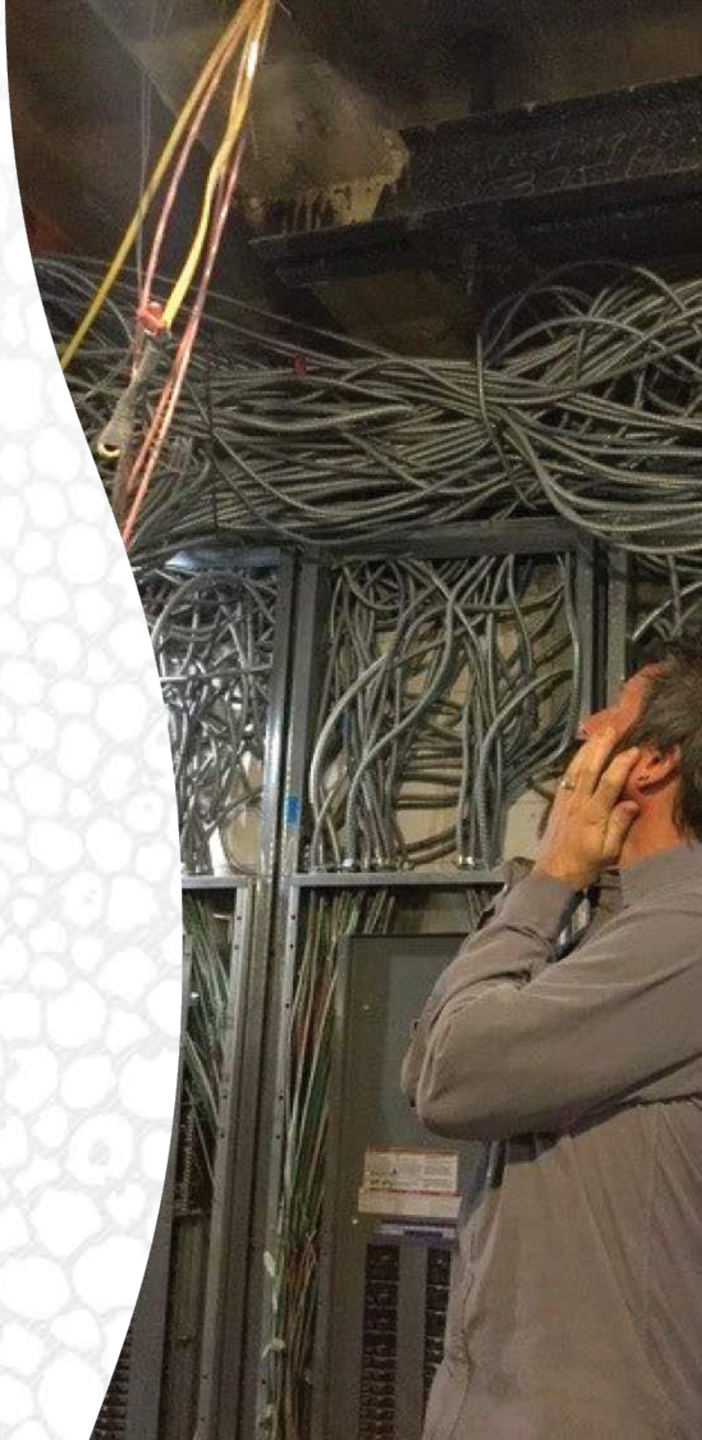
Collaborating with Energy Providers

- Integrate sensors for ambient light, temperature, humidity
- Adjust lighting in real-time based on environmental data
- Energy Savings: Optimize lighting use as function of environment
- Example
  - Avg Cannabis facility grows at ~1,000 PPFD
  - 1:1 yield increase up to ~1,800 PPFD
  - Temperature and nutrients need to be accounted for

https://www.cannabisbusinesstimes.com/lighting/led-lighting-cannabis-cultivation-facility/article/15694212/growing-under-high-light-intensities
Adaptive lighting control research: https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Publications/Research/Other-Technical-Reports/21-19-Adaptive-Lighting-Controller-Technology-for-Greenhouses.pdf
Adaptive lighting in outdoor applications (principles applicable to greenhouses): https://cltc.ucdavis.edu/publication/adaptive-lighting-outdoor-security-applications

Unlocking Energy Savings with Advanced Controls

- Horticulture can benefit from traditional lighting control strategies adapted to application
- Specification, installation, programming, and maintenance must be user friendly
- Education is a must! Training and outreach opportunity.
- Can lead to significant savings as seen in commercial lighting



- Overall energy savings potential in horticultural lighting: https://www.energy.gov/sites/prod/files/2020/07/f76/ssl-agriculture-jun2020.pdf
- Smart greenhouse technology overview: https://research.uga.edu/news/smart-greenhouses-could-slash-electricity-costs/

THANK YOU

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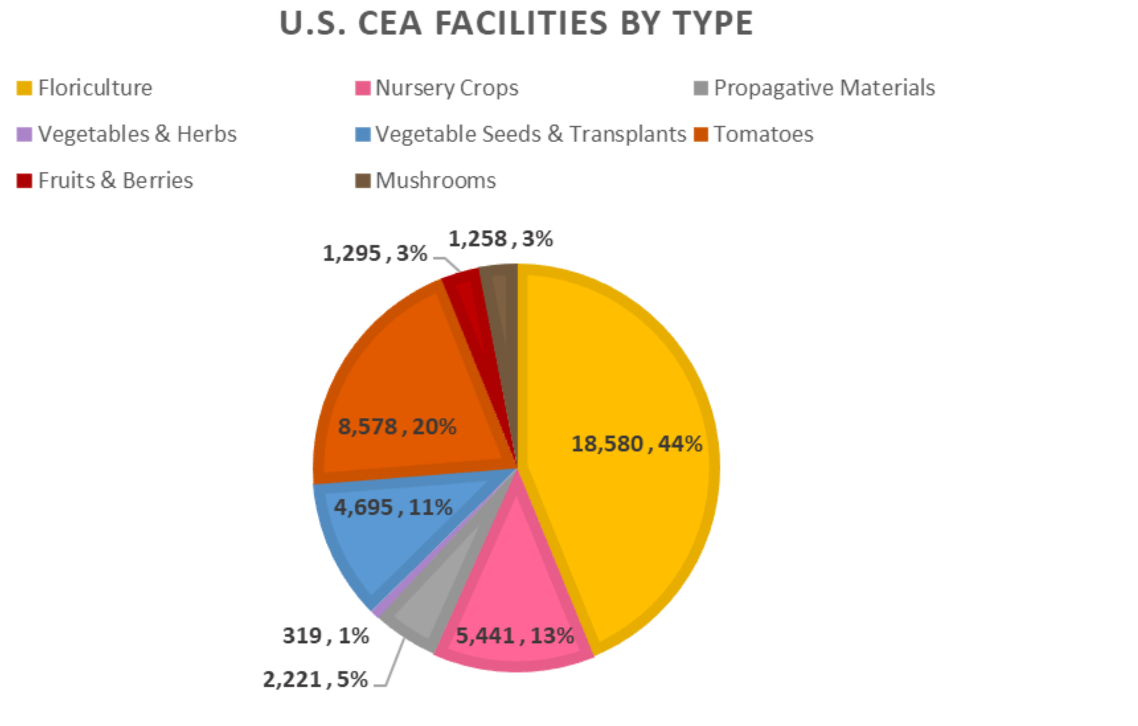
Savings Beyond LED:
Horticultural Lighting Controls Program Opportunities

ENERGY RESOURCES INTEGRATION, LLC

October 2024

U.S. CEA INDUSTRY



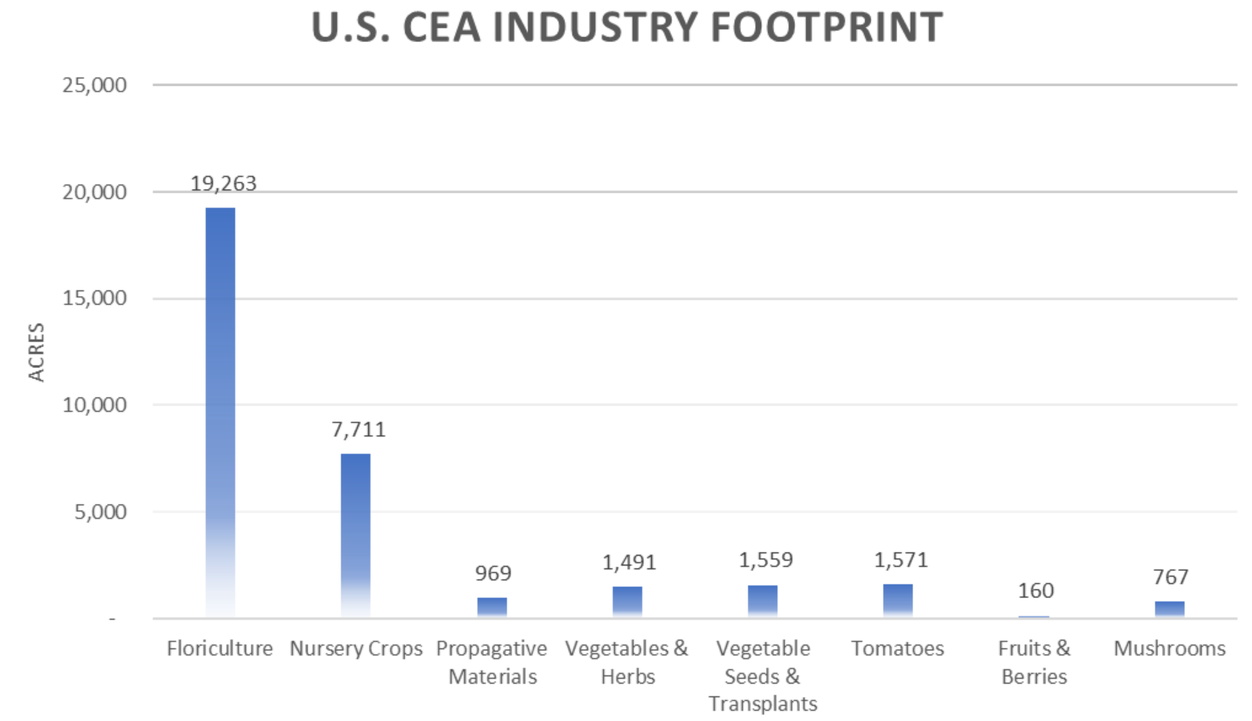


Figure Data Source: USDA, 2024.

WHY MANAGE CEA ENERGY?

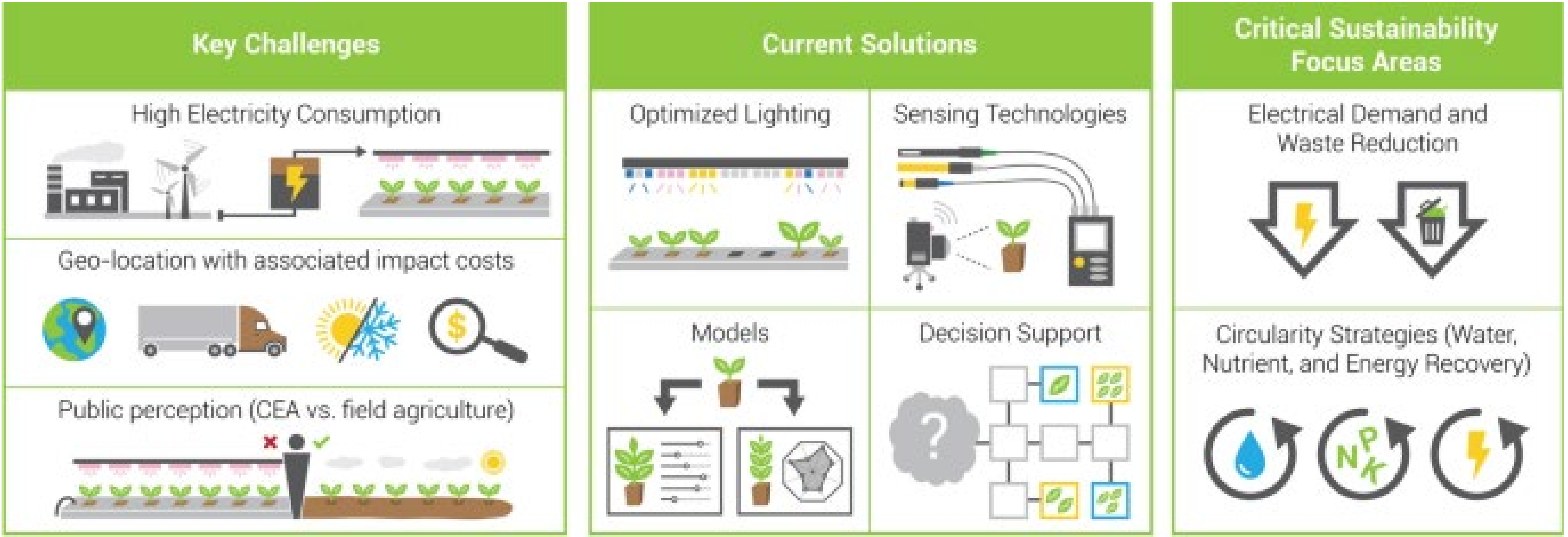


Figure Data Source: Coon, D., Lindow, L., Boz, Z. et al. 2024.

BENEFITS OF EFFICIENT CEA

- Profit margins for CEA businesses average only 6 – 10%

- Reducing energy use from process systems in greenhouses and indoor farms would make a dramatic impact on **CEA industry resiliency**.

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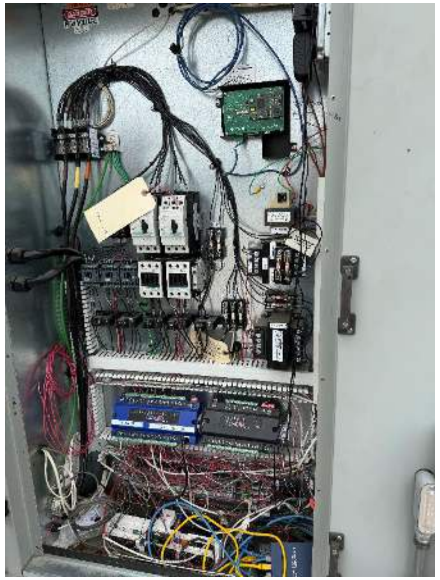
BARRIERS TO ENERGY EFFICIENCY






CEA facilities use significant electricity for **lighting, HVAC, and irrigation** processes.

Managing electricity use starts with measuring energy use.

Energy monitoring at the system level can be a hurdle for energy management.

INDOOR FARM ELECTRICITY USAGE

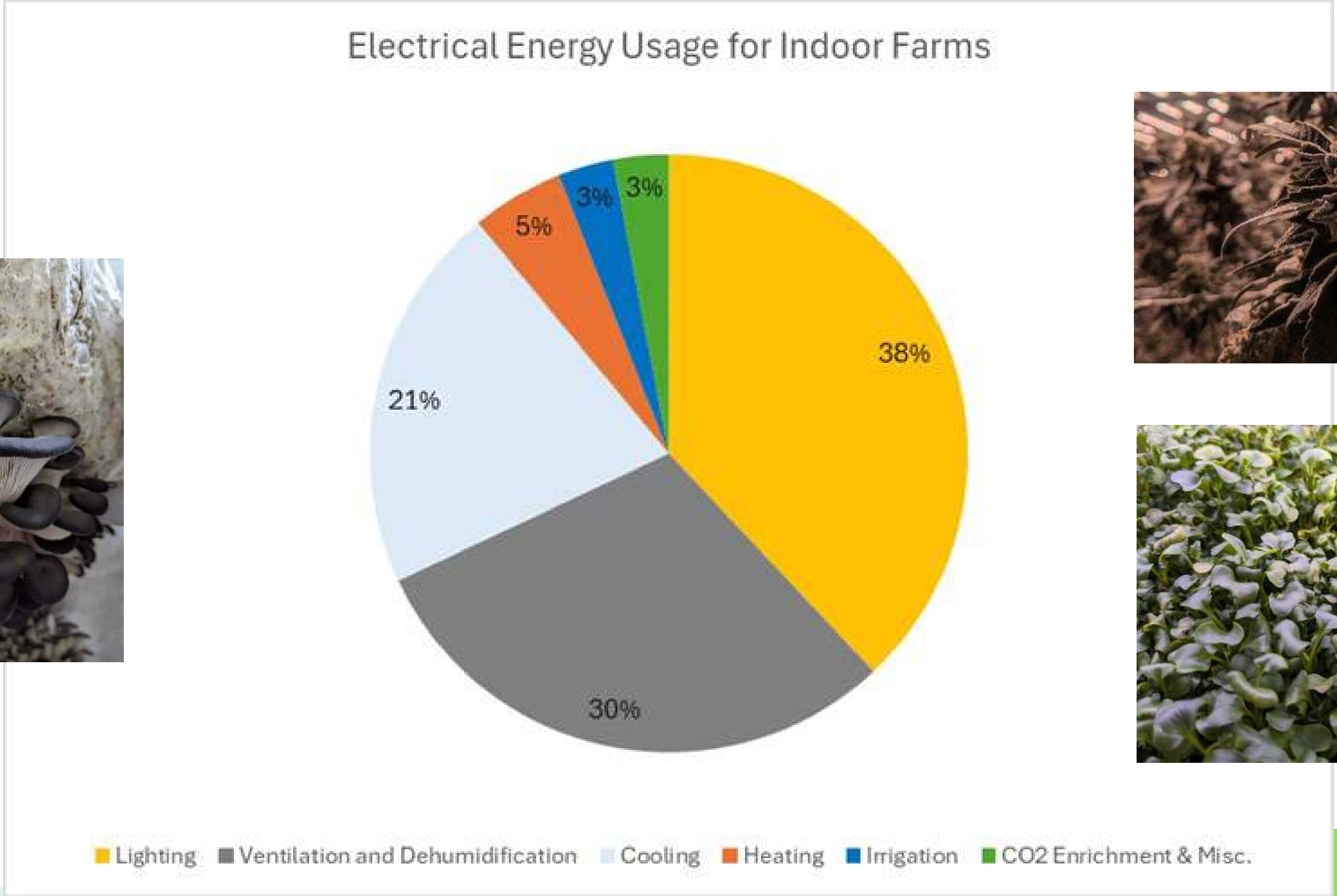
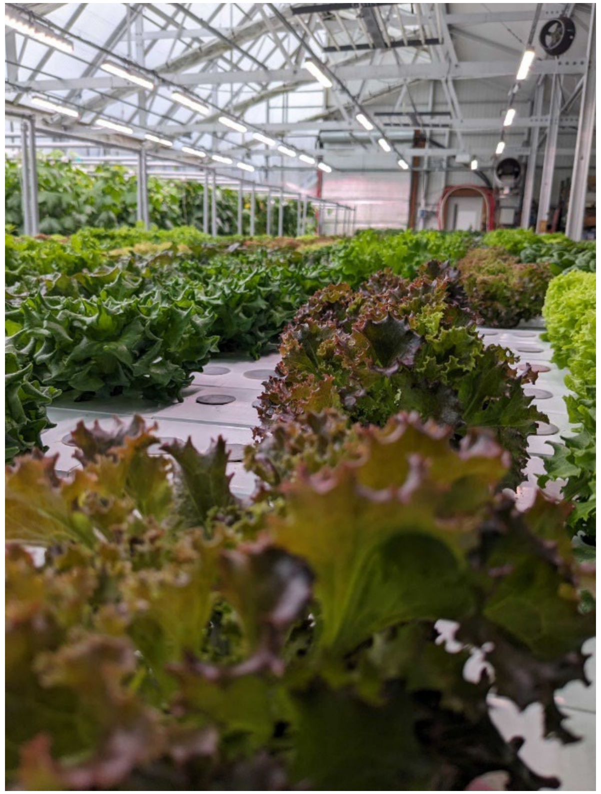


Figure Data Source: SCE, 2021.

WHAT'S NEXT AFTER LED?

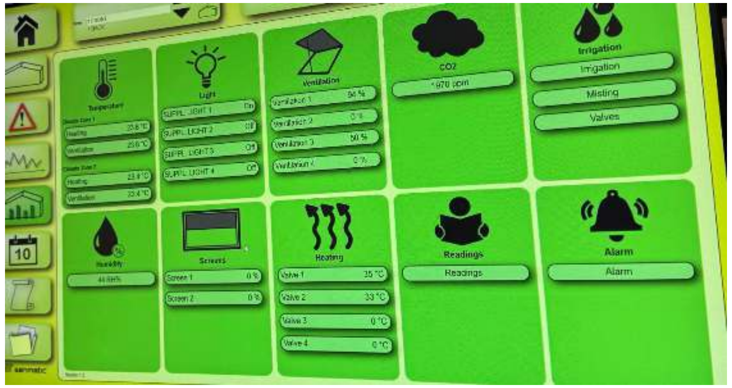
- Since 2017, LED horticultural lighting systems have increased in efficacy by up to 50%
  From 1.7 µmol/J to 2.6 to 3.4 to ??

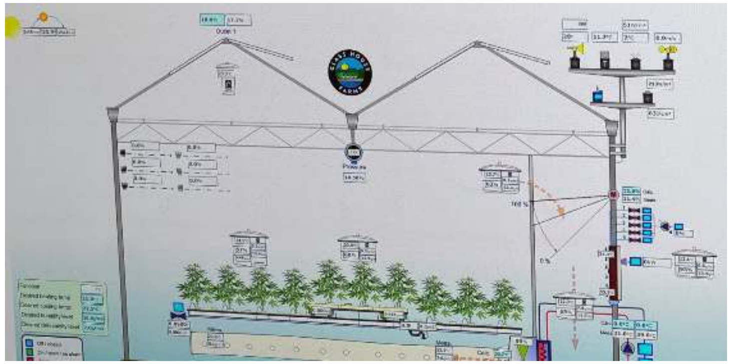
- **Automation presents the next frontier** for energy management



EFFICIENCY VIA AUTOMATION

- Controls strategies can **save up to 70%**
  - Scheduling
  - Staging
  - Modulating
    - Dimming (lights)
    - Varying speed (fans and pumps)
  - Machine learning & AI
    - Predictive models using historic data



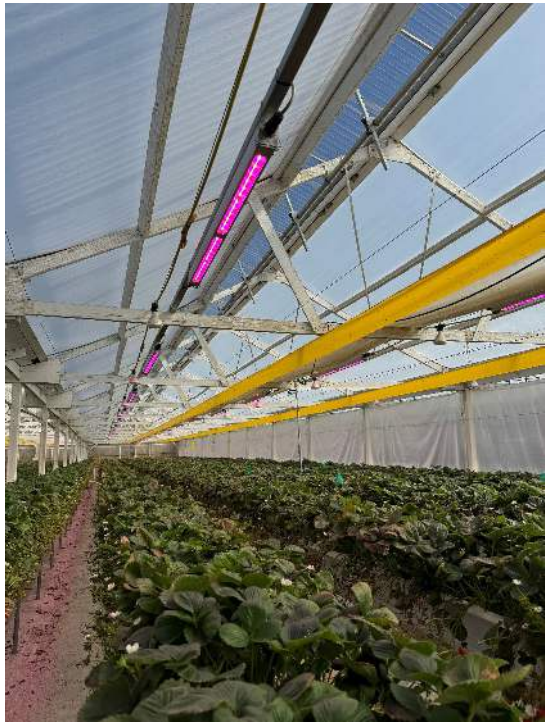


CALNEXT MARKET & FIELD STUDY

Utility-Funded Emerging Technology Research

Smart Controls for Data-Driven Indoor Agriculture Field Evaluation

- Funded by Pacific Gas & Electric (PG&E), San Diego Gas & Electric (SDG&E), and Southern California Edison (SCE)
- 18-month scope
- Started in 2024, completing in 2025
- Inclusive of all CEA: food, floriculture, and cannabis
- Focusing on major energy-consuming systems: lighting, HVAC, and irrigation



CALNEXT MARKET & FIELD STUDY

Utility-Funded Emerging Technology Research

Smart Controls for Data-Driven Indoor Agriculture Field Evaluation

Stakeholders:

- Investor-owned electric utilities: PG&E, SDG&E, and SCE
- Cornell University School of Integrated Plant Sciences
- Energy Solutions
- Greenhouse Lighting and Systems Engineering (GLASE) consortium
- Microclimates, Inc.
- Participating PG&E, SDG&E, and SCE customers
- Participating industry experts

Technology transfer partners:

DesignLights Consortium

GrowFlux

Sollum Technologies

Hoogendoorn Growth Management

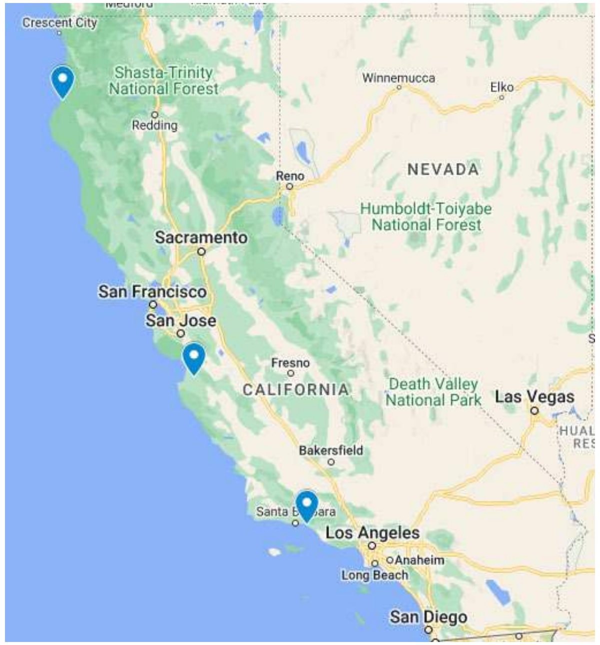
PRELIMINARY FINDINGS

Measure System	Measure Name	Measure Description	Process Electricity Savings Potential
Lighting	Dimming Controls	Reduction in horticultural light fixture wattage coincides with improvements in PPE	8% increase in PPE when fixtures are dimmed 50%
	Spectral Tuning	Tune horticultural lighting spectrum for energy efficient fixture PPE by applying light recipes with more red diodes	40% or more
	Daily Light Integral (DLI) Controls	Reduce horticultural lighting system operation to maintain consistent DLI based on predictive or measured solar data	20 – 69% in greenhouses
HVAC	Automated Greenhouse Vent Control	Automate greenhouse ventilation controls to reduce unnecessary operation.	17 – 21%
	Automated Greenhouse Curtain Control	Reduce solar radiation entering greenhouses to reduce cooling demand by employing shade curtains	50 – 60%
	Automated CEA Fan Control	Automate CEA HVAC fan controls to reduce unnecessary operation.	Up to 36%
	VPD Optimization	Optimize Vapor Pressure Deficit (VPD) for specific crops, and optimize space temperature and humidity setpoints for optimum energy efficiency while maintaining target VPD	25 – 50%
Irrigation	Variable-Speed Pump Control	Equip irrigation pumps with variable speed motors, and control pump speed in reference to loop pressure, allowing reduced pump speeds when partial irrigation capacity is required	27 – 35%
	Sensor-Based Irrigation Controls	Control irrigation valves based on substrate moisture content rather than on timed schedules	33 – 50%

FIELD DEMONSTRATION

Demonstrate Smart CEA Controls Strategies in Commercial Operations

Quantify energy savings potential from smart lighting, HVAC, and irrigation controls strategies in greenhouses and indoor farms.



Measurement and Verification

- Six-month data collection at three commercial CEA operations (two greenhouses, one indoor farm) beginning in September 2024
- Three crops: lettuce, orchids, and mushrooms
- Three California climate zones
- Final report will be published in 2025 at: https://www.etcc-ca.com/reports/smart-controls-data-driven-indoor-agriculture-field-evaluation

CONTACT ME

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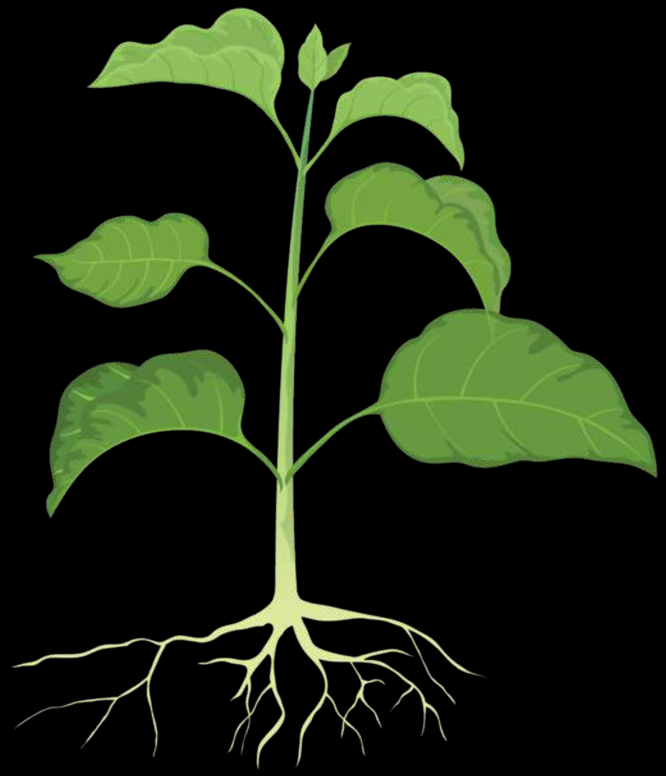
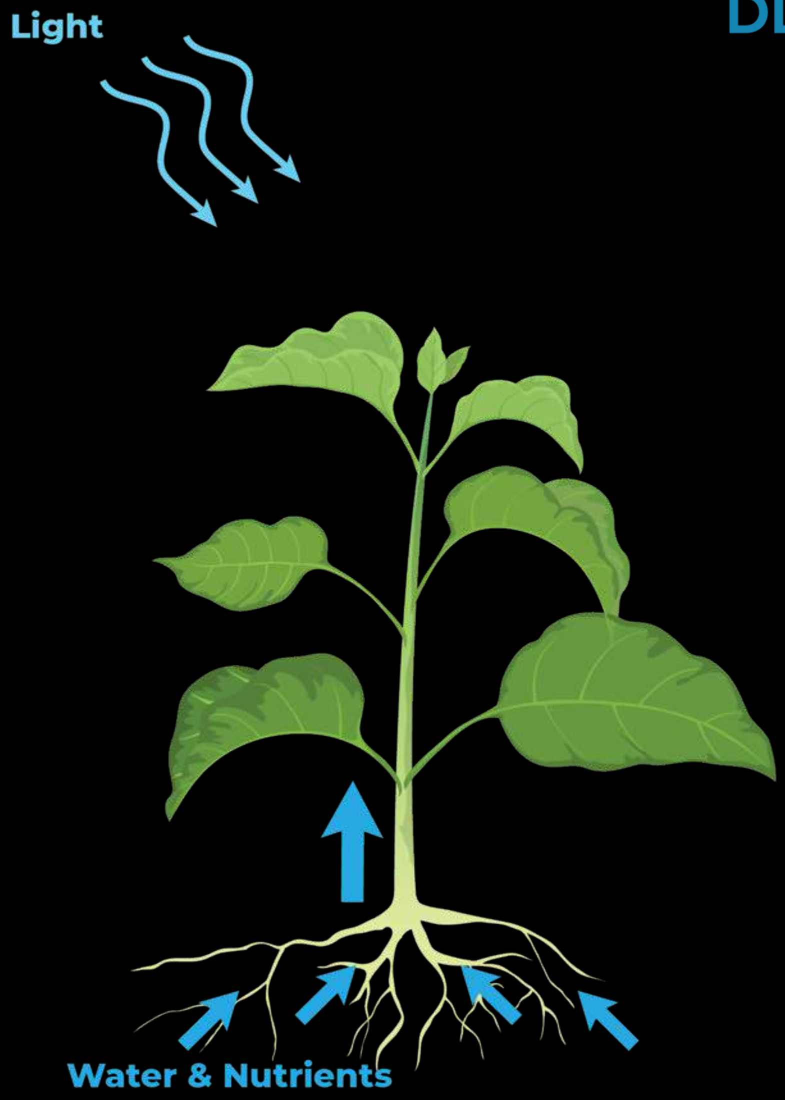
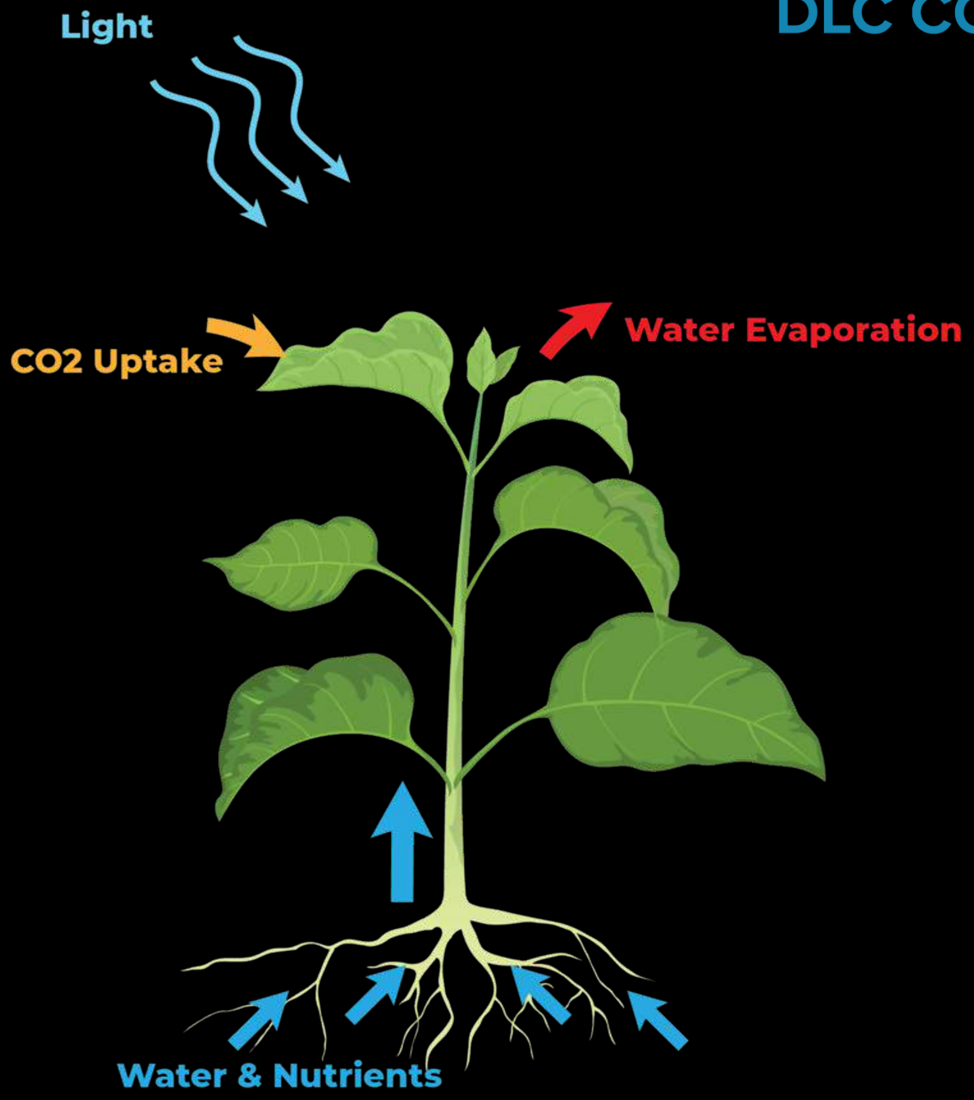
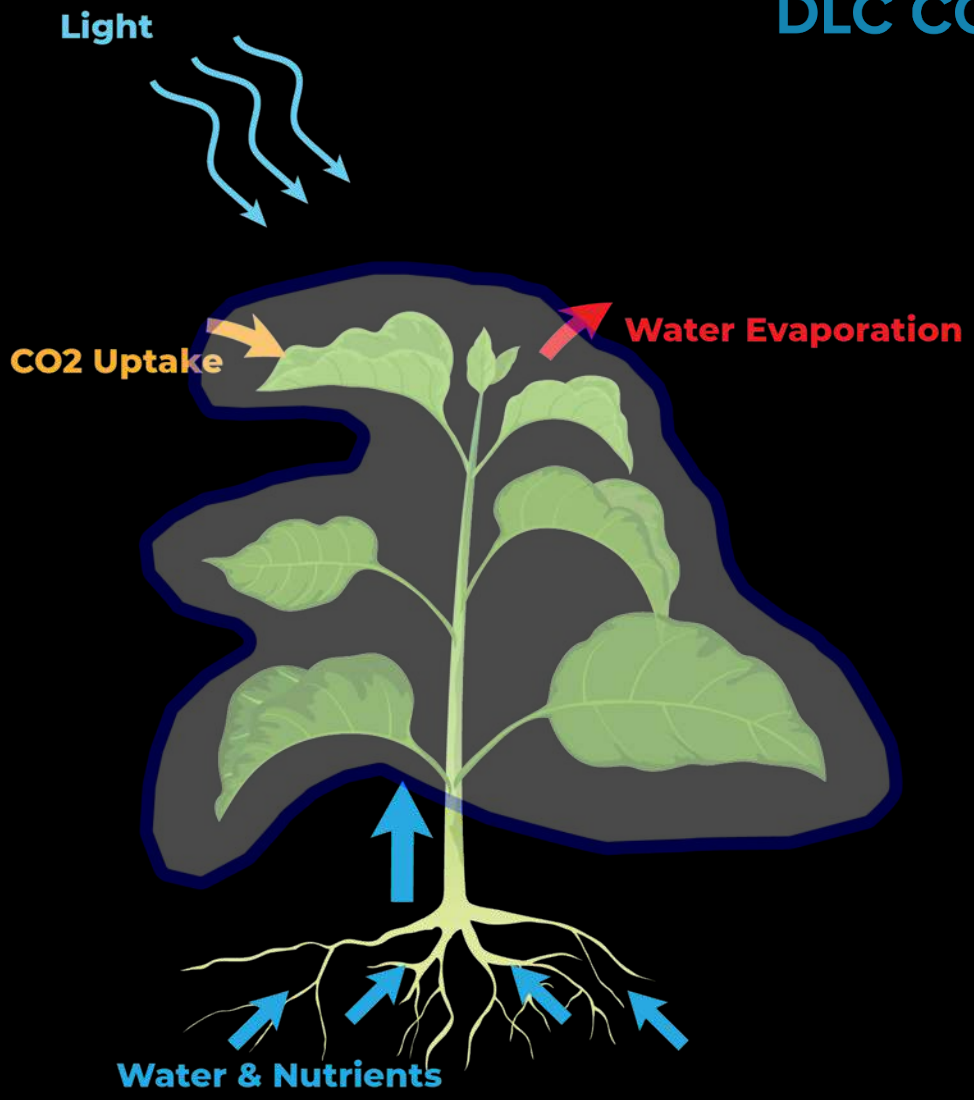


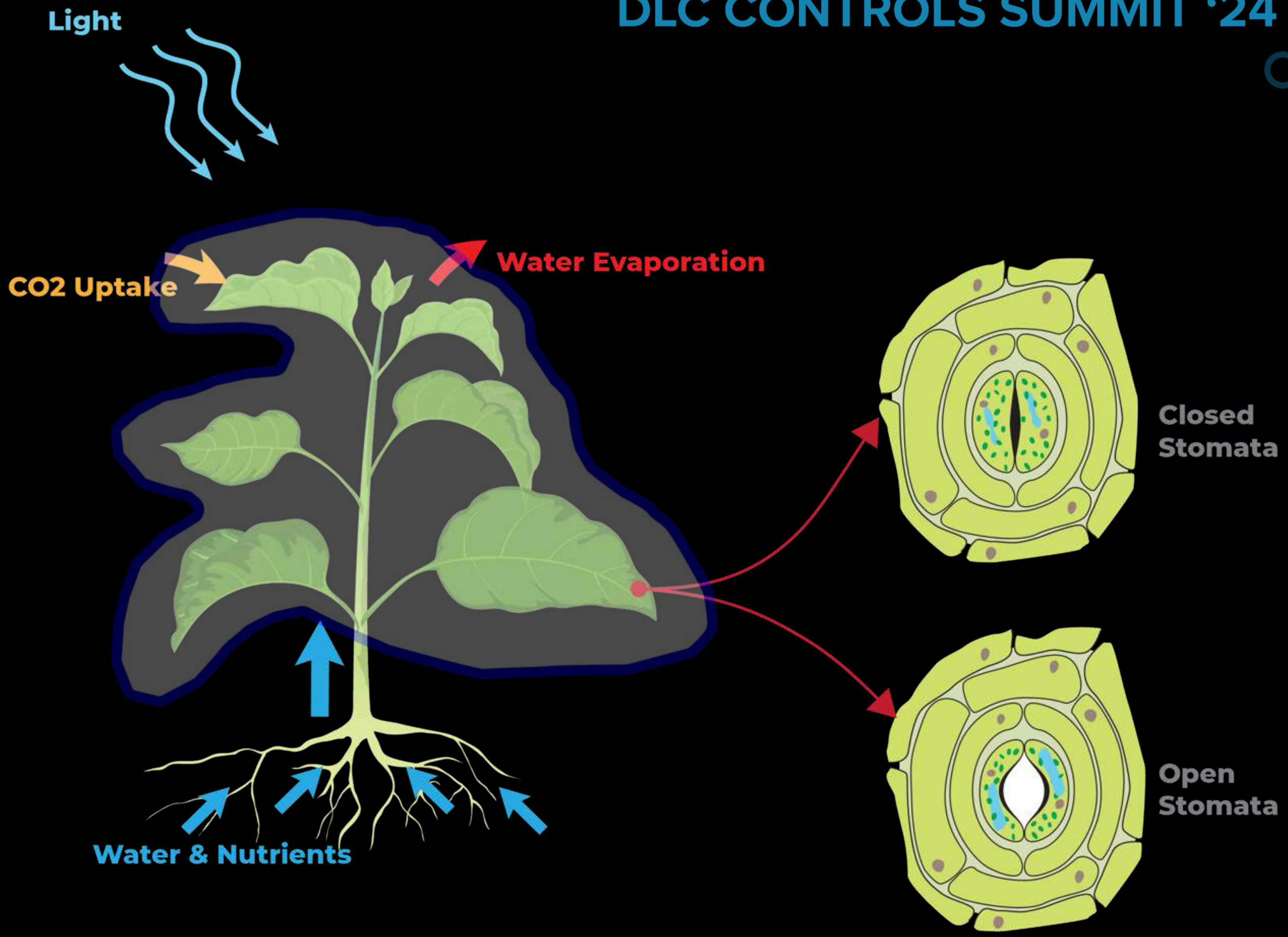

Light
Water & Nutrients


Light
CO2 Uptake
Water Evaporation
Water & Nutrients

Microclimate



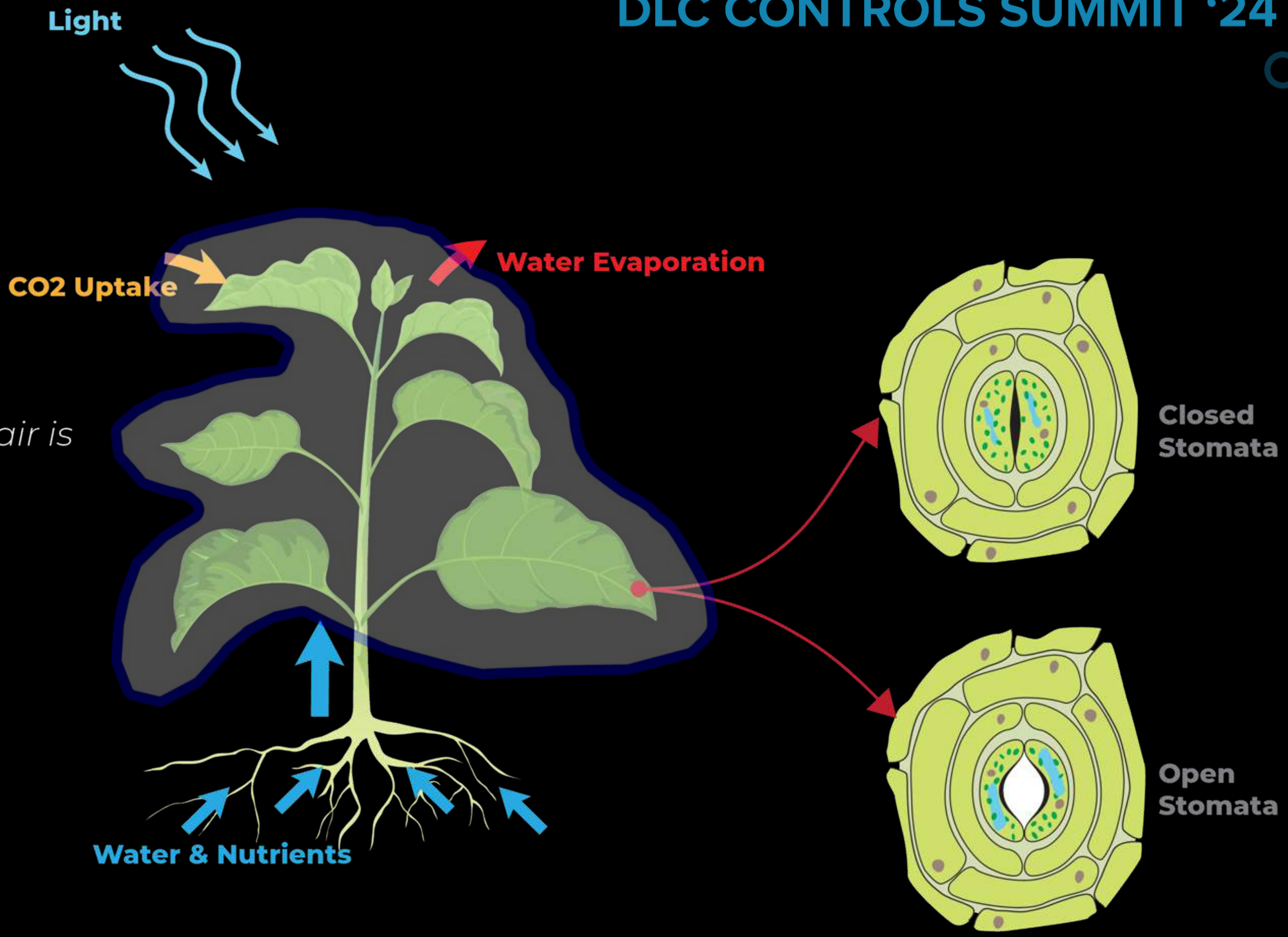
Microclimate



Microclimate

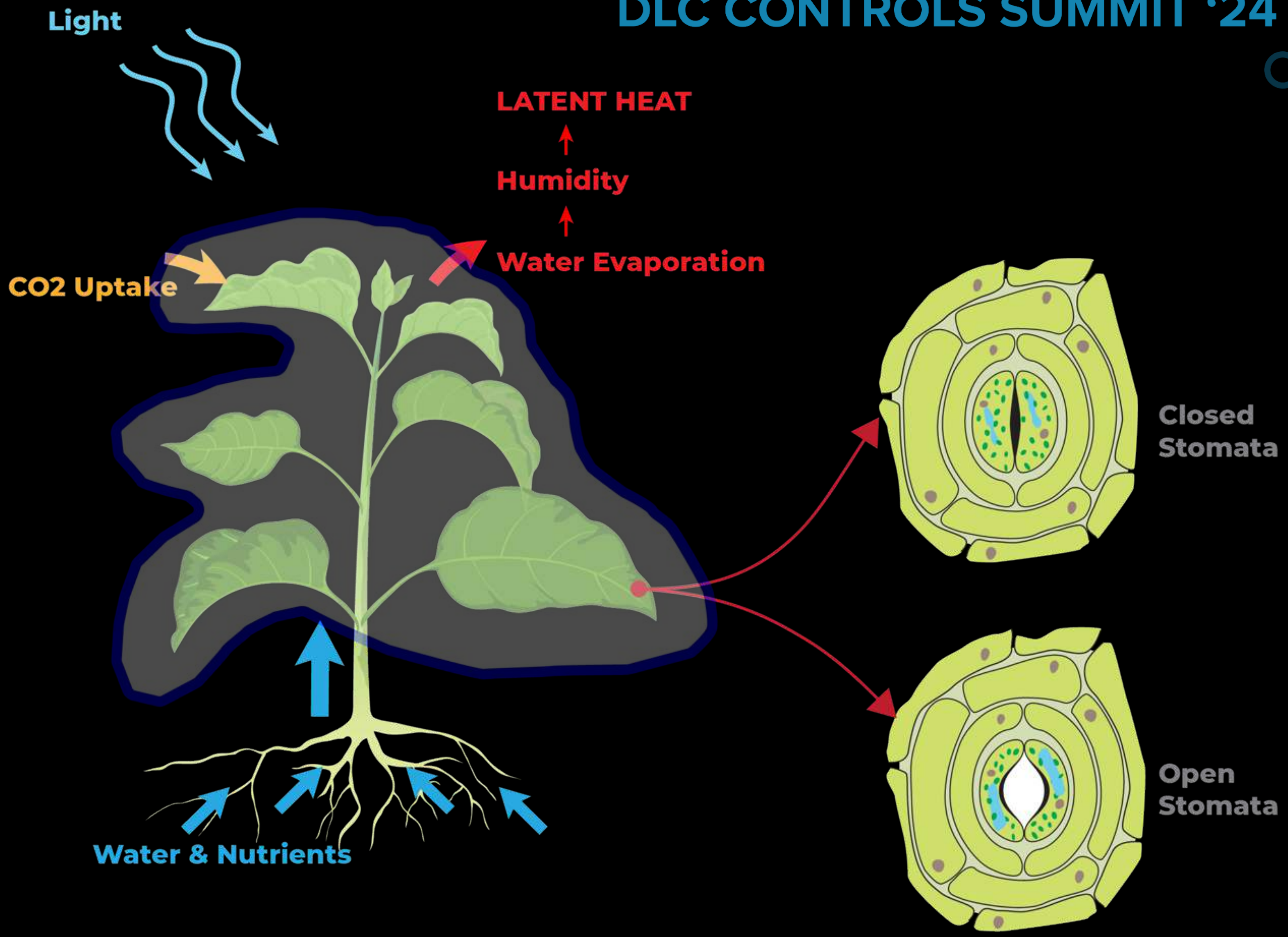
Vapor Pressure Deficit (VPD)

a measure of how ‘thirsty’ the air is



Latent Heat

- *The energy consumed when water evaporates*
- *Requires additional energy to remove*



Latent Heat

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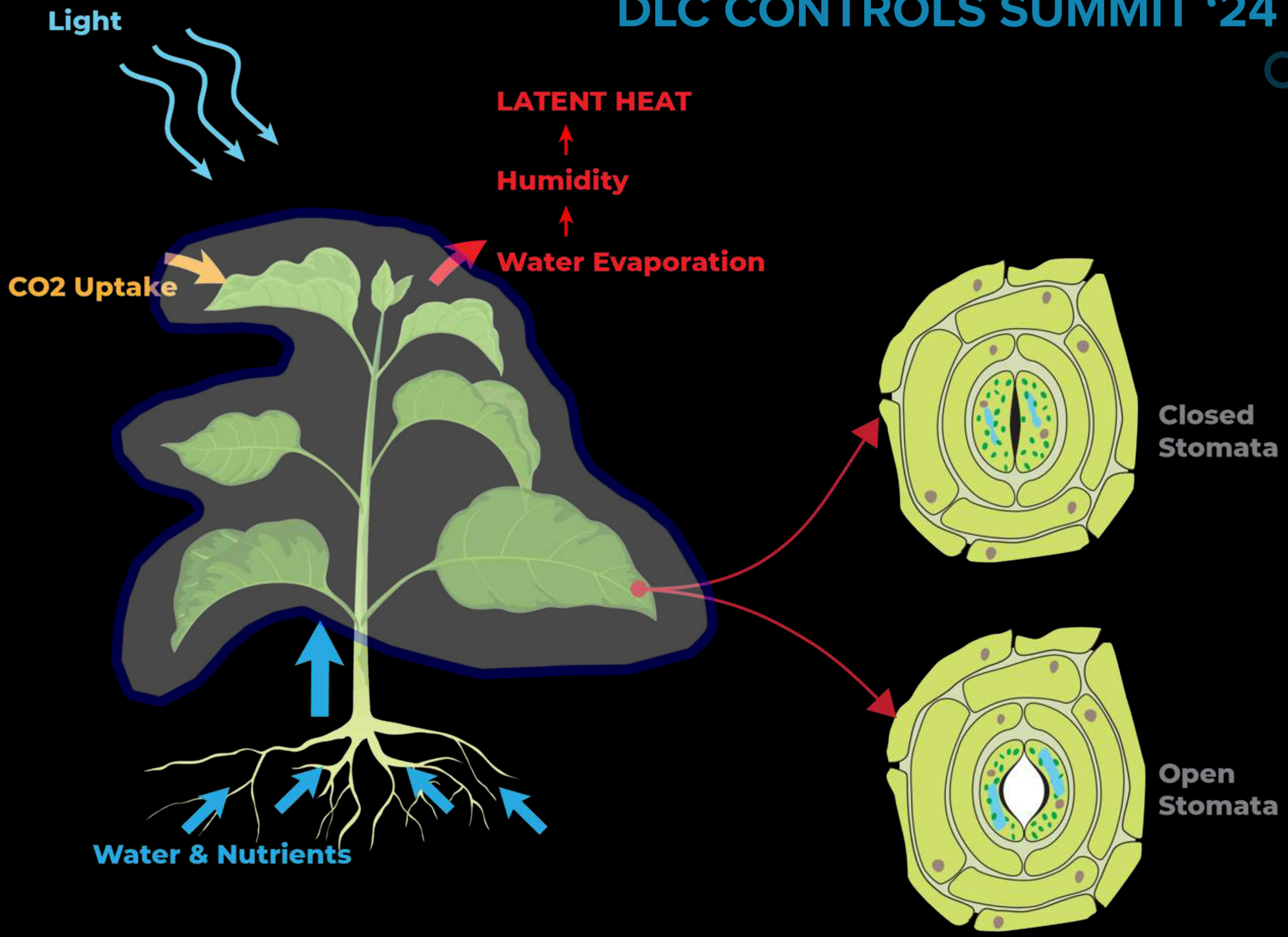
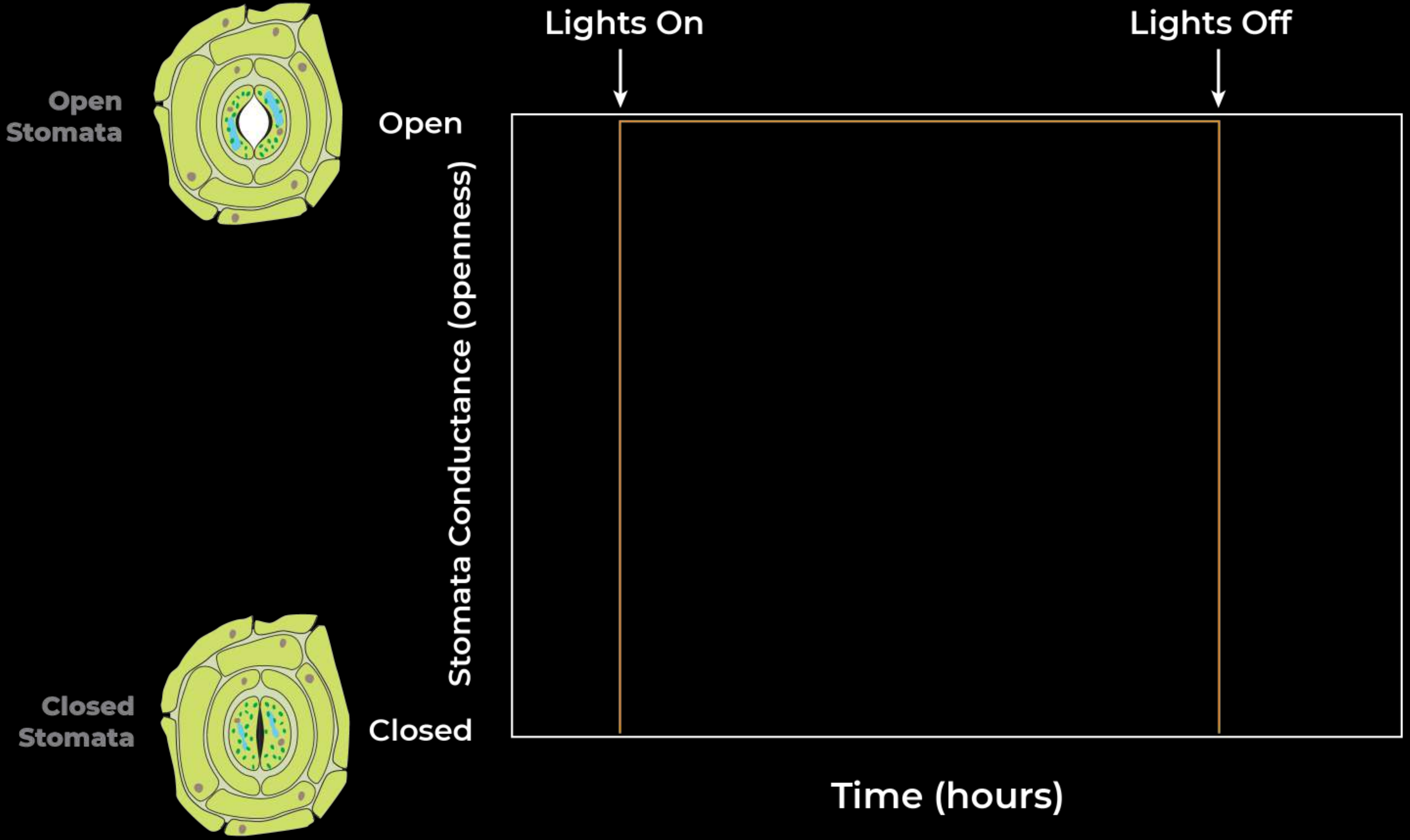
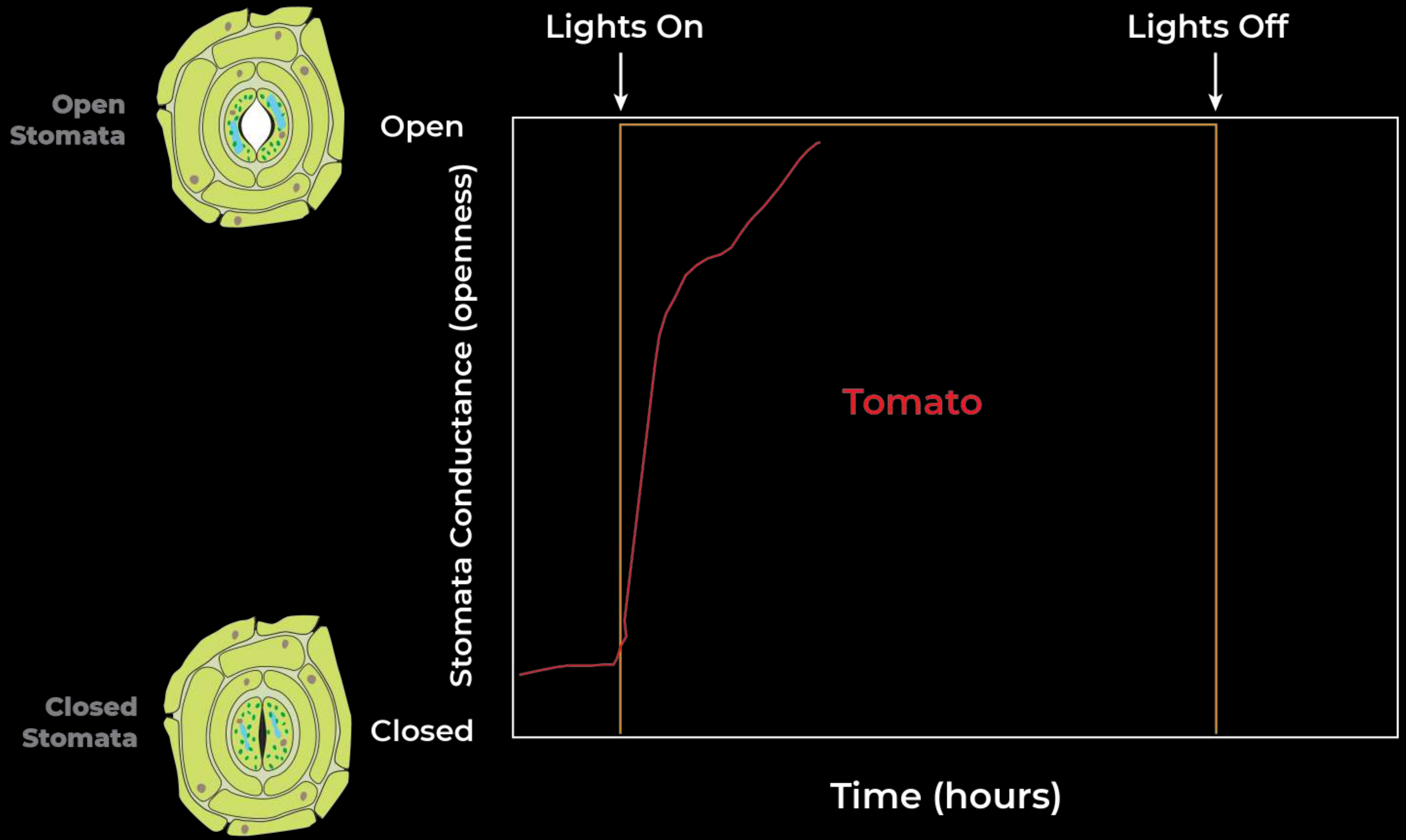
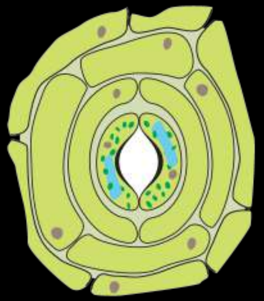


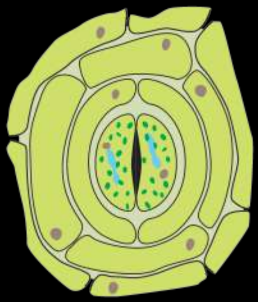


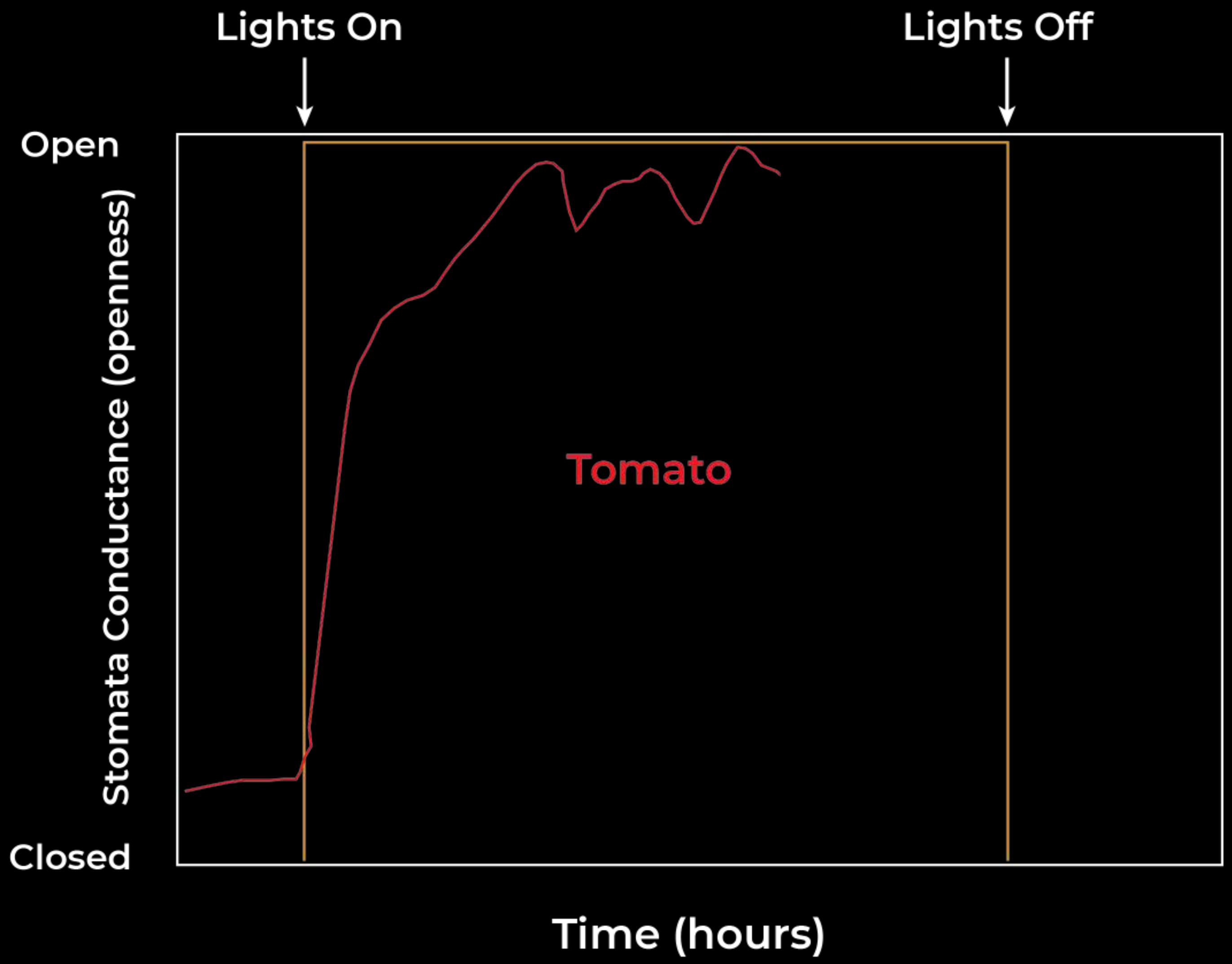
Courtesy of apogee INSTRUMENTS

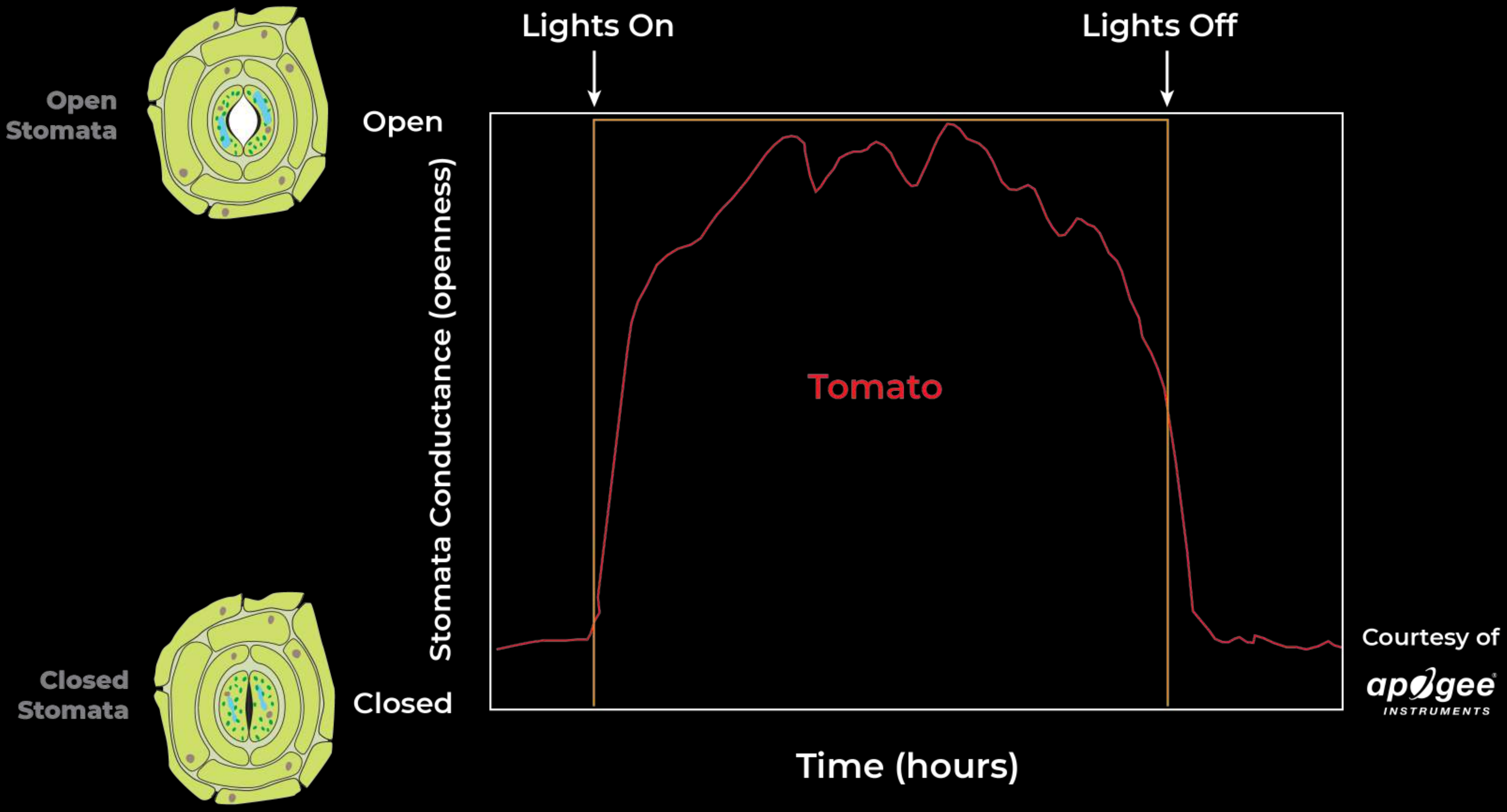


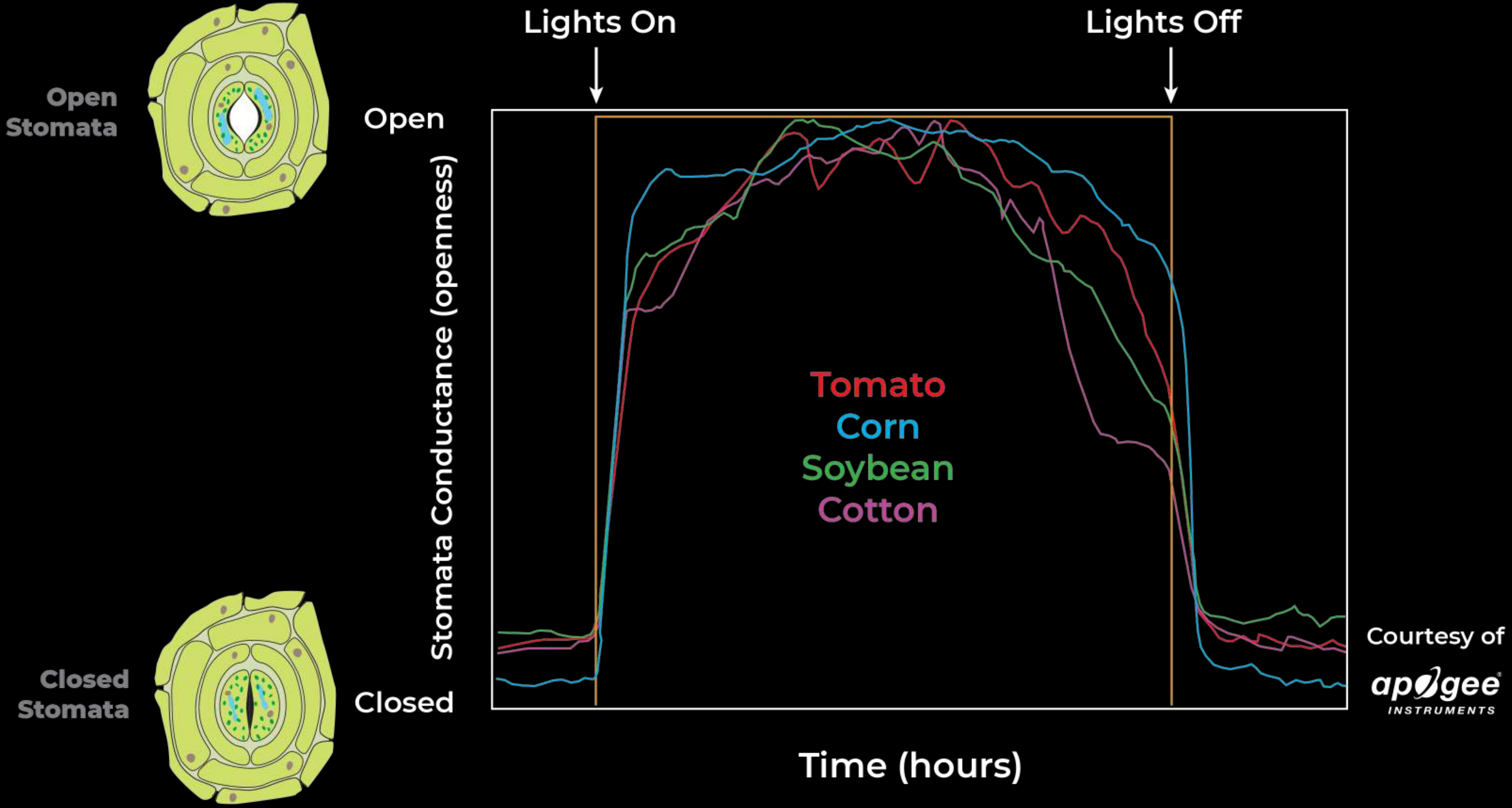
Courtesy of apogee INSTRUMENTS


Open Stomata

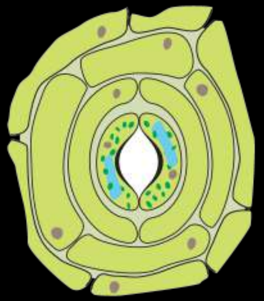

Closed Stomata

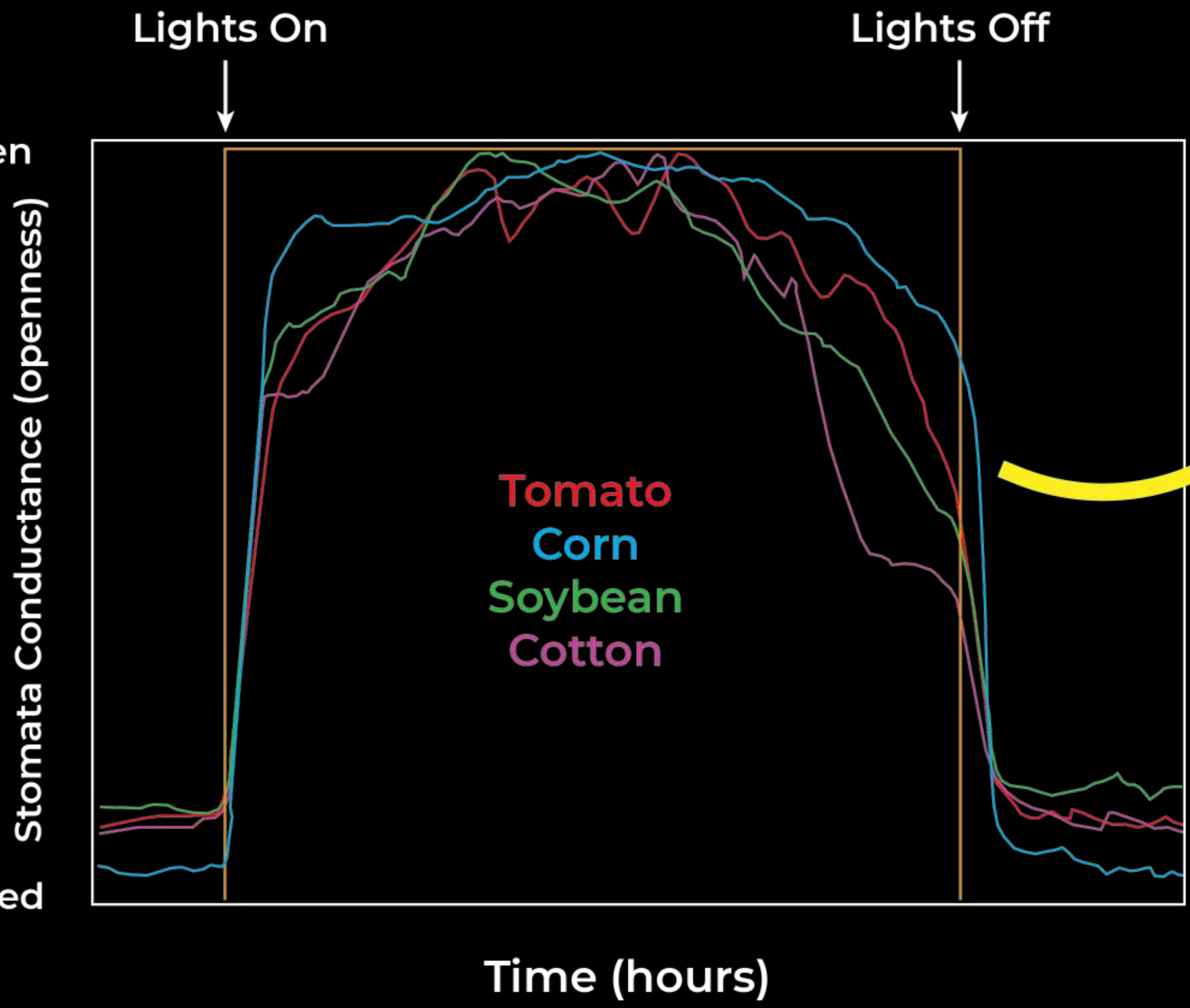

Lights On
Lights Off
Open
Closed
Stomata Conductance (openness)
Tomato
Time (hours)
Courtesy of
apogee INSTRUMENTS

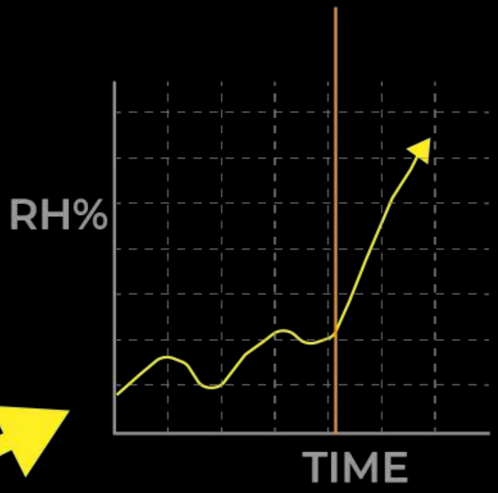

Open
Stomata
Closed
Stomata
Lights On
Lights Off
Open
Closed
Stomata Conductance (openness)
Tomato
Time (hours)
Courtesy of
apogee
INSTRUMENTS


Open Stomata
Closed Stomata
Lights On
Lights Off
Open
Closed
Stomata Conductance (openness)
Tomato
Corn
Soybean
Cotton
Time (hours)
Courtesy of
apogee INSTRUMENTS

Open Stomata

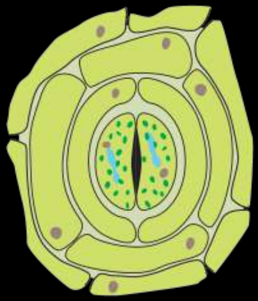


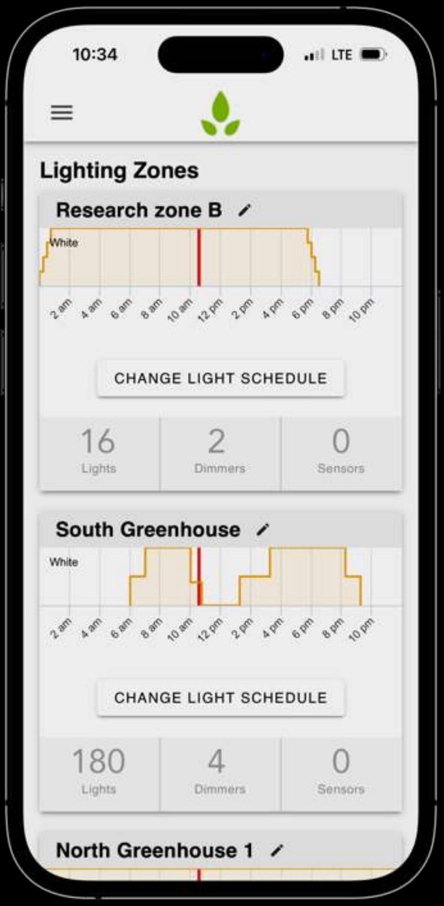


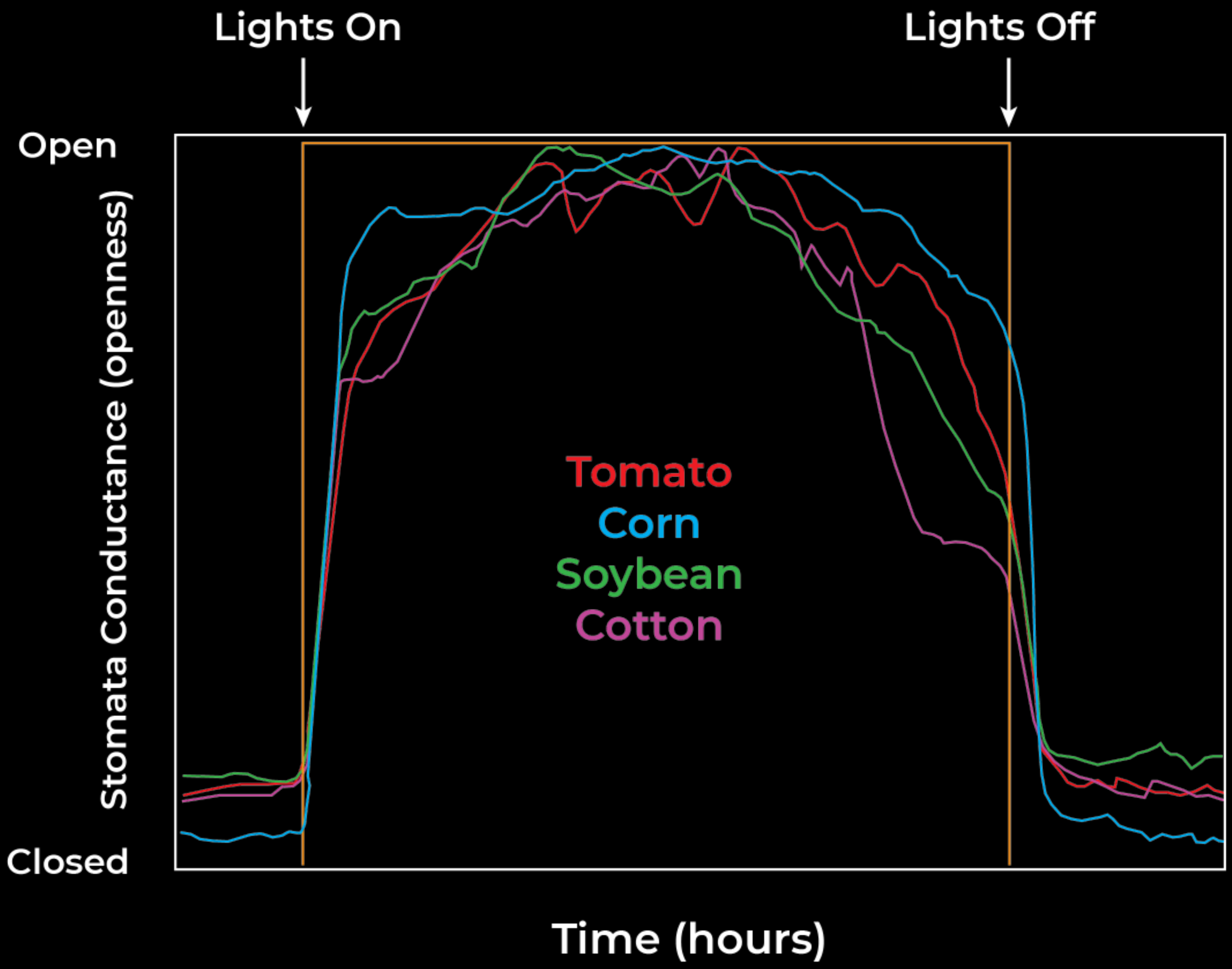


Courtesy of apogee INSTRUMENTS

Closed Stomata

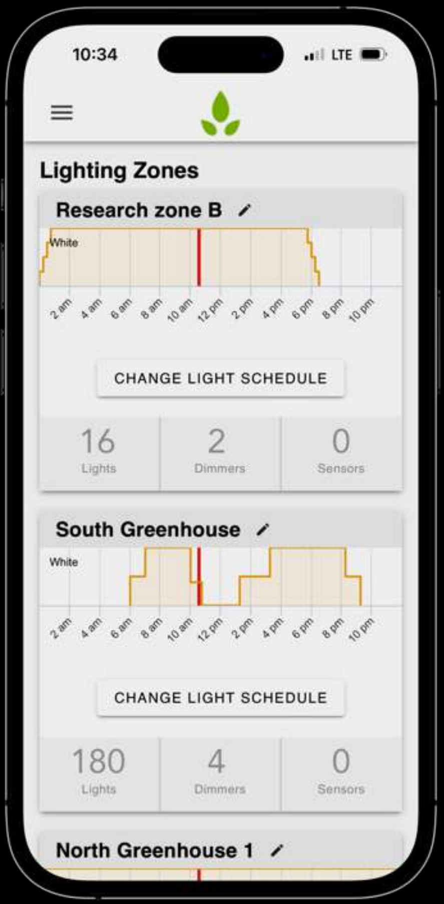


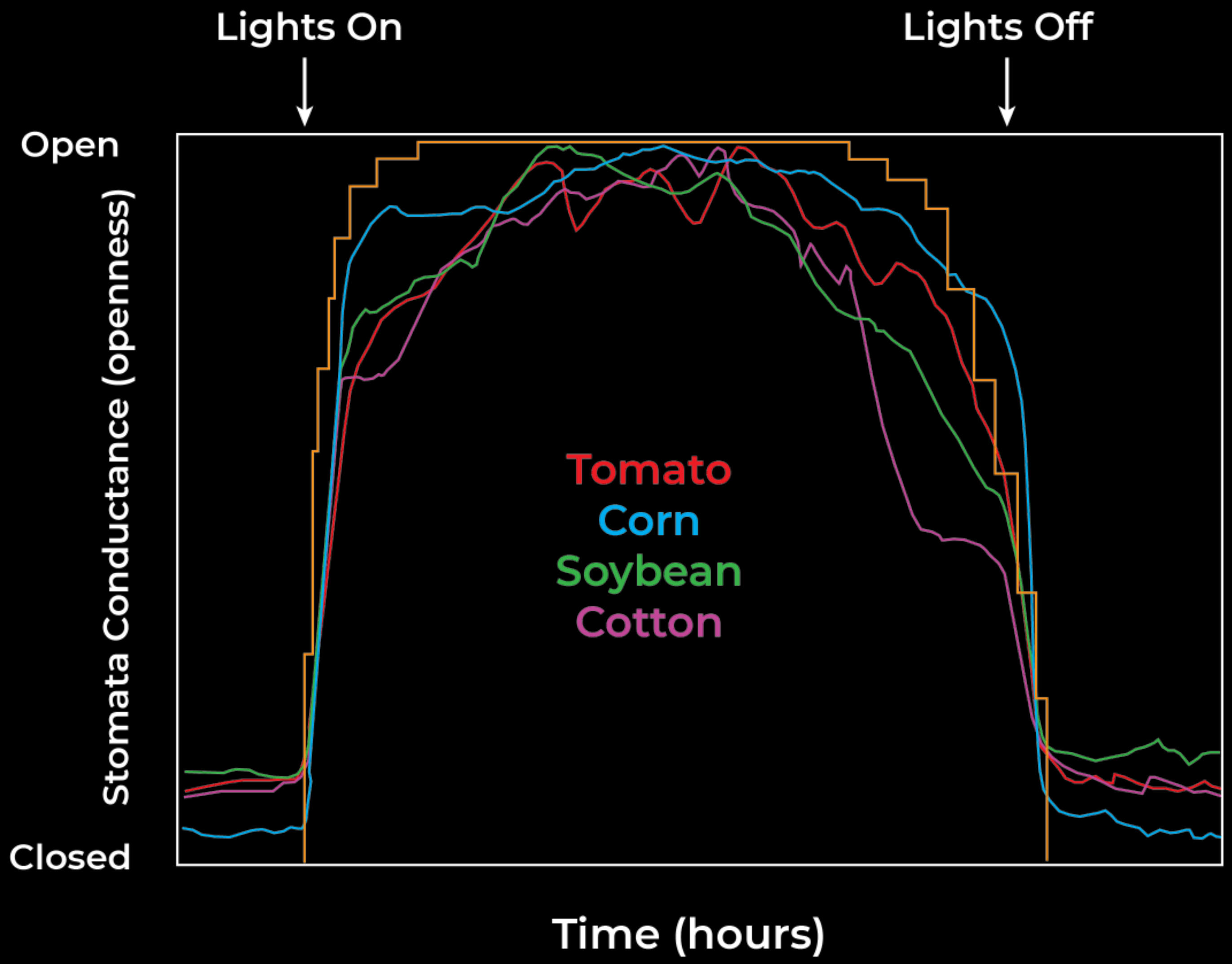




Courtesy of

apogee INSTRUMENTS





Courtesy of apogee INSTRUMENTS

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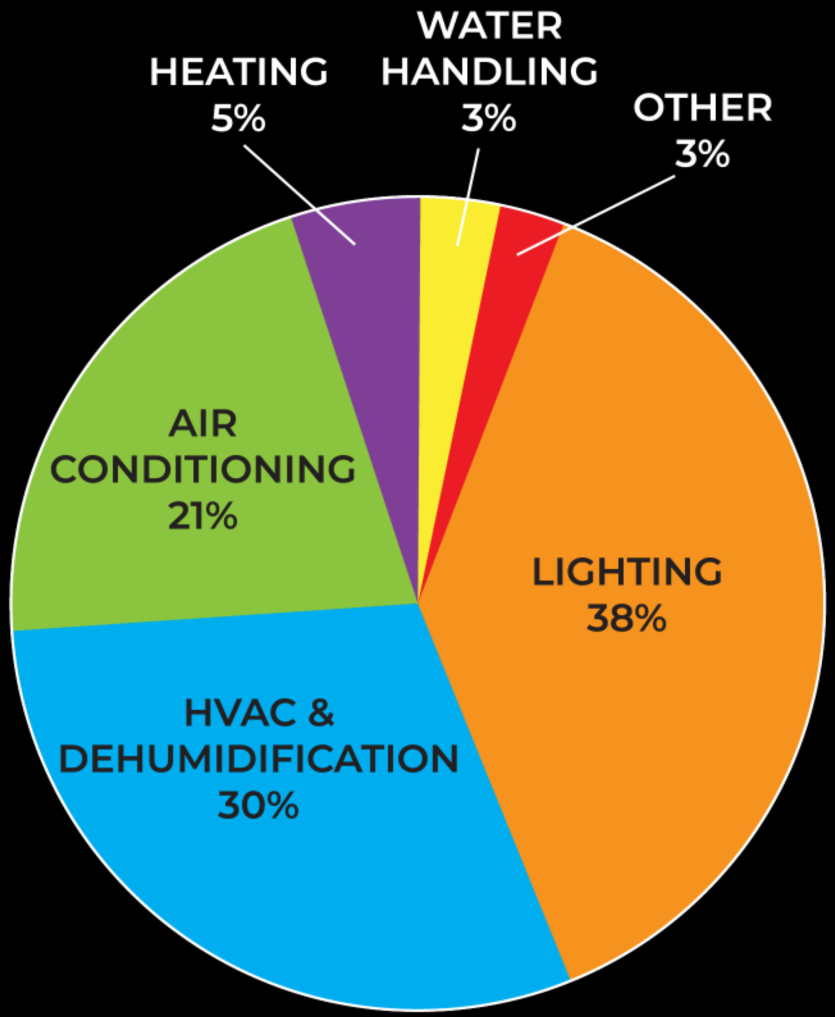
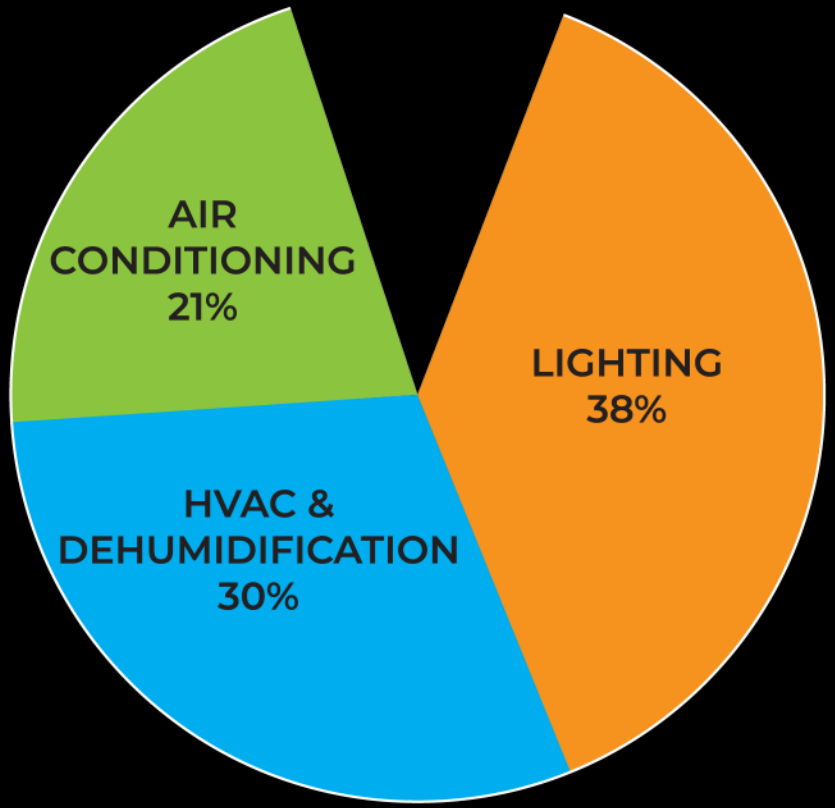
How much energy does each system use?



Courtesy of Resource Innovation Institute

Where are today?

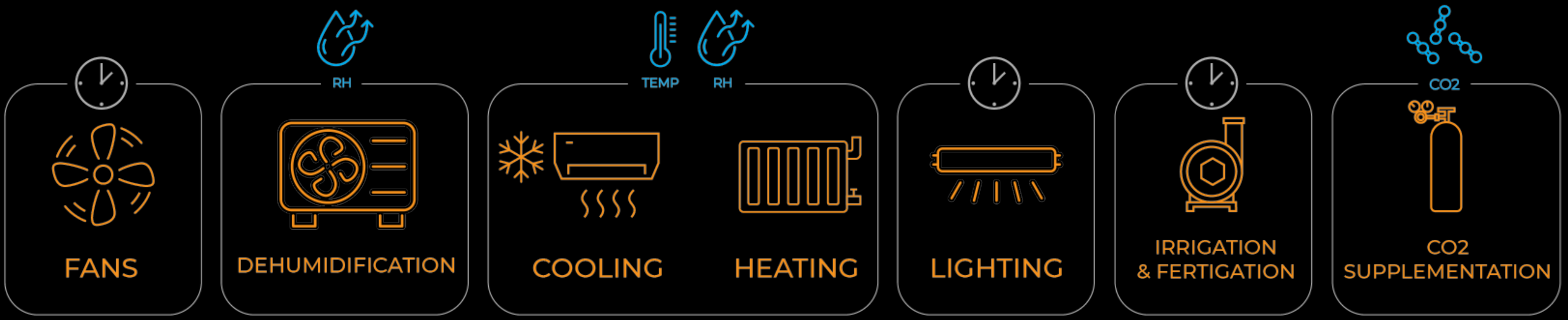


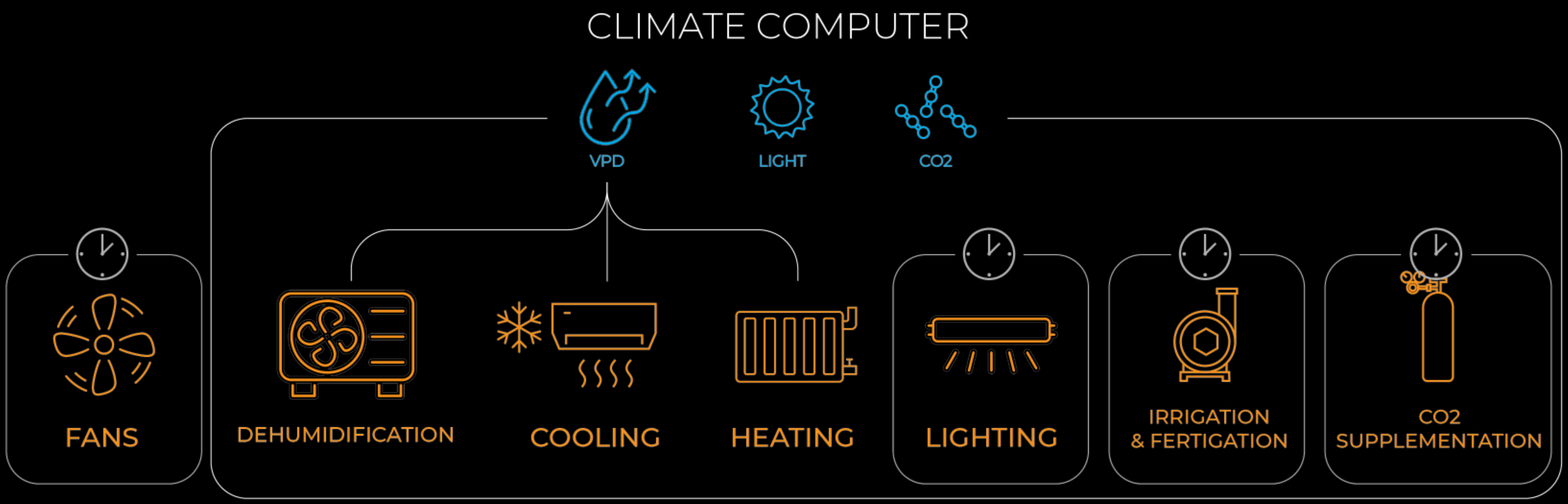
The most efficient lights = ~70% of theoretical efficiency

(not much room for improvement)

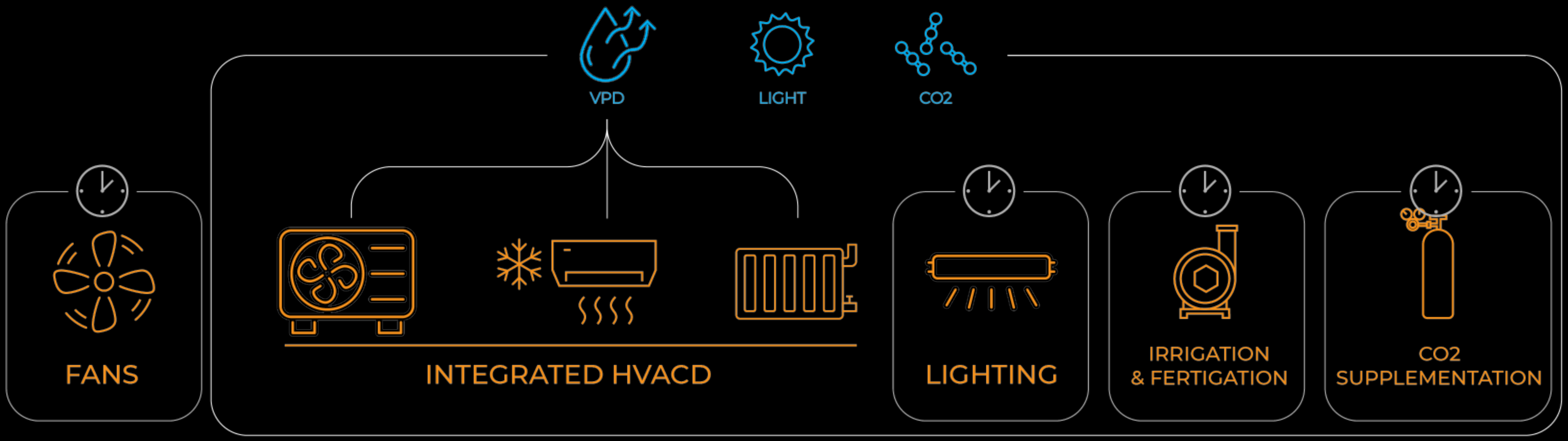
More efficient HVAC
= higher capital costs

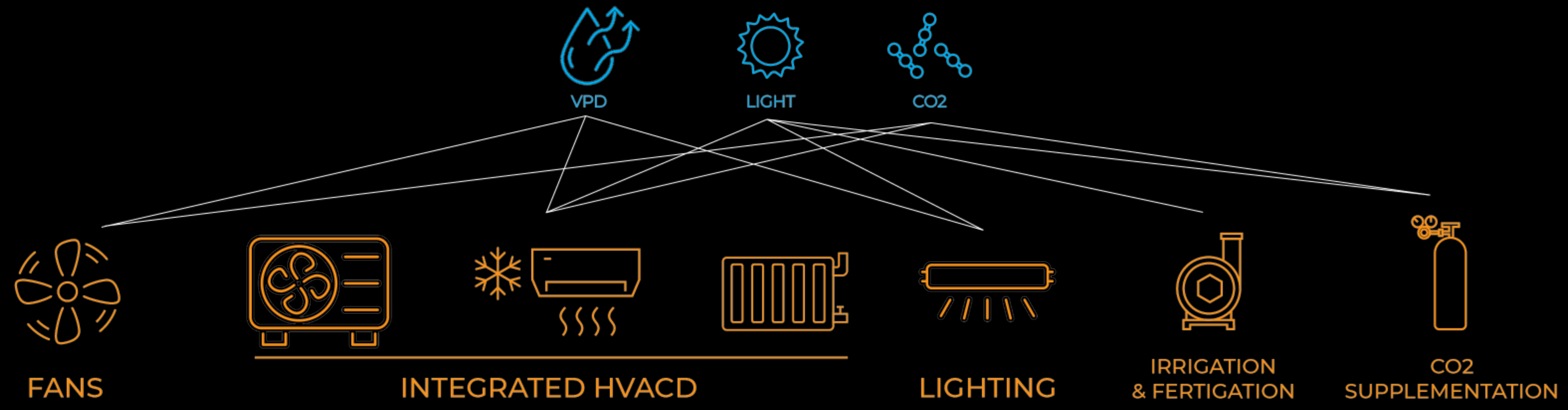

FANS
DEHUMIDIFICATION
COOLING
HEATING
LIGHTING
IRRIGATION
& FERTIGATION
CO2
SUPPLEMENTATION


FANS
RH
DEHUMIDIFICATION
TEMP
RH
COOLING
HEATING
LIGHTING
IRRIGATION
& FERTIGATION
CO2
CO2
SUPPLEMENTATION


CLIMATE COMPUTER
VPD
LIGHT
CO2
FANS
DEHUMIDIFICATION
COOLING
HEATING
LIGHTING
IRRIGATION
& FERTIGATION
CO2
SUPPLEMENTATION

CLIMATE COMPUTER





How do we make progress?

- Software controlled lighting systems with dimming capability
- In-canopy microclimate sensors
- Incentivize measurement & verification
- Incentivize granular control

Question for a panelist?

Mohammed Yousif

Independent Electricity System Operator

Tom Hamilton

Fluence

Eric Noller

Energy Resources Integration

Eric Eisele

GrowFlux

Thank you all for attending!