State of LIGHTING Report 2024

Dive into our exclusive research, learn more about fixture specs, see how you can use rebates to offset upgrade costs, and find out how one grower made lighting changes during the last several years.

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State of LIGHTING Report

SPONSOR MESSAGE

WE'RE BACK

Actually, Philips brand horticulture LED lighting has been here all along but we're back to learn and share more about how growers are using horticulture lighting.

In 2016, we partnered with Greenhouse Management for our first State of Lighting project at a time when horticulture LED lighting was considered new technology and viewed with a fair amount of skepticism. In 2016, we posed the question: Are you "considering installing, replacing, or expanding your LEDs in the next 3 years?" 65% of respondents said no.

Eight years later, research shows that 77% of growers have begun the transition to LEDs. Which brings us to another interesting statistic, 4 of the 8 LED companies named as an LED provider in the 2016 study are no longer in business. This may be attributed to a flood of "lighting manufacturers" trying to cash in on the hot lighting market.

One thing that hasn't changed in the 17 years since the Philips horticulture LED team was formed is our commitment to product quality, knowledge, research, and direct grower support. Our boots on the ground in the U.S. and Canada, and around the world, are ready to help you with your lighting needs and share our lighting, technical, and horticulture knowledge.

So, we're not going anywhere. We're ready and eager to help. If you're thinking about installing or expanding your LED lighting installation, or taking the first step into LED lighting, Philips is the right place to start.

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Horticulture LED

Grow with the pros

George Sant & Son Greenhouses
Kleinburg, Ontario

George Sant & Sons is Canada's premier pre-finished supplier and a Ball Horticulture rooting station, supplying top quality rooted material throughout North America. For their 2019 growing season, they installed a small two-bay trial of Philips LED toplighting linear. Due to the trial's success, the Sant team expanded their Philips toplighting installation in 2021, and 2022, and again in 2023. The Sant team discovered the many benefits of propagating young plants under Philips LEDs including more compact plants, stronger rooting, and improved plug quality.

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Philips GreenPower
LED toplighting linear

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The age of the LED

More growers are joining the luminaries as they transition to more efficient ways to light crops.

BY PATRICK ALAN COLEMAN

SUPPLEMENTAL AND PHOTOPERIOD LIGHTING and indoor artificial/sole-source lighting have become something of a standard practice for growers. We've seen that trend in our own biennial State of the Lighting reports. Nowhere is that trend more evident than in the core questions we ask our respondents: Does your location use supplemental/artificial lighting in its production of crops under cover?

When we asked that question in 2018, 62% said they were not using supplemental lighting of any kind, while 38% had invested in adding lighting to their operation. Six years later, the same question yielded results that were completely inverted. This year, more than twice as many operations than 2018 reported using supplemental lighting, representing 75% of respondents. On the other hand, the percentage of those who were not using supplemental lighting halved over that same period to just 24% of respondents.

"In the last few years, we have definitely seen many growers switch over to LEDs. The technology has been around long enough now that the prices have come down and growers have seen their peers install LEDs and have success. They see the benefits," says Roberto Lopez, associate professor of floriculture and controlled environment production at Michigan State University. "Those that have switched from HPS to LEDs comment most on the energy savings."

Given that the state of lighting has changed so much over the years, it only makes sense that the focus of this report shifts as well. Instead of focusing on if or when greenhouse managers are going to install lighting, we're zeroing in on the type of lighting they're choosing and why. And the results are illuminating.

This year's report found that more than twice as many operations than 2018 reported using supplemental lighting, representing 75% of respondents.

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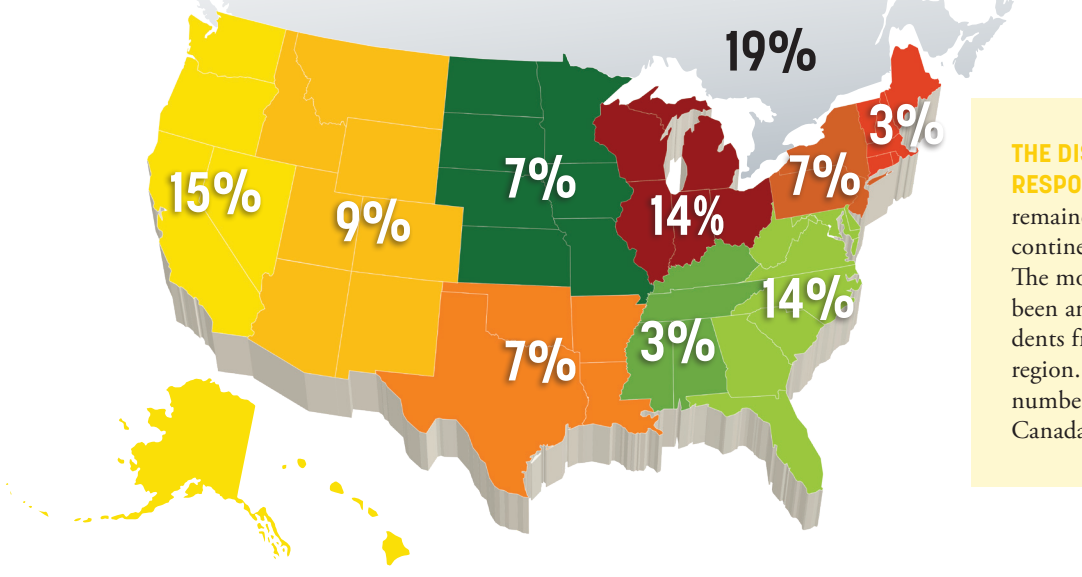
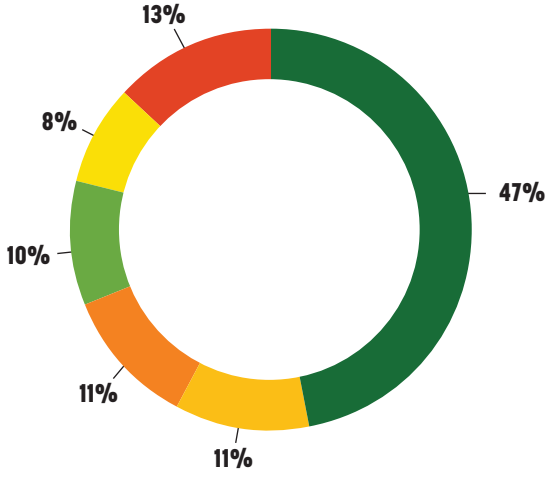
Grower characteristics



THE DISTRIBUTION OF RESPONDENTS has largely remained stable across the continental United States. The most notable shifts have been an increase in respondents from the Western region. And since 2018, the number of respondents from Canada has doubled.

How many square feet (square meters) does your location devote to growing crops under cover?



- less than 25,000 sq. ft. (less than 2,323 sq. m.)
- 25,000 - 49,999 sq. ft. (2,323 - 4,645 sq. m.)
- 50,000 - 99,999 sq. ft. (4,645 - 9,290 sq. m.)
- 100,000 - 249,999 sq. ft. (9,290 - 23,226 sq. m.)
- 250,000 - 499,999 sq. ft. (23,226 - 46,451 sq. m.)
- 500,000 sq. ft. or more (46,452 sq. m. or more)

THE LARGEST CHANGE in size in the last six years is among those with operations of 500,000 square feet or more. When we asked the question in 2018, only 7% of respondents were growing in such large spaces. That number has nearly doubled to 13% in 2024. Perhaps related to that jump in large operations, over half of survey respondents reported between $250,000-$499,999 in revenue (in USD) from crops grown under cover in 2023.

Most survey respondents were involved with supplemental lighting. Over 60% reported either direct involvement in the purchasing, the use or both the purchasing and use of lighting in their growing operations.

To supplement or not to supplement?

Does your location use artificial/supplemental lighting in its production of crops under cover?

76% Yes **24%** No

Why are you NOT currently using artificial/supplemental lighting in your under-cover production? (Select all that apply.)

- **48%** Satisfied with crop production under natural light levels
- **26%** Our under-cover facility does not support lighting
- **48%** Too costly to implement lighting
- **13%** Too complicated to implement lighting
- **6%** Adding lighting will not improve crop production
- **6%** I am not a decision-maker or influencer in the use of lighting
- **19%** *Other responses included: Heating is highest priority; considering it for future use; require more research

DESPITE SUPPLEMENTAL LIGHTING being the norm with respondents, 24% reported not using additional lighting in their operations. Of the reasons selected for a lack of additional lighting, two stood out: the inhibitive cost of implementation and satisfaction with current crop production (both options picked by 48% of respondents).

"A lot of utility companies are offering rebates," Lopez notes. "That has been an incentive for growers that in some instances can get 50% of the cost covered by the utility to replace HPS lamps or other fixtures. Some growers may not need to use supplemental lighting for very long. If they're only using it two months out of the year, then is it really cost effective?"

For what reasons does your location use artificial/supplemental lighting? (Select all that apply.)

- **77%** Daylength extension
- **73%** Supplemental lighting during low-light periods
- **22%** Sole-source lighting
- **7%** * Other responses included: Modified spectra; night interruption lighting

FOR THE 76% of respondents who reported using lighting, increasing daylength was the main reason for use (77%), followed closely by providing supplemental light during low-light periods (73%). Others reported using lighting for germination and modifying the light spectra available to plants.

The results suggest a slightly greater interest in photoperiodic lighting over supplemental, Lopez notes. "Photoperiodic lighting is used to increase the daylength to either promote flowering of long-day plants or inhibit flowering of short-day plants."

Are you currently using LED in your under-cover production?

77% Yes **23%** No

Why are you NOT using LED for your artificial/ supplemental lighting? (Select all that apply.)

18%
Satisfied with crop production under natural light levels

0%
Under cover growing facility does not support lighting

36%
Too costly to implement lighting

5%
Too complicated to implement supplemental lighting

9%
Adding supplemental lighting will not improve crop production

54%
* Other responses included: Currently using HID; currently using incandescent; currently using HPS; unsure of how to choose the best LEDs; need the radiant heat from other lighting; ROI questions

BREAKING IT DOWN EVEN FURTHER, responses show the spread of LEDs. Nearly 80% of respondents said they use LED lighting, compared to just 23% who were not employing the method. For those who were avoiding LEDs, the biggest concern for 38% was the cost. Several respondents reported that the lighting didn't provide heat, which was important to their operation.

"There's a misconception that LEDs don't produce heat. They do produce heat. These days, LED fixtures have a heat sink," Lopez says.

That's different than HPS lighting which radiates heat into the environment and therefore increases plant temperature, which in turn increases the rate of plant development. Because of that, some growers who have switched to LED voice concerns about increased heating costs. However, Lopez notes, the heat that is produced by lights is not an efficient or cost-effective way to heat a greenhouse.

"Even though you may need to increase your heating with LEDs, that natural gas or propane heater or boiler is still much more efficient at heating than your HPS ever was."

But these stats may change in the next three years, considering a full 50% of respondents reported they were considering installing, expanding or replacing their current lighting with LED lighting in that period.

Nearly 80% of respondents said they use LED lighting, compared to just 23% who were not employing the method.

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Lighting them up

What type of lighting are you using for each of types of crops you grow under cover?

	Liners & plugs	Tissue culture &/or seed germination	Finished bedding plants/ perennials
Fluorescent	21%	21%	8%
HID (HPS or metal halide)	32%	8%	11%
Incandescent	23%	0%	23%
LED	25%	17%	6%
Other	22%	22%	0%
None	17%	17%	17%

	Finished potted plants	Cut flowers
Fluorescent	21%	12%
HID (HPS or metal halide)	19%	5%
Incandescent	38%	0%
LED	19%	5%
Other	33%	0%
None	33%	0%

	High-wire crops (cucumber, tomato, pepper, eggplant)	Lettuce, leafy greens
Fluorescent	0%	8%
HID (HPS or metal halide)	16%	5%
Incandescent	0%	0%
LED	12%	9%
Other	0%	11%
None	17%	0%

	Microgreens	Soft fruits (strawberries, blueberries, raspberries)
Fluorescent	4%	4%
HID (HPS or metal halide)	0%	3%
Incandescent	0%	15%
LED	0%	6%
Other	11%	0%
None	0%	0%

MOST CROPS BEING GROWN BY RESPONDENTS OF OUR SURVEY ARE ORNAMENTAL. A full 94% reported growing finished bedding plants, finished perennials or finished potted plants. Slightly fewer respondents, about 82%, reported growing for propagation, including rooted liners and plugs or tissue culture and seeds. Three-quarters of respondents grow food crops, with 26% growing high-wire crops (cucumber, tomato, pepper, eggplant) and slightly fewer (24%) growing lettuce and leafy greens.

Again, Lopez suggests this points to a need for photoperiodic lighting tactics over supplemental. "Photoperiodic is low-intensity light to induce flowering of long-day plants, whereas supplemental lighting is high-intensity lighting where you are providing enough light that the plant is using it for photosynthesis," he says.

Those reporting growing for propagation are more likely using supplemental lighting. "Young plants are where you see the biggest benefit from supplemental lighting," he adds.

Looking at the lighting mix, LEDs were the most reported lighting used (72%) and lit the most crops grown undercover. They were the primary lighting source for nearly all crops except for cut flowers and microgreens.

The next most popular lighting source in the mix was high-intensity discharge lighting (HID), including high-pressure sodium (HPS) or metal halide lamps. Just over 42% of respondents reported using HID in their lighting mix, with it primarily being applied to liners and plugs, followed by high-wire crops. The third most popular lighting in the mix was fluorescent lamps for sole-source lighting, used by 27% of respondents and applied relatively evenly across crops.

"These are the crops that have not been traditionally lit, and it's likely that these growers simply haven't switched to LED," Lopez says.

Taking the LED

What is your level of agreement with each of the following statements about LED lighting?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
LED lighting reduced my location's energy costs	6%	5%	30%	33%	27%
LED lighting improved the quality of my location's crops	5%	5%	24%	38%	29%
LED lighting reduced the production time of my location's crops	5%	7%	41%	29%	18%
The brand(s) of LED lighting used by my location are satisfactory	5%	9%	29%	40%	17%
The cost of LED lighting is worth the value received	6%	4%	30%	39%	21%
Overall, I am satisfied with the LED lighting used at my location	4%	9%	22%	40%	26%

GROWER SENTIMENTS of LEDs are positive overall based on responses. When asked if LED lighting improved the quality of their location's crops, 67% agreed or strongly agreed that it had. Those positive sentiments are just as strong for overall satisfaction of LEDs at their location, their specific LED brand and the value LEDs provide. But the sentiment becomes more neutral when it comes to reducing energy costs and the reduction of production time.

"I think the reason for that neutrality is because you have growers in the mix that went from not using any lighting in their operations to using LEDs," Lopez says. For those who are new to lighting, energy savings are not as apparent. "When you go from not using that much electricity to a $5,000 electric bill, you're going to be skeptical."

He says that even for those that were using HPS, potential savings could be masked by the fact that LED intensities can be increased above those offered by HPS. Increasing lighting intensity with LEDs can keep costs similar, even after switching from HID lighting types. "Growers might have doubled the intensity or added a lot more LEDs in the facility," Lopez notes.

Is your location considering installing, expanding and/or replacing your current artificial/supplemental lighting with LED lighting in the next 3 years?

50% Yes

20% No

30% Unsure

HALF OF RESPONDENTS plan to expand or replace their current lighting in the next three years.

But some report that the replacement isn't easy, considering cost or logistics.

Renato Zardo, director of cultivation at Great Lakes Growers in Ohio, said the company has been using LED for 12 years to light lettuce. While the operation uses an extensive amount of LED, it has not engaged in spectrum shifting or dimming.

"To add light when you are in production is not convenient at all. It's very risky," Zardo says. While he'd like to upgrade, he doesn't know that the returns are worth the risks of trying new LED technologies. "When I'm extending, or building, that's a different scenario."

Bob VanWingerden, co-owner of Catoctin Mountain Growers in Maryland, would like to see LEDs become more affordable. He uses 90% LED for supplemental lighting on begonia and mum crops, though he does still use HPS on a boom for night interruption. His switch from HPS was due to the maintenance and care required for HPS lights. He was aided by government grants to make the switch.

"It's still a steep price tag," VanWingerden says. "What the LED companies could do is make their lights cheaper."

But as LEDs become even more widely used and technology improves, the affordable future of LEDs may be coming. GM

Decision-making tools

From efficacy to quality, the DesignLights Consortium provides lighting research for growers.

BY KASEY HOLLAND

MOUNTING DEMAND for locally grown food and a projected 70% increase in food production needs by 2050 necessitates rapid, scalable adoption of agricultural solutions that are both practical and sustainable.

Expanding at an annual compound rate of 24% globally and predicted to hit $3 billion in the US this year, the controlled environment agriculture (CEA) market is an attractive candidate to meet this demand. CEA's benefits include more efficient use of water and higher yields per unit of area — pluses for the environment and the bottom line. However, adding artificial lighting to the equation can impact both the sustainability and economics of a CEA facility.

A January 2024 U.S. Department of Agriculture study (**bit.ly/ERS-CEA**) noted that "the primary concern of indoor farms is the energy cost, specifically lighting needed to grow crops." And, since horticultural lighting is among the fastest growing segments of electric load for many utilities, this is a concern for the grid as well. To address this, the U.S. Department of Energy has recommended that the nation's growers transition their lighting to all LED technology, a move projected to reduce electricity usage by 34% and costs by approximately $350 million annually.

Like other LED fixtures, horticultural LEDs are long-lasting and super-efficient. As the CEA industry has moved toward more energy-efficient

As the CEA industry has moved toward more energy-efficient practices, LED-based horticultural light has emerged as a neat solution.

PHOTOS PROVIDED BY THE AUTHOR

PHILIPS

Horticulture LED

Grow with the pros

Great Lakes Greenhouses
Leamington, Ontario

"We selected the Philips LED toplighting because of the product's dimming capabilities. The lights are paired with Philips GrowWise system, which helps us control our energy usage with maximum efficiency while supporting our crop health. GrowWise is a complex system, yet anyone can use it, from our company president to a general labourer. It's easy and it works when you need it to work. If there is a power outage, the GrowWise system has redundancy in place to ensure continuity with the lights. Philips GrowWise has made everything so much easier."

innovation + you

Philips GreenPower LED toplighting compact

Philips GreenPower LED toplighting linear

Philips GrowWise Control System

See the Great Lakes story

practices, LED-based horticultural light has emerged as a neat solution — with some state codes requiring LEDs and others offering incentive programs through electric utilities to encourage use of products above certain efficacy ratings.

The DesignLights Consortium (DLC), a nonprofit dedicated to reducing energy use, associated carbon emissions and light pollution through quality lighting and controls, maintains a list of more than 800 horticultural lighting products deemed rebate eligible through independent efficacy, quality and safety testing. Conforming with the DLC's Horticultural Technical Requirements (**bit.ly/DLC-HTR**), products on the Horticultural Qualified Products List (QPL) are more than 35% more efficient than the next-best non-LED option (the 1000W double-ended high pressure sodium luminaire). By year's end, products on the QPL are expected to encompass at least 90% of the overall non-residential LED-based horticultural lighting market.

Other considerations

While greater efficiency is a constant feature across all kinds of LED products, there's a lot more involved for horticultural lighting — largely because there's a lot at stake to ensure this specialized segment of the LED market meets the specialized needs of end-users. Different lighting spectra, for example, can influence factors as diverse as plant rooting, growth rate, flowering and leaf color.

In addition, horticultural lighting must meet UL standards for safety issues that are unique to indoor cultivation environments. Fixtures manufactured for CEA also must emit light that falls within the photosynthetically active radiation (PAR) wavelengths that are conducive to effective plant growth and take into account specific spectral effects that vary by individual crop. Plant canopy height within the facility and compatibility with HVAC and shading systems to meet overall temperature and humidity needs, as well as unintentional light pollution from greenhouse lighting, are among additional considerations.

Notwithstanding differences among cultivation facilities and processes, there are some fundamental questions all facility operators should consider before purchasing and installing horticultural LEDs, such as:

- What is the correct intensity of light for my plants?
- How much light do my plants need throughout the day?
- What spectrum of light will work best for my plants?

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PHOTO © ADOBESTOCK

- Should I replace my existing high-pressure discharge (HID) lamps one-to-one with LEDs?
- How will LEDs affect my HVAC or dehumidification process?
- What are the options for managing fixture heat besides passive cooling?
- Are LEDs safe for employees to work around?
- What are the benefits of horticultural lights that offer ultraviolent or infrared as part of their output?
- How does spectral tuning affect plant growth?
- How do I know if I need supplemental lights for my greenhouse?
- Can I automate my auxiliary lights to achieve optimal daily light integral (DLI) — light received from all sources, sunlight and supplemental?
- What advanced lighting control methods might benefit my facility?

Tools for growers

With so much to consider, the DLC's Horticultural QPL is a useful tool for taking the guesswork out of the product selection process in terms of the quality, efficacy and safety of listed fixtures. It provides rated spectral intensity for all listed products, for example, as well as information about fixture cooling methods and spectral tuning (a control feature that allows some fixtures to change their spectral output).

Importantly, since inclusion on the DLC's Horticultural QPL requires third-party testing to validate conformity with UL safety standards and performance criteria — including damp-location rating and energy efficiency — CEA operators can be sure that listed luminaires are not just safe and effective, but also eligible for cost-saving utility rebates and incentives.

Accessing the QPL to browse and compare products is easy. Simply create a free MyDLC account, log on and select "Find Products." Effective March 31, 2024, Version 3 of the DLC's Horticultural Technical Requirements now displays additional useful information on the specific type of CEA application listed fixtures are intended for, as well as controllability information, dimensions and product images.

The DLC's horticultural lighting program will continue to update its technical requirements as we aim to keep pace with industry developments and grower needs. We recently announced the appointment of a Horticultural Lighting Controls Technical Working Group comprising cultivators, lighting manufacturers, lighting controls and sensor manufacturers, engineering/design/construction consultants, nonprofits and researchers to help us expand the role of connected and integrated lighting solutions that enhance both energy use and crop production.

IN DEVELOPING its horticultural lighting requirements, the DLC has also collaborated with several standards and research entities, all of which are reliable sources for more details about topics addressed in this article.

- The American Society of Agricultural and Biological Engineers (**bit.ly/national-standards**)
- The Illuminating Engineering Society, in particular, the IES Horticultural Lighting Standard (**ies.org**)
- Greenhouse Lighting and Systems Engineering (**glase.org**)
- The Resource Innovation Institute (**resourceinnovation.org**)
- Rensselaer Polytechnic Institute Lighting Enabled Systems & Applications Center (**lesa.rpi.edu**)

As the horticultural lighting market expands, growers will increasingly need high-quality products with reliably vetted performance claims. By streamlining the process of exploring and comparing fixture options, the DLC's Horticultural Lighting QPL can save growers time and money, improve crop yields and contribute to the sustainability of indoor agriculture. GM

FOR MORE: **DESIGNLIGHTS.ORG**

Kasey Holland is technical manager for the DesignLights Consortium's Horticultural Lighting Program. **kholland@designlights.org**

Inclusion on the DesignLights Consortium's Horticultural Qualified Products List requires third-party testing to validate conformity with UL safety standards and performance criteria.

Offset costs

Energy-efficient upgrades often qualify for rebates and other incentives. Make sure you're taking advantage of these programs. BY CODY ALLEN

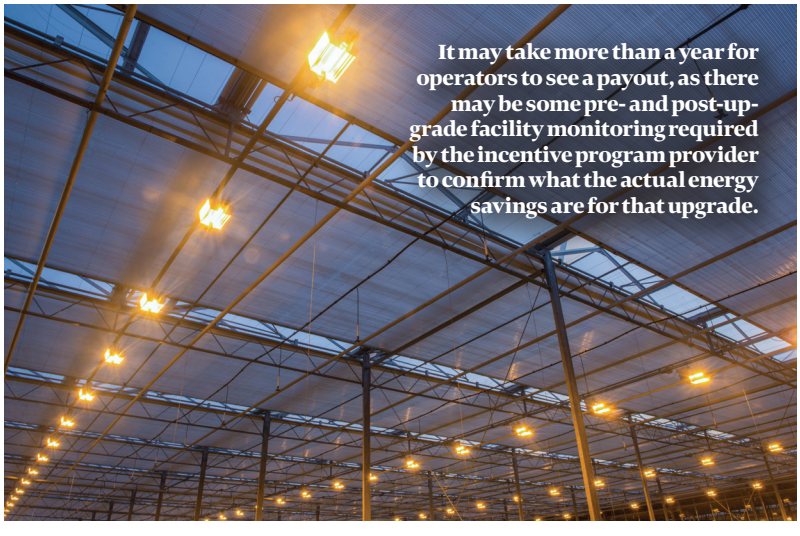
CEA FACILITY UPGRADE PROJECTS may be eligible for various incentive and rebate projects that can offset costs for a variety of equipment — or even make those projects economically feasible.

To help understand how these programs work and their requirements and opportunities, review these tips to help you connect with utilities, as well as state and federal program administrators, to unlock rebates and incentives for energy-efficient system upgrades.

Do your research

When it comes to learning about, and applying for, utility incentives and rebate programs, it's important that CEA operators not only turn to key partners, like their contractors and systems providers, but also do their own investigation into what is available to them in their states of operation.

Utility programs are typically governed by state regulators like the Public Service Commission. And sometimes, there are laws or legislation in place that are out of the utilities' control. Contractors who have experience with generous incentive programs in certain states may not think it's worthwhile to apply for another state's incentive program, but that hurts the customer.



It may take more than a year for operators to see a payout, as there may be some pre- and post-upgrade facility monitoring required by the incentive program provider to confirm what the actual energy savings are for that upgrade.

When doing your own research, it's important to look outside of programs that are CEA-specific. CEA operators should look at not only utility programs, but also other state grants and programs that could be available through the state or through federal government agencies like the USDA.

There may be significant savings opportunities in federal programs through the USDA, REAP (Rural Energy for America Program), EQIP (Environmental Quality Incentives Program) or programs funded through the Inflation Reduction Act (IRA). For example, depending on the size of the operation, CEA facilities can sometimes qualify for small business programs, or even commercial and industrial (C&I) rebates. Depending on the rate class, it could fall into a small business program rather than a C&I program.

In certain cases, programs look at a business' energy use (measured in kilowatts) at peak times rather than facility size. And just because you see that you don't qualify for a C&I program, it doesn't mean there's not another program within that suite of utility programs for which you may qualify. The best thing to do is to call an energy adviser that represents that utility if you have any questions about those programs.

Have conversations with utilities and policymakers

Just because programs may not work for your operation or be available to your business doesn't mean there are no opportunities. CEA operators can develop custom solutions with utility incentive program operators and policymakers. That's particularly true if a program isn't available due to spending caps from poor policy decisions.

Operators should come to the table, explain why the program's not ideal and offer an example of a program that's very successful. Show policymakers the structure and inform them why the policy should change. When a business owner is offering a solution, policymakers tend to be willing

to make modifications to improve the existing program or create a CEA-specific pathway.

That said, eligibility for customized solutions or program changes is dependent on what the CEA facility wants to upgrade. For example, in states like California, where the baseline lighting technology for CEA operators is already established as high-efficiency LEDs, minimal qualifications and requirements may not make you eligible for significant funds to upgrade to LED systems.

Generally, utilities and rebate program providers are willing to look at each proposed project and add new measures by which to evaluate efficiency and sustainability. Utilities want to be proactive and to make an impact within the CEA industry. Be willing to bring up ideas and options that they could explore.

Get your paperwork in order

Unlocking rebates and incentives, whether from utility, state or federal programs, often will require businesses to submit a not-insignificant amount of paperwork. Entering into an agreement with the program provider starts with the application document.

Having accurate energy or water use measurements over varying periods will be needed on both standard and custom-designed projects. For new builds, program administrators will often want to review facility blueprints. We want to look at the plans put together by the architect and engineers so that we can compare against the state standards to see what we can help out with for improvements from an energy standpoint.

Custom project applications are more complex and take more time to complete than applications for standardized programs. It may take more than a year for operators to see a payout, as there may be some pre- and post-upgrade facility monitoring required by the incentive program provider to confirm what the actual energy savings are for that upgrade.

If it's a custom project, you need to document a brief overview of what you want to do, including the baseline equipment in the state, what's in the facility currently and what you want to upgrade to make efficiency improvements to the facility.

Types of upgrades that may require longer incubation periods can include new technology installs that are mostly unproven in the market or for which there are no established baselines. These programs are governed by the Public Service Commission, and we have to show and document that there are truly energy savings there. Otherwise, we're not doing justice to the ratepayers who are funding these programs.

It's also important to note that changes to upgrade plans can delay rebate and incentive delivery, and CEA operators could see drops in rebates if the changes result in lesser energy savings. Utilities may also only pay out a part of the promised incentive if the upgrades are completed in phases or may opt to wait until the entire upgrade project is complete to pay for rebates.

Outside of LED lighting upgrades, states and federal agencies are also looking at high-efficiency HVAC systems, combined HVAC and dehumidification units and water-saving technologies.

Consider upgrades beyond lighting

CEA facility operators may be most familiar with incentive and rebate programs focused on LED lighting upgrades, as lighting often represents the highest energy demand (especially for indoor farms). But states and federal agencies are also looking at high-efficiency HVAC systems, combined HVAC and dehumidification units and water-saving technologies.

The biggest challenge the utilities have is proving that baseline. I encourage CEA growers not to be discouraged if it takes time to really establish that baseline.

Regional climate and industry differences can significantly alter program incentives and wait times. It sometimes takes time to have a proof-of-concept show that there's resource savings to be had. So sometimes, it can take a bit of time to close those deals out, but it's definitely well worth the effort. There can be financial savings of hundreds of thousands to sometimes millions of dollars, plus a lot of energy savings and a reduction in your operating costs, too.

Keep track of program timelines

Understandably, CEA operators may elect to push off efficiency upgrade projects amid the bustle of day-to-day operations. However, energy-efficiency rebate programs often operate under specific eligibility timelines, meaning pushing off projects can lead to operators missing out on thousands, or even millions, of dollars of incentives.

These utility programs are typically approved by the Public Service Commission for a certain number of years. Typically, that's anywhere from a one-year to a five-year or more process. On average, programs operate on three- or four-year cycles.

If CEA operators apply for these programs near the end of the eligibility period, or if upgrade projects extend past those cycles, the utility can't really make any promises, considering the programs aren't technically approved with the Public Service Commission. So, be mindful of the dates these programs technically end and when that funding ends so you can plan accordingly and make sure that you're taking advantage of the incentive funds. GM

Cody Allen is the director of ICF's Utility Program & Services Division (**icf.com**).
Used with permission, this originally appeared on the Resource Innovation Institute (RII) blog (**resourceinnovation.org**). ICF is an RII member.

Early adopters

LEDs were new to the market when Walters Gardens set up its first lighting trial. Now 3 acres of greenhouse space are under LED lighting.

ZEELAND, MICHIGAN-BASED WALTERS GARDENS grows millions of perennial liners each year, which are shipped to independent garden centers, wholesale growers, landscapers and municipalities across the U.S. and Canada. Walters Gardens was an early adopter of LED lighting technology, and we asked Aren Phillips, greenhouse systems manager, to describe the process of trialing and implementing LEDs throughout the operation.

Greenhouse Management: **What precipitated the idea to trial LEDs in the first place?**

Aren Phillips: The idea came about because we were looking to expand our lighted growing areas, but not drastically increase our energy costs. Commercial LEDs were just hitting the market, so we wanted to test them in our trials department back in 2017. This was our first trial.

GM: How big was the trial, and what crops did you test them on?

AP: The first trial was pretty small compared to what we light now with LEDs. It was a few linear modules that were red and blue — very purple and harsh on the eyes. We trialed LEDs mainly on trade show plants and some plugs for that first trial. We have since moved on to production trials, then finally stock and propagation trials in the last few years.

GM: What were the results that made you a believer in LEDs?

AP: We saw that we did not lose any crop time on finished product with no

Walters Gardens' newest propagation range is lit by LEDs.

PHOTOS PROVIDED BY WALTERS GARDENS

Aren Phillips, greenhouse systems manager, Walters Gardens

detrimental effects, although there were a few yellow-leaved varieties that did not like the intense light. We also noticed that we could finish dark-leaved varieties with a true dark color for our customers in cloudy Michigan winters. Before LEDs, we would ship them looking green because of the lack of natural UV light. We have also noticed that our plugs tend to be more compact, but this depends on genus. We have now moved on to lighting some of our stock pots for cutting production and parts of our propagation ranges with no adverse effects.

GM: What are the benefits of LEDs compared to the type of lighting you previously used?

AP: LEDs are becoming so cost effective that there is really no way we that we would go back to HPS lamps. They are highly versatile and can be used for many applications. There are no parts to replace, and warranties are outstanding, depending on the manufacturer. Also, depending on your energy company, there are sizeable rebates available for reimbursement.

GM: How big were the learning curves regarding production when switching to LEDs?

AP: The main learning curve is around the importance of lighting units. It's time to move past lux, lumens and foot candles and use photosynthetic active radiation (PAR), moles and micromoles. It is much more universal and easier to calculate and understand. You want to make sure that you are still hitting your target micromole level and daily light integral (DLI) when replacing or installing new lights.

I would recommend checking out DesignLights Consortium, a nonprofit organization that rates commercial lighting fixtures based on many factors, with photosynthetic photon efficiency being key.

GM: How many square feet of greenhouse space are currently equipped with LEDs?

AP: We are up to about 3 acres of greenhouse space that is now LED lighting. We keep expanding every year with new trials and new types of growing ranges. We are not considering new installations of HPS.

GM: Are they only in propagation areas?

AP: Our propagation areas were actually the last type of ranges that we lit with LEDs, so now we have them there as well. We are now using LEDs in stock, propagation, finishing, holding and trials.

GM: What are your top three pieces of advice for growers thinking about switching to LEDs?

AP: One, to maintain leaf temperature, greenhouses could be kept about 2 degrees warmer due to the lack of infrared heating that you lose from HPS lamps, but it is not necessary. All things considered, I would rather heat with my heaters and light with my lights. It's just more efficient.

Two, because of the huge number of varieties in ornamental horticulture, tunable spectrum LEDs are really in the realm of R&D. They are just too expensive (you pay for diodes that are off when not tuned to that spectrum). So, if you want to do your own research on the varieties you grow, I would go down this route. If you are looking to light a large area with a high turnover rate, then go with a set spectrum. Ask your supplier for their research and decide from there.

Three, in supplemental lighting, look for LEDs that are dimmable and able to connect to an environmental controls system. They are able to dim when the sun comes out and brighten when it fades, maintaining a constant micromole level. This is really the next step in lighting efficiency and controllability. GM

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Red and far-red light

It's important to know how red and far-red light act as a signal to plants in a greenhouse environment.

BY CHRISTOPHER J. CURREY

LIGHT AFFECTS PLANT GROWTH in several different ways. In addition to promoting photosynthesis and growth (light intensity) or controlling flowering and dormancy (daylength), the light spectrum or quality can serve as a signal to influence growth and development of greenhouse crops.

Although different colors or spectra of light serve as signals for different aspects of plant growth and development, red and far-red light and the red-to-far-red ratio (R:FR) play important roles for many greenhouse crops.

Understanding red and far-red

Understanding how red and far-red light act as a signal for plants can subsequently help you understand how it is managed.

Phytochrome is a photoreceptor that senses red and far-red light. It is photoreversible pigment, meaning that it changes forms depending on the light it senses. Phytochrome red (Pr) senses red light with a peak around 630 nm and, after sensing the red light, changes into phytochrome far-red (Pfr). When Pfr senses red light at a peak around 760 nm, it converts to Pr. There is never a time when all phytochrome is entirely Pr or Pfr; rather, the two forms simultaneously exist, and their relative proportion to one another — the phytochrome photoequilibrium (PPE) — acts as a signal to influence plant responses to light quality.

One of the most important plant physiological effects of red and far-red

Leaves preferentially absorb red light for photosynthesis, so whether shade is created on the bench from neighboring plants with close spacing or from hanging baskets above, stem elongation is promoted in shade-rich conditions via far-red light.

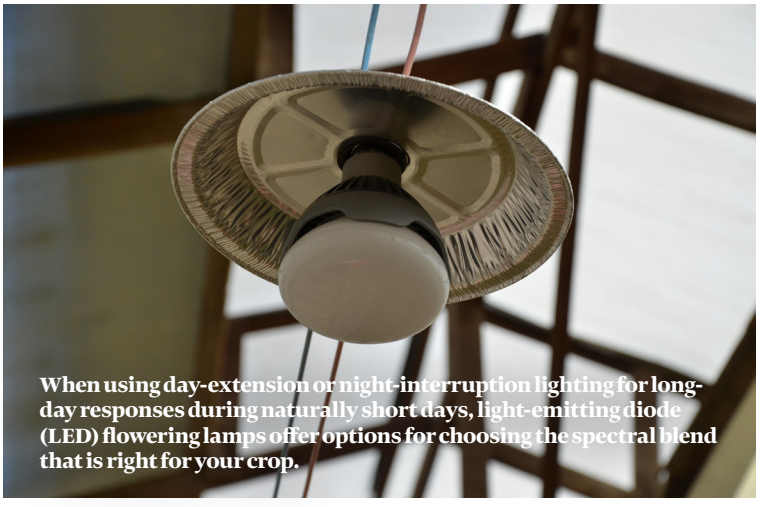
PHOTOS PROVIDED BY THE AUTHOR

light on plants is their effect on stem elongation. When plants are growing in conditions with a higher proportion of far-red light, it promotes stem or internode elongation characterized as the "shade avoidance response." The phrase "shade avoidance response" comes from the fact that when plants are growing in shade created from other plants, this environment is rich in far-red light, since leaves preferentially absorb red light for photosynthesis.

In production greenhouses, there are ways environments rich in far-red light can be created. The first and most common is when plants are grown at high densities or with close spacings. Think about the vase-like appearance of mums or the stretched stems of poinsettias when they are grown close together, compared to the more rounded and compact forms when plants are grown at lower plant densities and with more space between plants.

In addition to spacing affecting the R:FR ratio, hanging baskets suspended above crops similarly affect the light quality below them; the foliage of plants in hanging baskets will preferentially absorb red light and lower the R:FR ratio for plants on benches or floors below them, and this effect increases as the number of hanging baskets increases. Lights used for supplemental or photosynthetic lighting, such as high-pressure sodium (HPS) lamps and high-intensity light-emitting diodes (LEDs), are usually rich in red light, which can help compensate for lower R:FR ratios created by close spacings or hanging baskets.

Flowering for many ornamental greenhouse crops is controlled by daylength, with short- and long-day plants flowering in response to short days (or long nights) and long days (or short nights), respectively. Under naturally short days, photoperiodic lighting such as day-extension or night-interruption is used to extend the daylength or interrupt the night, respectively, to promote flowering of long-day plants, or to inhibit flowering of short-day plants.



When using day-extension or night-interruption lighting for long-day responses during naturally short days, light-emitting diode (LED) flowering lamps offer options for choosing the spectral blend that is right for your crop.

The R:FR ratio effective for extending the day or interrupting the night is different between these different types of photoperiodic response groups.

For short-day plants, red light is essential for plants to perceive "day," and far-red light alone is not effective. Alternatively, long-day plants require a sufficient amount of far-red in addition to red light to perceive "day," and red light alone is not effective. Although responses vary among photoperiodic response groups, this doesn't mean you need separate lights for managing photoperiod for short- and long-day plants.

Traditionally, incandescent light bulbs have been used for both short- and long-day plants, as their R:FR was effective for both crops. When compact fluorescent lamps began to be used for day-extension and night interruption, they were effective for short-day plants but were less effective for some long-day plants because of the low levels of far-red light; using both incandescent and compact fluorescent lights together improved the R:FR ratio for long-day plants and alleviated this delay. The introduction of LED "flowering lamps" — different from the lights developed for supplemental lighting — has provided producers with a selection of different lights with varying R:FR ratios, as well as a long luminous lifespan and energy efficiency.

Efficient seedling plug production requires fast and uniform germination. In addition to having specific temperature and moisture requirements, some seed-propagated species require light for germination. Specifically, red light can promote germination of these species, while far-red can inhibit it.

The evolutionary adaptation to this R:FR light as a signal is very similar to the shade avoidance; more red light or a higher R:FR light ratio would indicate a seed is not being shaded out and upon germination would receive ample sunlight to grow, whereas more far-red light or a low R:FR ratio would indicate a seed is being shaded by another plant and may not receive sufficient light to grow after germination. As with electrical light sources used for flowering control, be mindful of any lighting used to promote germination in germination chambers to be sure there is a sufficiently high R:FR ratio.

While we commonly think about light intensity and daylength for producing high-quality crops efficiently, keeping in mind the effects of red and far-red light and the R:FR ratio on crop growth and development will help avoid unwanted stretch, problems with flowering control or delays in germination. GM

Christopher J. Currey is an associate professor of horticulture in the Department of Horticulture at Iowa State University. **ccurrey@iastate.edu**

PHILIPS

Horticulture LED

Grow with the pros

Sunterra Farms Greenhouse
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