FLUENCE

FLUENCE INDOOR LED RETROFIT GUIDE

Everything Cannabis Growers Must Know About Switching From HPS to LEDs

Early pioneers of LEDs tended to focus on how much energy light-emitting diodes would save compared to the then-standard high-intensity discharge (HID) lighting. Growers' operating expenses dropped while quality of light stayed high.

Now, growers are using LEDs to do more than simply reduce operating expenditures (OpEx). They're increasing their light intensities and getting the most from their existing electrical service. They're maximizing production within their existing facilities without costly renovations. And skillful growers are achieving more precise environmental control due to better temperature stability.

As of 2020, 52% of commercial growers reported using LEDs — an increase of 37% since 2016.[1] This trend is expected to continue into the next decade as more growers choose to increase their light levels and cut costs.

This guide explains everything you need to know to make the switch from HPS and tap into the benefits of LEDs. You'll learn:

- How to get the maximum LED rebate from your utility company
- What to change in your grow room and what to consider when you retrofit
- The financials of LEDs from A to Z
- How to avoid common LED mistakes that could hurt your operation

[1] Cannabis Business Times. "State of the Cannabis Lighting Market." 2020.

About Fluence Bioengineering

When you're ready to make the switch to LEDs, the Fluence Lighting Design team and Fluence Commercial Consultation team will be with you every step of the way. Our lighting designers start by assessing your facility, current lighting, and production goals; we coordinate with your utility service to get you the best possible incentives. Following the installation, our horticulture service specialists offer their expertise to answer questions about lighting strategy, environmental management, and parameters to optimize the crop responses.

Why Are Growers Switching to LEDs?

In recent years, wholesale flower prices have trended downward. As new licensees come online, experts expect cost pressures to rise. To be competitive, cultivation companies need to lower their costs and increase yield while also distinguishing their product based on quality. Light-emitting diode fixtures accomplish all three.

Some jurisdictions such as Massachusetts and California are either considering or implementing laws that require efficient cultivation and reduced environmental impact. LED lighting may be required in these markets and others in the future.

More Light = More Revenue

According to research, a 1% increase in photosynthetic active radiation (PAR) corresponded to a 1% increase in harvestable product up to light levels of 1,500 µmol/m²/s or higher. (Note: Yield increases are dependent on environmental control, facility, grower capabilities, and cultivar, among other factors.)

With LEDs, leading growers are now providing much higher lighting densities during reproductive growth with the same electrical input as their old HPS systems. The great potential to increase yield does not require significant increases in other operating expenses. Additional light translates directly to profit.

Lower Operating Expenses

Commercial LED fixtures achieve 2.6 micromoles (µmol/J) of photosynthetic photon flux (PPF) per joule (J) of electricity over their service life when output degradation is taken into account. HPS fixtures average 1.9 µmol/J, if cultivators relamp with new bulbs according to manufacturer recommendations.

Unlike HPS lamps, LEDs require little to no maintenance, and they never need new bulbs. Retrofitting with LEDs eliminates HPS's relamping expenses, which total $60 per HPS fixture annually, not including time or labor.

Better Environmental Control and Pest Management

LEDs bring thermal stability to your grow room to make environmental control easier. By converting more electrical energy into light, they reduce the heat delivered into the growing space. So, as LED lights turn on and off, the room does not experience as much variability in thermal input, temperature, or relative humidity (RH).

Broad spectrum ("white") LEDs also improve your technicians' ability to scout for pests. Because of their higher color rendering index (CRI), they make inspecting for insects and microbial pathogens easier than it is with other lights.

LEDs Enable Multi-Tier Growing

LEDs can hang closer to the canopy than HPS fixtures because of their lower infrared (IR) heat output and potential for arrangement in wide arrays. Today, growers are retrofitting with two-tier or three-tier benching to expand their production capacity while avoiding costly facility expansions.

Multi-tier LEDs are especially suited for growers with large license allowances and small facilities. Cannabis-specific real estate comes at a premium, and vertical growing enables cultivators to expand up rather than out. Production can double with two-tier racking, or triple with three-tier racking, depending on the floor plan, environmental control optimization, and other factors.

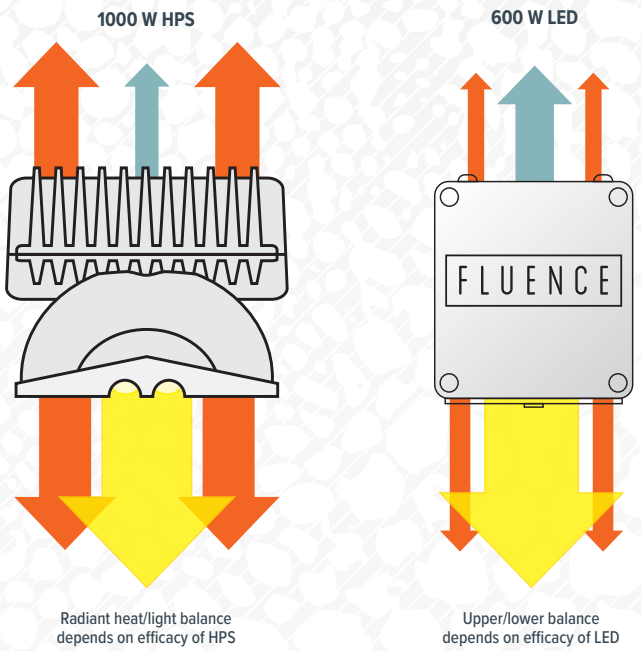
HOW CULTIVATION CHANGES WITH LEDS

Revising Your Lighting Plan

The primary difference between LEDs and HPS is efficacy. LEDs produce more light and less heat with the same electrical input [Figure 1]. Because growers can get more light out of their existing electrical capacity, many are choosing not to reduce their electrical budget; instead, they're increasing their light levels and production capabilities by matching the wattage of their old system.

Of course, you may want to maintain prior light levels. Fluence 600W LED fixtures have approximately the same PPF capability as a 1000W HPS at a lower electrical expenditure. Your lighting designer can help ensure that you achieve similar light distribution. The only other change would be a reduction in your energy costs associated with lighting and HVAC.

[Figure 1]



Matching Wattage

The photosaturation point of cannabis — the point at which more light will not compel more growth — exceeds 2,000 µmol/m²/s during reproductive growth of many cultivars. When you choose high-intensity LEDs, you can leverage the plants' potential for much larger harvests and quicker production cycles than you could achieve at lower levels typical of HPS (≈800-1,000 µmol/m²/s).

Fluence customers have observed 1:1 increases in yield based on increases in photosynthetic photon flux density (PPFD). That is, a 1% increase in PPFD drives a 1% increase in yield up to 1,500 µmol/m²/s.[2] That is, increasing from 800 to 1,500 µmol/m²/s can net a 88% increase in harvest weight. PPFD levels above 1,500 µmol/m²/s drive yield increases as well but generate diminishing yield returns of 0.5-0.8% per percentage increase in PAR.

Results vary by grow system and cultivar. Some light-hungry cultivars may respond more vigorously to higher PPFD. Ultimately, growers who manipulate environmental conditions and operating procedures in response to higher PPFD will realize the best results.

Plants photosynthesize more when you increase PPFD, so you can expect increased biomass in your grow rooms compared to the PPFD of HPS. To avoid conditions that breed pathogens, it is vital to control air movement, temperature, humidity, and vapor pressure deficit (VPD). LEDs benefit each factor of the equation. These topics are discussed further in the Environmental Control section of this guide.

[2] Eaves, J., et al. "The Profitability of Growing Cannabis Under High-Intensity Light." Agronomy Journal. 2020.

Enabling Multi-Tier Cultivation

Growing vertically with two or three racks of plants presents special challenges yet has a substantial upside. A three-rack system can triple your productivity per square foot of space. The higher capital expenditures (CapEx) of a vertical farming installation — mobile benching, air delivery systems, irrigation, new genetic selections — are quickly offset by the increased revenue.

Challenges and Considerations of Multi-Tier Cultivation

- **Air circulation:** Packed-in plants require air movement that's impossible to achieve with circulating fans. The plants, lights, and racks obstruct airflow and CO_2 supplementation. You'll need ducts within the racking to move conditioned air through the canopy on all levels. Temperature stratification can be an issue.
- **Spacing and workflow:** A three-tier installation leaves less overhead space for worker access than two-tier installations. Irrigation plumbing and air ducts reduce overhead space, making crop management more difficult. Work flows will change with either configuration.
- **Light distribution:** Fixtures such as the Fluence SPYDR can provide corner-to-corner light distribution with minimum spillover. Hanging height and racking height are critical for consistent PPFD levels across the canopy.
- **Irrigation and wastewater:** Plumbing for irrigation lines and wastewater management take planning. Your pumps will need to perform more work to lift hydroponic solution to the racking height, and you'll need a drainage system to retrieve the spill off.

Daily Light Integral

Daily light integral (DLI) is the total amount of light that plants receive during the photoperiod, as measured in moles of photons per day (a mole is a unit of quantity, similar to a dozen). As you increase your PPFD, DLI serves as a cumulative metric for how much light you're giving your plants in total per day, not just how much they're receiving in the moment.

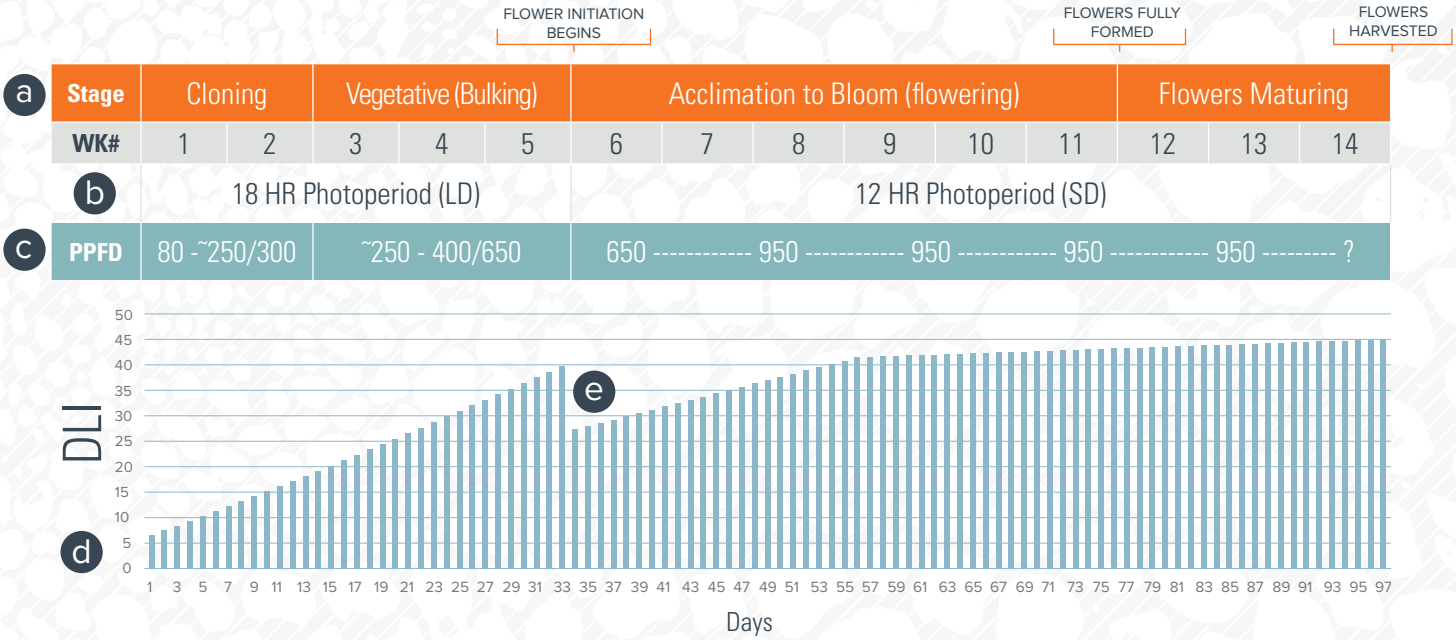
DLI changes throughout the production cycle, varying from 20 mol/m²/day in early vegetation to 45 mol/m²/day or more during flowering. A decade ago, a DLI of 30-43 was the standard application for the flowering period, but that number fell short of the plants' capabilities. LED growers are now discovering the benefits of DLI in the range of 43-48.

DLI levels as high as 85 may be commonplace in the future. Research shows a linear production response well above the 43-48 range.

A critical aspect of high-DLI cultivation is managing the transition to reproductive growth. Whenever you initiate flowering by changing your photoperiod, DLI drops dramatically. If the photoperiod drops by a third (from 18 hours to 12 hours), so too does DLI [Figure 2]. You'll need to build up slowly to high PPFD again, increasing PPFD by approximately 100 µmol/m²/s to achieve around 45 mol — or your target level. Increasing levels too quickly damages chlorophyll pigments, causing photobleaching.

[Figure 2]

PPFD (µmol/m²/s) **& DLI**



Good Environmental Control Drives Growth

Environmental control is as important as PPFD when it comes to production rate. Controlling an indoor environment hinges on two primary variables: heat and moisture. LEDs affect the balance by lowering the thermal input throughout the room and near the plants. In the case of a PPF match, or in the case of a watt-for-watt replacement, LEDs may increase biomass and irrigation requirements. To calculate precisely how LEDs will change your environment, you must know the different types of heat in the cultivation environment and revisit the concepts of VPD.

Dial-In Your Vapor Pressure Deficit

VPD is a key environmental metric for your crop. It's the measurement of the difference (i.e., the deficit) between the moisture content of the air versus how much moisture the air is capable of holding when saturated at 100% RH.

VPD influences moisture's tendency to evaporate or condense. Moreover, it affects plants' ability to cool themselves via evapotranspiration (the process of releasing moisture through the leaves) and to translocate nutrients up from the growing medium.

VPD Dynamics

- **Low VPD (high humidity/lower temperature)** causes condensation that leads to pythium, botrytis, and powdery mildew, and a failure to transpire and translocate nutrients.
- **High VPD (low humidity/higher leaf temperatures)** causes excessive transpiration and stress, wilting, rapid dry-back of growing medium, and condensation when temperatures drop.

HPS lights cause dramatic temperature swings as they turn on and off, leading to fluctuations in VPD and nighttime humidity spikes. Furthermore, HPS systems often require venting, causing environmental variability and suboptimal CO_2 levels. Conversely, LEDs mitigate these problems by introducing less heat (per photon) into the grow room and by maintaining steadier leaf temperatures throughout the transition from photoperiod to nocturnal period.

Infrared Radiation

The HPS spectrum contains significant radiant heat in the form of infrared radiation (IR) [Figure 3]. IR is electromagnetic radiation that crops absorb as wavelengths of heat energy (like a heat lamp in a sauna). The extra heat from HPS warms the leaves directly and leads to greater temperature changes when the lights cycle off.

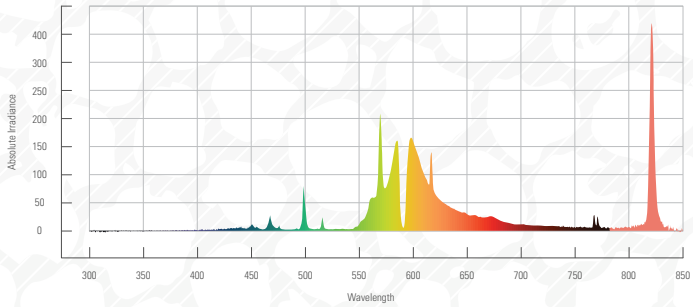
LED fixtures, by contrast, emit low levels of IR in their spectrum. They primarily release convective heat and warm the air above the fixtures — not the plants directly. In short, LED fixtures are like radiators, and HPS fixtures are like sauna lamps.

Maintaining Leaf Temperature Under LEDs

LED-lit cannabis thrives at a higher temperature setpoint than HPS-lit cannabis. Why? Because the HPS spectrum you were using before contained significant IR that heated the plants' leaves directly. Plant temperature — not air temperature — drives physiological functions, so with lower leaf temperatures you will need to increase the air temperature to compensate.

Note that the same VPD can be achieved at different ratios of humidity and temperature [Figure 4]. A VPD chart, which correlates temperature and humidity, shows suitable VPD ranges. With a higher temperature set point, you'll need to slightly reduce humidity to maintain optimal VPD. This may change your approach to cooling and dehumidification [Table 1].

[Figure 3]



[Figure 4]

QUICK REFERENCE CANNABIS VPD CHART

Temp °F	RELATIVE HUMIDITY													
	100%	95%	90%	85%	80%	75%	70%	65%	60%	55%	50%	45%	40%	35%
87°	0.00	0.22	0.44	0.66	0.88	1.10	1.32	1.54	1.76	1.98	2.19	2.41	2.63	2.85
86°	0.00	0.21	0.42	0.64	0.85	1.06	1.27	1.48	1.70	1.91	2.12	2.33	2.55	2.76
85°	0.00	0.20	0.41	0.61	0.82	1.02	1.23	1.43	1.64	1.84	2.05	2.25	2.46	2.66
84°	0.00	0.20	0.40	0.60	0.80	1.00	1.19	1.39	1.59	1.79	1.99	2.19	2.39	2.59
83°	0.00	0.19	0.38	0.58	0.77	0.96	1.15	1.35	1.54	1.73	1.92	2.12	2.31	2.50
82°	0.00	0.19	0.37	0.56	0.75	0.93	1.12	1.31	1.49	1.68	1.87	2.05	2.24	2.43
81°	0.00	0.18	0.36	0.54	0.72	0.90	1.08	1.26	1.44	1.62	1.80	1.98	2.16	2.34
80°	0.00	0.18	0.35	0.53	0.70	0.88	1.05	1.23	1.40	1.58	1.75	1.93	2.10	2.28
79°	0.00	0.17	0.34	0.51	0.68	0.85	1.01	1.18	1.35	1.52	1.69	1.86	2.03	2.20
78°	0.00	0.16	0.33	0.49	0.66	0.82	0.98	1.15	1.31	1.48	1.64	1.81	1.97	2.13
77°	0.00	0.16	0.32	0.48	0.63	0.79	0.95	1.11	1.27	1.43	1.58	1.74	1.90	2.06
76°	0.00	0.15	0.31	0.46	0.61	0.76	0.92	1.07	1.22	1.38	1.53	1.68	1.83	1.99
75°	0.00	0.15	0.30	0.44	0.59	0.74	0.89	1.04	1.19	1.33	1.48	1.63	1.78	1.93
74°	0.00	0.14	0.29	0.43	0.57	0.71	0.86	1.00	1.14	1.29	1.43	1.57	1.72	1.86
73°	0.00	0.14	0.28	0.42	0.56	0.69	0.83	0.97	1.11	1.25	1.39	1.53	1.67	1.80
72°	0.00	0.13	0.27	0.40	0.54	0.67	0.80	0.94	1.07	1.20	1.34	1.47	1.61	1.75
71°	0.00	0.13	0.26	0.39	0.52	0.65	0.78	0.91	1.04	1.17	1.30	1.43	1.56	1.69
70°	0.00	0.13	0.25	0.38	0.50	0.63	0.75	0.88	1.00	1.13	1.25	1.38	1.50	1.63
69°	0.00	0.12	0.24	0.36	0.49	0.61	0.73	0.85	0.97	1.09	1.21	1.33	1.46	1.58
68°	0.00	0.12	0.23	0.35	0.47	0.58	0.70	0.82	0.94	1.05	1.17	1.29	1.40	1.52
67°	0.00	0.11	0.23	0.34	0.45	0.56	0.68	0.79	0.90	1.01	1.13	1.24	1.35	1.46
66°	0.00	0.11	0.22	0.33	0.44	0.55	0.65	0.76	0.87	0.98	1.09	1.20	1.31	1.42
65°	0.00	0.11	0.21	0.32	0.42	0.53	0.63	0.74	0.84	0.95	1.05	1.16	1.26	1.37
Vegetative, VPD = 0.80 to 0.95						Flowering, VPD = 0.96 to 1.15				Stress VPD = 1.16 to 1.35				

[Table 1]

RELATIONSHIPS BETWEEN ENVIRONMENTAL VARIABLES

Air Temperature	Relative Humidity	Vapor Pressure Defecit	Water Demand	Evapotranspiration
↑	↓	↑	↑	↑
↓	↑	↓	↓	↓

Understanding Latent Heat

Dehumidification is heat removal. A reduction in humidity won't change **sensible heat** (i.e., the number on the thermometer) but dehumidification reduces **latent heat** (i.e., energy released or absorbed), which can influence sensible heat later.

Latent heat is the energy released or stored when a substance goes through a **phase change** (e.g., from liquid to vapor, or from liquid to solid). It takes extra heat energy for these phase changes to happen.

Therefore, if the VPD drops, the moisture in the air condenses and releases its stored heat. And if VPD rises, water evaporates and plants transpire moisture into the air again, storing the moisture as latent heat. Dehumidification removes that latent heat from the growing environment and increases VPD.

The most critical preventative measure against uncontrolled latent heat and VPD swings is consistent temperature, which is something LEDs can help you achieve by eliminating the on-off temperature changes of HPS.

> ***"We recommend that customers work with an HVAC engineering firm whose core competency is horticulture and latent load removal. There are a lot of 'HVAC guys' out there who only design for human-centric needs. Horticulture is different."***
>
> **— Aaron Fellabaum, Director of Strategic Accounts**

HVACD Dynamics and Better Environmental Control

For most LED retrofits, the grow room's existing heating, ventilation, air conditioning and dehumidification (HVACD) system works well. Unless the system was previously undersized or unsuitable — or you are switching to a multi-tier setup with additional biomass — there's rarely a need to change your HVACD system.

But an LED-lit room should have a higher ambient temperature to compensate for lower leaf temperatures. You may need to adjust your HVACD settings to compensate for the fact that the air conditioner is used less with LEDs.

Most HVACD systems without dedicated dehumidification provide a degree of secondary dehumidification based on how they cool the air. That is, when the HVACD blows air across the cooling element to lower its temperature, some moisture condenses on the cooling surface. When you're running a higher temperature in an LED room, the air conditioner doesn't run as often, meaning it won't provide that incidental dehumidification. You may need to reconfigure your HVACD or add a standalone dehumidifier.

Another reason for increased dehumidification loads is increased biomass. When you raise PPFD, everything in the grow room accelerates. Plants photosynthesize faster and grow more vigorously. Irrigation events increase, and transpiration increases in linear fashion with PPFD.

Airflow

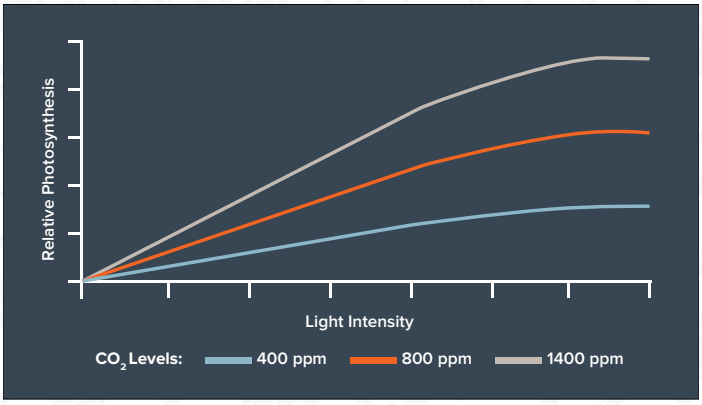
In a high-PPFD grow room, airflow is critical for avoiding hotspots and microclimates. If you're increasing PPFD — and the rate of photomorphogenesis — expect linear increases in transpiration and a greater need for airflow. The best way to achieve optimal air movement is by delivering air within the canopy and installing return ducts above. This up-and-out airflow pattern removes transpiration evenly. Overhead circulating fans are also acceptable, but fans placed along the perimeter of the canopy may cause stomatal closure in the plants closest to the edges.

For multi-tier rooms, inner-rack delivery airflow systems are critical for moving air around benching and lights and for preventing stagnation. The supply of air from the HVACD — which is colder and drier than the room's setpoints — should be mixed with the ambient air to achieve homogeneous temperature before delivering it into the canopy.

Removing Limiting Factors

Every cultivation vector will scale along with your light levels. To keep pace with your lighting system, your CO_2 supplementation and fertigation will need to increase, too. A single suboptimal growing condition can reduce your returns.

[Figure 5]



Increase Temperature and CO_2

The amount of CO_2 you'll need in your grow room will scale with how much PAR plants receive [Figure 5]. Be prepared to deliver up to 1,500 ppm of CO_2 during the reproductive stage if you're increasing your PPFD over 1,000 µmol/m²/s.

Once again, your LED-lit crops will do best at a higher ambient temperature because LEDs deliver much less IR heat to the leaves than HPS. To compensate, increase your ambient temperature set point by 5 F when retrofitting your room from HPS to LEDs.

Increase Irrigation

Make sure to keep an eye on your growing media as you accelerate production with more light. Higher PPFD levels drive higher transpiration rates and more biomass, leading to faster dry-back of the growing media.

Nutrients and salts can build up unexpectedly, leading to nutrient lock out and slowed growth. Additional irrigation events may be necessary, as well as adjustments in nutrient concentrations to avoid under- or over-feeding. Reference the *Fluence Cannabis Cultivation Guide* for more info on mineral ratios and measuring the nutrient concentration of your growing media.

Phase In New Technology

Many growers believe they must undergo a massive one-time LED retrofit to receive their incentive. But, in fact, most companies phase in LEDs, and utilities understand why. Rest assured that your incentive will remain available if you follow the application process correctly.

When you implement LEDs in one or two rooms to start, you get a chance to learn the new technology without upending your whole operation. Your production will remain steadier when you trial the technology before going full-LED, and you'll likely reap more benefits sooner.

LED FINANCIALS AND ROI

CapEx and OpEx work differently for LEDs and HPS fixtures. LED technology requires higher CapEx spending due to expensive materials and fabrication processes. HPS fixtures are cheaper to manufacture but more expensive to operate, and they can't equal the production rate of LEDs of similar wattage.

When you predict your return on investment, be certain to predict your *actual* ROI. Most growers merely calculate a payback period based on their prior revenue and the anticipated OpEx reductions. They forget to factor in increases in revenue from higher PPFD.

Cultivators typically select one of the following options when considering LEDs:

- **HPS Baseline:** Continue using HPS fixtures and investing in maintenance
- **1-for-1 PPFD Match:** Replace HPS fixtures with LED fixtures to recreate PAR levels and reduce energy costs
- **Wattage Match:** Replace HPS fixtures with a greater number of LEDs to increase PPFD levels without increasing electrical consumption
- **Multi-tier:** Install vertical benching to increase canopy area while maintaining or increasing PPFD

Other system configurations are common, such as exceeding prior PAR levels with more LED fixtures but not fully matching wattage. Sometimes growers retrofit only some of their fixtures, creating a checkerboard of LEDs and HPS.

A detailed ROI table is available on page 16 of this guide.

Option #1: The HPS Baseline

Higher OpEx

Continued use of HPS requires no CapEx spending but considerable OpEx. According to a 2017 study by the Sacramento Municipal Utility District, LEDs reduce lighting-driven electrical costs by 34% and overall electrical costs by as much as 25% when HVACD savings are included in the analysis.[3]

Ongoing bulb replacements and reflector maintenance also stack on considerable costs. The PPF output of HPS bulbs degrades at a rate of 1% for every 1,000 hours of run time. And reflectors naturally lose their reflective efficiency as they collect pollen and dust.

A 12-hour photoperiod warrants a bulb change every 1.5-2 years when output drops by more than 5%. HPS manufacturers also recommend replacing or cleaning reflectors in dirty environments. The cost of these materials varies widely by order volume, but when relamping OpEx is annualized a commercial grower can expect a $60/year maintenance budget per fixture.

Note: LEDs also experience output degradation, though they do not require maintenance spending. LEDs lose approximately 1% output per year throughout their service life of ten years or more. After ten years, the fixtures reach their Q90; they produce 90% of their original PPF. However, during that period, HPS fixtures would have required two or three relampings.

Opportunity Costs

Continuing to use legacy technology means cultivators are losing out on yield and quality that can be gained with higher PAR levels. LEDs introduce more light to the grow room while HPS has reached its limits. Harvest weight (especially dry weight) corresponds directly — in linear fashion — with higher light levels, so cultivators who do not switch fail to reap these rewards.

[3] Sacramento Municipal Utility District. “Amplified Farms 2017 Indoor Horticulture Lighting Study.” 2018.

Option #2: Direct 1-for-1 PPFD Match

In a direct retrofit, cultivators replace each HPS fixture with an LED fixture that has similar PPF capabilities but uses less energy. This type of installation lowers OpEx and best leverages the available incentives and rebates.

Incentives and Simplicity

Most LED installations qualify for energy efficiency incentives or rebates from local utility companies. Cultivators who take advantage of these programs typically receive a payout of 25% of the project cost to offset CapEx.

Facility reconfigurations are rarely needed with a PPFD-match retrofit. Hanging the lights is the only additional cost in the budget. Modifications to HVACD equipment are usually unnecessary. However, it's important to work with a qualified lighting manufacturer to maintain good light distribution.

Lower OpEx Without Revenue Increase

In addition to decreasing electrical demand from the lighting, PPFD-match retrofits reduce HVACD usage. As mentioned above, LEDs produce less heat than HPS, and LED-lit plants prefer warmer ambient temperatures due to less IR, translating to reduced HVACD runtime.

A 1-for-1 PPFD retrofit may increase yields due to better VPD stability or spectral composition but will not achieve the dramatic production gains of increased PPFD. The payback is based on cost reductions. Two years is the average period for 100% ROI. However, the lower OpEx extends years afterward, and most systems achieve a >200% ROI within five years.

A detailed ROI table is available on page 16 of this guide.

[4] Eaves, J., et al. "The Profitability of Growing Cannabis Under High-Intensity Light." Agronomy Journal. 2020.

Option #3: Matching Wattage

A wattage-match installation increases PPFD while maintaining previous energy use. Matching the wattage of HPS increases CapEx considerably, but the high revenue potential quickly offsets the investment. **With a wattage-match install, the three-year ROI can approach 1,500%.**

A detailed ROI table is available on page 16 of this guide.

The Light-to-Revenue Ratio

Research shows — and customers attest — that increasing PPFD by 1% can increase harvest weight by 1%.[4] Yet there are many factors in play, and some cultivators observe a lower increase in yield because of genetic constraints, poor environmental control, CO_2 supplementation, operating procedures, and a host of other factors. Even in the case of lower ratios of harvest to PPFD increase, cultivators realize revenue gains that overcome costs in less than two years.

Various cultivars respond differently to light increases; however, lower returns on high PPFD lighting are usually caused by poor environmental control. Another factor in the potential yield increase of a wattage-match retrofit is the prior PPFD level. If PPFD was already high (>1,100 µmol/m^2/s), then additional increases will net lower returns. For capable cannabis growers, PPFD levels well in excess of 1,500 µmol/m^2/s continue to be profitable due to the crop's high photosaturation point and market value. Growers who struggle with environmental control will achieve suboptimal returns on high-PPFD lighting.

Facility Modifications

The dramatic increase in PPFD may entail minor or moderate facility modifications. If your facility has an inadequate airflow system, irrigation system, or poorly configured HVACD, you may need to correct those issues to take full advantage. However, the majority of wattage-match installations do not require extensive renovations.

Matching wattage increases transpiration in linear relationship to increased PPFD levels. With accelerated growth and increased biomass in the grow room, you may need more dehumidification and fertigation. Investing in higher-capacity pumps or increasing your latent cooling may be necessary.

Option #4: Multi-Tier Cultivation

Converting a facility to vertical cultivation requires extensive renovation but less capital than expanding your building's footprint. Multi-tier cultivators can choose between two-level racking or a more complex three-level system that has higher potential returns.

The infrastructure for multi-tier can total more than half of the project costs because of the new racking and airflow system [Table 2]. You'll likely want to capture as much of your floor area as possible with mobile benching, and mobile benching requires complex systems for irrigation and drainback. Three-level systems necessitate scissor lifts for access.

The increased plant count in the room demands increased dehumidification and air movement capabilities, which drive up CapEx. However, OpEx does not increase much due to the higher electrical efficiency of the lighting. PPFD stays about the same with a multi-tier retrofit; the additional revenue comes from the expanded canopy area.

Cultivating for the Future

Multi-tier installations are changing how cannabis is cultivated indoors. So, when you select a multi-tier retrofit, your standard operating procedures (SOPs) will undergo a major revision that can have a costly learning curve.

While a multi-tier operation offers the greatest revenue gain over HPS, it is not for everyone. Three-level systems require dramatically different workflows and may pose more problems than double- or single-level setups. Issues with pathogens, irrigation, and air movement may impact revenue in the first few crop cycles, as will the slight interruption during construction.

[Table 2]

INFRASTRUCTURE UPGRADE COSTS	1:1 PPFD MATCH	1:1 WATTAGE	TWO-LEVEL
Upgraded Irrigation System	$ -	$ 4,000.00	$ 5,000.00
Rack / Table	$ -	$ -	$ 76,800.00
Dehumidification Upgrades	$ -	$ -	$ 19,000.00
Installation / Construction	$ 2,450.00	$ 7,200.00	$ 7,200.00
Air Movement Upgrades	$ -	$ -	$ 28,800.00
TOTALS	**$ 2,450.00**	**$ 11,200.00**	**$ 136,800.00**

ROI TABLE ASSUMPTIONS	
Estimated Grams per Square Foot	50
Estimated Cycles per Year	5
Estimated Price per Pound ($)	$2,000
Estimated Cost per Pound ($) HPS	$600
Estimated Cost per Pound ($) LED	$600

PREDICTED ROI	BASELINE HPS	1:1 PPFD MATCH	DELTA	WATTAGE MATCH	DELTA	TWO-TIER	DELTA
Canopy Square Feet	1120	1120	0	1120	1120	1920	800
# of Light Fixtures	70	70	0	120	120	120	50
Wattage per Fixture	1048	630	418	630	418	630	418
Cost per Light Fixture	$0	$1,000	-$1,000	$1,000	-$1,000	$1,000	-$1,000
Annualized Re-Lamping Cost ($60/fixture)	$4,200	$0	$4,200	$0	$4,200	$0	$4,200
kWh Cost in Bloom at $.125	$40,165	$24,145	$16,020	$41,391	-$1,226	$41,391	-$1,226
kWh Cost for HVAC at $.125	$52,324	$43,756	$8,568	$52,324	$0	$52,324	$0
Rebate per Light Fixture	$0	$250	$250	$250	$250	$250	$250
Net Cost per Light Fixture	$0	$750	-$750	$750	-$750	$750	-$750
Upgrade Cost (see "Upgrade Cost" table at right)	$0	$2,450	-$2,450	$11,200	-$11,200	$136,800	-$136,800
All in CapEx	$0	$54,950	-$54,950	$101,200	-$101,200	$226,800	-$226,800
All in Yearly OpEx	$96,688	$67,900	$28,788	$93,715	$2,973	$93,715	$2,973
Average PPFD (PAR) Intensity	900	900	0%	1,420	58%	900	0%
Estimated Annual Room Yield (Lbs)	617	617	0	974	357	1,058	441
Estimated Annual Revenue ($)	$1,234,589	$1,234,589	$0	$1,947,907	$713,318	$2,116,438	$881,849
Estimated Annual Gross Margin ($)	$767,524	$796,312	$28,788	$1,269,820	$502,296	$1,387,791	$620,268
Estimated Simple Payback Period (Months) Post Harvest / Sale		22.9		2.4		4.4	

CASE STUDY:
PPFD and Increased Yields

An LED trial at OutCo Labs documented how yield correlates with PPFD as well as the gains possible with Fluence LEDs. As a research-oriented cultivation firm, OutCo wanted to know the optimal PPFD for cannabis and how the Fluence SPYDR Series would compare to existing HPS fixtures in a controlled setting.

Their team tested four LED light intensities against an HPS room that received 700 µmol/m²/s during flowering. Ultimately, the Fluence SPYDR Series fixtures — which delivered 800 µmol/m²/s while using 44% less energy than the 1000-watt double-ended HPS — increased trimmed flower weight by 13.5% [Figure 6].

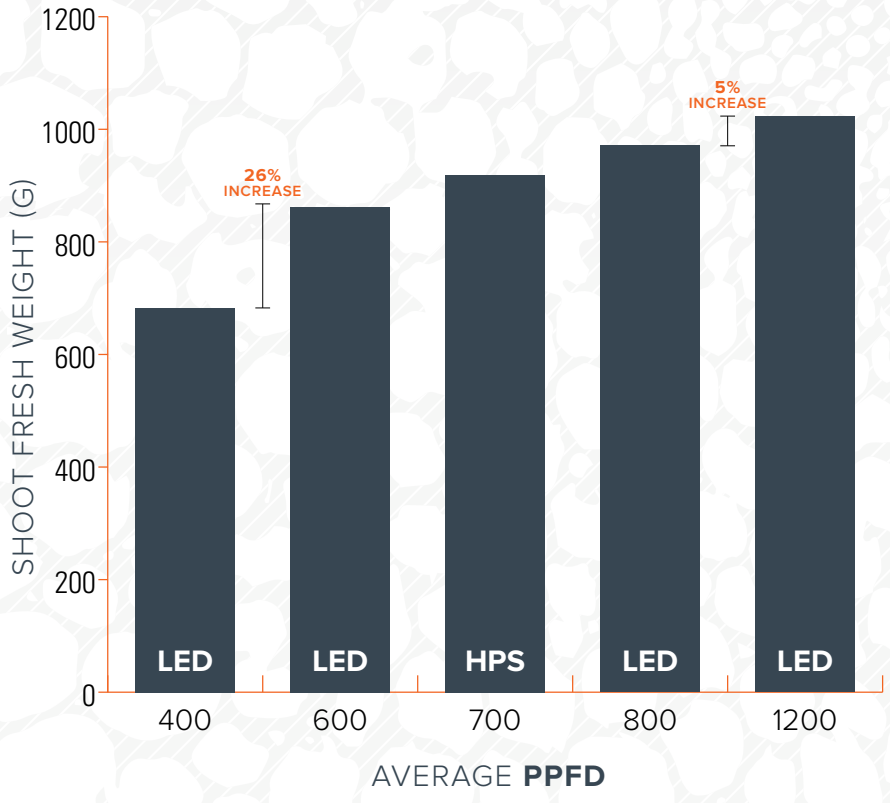
Each of the four LED treatments — which ranged from 400-1200 µmol/m²/s — showed increases in cannabinoid content. The HPS room averaged 19.1% THC-A while the LED-lit rooms ranged from 20.8-21.7% THC-A.

The results led OutCo to conclude light quality (i.e., spectrum) influences cannabinoid content more so than light intensity — and that the Fluence spectrum had outperformed the HPS spectrum.

A Disproportionate Increase in Revenue

By increasing both the dry weight and cannabinoid content of the harvest, OutCo increased revenue by +13.5% without significantly increasing other expenses. In fact, overall electrical expenditures went down due to lower HVACD costs.

[Figure 6]



Other ROI Variables

Competent environmental control and pest management are the biggest factors in ROI for high-PPFD lighting. Without the right growing conditions, cultivators struggle to achieve maximum returns.

Spectrum is a critical consideration for indoor growers as it influences yield, crop quality, and electricity costs. Indoor cannabis applications need a balanced broad spectrum in order to avoid photobleaching, to ensure secondary metabolite production (cannabinoids), and to improve pathogen scouting.

Access to rebates plays a role in ROI percentages because it reduces CapEx, but a wattage-match or multi-tier installation will bring significant revenue gains. Revenue always overwhelms costs — regardless of rebates.

An expertly designed lighting system will offset additional nutrient costs associated with a greater yield by reducing pest management costs. Also, the remaining service life of your existing HPS system and your local climate are factors to consider when calculating ROI.

> ***"As of spring 2021, the Fluence rebate program has saved customers more than $15M on their LED fixtures. With our close collaboration with customers and their local utility providers, we are able to facilitate rebate applications to get the most out of the local incentives."***
>
> **— Brady Nameth,**
> **Fluence Utility Rebate Coordinator**

YOUR ROADMAP TO LED INCENTIVES

You may qualify for a sizable incentive to offset your system's installation cost. Many Fluence customers secure a 20-30% incentive, and some have received more than 50% rebates from their utility company.

The Fluence Rebate and Incentive team is dedicated to working with you, your utility service, and their documentation to get you the largest incentive possible. It is imperative that you contact Fluence and your utility company early in this process because it may require months of preparation. Still, it is never too late to save.

Why Utilities Will Pay You to Use Less

In most jurisdictions, regulators require utility companies to meet the needs of local residents and businesses. As those needs increase, the demand can strain their supply capacity. Because regulators must approve the fees that utilities charge customers, utilities cannot easily raise their rates to offset investments in new generation facilities.

For utilities, the strategy of demand-side management and incentivizing energy efficiency is a more sensible strategy. Moreover, because cannabis is a fast-growing and energy-intensive industry, many utilities are offering incentives for cultivators to reduce their energy consumption.

Types of Rebates and Incentives

The various utility companies structure their incentive programs differently. Some offer a prescriptive rebate based on the purchase of a qualified LED fixture that replaces a legacy product one-for-one. Others provide an incentive based on the electrical usage offset by the retrofit project overall.

An incentive implies an upfront payout; a rebate usually happens after the purchase. Some utilities use a hybrid model that combines rebates and incentives. Regardless of your program type, start the process early and contact your utility long before your project begins. Many cultivators lose access to their incentives because they did not meet deadlines or follow the application sequence.

Prescriptive Rebates

Utilities grant rebates when cultivators replace legacy fixtures with more efficient versions. To simplify their rebate process, utilities often reference a list of products vetted by a third-party organization (usually the Design Lights Consortium). The DLC tests LED fixtures to ensure that they reliably perform as stated by the manufacturer and meet energy-efficiency metrics.

Confirm your rebate with the utility company **before** purchasing an eligible product. Though a rebate applies after a purchase, it's still important to confirm funding availability and product eligibility.

Some utilities that don't have incentive programs may consider proposals for individualized incentives on a case-by-case basis. Contact a Fluence representative for consultation.

Custom Incentives

Although incentives require a lengthier application process than rebates, they typically result in a higher payback. For a custom incentive, the utility will require information about your old fixtures, your new fixtures, and your lighting plan before the project begins. With the help of your lighting manufacturer, they'll compare your retrofit to the baseline consumption of an HPS system.

You'll receive an incentive in proportion to your energy savings and reduction in demand power. Demand power is the instantaneous power requirement, measured in kilowatts (kW); energy use is the sum usage, measured in kilowatt-hours (kWh). Both are important to utilities as they manage moment-to-moment loads on the electrical grid.

Once the project's electrical savings are verified, the utility will issue your authorization to proceed. After the installation, you will be able to choose between a statement credit and a one-time payment. Fluence recommends a one-time payment to offset project costs.

Approval for custom rebates is more complex than submitting the project invoice to the utility after completion. Start early! Contact your utility to ask about potential rebates and engage with a lighting manufacturer before your project begins.

Hybrid Programs and Individualized Incentives

Utility companies that are familiar with indoor cultivation may offer hybrid programs combining prescriptive rebates with custom incentives based on usage dynamics. These programs use calculators to accurately predict how a particular LED fixture type will affect overall usage with predicted HVACD reductions and how the system will impact the power grid at peak hours during the day.

If incentive programs do not exist in your area, you may still be able to negotiate an incentive with the help of your lighting manufacturer. When utilities understand the systemic benefit of LEDs — and how HPS fixtures are straining their infrastructure — many will follow the lead of other utilities and incentivize your choice.

Claiming LED Incentives *Without* Reducing Your Use

Matching the wattage of your old HPS system will dramatically increase production, but it won't reduce the strain on the utility infrastructure. However, your utility may support your project with a financial incentive if you or your lighting manufacturer can argue the case well.

A projective model can demonstrate the energy savings of LEDs as compared to HPS based on equivalent PPF levels. Working with your utility in this way often requires educating them about the interactive effects of lighting, lighting schedules, and HVACD. The Fluence Rebate and Incentive team stands ready to assist you in this process.

What is incremental cost?

Utilities use an incremental cost cap when calculating your incentive. The incremental cost is that of the LED system minus the cost of the legacy technology you would have purchased in its place. Utilities apply the incentive percentage to the difference in your spending.

For example, if your LED fixture cost $1,200 and your HPS would have cost $350, the difference is $850. If the program had a 70% incremental cost cap, the maximum incentive would be $595 (or 70% of $850).

Tips for Avoiding Incentive Pitfalls and Optimizing Your Payback

Establish a relationship with your utility account manager

You may not realize that you have an account manager at your utility company. Calling them to introduce yourself is the first and easiest step in assessing your incentive eligibility. They can tell you about opportunities that exist or developments to consider.

Contact an experienced lighting manufacturer

There are administrative pitfalls for every state, provincial market, zone, and facility type. The Fluence Rebate and Incentive team has worked with dozens of utilities across North America, garnering millions of dollars in rebates for our clients. We can help you navigate the process and educate your utility about horticultural lighting if needed.

Check the timing of your incentive

Utilities allot funding on an annual basis, and these funds run out. Your lighting manufacturer can help ensure the availability of funds as you establish a timeline for your project. Also note that annual funding allocations can work in your favor if you install LEDs in two phases during two fiscal periods.

Get pre-approval and stick to deadlines

Pre-approval is critical for incentives and rebates alike. Rebates may seem simple and retrospective, but you should discuss your purchase with your account manager. Also understand your deadlines and documentation needs and adhere to them. Program technicalities cause many cultivators to lose their incentives.

Don’t let your lighting manufacturer bundle financing with incentives

When a manufacturer promises to take care of all financial aspects of the project, be wary. Transparency is paramount. If your potential rebate is bundled with a loan, the process becomes more complicated and prone to manipulation and error.

SELECT A FIXTURE AND MANUFACTURER

Select a Quality Fixture

Avoid poor-quality LEDs. Choose products listed on the DLC Qualified Products List (QPL), which have been reviewed to verify that their output meets efficiency requirements and manufacturers' claims for efficiency.

The DLC QPL is what utility companies use when determining which products are eligible for rebates, and you should, too. All fixtures on the QPL have efficiencies of ≥1.9 µmol/J, warranties of five years or more, IP water-resistance ratings, and safety certifications.

Most importantly, the DLC assesses every fixture's output, reliability, and longevity. For additional assurance of reliability, select a product with passive cooling capabilities. Actively-cooled fixtures — those with fans or circulating fluids — are more prone to failure due to their moving parts.

Work With a Full-Service Lighting Manufacturer

Lighting can enhance or hinder your success as a cannabis cultivation firm. That's why your lighting manufacturer must be more than an equipment supplier; they also should be a trusted partner.

Fluence offers specialized horticultural support and collaborative research opportunities for high-volume customers and strategic accounts. The Fluence Horticultural Services team is well-versed in plant science and skilled in the real-world applications of commercial growing.

After installation, the Fluence Horticultural Service team can assist you with the following aspects of cultivation:

- Crop scheduling
- Crop development
- Production/process flow
- Pest management
- Disease management
- Sanitation
- Environmental management

If you're ready to reduce your operating costs and increase your revenue, reach out to a Fluence representative today. We can help you with the next steps by assessing your current lighting system, checking for utility incentives, and estimating your installation cost.

Visit **fluence.science/contact**
to speak with a Fluence representative
about your design consultation.

FLUENCE

Stay in the know, review our products, and share your grow:

www.fluence.science