SPECIAL REPORT

FLUENCE BY OSRAM

CANNABIS BUSINESS TIMES

FIVE YEARS OF RESEARCH

STATE OF THE CANNABIS LIGHTING MARKET

NOTE FROM FLUENCE CEO

DAVID COHEN

When I reviewed last year's results from the "State of the Cannabis Lighting Market" report, the world was in a very different place. At that time, I was writing to you all from the comfort of my office at the Fluence headquarters in Austin, Texas. Today, I'm working remotely and calling upon my 9-year-old to show me how to use Zoom.

I would be remiss if I didn't acknowledge the collective, global struggle we've all faced amid the COVID-19 pandemic. My team and I spoke daily with growers throughout the world facing unpredictable instability and uncertainty while all struggled to balance and adapt to a new working standard.

But through it all, one unwavering truth rang clear: Cultivators were and are responsible for growing and delivering the world's livelihood—our food and medicine. Our vision to help them grow smarter and our commitment to providing research-backed, advanced technology never felt more crucial than during the early moments of the pandemic.

I am amazed every day by the steadfastness of today's innovative cultivators. As cities shut down, dispensaries, grocers and other essential businesses doubled down for their communities—producing, shipping and delivering goods to quarantined families, patients and citizens who needed critical assistance. Cannabis growers and operators adapted to changing consumer shopping patterns—some experiencing upswings in sales and others adjusting to life without revenue from tourists.

In last year's report, I touted how thought leaders and policymakers were contributing to the growth of cannabis markets. I discussed how a fervent commitment to research and an investment in the most advanced cultivation technology would propel the industry into its next phase of maturity. Despite the global upheaval in our food and medical supply chains due to COVID-19, those factors have not changed. In this year's report, you'll see that LED adoption continues to rise and that more growers are placing greater emphasis on scientific research to support product development. Fluence is meeting that demand through our own in-house scientific research program. You'll be hearing from us in the coming months about our global cannabis projects, where we're exploring the interaction between light and plant quality with some of the world's most innovative cultivators.

As we approach the end of a challenging, strange year, I am inspired by the growers who persevered and went above and beyond to serve their customers and patients. I saw the same perseverance in my own team, and I applaud those who found comfort in a new normal, balance in an unfamiliar routine and the determination to deliver the highest-quality products to customers throughout the world.

> "I AM INSPIRED BY THE GROWERS WHO PERSEVERED AND WENT **ABOVE & BEYOND** TO SERVE THEIR CUSTOMERS AND PATIENTS."

DAVID COHEN
CEO, Fluence

PHOTO COURTESY OF FLUENCE

WHAT THE NUMBERS TELL US

72%

OF RESEARCH PARTICIPANTS

MEASURE **HOW MUCH LIGHT THEIR CROPS RECEIVE,** AN INCREASE SINCE THE 2016 STUDY, WHEN 55% SAID THEY TRACKED THIS.

WHEN *CANNABIS BUSINESS TIMES* FIRST PUBLISHED THE "STATE OF THE LIGHTING MARKET" REPORT FIVE YEARS AGO, the goal was to gain a greater understanding of how cultivators use lighting in their facilities. The now-annual study remains committed to answering important questions, such as, "What types of lighting are most commonly used during various growth stages? Are growers measuring the light that reaches their crops? What other metrics are growers tracking, and why are these important?"

Thanks to the continued support of Fluence by OSRAM, *CBT* has been able to consistently conduct this important study (using leading third-party research organization Readex Research) and ask these and new questions each year, discovering important benchmarks including what portion of energy costs are devoted to lighting to illuminate their canopies and how much money they invest in lighting equipment.

Now with five years of data, steady patterns have transformed into trends, and industry changes and continued challenges are reflected in the research results, too.

For example, in 2016, 43% of study participants said they *did not* measure how much light their crops receive. As the industry has matured and cultivators have refined their craft, lighting techniques have also improved, and now, nearly three-fourths (72%) of participants use light meters to take this measurement. Still, more than a quarter (28%) said they do not track this, and "ensuring consistent/even lighting across the crops" was the most reported challenge of all listed for growers in the 2020 study (17%).

These numbers can help us understand not only *what* challenges growers are facing, but *why* and potentially *how* they can be resolved.

As prominent Utah State University professor and researcher Dr. Bruce Bugbee, Ph.D., details later in this report (p. S11), measuring light intensity is crucial, as it is one of the biggest contributing factors to yield. "You may think your eyes can tell light intensity, but they cannot," he says. "Some less experienced growers don't realize how critical it is to measure the light intensity, so they've never measured it."

Other notable trends that emerged when *CBT* compared previous studies to this year's findings are included in the following pages. In addition, Dr. Bugbee and cultivators conducting in-house lighting research share their insights, what the numbers are telling them about their lighting practices and how they can continue to improve their strategies to boost yield and more.

CANOPY ILLUMINATION: LED USAGE CONTINUES TO INCREASE

One of the most consistent trends to emerge from *Cannabis Business Times*' five-year "State of the Lighting Market" study is the increasing adoption of light-emitting diodes (LED) lighting.

In 2016, about a fifth (21%) used LED lighting in propagation, and fewer used the technology in the vegetative (17%) and flowering (15%) growth stages. This year, more than half of cultivators reported using LED technology in each of the growth stages, making it the most-used lighting type across propagation, vegetative and flowering. Since 2016, the number of participants reporting using LEDs has grown by double digits in each stage.

PROPAGATION

When *CBT* first conducted this study, 65% of participants reported using T5 (high output/HO) lights (or other HO fluorescents) in propagation, while just 21% reported using LEDs. That statistic has evolved greatly, as 2020 findings show 63% of cultivators using LEDs in this growth stage, while 37% use T5 or other HO fluorescents. The use of most other lighting types in this stage has remained largely unchanged, with the exception of compact fluorescents, which 17% of growers report using in this year's study versus 9% in 2016.

VEGETATION

Growers use a variety of lighting types in the vegetative growth stage. The 2016 study showed a slight variation among a handful of lighting types: 37% of cultivators reported using T5 lights, 31% used high-pressure sodium (HPS) lights, 23% used quartz metal

LIGHTING USED IN **PROPAGATION**

	2016	2020	2016-2020 % point difference
compact fluorescent lights	9%	17%	↑8 pts.
high-pressure sodium (HPS) lights	16%	14%	↓2 pts.
light emitting diodes (LEDs)	21%	63%	↑42 pts.
magnetic induction lights	1%	4%	↑3 pts.
metal halide (MH) lights - ceramic	10%	15%	↑5 pts.
metal halide (MH) lights - double-ended	N/A	4%	N/A
metal halide (MH) lights - quartz	6%	1%	↓5 pts.
sulphur plasma lights	2%	3%	↑1 pt.
T5 (high output/HO) lights (or other HO fluorescents)	65%	37%	↓28 pts.
other	6%	6%	0 pts.

Total may exceed 100% because respondents could select all that apply.

MAJORITY OF PARTICIPANTS USE LEDS BUT DO NOT EXPLORE UTILITY REBATES

Despite the dramatic increases in growers using LEDs, with the exception of 2018, the number of cultivators exploring utility rebates to offset the lighting technology's cost has largely remained the same, with 37% of participants reporting they considered rebates this year compared to 40% in 2017 (the first year *CBT* posed the question) and 51% in 2018.

Of those who explored rebates in this year's study, 19% submitted and received them, which is higher than the 2019 study (12%). Another 5% applied but did not receive rebates, and 14% are exploring but have not moved forward yet. A majority of participants (62%) said they did not apply for nor investigate these rebates, with 38% indicating they were not aware of this cost-saving option.

LIGHTING USED IN **VEGETATION**

	2016	2020	2016-2020 % point difference
compact fluorescent lights	3%	8%	↑5 pts.
high-pressure sodium (HPS) lights	31%	12%	↓19 pts.
light emitting diodes (LEDs)	17%	58%	↑41 pts.
magnetic induction lights	N/A	4%	N/A
metal halide (MH) lights - ceramic	20%	19%	↓1 pt.
metal halide (MH) lights - double-ended	N/A	8%	N/A
metal halide (MH) lights - quartz	23%	2%	↓21 pts.
sulphur plasma lights	2%	2%	0 pts.
T5 (high output/HO) lights (or other HO fluorescents)	37%	20%	↓17 pts.
other	8%	4%	↓4 pts.

Total may exceed 100% because respondents could select all that apply. 2020 participants who selected none: 1%. 2020 participants who did not answer the question: 3%

As seen in propagation and veg, **LEDs are now used by the largest number of participants in flowering,** with 52% indicating they grow with this lighting type, up 37 percentage points from the 2016 study.

LIGHTING USED IN **FLOWERING**

	2016	2020	2016-2020 % point difference
compact fluorescent lights	3%	3%	0 pts.
high-pressure sodium (HPS) lights	62%	40%	↓22 pts.
light emitting diodes (LEDs)	15%	52%	↑37 pts.
magnetic induction lights	1%	2%	↑1 pt.
metal halide (MH) lights - ceramic	7%	7%	0 pts.
metal halide (MH) lights - double-ended	N/A	6%	N/A
metal halide (MH) lights - quartz	5%	0%	↓5 pts.
sulphur plasma lights	1%	3%	↑2 pts.
T5 (high output/HO) lights (or other HO fluorescents)	8%	6%	↓2 pts.
other	5%	6%	↑1 pt.

Total may exceed 100% because respondents could select all that apply. 2020 participants who selected none: 2%. 2020 participants who did not answer the question: 2%

halide lights and 20% grew with ceramic metal halide lights. Each year, LED adoption in this growth stage has increased, and in 2020, 58% reported using LEDs, up from 46% in 2019 and 17% in 2016. The second most-used lighting type this year is T5 (high output/HO) lights, with a fifth of participants (20%) noting they use this technology in their veg rooms, reflecting a 17 percentage point drop from five years ago. Ceramic metal halide usage has stayed consistent, with 19% of participants reporting they use this lighting type in this year's study.

FLOWERING

Another significant change in the five years *CBT* has conducted this study is the lighting type participants report using in the flowering stage. In 2016, HPS lights were the most-preferred lighting type—62% of cultivators said they used them in their flowering rooms. This year, that figure dropped by 22 percentage points, with 40% reporting using HPS (single and double-ended) in this final growth stage. As seen in propagation and veg, LEDs are now used by the largest number of participants, with 52% indicating they grow with this lighting type, up 37 percentage points from the 2016 study.

Portion of growers who said they are planning on implementing LED lighting **during the flowering** period within the next 12 months:

2016 **22%**

2020 **38%**

Note: 2020 data based on the 47 participants who said they do NOT use LEDs in the cannabis flowering cycle.

LIGHT SELECTION: INTENSITY MATTERS MOST

Last year, light intensity and energy efficiency tied as the most important factor cultivators consider when making lighting decisions. In 2020, the largest percentage of participants (84%) once again noted light intensity as crucial when deciding on illumination technology; but tied for the top spot is light spectrum, with 84% noting it as "important" or "very important". Other lighting factors that growers indicated as "important" or "very important" included product warranty (75%), scientific research supporting product development (also 75%), energy efficiency (73%) and price (68%).

When looking at the top 10 factors, dimmable light intensity (57%) and customizable light spectrum (54%) ranked on that list in 2020, but not in 2019. Although the most important factors may shift slightly year to year, one major takeaway is that light intensity has remained a top consideration.

DATA COLLECTED	2017	2020	% pt. change vs. 2017
humidity	82%*	88%	↑6 pts.*
ambient room temperature	79%	85%	↑6 pts.
nutrient solution pH	76%	76%	0 pts.
relative humidity	81%	72%	↓9 pts.
yields	67%*	67%	0 pts.*
CO_2 concentration	62%	66%	↑4 pts.
light intensity (PPFD)	50%	55%	↑5 pts.
media pH	58%	54%	↓4 pts.
nutrient solution electrical conductivity (EC)	55%	51%	↓4 pts.
media EC	39%	38%	↓1 pts.
light quality (spectrum)	41%	33%	↓8 pts.
leaf surface temperature	30%	31%	↑1 pt.
root zone temperature	29%	29%	0 pts.
air speed	18%	19%	↑1 pt.
indicated at least one	95%	95%	0 pts.
NET: Light intensity (PPFD) and/or light quality (spectrum)	57%	64%	↑7 pts.
other	16%	6%	↓10 pts.
don't collect data	5%	4%	↓1 pt.
no answer	0%	1%	↑1 pt.

Total may exceed 100% because respondents could select all that apply.
**2018 responses are used because data was not tracked in 2017.*

DATA DRIVEN CULTIVATION

Since *CBT* first asked about which metrics growers track, 95% or more have indicated measuring at least one growing parameter each year. While most of the metrics tracked have stayed fairly consistent, ambient room temperature is the most commonly measured (85% in 2020, up 6 percentage points since 2017). Relative humidity ranks second, with 72% of cultivators saying they track this metric (down 9 percentage points vs. 2017). The number of participants measuring light intensity (PPFD) has also increased by 5 percentage points, with more than half (55%) now monitoring that metric. A smaller portion of growers also reported measuring light spectrum in this year's study, with about a third (33%) indicating they examine light quality compared with 41% in 2017.

IMPORTANCE OF LIGHTING

How important are each of these factors when purchasing a lighting fixture?

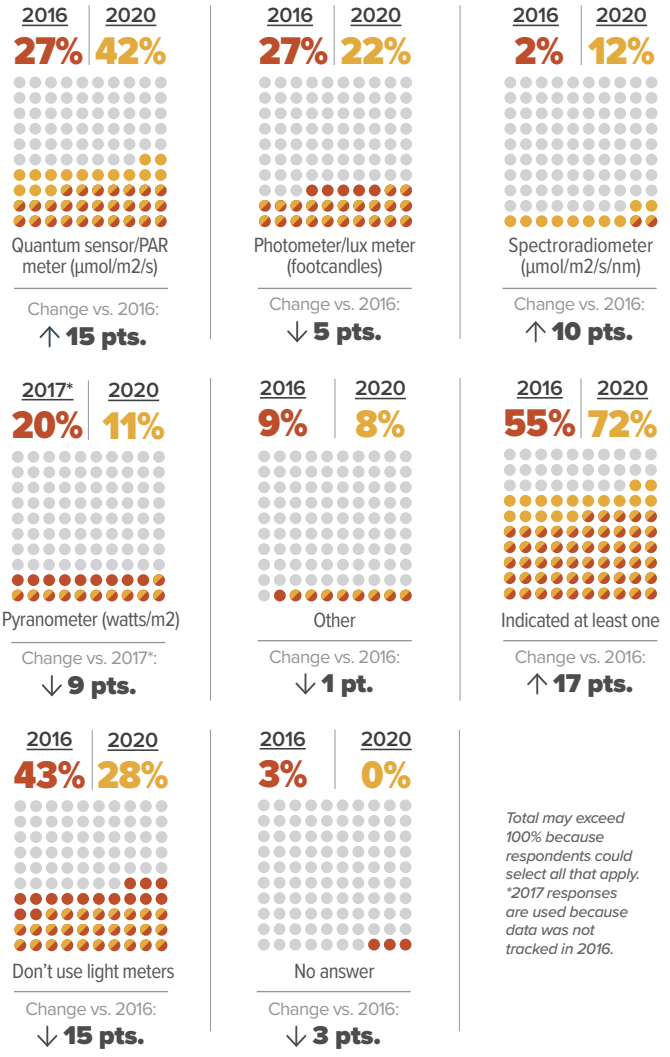
	1	2	3	4	5	6	7	8	9	10
TOP 10 IN ORDER - 2019	TIED energy efficiency & light intensity	TIED light spectrum & price	product warranty	manufacturer's customer service reputation	recommendation from colleague/ peers	scientific research for product development	personal familiarity with product**	knowledge of salesperson	passive cooling mechanism**	must be LED
TOP 10 IN ORDER - 2020	TIED light intensity & light spectrum	TIED product warranty & scientific research for product development	energy efficiency	price	manufacturer's customer service reputation	dimmable light intensity*	customizable light spectrum*	recommendation from colleague/ peers	knowledge of salesperson	must be LED

*Not in 2019's top 10 responses,
**Not in 2020's top 10 responses

MORE CULTIVATORS **MEASURE LIGHT**

In 2016, about half of cultivators (55%) said they regularly tracked how much light their crops receive. That number has increased during the past five years, and now 72% of cultivators indicated they used at least one type of light meter to measure how much light their crops receive. The most common instrument participants reported using in this year's survey is a quantum sensor/photosynthetically active radiation (PAR) meter (42%, which is an increase compared to previous studies). In 2016, although it was still one of the top instruments used, 27% of cultivators reported using the quantum sensor/PAR meter, and 27% reported using a photometer/lux meter. Fewer cultivators reported using the photometer/lux meter (22%) in this year's study, though it is still the second most-used instrument.

LIGHT METERS USED ● 2016 | ● 2020



*Total may exceed 100% because respondents could select all that apply. *2017 responses are used because data was not tracked in 2016.*

TOP 5 LIGHTING CHALLENGES 2018 VS. 2020

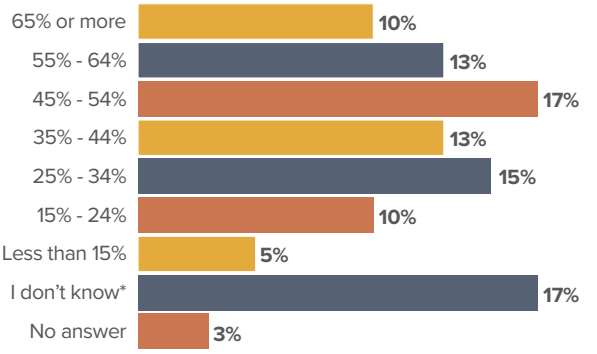
Top lighting challenges have remained somewhat consistent when comparing this year's research to the 2018 study, the first year *CBT* asked about those challenges. Cultivators indicated that lighting's impact on plant growth and terpene/cannabinoid development was the most difficult aspect of lighting in 2018 (21%) and 2019 (22%). In this year's study, the question was split to examine if both plant growth *and* terpene/cannabinoid development were top challenges for growers. In 2020, they still ranked among the top three challenges, along with ensuring consistent/even lighting across the crops (17%). Managing heat load (12%) and energy costs (13%) also have continued to be among the top five challenges for growers.

Electricity to power lighting (see bottom chart) remains one of growers' largest expenses, as it was in 2016. In this year's survey, 39% of participants said they spent 45% or more of their operation's 2019 electricity costs on lighting.

What is your cannabis cultivation operation's **greatest challenge** when it comes to lighting?

RANK	TOP 5 IN 2018	TOP 5 IN 2020
1	lighting's impact on plant growth and terpene/cannabinoid content	ensuring consistent/even lighting across the crops
2	managing heat load	lighting's impact on plant growth (yield, internodal spacing, etc.)
3	managing energy costs	lighting's impact on terpene/ cannabinoid content
4	deciding which type of lighting to utilize at various growth stages	managing energy costs
5	adjusting lights to environment	managing heat load

What percentage of your cannabis cultivation operation's **electricity costs** were spent on lighting in 2019?



**Responses include those who don't know or were unable to separate from total electricity costs.*

WHERE CULTIVATORS ARE GROWING & HOW MUCH THEY SPEND ON LIGHTING

Each year, *CBT* asks participants to provide details about their facilities to gain some context for the data and to learn more specifically about cultivators who are using lighting to power their grows. The majority of cultivators who participated in this year's research said they rely on lighting technology exclusively with no help from the sun to illuminate their canopy: 85% of participants reported growing in an indoor facility, while 29% grow in a greenhouse with supplemental lighting. (Some research participants indicated they grow in both facility types, so the total exceeds 100%.) Grow sizes varied greatly, with 19% cultivating in production spaces of 50,000 square feet or more, and 19% with canopies covering less than 1,000 square feet.

This year was the first time *CBT* obtained lighting-spending data to develop benchmarks; study participants were asked how much they invested in lighting equipment when it was first installed. As with facility size, responses varied here, too, with 12% at the top end of the spectrum, spending $200,000 or more, and 13% investing less than $10,000.

CULTIVATION FACILITY TYPES

In what **type of facility** does your operation grow cannabis?

85% indoor facility

29% outdoors**

29% greenhouse with supplemental lighting

8% greenhouse without supplemental lighting**

94% NET: indoor facility and/or greenhouse with supplemental lighting*

*Total may exceed 100% because participants could select all that apply. *To examine lighting trends among cultivators specifically, CBT's research looked at the responses of 94% of participants, or the 103 participants who grow indoors and/or in greenhouses using supplemental lighting. **Responses from participants who grow outdoors or in greenhouses without supplemental lighting ONLY were excluded from the final report.*

QUICK STATS

- **34,200 sq. ft.** AVERAGE CANOPY SIZE
- **8,540 sq. ft.** MEDIAN CANOPY SIZE
- **$183,000** AVERAGE COST OF LIGHTING TECHNOLOGY WHEN IT WAS FIRST INSTALLED
- **$27,500** MEDIAN COST OF LIGHTING TECHNOLOGY WHEN IT WAS FIRST INSTALLED

What is **the area** of your operation's cannabis crop production (total plant canopy)?

100,000 sq. ft. or more	8%
80,000- 99,999 sq. ft.	4%
50,000 - 79,999 sq. ft.	8%
25,000 - 49,999 sq. ft.	7%
10,000 - 24,999 sq. ft.	19%
5,000 - 9,999 sq. ft.	13%
2,500 - 4,999 sq. ft.	10%
1,000 - 2,499 sq. ft.	12%
500 – 999 sq. ft.	13%
Less than 500 sq. ft.	7%

What was your cannabis cultivation operation's **average kilowatts per hour** (Kwh) output in 2019?

10 million or more	4%
5 - 9.9 million	3%
3 - 4.9 million	5%
2 - 2.9 million	0%
1 - 1.9 million	6%
750,000 - 999,999	7%
500,000 - 749,999	6%
250,000 - 499,999	5%
150,000 -249,000	6%
75,000 -149,000	8%
Less than 75,000	32%
No answer	19%

Approximately **how much did your organization spend** when it first installed lighting equipment for propagation, vegetative and flowering rooms?*

$200,000 or more	12%
$100,000 - $199,999	6%
$50,000 - $99,999	10%
$20,000 - $49,999	12%
$10,000 - $19,999	13%
$5,000 - $9,999	8%
less than $5,000	5%
no answer	24%

**12% of participants said initial installation was more than 10 years ago.*

VERTICAL FARMING-VEGETATION

Does your cannabis operation **use vertical rack systems** for cannabis ***vegetation*** (*not* including propagation)?

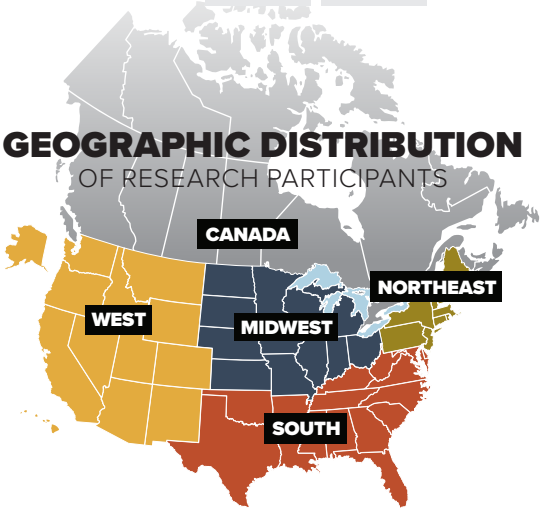
TIERS	2017	2020	2017-2020 % point difference
>5	N/A	2% YES	N/A
5	2% YES	2% YES	0 pts.
4	4% YES	6% YES	↑2 pts.
3	8% YES	11% YES	↑3 pts.
2	17% YES	17% YES	0 pts.
NET: Yes	31%	38%	↑7 pts.
NET: No	68%	62%	↓6 pts.
No, but **considering doing so** in the next 12 months	35%	28%	↓7 pts.
No, and **not considering doing so** in the next 12 months	33%	34%	↑1 pt.
No answer	1%	0%	↓1 pt.

VERTICAL FARMING-FLOWERING

Does your cannabis operation **use vertical rack systems** for cannabis ***flowering***?

TIERS	2017	2020	2017-2020 % point difference
>5	N/A	1% YES	N/A
5	2% YES	2% YES	0 pts.
4	2% YES	2% YES	0 pts.
3	4% YES	7% YES	↑3 pts.
2	5% YES	9% YES	↑4 pts.
NET: Yes	13%	20%	↑7 pts.
NET: No	85%	75%	↓10 pts.
No, but **considering doing so** in the next 12 months	27%	23%	↓4 pts.
No, and **not considering doing so** in the next 12 months	59%	51%	↓8 pts.
No answer	2%	5%	↑3 pts.

GEOGRAPHIC DISTRIBUTION OF RESEARCH PARTICIPANTS



In what regions does your cannabis cultivation business currently operate?

39% **16%** **12%** **30%** **13%** Other: 1%

ABOUT THE RESEARCH & PARTICIPANTS

Readex Research conducted the study and compiled the data for the "2020 State of the Cannabis Lighting Market" report. The survey was sent to *Cannabis Business Times* magazine subscribers with known email addresses and/or e-newsletter subscribers located in the United States, Canada, or other (unknown) North American locations in August and September 2020. Results are based on 103 participants who own or work for an operation that cultivates cannabis indoors and/or in greenhouses with supplemental lighting, unless otherwise indicated. Cultivators who grow outdoors or in greenhouses without supplemental lighting were excluded from the results. The margin of error for percentages based on the 103 participants who indicated they own or work for a cultivation operation that grows cannabis in an indoor facility and/or greenhouse with supplemental lighting is approximately ±9.6 percentage points at the 95% confidence level.

▲ Flowering bay at The Green Organic Dutchman's (TGOD) Ancaster, Ontario, facility

PHOTO BY DAVID BERNARD-PERRON

LIGHT INTENSITY

BENEFITS AND BOUNDARIES

Researchers and growers are experimenting with photosynthetically active radiation to determine just how much they can boost yield and cannabinoid content.

BY **JOLENE HANSEN**

Of all the components that go into a world-class cannabis cultivation facility, lighting is one aspect that gets the most attention. As lighting research and technologies advance, the cannabis industry seeks an increased understanding of how light and cannabis interact. Light intensity is a crucial factor in that quest.

Utah State University professor and researcher Dr. Bruce Bugbee, Ph.D., notes that lighting discussions often focus on color, but he suggests that emphasis is misplaced. "Intensity is more important than colors. It's significantly more important," Bugbee says. A better understanding of light intensity and how to optimize it is key to lighting success.

SETTING A STANDARD

When considering lighting for homes and offices, most laypeople equate intensity to lumens or even foot candles. But those measurements fall short when considering horticultural lighting systems to influence plant growth.

Bugbee explains that photosynthetic photon flux density (PPFD) is the standard unit of measurement for light intensity in horticultural settings. Measured in micromoles of photons per square meter per second (µmol/m2/s), PPFD reveals the amount of photosynthetically active radiation (PAR) reaching the leaf surface.

More than half of cannabis cultivators measure PPFD, according to 2020 data from the "State of the Lighting Market" research (p. S6), as 55% indicated they track this metric.

David Bernard-Perron, vice president of growing operations for The Green Organic Dutchman (TGOD), compares PPFD to the flow rate of water when trying to fill a cup. The higher the PPFD, the greater the flow. But instead of a cup capturing water, the leaf surface of the plant captures light to fuel plant growth.

In Bugbee's opinion, the biggest misconception about light intensity is that it is easily quantified by the human eye. "You may think your eyes can tell light intensity, but they cannot," he says. "Some less experienced growers don't realize how critical it is to measure the light intensity, so they've never measured it." When growers use light meters to measure intensity properly, epiphanies occur. And once light is measured, it can be controlled.

Bugbee says that the most important concept growers should understand about intensity is simple: "The more light that's given, the faster the plants will grow." He adds that many growers could enjoy significantly higher yields by increasing the lighting in their grows. *(Editor's note:* Environmental conditions may need to be adjusted to account for the additional light.)

BALANCE NATURAL AND SUPPLEMENTAL LIGHT

Bernard-Perron likens TGOD's Ancaster, Ontario, hybrid greenhouse to a warehouse with a glass roof. Lit primarily by natural light, the 150,000-square-foot facility is outfitted with 800 PPFD of all-LED supplemental lighting. Although the capital expenditure for LEDs is higher compared to other lighting types, Bernard-Perron believes the return on investment for LEDs is "absolutely there."

> "Cannabis is a plant that you can push a lot of light into, **but there's still a maximum amount.**"
>
> – DAVID BERNARD-PERRON, VP OF GROWING OPERATIONS, THE GREEN ORGANIC DUTCHMAN

The natural light captured by the greenhouse can reach 1,400 to 1,600 PPFD on sunny days. Bernard-Perron says TGOD typically reserves the supplemental 800 PPFD for cloudy days or short winter days with limited natural light.

"In winter, the lights are on all the time," he says. "Depending on if the plants are in a flowering cycle—so a short-day cycle—or if they're in a vegetative cycle—a long-day cycle—we're going to give them the 800 PPFD of light."

Bernard-Perron ties his PPFD-cup analogy to the notion of daily light integral, the amount of PAR a plant receives each day as a function of light intensity and duration. Along with the water's flow rate comes the consideration of how much water the cup can or should hold.

PHOTO BY AMER NABULSI

Plants in TGOD's propagation room. When increasing light intensity, it's important to examine other inputs plants receive, as well, says TGOD's David Bernard-Perron.

"When is your cup going to start to overflow? When is it going to create damage to the cup itself? Cannabis is a plant that you can push a lot of light into, but there's still a maximum amount," he says. "Then at some point, if light is no longer your limiting factor in your environment, is it CO_2? Is it environmental conditions? Is it nutrients?"

Bernard-Perron's internal R&D focuses on answering those questions and more. "We've really just harnessed the tools that we have and started working with notions of daily light and varying light intensities over time," he says. One example is pushing more light into plants the day before a cloudy day is forecast, so daily light integrals are met through averaging during the week.

TGOD also is exploring light quality and UV light's effect on plant morphology and secondary metabolites. "A really good metric to think about is the milligrams of secondary metabolites per [square foot] per year that you're producing, and light is one of the key drivers to that," Bernard-Perron shares.

"There's still so much to learn about this crop and what we're doing," he says. "We're doing a lot of intensive work with photoperiod and the light duration, the light quality and all that, but nothing that has been yet deployed at scale."

Compassionate Cultivation based in Austin, Texas, is growing cannabis under different light intensities and examining how that impacts yield and plant quality.

INTENSITY CEILINGS AND EFFECTS

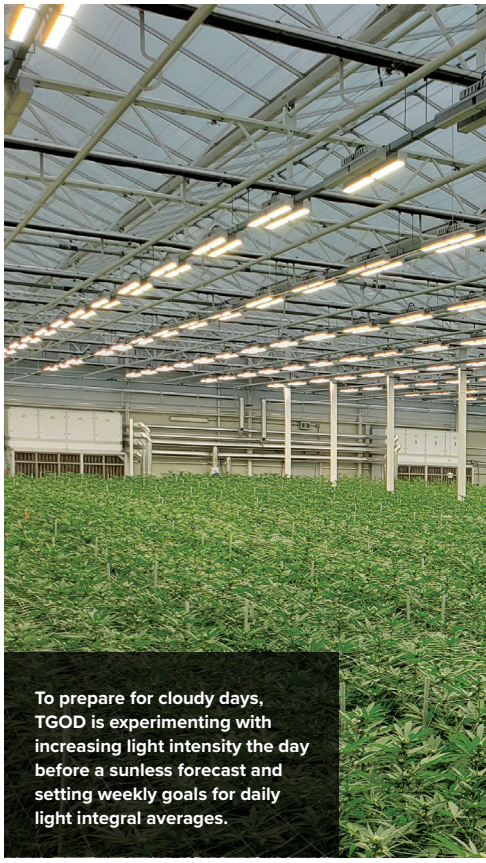
As head grower for Austin, Texas-based Compassionate Cultivation, Jason Sanders has a front-row seat to cannabis research illuminating light intensity and its effects. In May, the medical cannabis company announced it was conducting lighting research, and it now devotes a significant amount of its 2,000 square feet of indoor cultivation space to trials.

The trials take place in portions of three 500-square-foot flower rooms, with one experiment per room. Each room is divided into four sections. One section serves as a control while three sections introduce different variables.

The light-intensity study, now in its second go-round, explores the impact of light treatments ranging from 1,000 to well above 2,000 micromoles of PAR. (In comparison, Bugbee says field-grown plants receive 2,000 micromoles from the sun at mid-day on a sunny day.)

Sanders says the study's goal is to identify the ceiling for light intensity in cannabis cultivation. Yield levels at different light intensities also are of concern. While it's still too early to quantify results, Sanders says the team has been "amazed" at how much light cannabis can handle and the higher yields tied to higher light.

Additional studies focus on spectra and the hypothesis that broad-spectrum light will create higher yields. "We're learning a lot right now on what spectrum is producing the best," Sanders shares. The team also is exploring the effect of ultraviolet B (UVB) light incorporated at various intervals during flowering.



To prepare for cloudy days, TGOD is experimenting with increasing light intensity the day before a sunless forecast and setting weekly goals for daily light integral averages.

For every study, the team analyzes yield, cannabinoid levels, and terpene levels and profiles. Results are expected to be released in early 2021.

THE BENEFITS OF MIXING

Many cultivators use a variety of lighting types for their grows. "Historically, we've always looked at vegetative rooms needing more blue lights, whether it be ceramic metal halide or even the T5 [fluorescents]. Then as we go into flower, we go towards a warmer light or reds and oranges, so we've gone to HPS," Sanders shares. "I

TGOD PHOTO BY DAVID BERNARD-PERRON; COMPASSIONATE PHOTO COURTESY OF FLUENCE

HANSEN HEADSHOT COURTESY OF JOLENE HANSEN

> Bright lights are important for cannabis. **That's the take-home message."**
>
> – DR. BRUCE BUGBEE,
> PROFESSOR AND RESEARCHER,
> UTAH STATE UNIVERSITY

think what we're learning is that we still like a broad spectrum, even in veg."

Prior to starting LED research, Compassionate used double-ended HPS bulbs. "We were running under 1,000 micromoles with HPS, and now we're well above that with LEDs. We're seeing a dramatic plant response with that—increased yield, better vigor, actually shorter plants," Sanders says.

Bernard-Perron explains that HPS or MH lights are less energy-efficient than LEDs because more energy ends up as radiant heat. But from a grower's perspective, that can be a positive thing: Plants respond to a warmer leaf surface with evapotranspiration, which in turn drives nutrient uptake. It can also be a benefit in some cold climates.

TGOD mixes HPS and LED lighting in its facility in Valleyfield, Quebec, where the climate is colder and electricity prices are significantly lower than in Ontario. "We get free heat from the HPS for the environment in the winter, while maintaining this full transpiration drive in the plants," Bernard-Perron says. He reminds growers to keep the effect on room temperature in mind when switching between lighting types.

STAY FOCUSED ON THE WHOLE

Bernard-Perron advises growers to consider all environmental conditions: While lighting is a big piece of the puzzle, it's still just one piece. "Everything ties in together," he says. "Good light quality is important, but also pay attention to what's going on in your grow room."

Bugbee points out two common errors: In one scenario, plants lack sufficient light and grow poorly, but growers suspect a fertilizer problem or something else. In the second, plants struggle under high light, and lights get blamed. But other factors—such as fertilizer or water not optimized for high light—might be at fault. "Bright lights are important for cannabis. That's the take-home message," he says.

Sanders advises growers to run their own small trials and do side-by-side comparisons before making any sweeping lighting change.

Bernard-Perron echoes this, advocating running small R&D trials to make sure your hunches work at scale without jeopardizing your investment—or adding stress. "We manage the stress on the plant, but we also have to manage the stress on ourselves sometimes because it's never ending," he says. "It's good to try new things, but in a way that we make sure it's going to be successful."

JOLENE HANSEN is a Minnesota-based freelance writer specializing in the cannabis, hemp and horticulture industries. Reach her at jolene@jolenehansen.com.

7 TIPS FOR A SUCCESSFUL LIGHTING RETROFIT

BY MICHELLE SIMAKIS

After five years, LivWell's LED lighting conversion is almost complete. Here's what the Denver-based, indoor cultivator learned along the way.

As chief scientist for LivWell, Andrew Alfred's priorities include testing any potential facility update or growing change before implementing it at scale.

For the past seven years, one of the inputs Alfred has researched extensively is lighting. Alfred was interested specifically in light-emitting diode (LED) technology for its energy-saving potential, but before considering a widespread change for the vertically integrated company's 2-acre canopy in its flagship cultivation facility in Denver, he wanted to be sure plant performance wouldn't suffer.

"Seven years ago, one of the LEDs that we had in our flower rooms looked like a car engine. It weighed 80 pounds," Alfred says. "We didn't know how to use the LED light. We didn't know that you had to raise the temperatures in your room to account for the loss of radiant heat."

Another common mistake cultivators made in the early days was simply swapping out one grow light for an LED light without calculating lighting density, which was "a growing pain that the industry had to reconcile."

However, both LED technology and cultivator knowledge have improved dramatically and quickly, Alfred says, and that includes everything from the lights to the mounting hardware. Working with nearly 20 North American and European LED lighting manufacturers, LivWell has conducted multiple cannabis trials over the years, adjusting environmental conditions to optimize plant performance.

Because of the improvements in yield and energy savings, for the past five years, the company has been incrementally converting its entire Denver facility to LED lighting and has almost completed the transition.

Here, Alfred shares some key takeaways he's learned and tips for cultivators who are considering a lighting retrofit in an existing facility.

Using LEDs, LivWell has expanded vertically, growing in two-tier systems in flower and three-tier systems in veg.

PHOTO COURTESY OF LIVWELL

1. Experiment before implementing any sweeping change.

Before updating lighting, Alfred recommends requesting samples or investing in a few lights and testing them first, comparing them to current fixtures and observing metrics like yield. Ensuring all parameters are adjusted for new lights, especially temperature, is also important when running trials "to make sure it's a fair fight," he says.

"The important thing to remember with temperature is that it is all about the plant, not just the temperature of the air. You can use tools like infrared thermometers to measure canopy temperature," he says. "Given the same air temperature, a plant under LED could easily be 5 degrees [F] cooler than a plant under HID [high-intensity discharge]," which could negatively impact yield. Raising the air temperature, targeting ranges in the low 80s, can be a successful strategy for growers.

2. Create detailed plans and review them with all involved.

Replacing existing growing lights for LEDs has been a five-year-plus project for LivWell, and in a few months, the transition will be complete. Creating a plan was integral for success, Alfred says, as was reviewing those plans with the lighting manufacturer and engineers. "You have to bring a lot of people to the table to plan that transition," he says. "We had to coordinate with all parties involved, such as the lighting manufacturers, electricians, [environmental] controls company, permitting office and our production staff."

> **"IT REALLY IS KIND OF A MONUMENTAL EFFORT, AND WHEN IT'S DONE TOO CASUALLY, IT MIGHT RESULT IN LOST PRODUCTION."**
>
> — ANDREW ALFRED, LIVWELL

3. Establish a relationship with your utility company account manager and ask about rebates.

Once LivWell reviewed and finalized the plans with the lighting manufacturer and engineers, they sent the details to their utility company for rebate pre-approval. Establishing a relationship with your utility company account manager is important for many reasons, whether you are planning on updating lighting or not, Alfred says. When LivWell first explored converting to LEDs, Alfred contacted his account manager to discuss the project and if they qualified for custom rebates.

Colorado was still a young market then, and the electrical engineers from the utility company were accustomed to measuring light using lumens, not photosynthetically active radiation (PAR), Alfred explains. By establishing a partnership with the company, he was able to demonstrate the importance of PAR and the significant savings from LEDs.

Now, engineers from the utility company regularly visit LivWell to review the lighting work and measure energy usage. And for every LED light LivWell has purchased, the utility provides 25% to 40% cash back on the investment.

"It takes a big burden off their power grid," he says. "It's better for our business, and it's better for the utility company."

4. Install incrementally to minimize downtime.

Once a rebate program is established, the operations team steps in to coordinate the installation, permitting requirements and construction details.

Minimizing the time that cultivation areas are offline is the most challenging aspect of a retrofit, but LivWell was able to do this by working through careful logistics and installing new lighting incrementally. For LivWell, sometimes that meant using a flowering room as a vegetative room temporarily while the actual vegetative room was being converted.

"If all equipment is staged and permits are in order, it can easily be done in under a month. If any of those pieces are missing, it can take a lot longer," Alfred says. "We had to be flexible with what kind of cultivation we did where to keep our production cadence going."

Because LivWell runs a perpetual harvest, sometimes they worked row by row, converting lights as each bench was harvested, using tarp barriers as temporary walls to protect plants.

"It really is kind of a monumental effort, and when it's done too casually, it might result in lost production," he says. "A good general contractor can quarterback the coordination."

5. Recalculate sensible loads, and consider other important measurements.

Because HVAC equipment is designed and set to work at specific sensible and latent loads, LivWell needed to work with engineers to recalculate the ratios based on the new lighting that does not emit as much radiant heat.

"A more technical challenge was figuring out how to keep our humidity setpoints while removing 40% of our sensible heat load," Alfred says. "We worked with our engineers to assess our HVAC's equipment to handle this change and, in some instances, found that we needed to upgrade our units. It's very important that anyone considering retrofitting to LEDs do this calculation beforehand." In some cases, it will require an equipment upgrade, or, at the very least, a setpoint change. "You don't want to go in blind without having thought through that first," Alfred says.

6. For vertical systems, calculate humidity, temperature, and extra floor space required.

Because LEDs emit far less radiant heat, growers who convert to this technology sometimes explore using vertical (tiered) growing systems, as lights can be closer to the plants. Although "the sky is the limit" regarding how many tiers cultivators could theoretically have, Alfred recommends caution here. LivWell sticks to two tiers in flower and stops at three in veg.

"The higher you go, the more challenging it gets," he says. "It can be difficult to make sure temperature, humidity and air movement are equivalent across all tiers. You don't want your top tier to be a different temperature than your bottom tier, which can happen, especially as you get taller and taller cultivation systems. You can get these stratifications of environment. It's just like switching to LED, and if you're switching to vertical growing and LED at the same time, there's an extra layer of making sure that you do your homework."

Cultivators must account for extra floor space needed for equipment in multi-level systems, as well, Alfred says.

"Consider how aisle and bench widths need to change between single-level and multi-level systems. You're going to need wider aisles for bringing a roller ladder … and you're typically going to want narrower benches to access the plants," he says. "This means that going vertical doesn't simply translate to two times or three times more canopy."

7. Have backup plans–and lights.

With all that's involved in a lighting conversion, unexpected problems can come up, and that includes issues with lighting equipment.

"Have a tough conversation with your lighting manufacturer about their equipment failure rates," Alfred says. "Less than 1% is a bare minimum starting point. Then, make sure the manufacturer sends surplus inventory to anticipate the need to immediately swap out lights that have issues. If a manufacturer can't speak to what their failure rates are, that's a red flag that they don't have a lot of experience with quality control and field installations at scale."

Retrofitting an existing facility with live plants can be challenging, Alfred says, but it's been worth it for LivWell.

"The LEDs often pay for themselves in 12 months just in energy savings alone," he says.

MICHELLE SIMAKIS is editor of *Cannabis Business Times*.

HEADSHOT BY KEN BLAZE

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