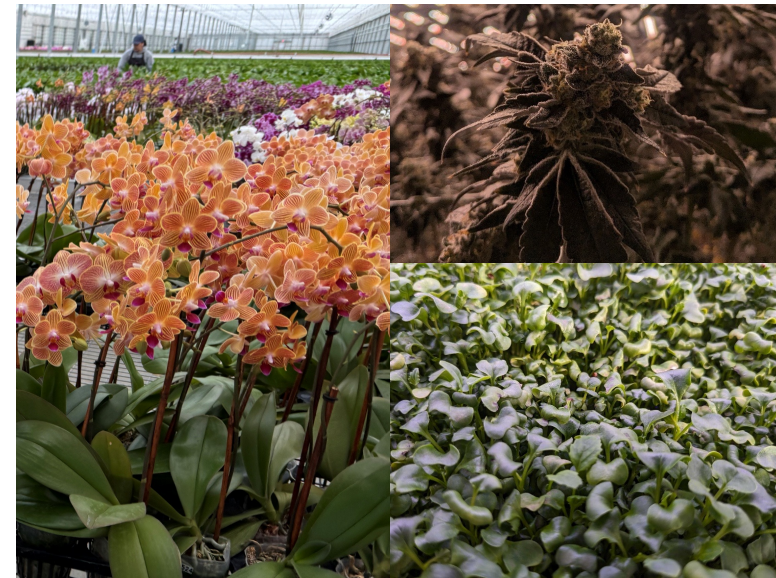


ET23SWE0067

# Smart Controls for Data-Driven Indoor Agriculture Field Evaluation

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Energy Resources Integration



# Executive Summary

Controlled Environment Agriculture (CEA) involves the cultivation and manufacturing of floriculture, food, and cannabis products. This project evaluated automated, integrated, and intelligent environmental controls technologies in use at indoor and greenhouse CEA facilities in California. 4,611 CEA businesses have 7,185 acres (313 million square feet) of facilities in California. Greenhouses for nursery or floriculture production use 61% of California CEA facility area. Two “smart controls” strategies are recommended for deemed measure package development to reduce electricity use from horticultural lighting and ventilation fans by 53 – 78% in greenhouses.

The intended audience for this project’s final report is utility energy efficiency program designers and implementers, commercial greenhouse and indoor farm operators, automation technology suppliers, and CEA facility designers and construction professionals.

# Project Timeline



**The Final Report will be shared at**

**<https://etcc-ca.com/reports/smart-controls-data-driven-indoor-agriculture-field-evaluation>**

**in October 2025.**

# Opportunities

Today's electric IOU measures and incentives for CEA facilities include:

- LED horticultural lighting
- Ventilation fans
- Pump upgrades
- VFDs for fans and pumps

Automation systems for greenhouses and indoor farms may qualify for custom incentives.

ROI for growers is unclear and the custom process is less attractive than prescriptive rebates.

To support the project goal of new workpaper development, the project's field demonstrations incorporate real-time energy monitoring with remote access for the team to view system-level energy consumption trends using cloud-hosted software.

Electric IOUs interested in developing a "smart CEA controls" rebate program can access and use this data to validate persistence of savings for various energy-saving process system automation strategies.

# Tech Transfer

The project team has worked with industry technology transfer partners including:

## *Automation technology manufacturers:*

- Microclimates
- GrowFlux
- Sollum Technologies
- Hoogendoorn Growth Management

## *Industry organizations:*

- DesignLights Consortium
- Cornell University Greenhouse Lighting and Systems Engineering (GLASE) consortium

# Hard-to-Reach (HTR) & Disadvantaged Communities (DAC)

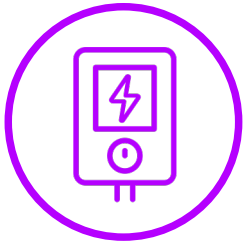
All four of the site visits were held at Hard-to-Reach (HTR) customer facilities.

All four of the field demonstrations were conducted at HTR customer facilities.

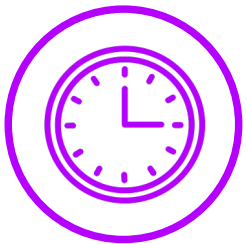




A barrier to creating new programs for CEA facilities is an understanding of the market landscape. The Market Study's results characterize the size of the California CEA market, the proportion of the major types of growers and facilities, and the potential energy savings from lighting, HVAC, and irrigation controls measures.



Another barrier for CEA efficiency is measurement and verification of energy savings. The Final Report will share the field demonstrations' results to estimate energy savings potential for the California market for the most impactful and cost-effective measures.



The project is directly supporting California's EE portfolio by identifying the next frontier of greenhouse and indoor farm measures for process systems to build upon existing offerings for horticultural lighting, ventilation, and irrigation equipment. Insights from this project can be used for EE educational programming as incentive programs are developed.



# Final Report

Findings from literature review, surveys, interviews, and site visits identified nine potential measures for inclusion in the Final Report:

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%



# Final Report

Program pathway #1: Confirm the baseline level of control for CEA lighting, HVAC, and irrigation controls in each IOU's territory.

Categories of Control Technology	Energy Savings Potential	Technology Scope
Level 0: Manual control	Lowest	Manual controls include on/off switches and allow growers to maintain system setpoints with a human touch.
Level 1: Basic control	Low	Basic controls include programmable thermostats and timers and allow growers to vary system setpoints and schedules independently at a system level, using simple hardware that reports actual conditions in the cultivation space.
Level 2: Automated controls	Moderate	Automated controls include standalone controls, like step controllers, and remotely monitor and control system setpoints and schedules independently at a system level. They use sensors that report actual conditions in the cultivation space.
Level 3: Integrated controls	High	Integrated controls include connected monitoring and automation systems exchanging information between multiple types of process equipment. They remotely monitor and control system setpoints and schedules across two or more process systems, using sensors that report actual conditions in the cultivation space.
Level 4: Intelligent controls	Highest	Intelligent controls use machine learning, artificial intelligence (AI), or data-driven logic to monitor conditions, determine setpoints and schedules simultaneously for all process systems using sensors reporting actual conditions in the cultivation space.

# Final Report

Program pathway #2: develop a deemed measure package for greenhouse supplemental lighting DLI controls.

Crop Type	Light Fixture Quantity	Average Electricity Savings (kWh)	Average % Savings	Average Demand Reduction (kW)	Average Area-Normalized Electricity Savings (kWh/ft <sup>2</sup> )
Leafy Greens	172	431,582	64%	49	43
Tomato	179	364,339	78%	52	36
Cannabis – Veg	417	951,246	58%	109	95
Cannabis - Flower	500	692,368	53%	79	69

# Final Report

Program pathway #3: develop a deemed measure package for greenhouse ventilation fan VFD controls.

Crop Type	Average Electricity Savings (kWh)	Average % Savings	Average Demand Reduction (kW)	Average Area-Normalized Electricity Savings (kWh/ft <sup>2</sup> )
All CEA Crops	123,342	63%	14	12

# Final Report

Program pathway #4: develop a unique outreach strategy for HTR CEA businesses in IOU territory.

Program pathway #5: Leverage controls equipment manufacturers and distributors to encourage technology transfer and recruit CEA customers and contractors to participate in new CEA controls incentive programs and/or project marketplaces.



**Thank you for joining my presentation!**

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