



LED GROW LIGHTING 101:

# A Guide to Greater Yields, More Harvests and Higher Profits

To maximize profits, indoor growers need to harvest high-revenue items in the shortest time possible. A new generation of LED lighting products can help you accelerate photosynthesis and generate a greater return on leafy greens, herbs, microgreens and cannabis, as well as specialty crops and flowers that have quick production cycles. This guide presents key considerations to explore, pitfalls to avoid and next steps to take when choosing a superior lighting solution for your greenhouse, indoor farm or controlled environment facility.

## GROWING UP

Worldwide, the outlook for controlled environment agriculture (CEA) is bright. In 2017, the global indoor farming market accounted for nearly \$107 billion USD and is expected to top \$171 billion by 2026.<sup>1</sup> Specifically, the vertical farming segment is anticipated to reach \$9.96 billion USD by 2025, surging ahead at a 21.3% CAGR.<sup>2</sup>

Urban densification, limited cultivation space and increasing demand for high-quality foods are just a few of the factors behind the budding popularity of CEA. Across North America, Europe and Asia especially, growers of all types are aiming to provide ideal conditions for plants to thrive.

It is no surprise that LED agricultural lighting is also expected to witness significant growth in the years ahead.<sup>3</sup> From small startups to commercial-scale farms, LED lighting systems that produce multiband color spectrum are already increasing yields and extending the availability of crops as part of a more efficient and sustainable operations strategy.

On one hand, LEDs can boost revenue by reducing lighting energy costs by about 50% compared to conventional high-pressure sodium (HPS) and fluorescent lamps.<sup>4</sup> On the other, having greater lighting control helps growers accurately predict output, harvest year-round and customize crops in a variety of ways.

Lighting technology is a critical component of the complete growing equation, and as CEA production hits high gear, LEDs can promote healthier plants and profits.

## OUR ADVANTAGE

GE Current, a Daintree company, connects indoor growers to relevant lighting products with their unique interests in mind. Leveraging decades of LED expertise and lighting technology innovation, we support CEA by delivering highly efficient solutions.

## REFERENCES

<sup>1</sup>ResearchAndMarkets; "Global Indoor Farming Market - Segmented by Growing System, Facility Type, Crop Type, and Geography- Growth, Trends, and Forecast (2019 - 2024)"; June 2019.

<sup>2</sup>Grand View Research; "Vertical Farming Market Worth \$9.96 Billion by 2025"; April 2019.

<sup>3</sup>Mordor Intelligence; "Indoor Farming Market - Growth, Trends, And Forecast (2019 - 2024)"; June 2019.

<sup>4</sup>Maximum Yield; "How Plants Breathe: The Stimulating Story of Stomata"; February 8, 2018.

## HELPING PLANTS REACH THEIR POTENTIAL

Every plant requires the same essentials: light, CO<sub>2</sub>, water and nutrients. The ability to control various elements of this growth “recipe” means plants can reach their full potential. However, each element must be carefully managed to optimize its impact on plant morphology, starting with light.

Sunlight spans a broad spectrum of radiation from UV to infrared wavelengths. Green wavelengths, for instance, are reflected more strongly by a plant’s leaves than red and blue wavelengths that are mostly absorbed and used as energy (thus the reason most plants appear green). Light can also “signal” a plant to develop in a certain way, such as encouraging greater leaf mass, taller stems or early flowering.

Of course, different plants have different needs and respond differently to light and the length of the growing day (the photoperiod). In recent years, significant strides have been made in isolating and combining specific light wavelengths using LED technology. Suddenly, growers have far greater control when using artificial light to help plants along.

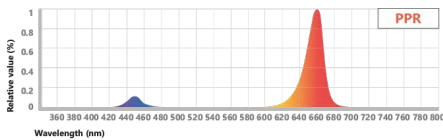
At Current, we make it easy to tailor light to the needs of individual crops. Our **Arize™ LED lighting systems** provide three color spectrum categories suited for each stage of the growth cycle. These include:

- **Type R:** High red light to optimize plant growth and photosynthesis.
- **Type B:** The perfect mix between Types R and V—light supports biomass and secondary metabolite production.
- **Type V:** Lowest red light for secondary metabolite production to promote plant structure and leaf mass.

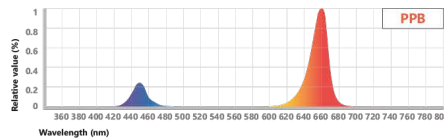
The optimal color spectrum depends on the type of plants you are trying to grow and your goals. Reach out to us or one of our trusted partners to help you determine the ideal light recipe for your crops.



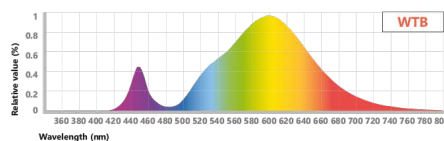
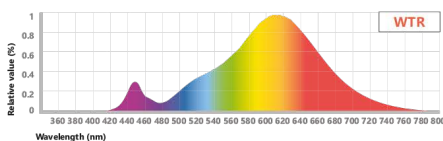
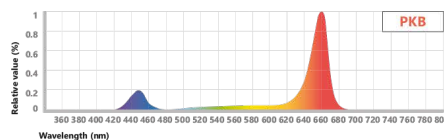
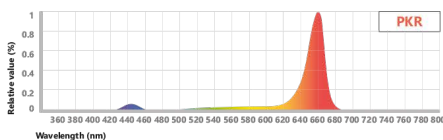
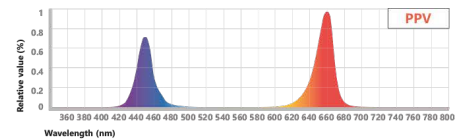
### TYPE R



### TYPE B



### TYPE V



# How Light Affects Common Crops

HORT AMERICAS, A LEADING HORTICULTURE SUPPLIER, OFFERS A CLOSER LOOK AT HOW LEDS MAKE IT POSSIBLE TO **IMPROVE THE QUALITY OF CROPS.**

By providing a specific light spectrum, plant photomorphogenesis can be regulated. Photomorphogenesis (Latin for “light shape change”) is a process by which plant architecture is mediated in response to light signals. Alongside photomorphogenesis, plant phytochemical content can also be modulated, which can have an impact on people’s health.

Light quality is one factor that affects the biosynthesis, metabolism and accumulation of phytochemicals. This means light affects not only plant shape and growth, but also taste, aroma, nutrition, chemical entities and more.

While there is still much to learn about how crops respond to different spectra, many studies have already been conducted, enabling the development of more effective lighting strategies. The following table summarizes recent research on light quality for common crops:

Light Quality	Tomato Response	Leafy Green Response	Cucumber Response	Pepper Response	Cannabis Response
<b>Far-Red</b>	By lowering R:FR ratio, tomato seedling stem elongation was significantly increased (Chia and Kubota, 2010).	Increased total biomass and leaf elongation (Stutte et al., 2009), decreased anthocyanin concentration (Stutte et al., 2009; Li and Kubota, 2009).	Stimulated stem elongation and leaf expansion at lower R:FR (Shibuya et al., 2019). Increased stem dry weight and sugar content (Cu et al., 2009).	Increased plant height and stem mass compared to red light alone (Brown et al., 1995).	
<b>Red</b>	Use of supplemental red light increased tomato fruit yield by 14% (Lu et al., 2012) and chlorophyll content compared to the control treatments (Yang et al., 2018).	Preharvest exposure reduced nitrate concentration (Wanlai et al., 2013; Ohashi-Kaneko et al., 2007; Samouliene et al., 2009; Samouliene et al., 2011). Increased phenolic (Li and Kubota, 2009; Zakauskas et al., 2011) and carotenoid (Brazaityte et al., 2014) concentration.	Increased number of leaves, root and shoot growth (Marques da Silva et al., 2016).	Increased number of leaves per plant and shoot length (Marques da Silva et al., 2016; Tang et al., 2019).	Significantly increased yield, tetrahydrocannabinol (THC) (Hawley et al., 2018) and cannabidiol (CBD) (Magagnini et al., 2018) content in bud tissue.
<b>Green</b>	Partial replacement of blue and red light with green increased plant growth in dense canopies, improving yield, chlorophyll and carotenoid concentration (Kaiser et al., 2019).	High light intensity promotes growth compared to fluorescent lamps (Johkan et al., 2012), reduced nitrate concentration and increased ascorbic, tocopherol and anthocyanin content (Samouliene et al., 2012).	Increased growth, leaf area, fresh and dry weight (Brazaityte et al., 2009; Samouliene et al., 2011; Novickovas et al., 2012) compared to HPS lamps.	Increased leaf area (Samouliene et al., 2012), growth, yield phenolic and carotenoid content compared to HPS lamps (Guo et al., 2016).	Significantly increased $\alpha$ -pinene, borneol (Hawley et al., 2018) and THC in bud tissue and antioxidant capacity compared to sunlight (Livadariu et al., 2018).
<b>Blue</b>	Proved to be required for normal chloroplast structure (Lu et al., 2012) and reduced internode length (Menard et al., 2006; Nanya et al., 2012). Used alone, blue light tends to reduce yield and photosynthesis efficiency compared to red (Lu et al., 2012; Menard et al., 2006).	Increased ascorbic acid (Ohashi-Kaneko et al., 2007), B-carotene (Lefsrud et al., 2008), anthocyanin (Ohashi-Kaneko et al., 2007) content, leaf expansion (Stutte et al., 2009) and root growth (Johkan et al., 2010). Decreased nitrate concentration (Ohashi-Kaneko et al., 2007).	Increased leaf area, fresh and dry weight and photosynthetic pigments compared to natural light and HPS lamps (Samouliene et al., 2012). Decreased hypocotyl elongation (Novickovas et al., 2012; Hernandez and Kubota, 2016).	Suppressed plant growth and biomass formation compared to cool white fluorescent lamps when used in high amounts (Hoffmann et al., 2015).	Increased polyphenols, flavonoids, fresh weight and protein compared to sunlight (Livadariu et al., 2018).
<b>UV</b>	There was a significant increase in carotene concentration when plants were exposed to UV light before harvest (Li and Kubota, 2009).	Increased anthocyanin concentration (Li and Kubota, 2009).	Positive results controlling powdery mildew (Suthaparan et al., 2017).		

Contact us for more helpful advice.

Far-red light can promote increased biomass and leaf elongation in herbs and vegetables.

## WHAT IS LIGHT QUALITY?

To understand light quality, consider that light particles have different amounts of energy determined by the wavelength of each particle. The relative number of light particles at each wavelength describes light quality (being one of three dimensions of light, including duration and quantity). In other words, light quality refers to the spectral distribution of light, or the relative number of photons of blue, green, red, far-red and other portions of the spectrum emitted from a light source. Some of these portions are visible, whereas others are not.

Source: [Greenhouse Product News](#)

## DID YOU KNOW?

Light isn't just critical to maximizing growth, manipulating plant color and shortening the harvest cycle. Light also governs the circadian rhythms of bacteria and fungi commonly found in growing rooms.

## LIGHT AS INFORMATION

All plants have photoreceptor proteins that interpret and respond to light—the “eyes and ears” of everything that grows, essentially. Today, scientists continue to crack the code behind these proteins and their ability to boost biological functions. With discoveries still being made, here's a summary of what we know so far:

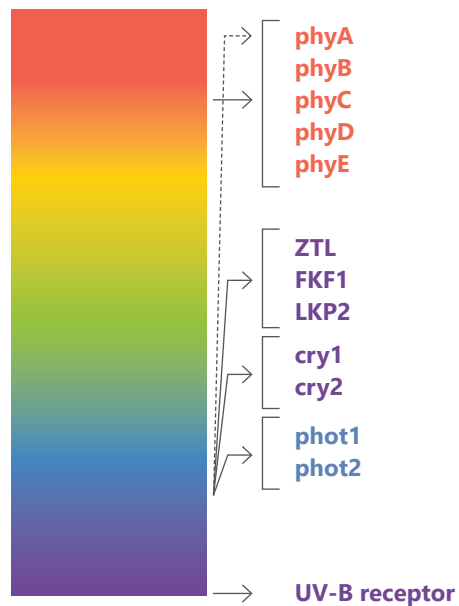
**PHYTOCHROMES** were first discovered over 50 years ago and are sensitive to far-red light and red light, impacting flowering, seed germination, pigment formation and more.

**CRYPTOCHROMES** receive blue light and UV-A and help regulate circadian rhythms in plants.

**PHOTOTROPINS** also receive blue light and control a range of responses such as stomatal opening and how chloroplasts move around in a cell.

**UVR8** is a protein first described in the early 2000s that senses UV-B light (280–315 nm) to support plant growth and survival. Scientists now suspect more than one UV-B receptor may exist.

**ZEITLUPE** is a family of blue light receptors that influences circadian timing by degrading the “clock” proteins in plants.



Photoreceptors are triggered by distinct light spectra, and scientists are learning more about them every day to take indoor growing to new heights.



# Benefits in Full Bloom

When choosing grow lights, it is important to consider metrics such as total photon output that is measured in photosynthetic photon flux (PPF) and photosynthetic photon flux density (PPFD). These terms can be confusing to growers, so what do they mean?

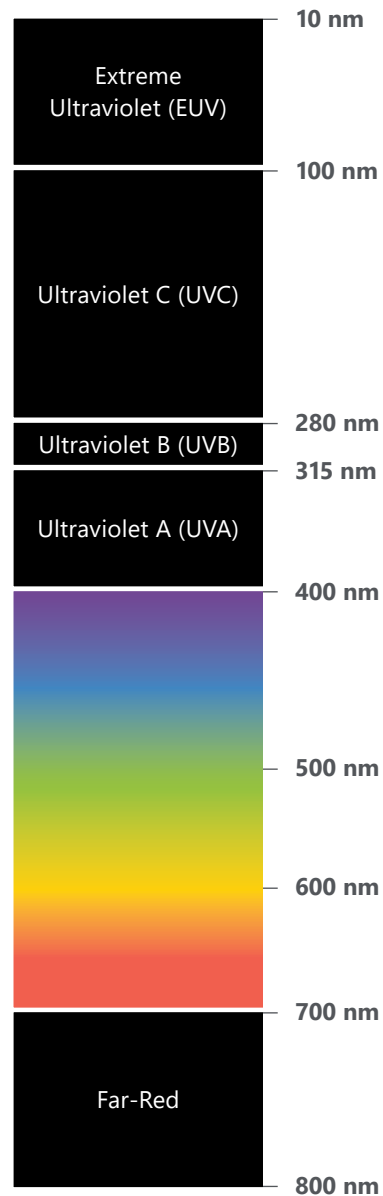
Let's start with photons (light particles) that have different properties depending on their wavelength. Of course, all plants perform photosynthesis, but not all photons support photosynthesis. Those that do are called photosynthetic photons and have wavelengths between 400 and 700 nanometers (nm). This spectral range of solar radiation is designated photosynthetically active radiation, or PAR.

PPF measures the total number of photosynthetic photons (those within the PAR wavelength) emitted by a light source (regardless of where the photons are sent), whereas PPFD measures how many of these photons will fall within a given surface area per second. It is important to know your total lamp output as well as how many photons it will deliver on your growing area. PPF and PPFD, respectively, describe that amount.

Counting photons (quadrillions of them) requires serious math and is the reason the micromole ( $\mu\text{mol}$ : equal to one-millionth of a mole, or approximately  $6.022 \times 10^{17}$ ) is the unit of measurement used to express PPF and PPFD. Moles, being an internationally recognized standard, are commonly used to count atomic-level quantities.

As light travels from the source, it disperses and loses intensity; thus PPFD values decrease as distances increase. When choosing your grow lighting, PPFD ratings can help guide you to products that will provide an effective coverage area for your crops.

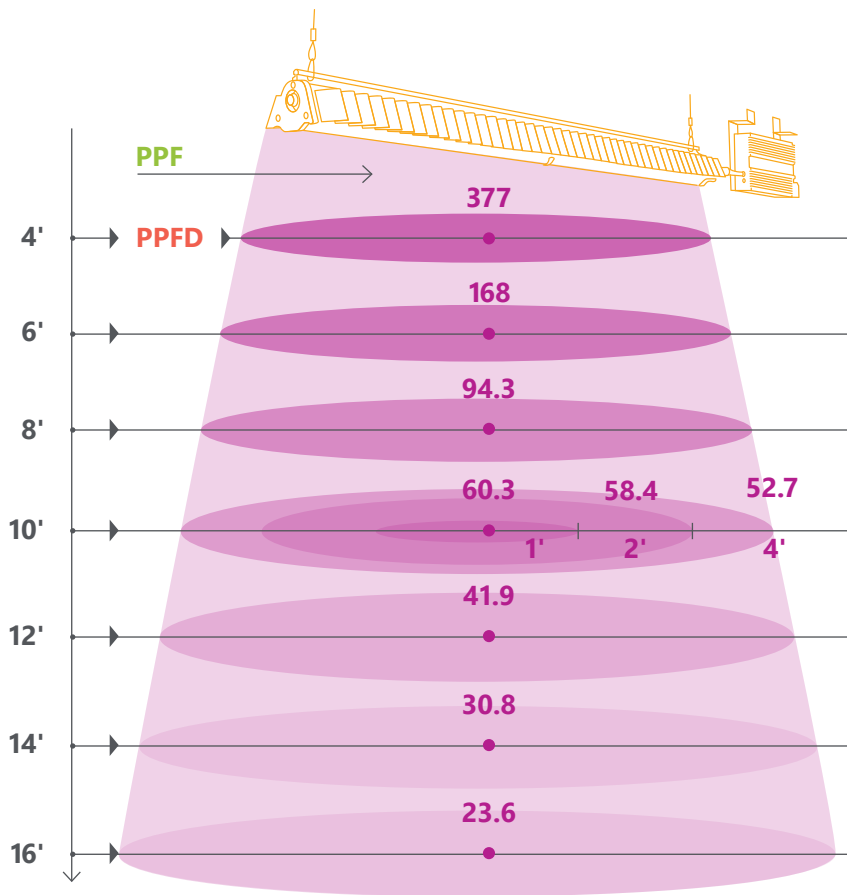
In all cases, consult with your trusted expert to validate manufacturer light plan claims by trialing products in your space before making a larger investment. Ultimately, the effectiveness of a lighting solution to provide the required PAR output also hinges on fixture design and construction, diode quality, optics and more.



Photosynthetic photons exist in the visible part of the light spectrum between 400 and 700 nm.

"A lot of growers don't have enough experience to make the decisions themselves. People like those at Hort Americas, working with the engineers at Current, can combine the grower's knowledge and pull that together to make the best decision as to what kind of light concentrations, how many fixtures, etc., are needed."

-Mohamed Hage, CEO, Lufa Farms



## ENHANCE GREENHOUSE GROWING

Current understands what it takes to cultivate the ideal growing environment. [Watch](#) as our scientists explain the importance of finding the right light.

PPF tells you how many photosynthetic photons a light source produces; PPFD tells you the amount of photons the plant will receive.



## WHY CONTROLLED ENVIRONMENT AGRICULTURE?

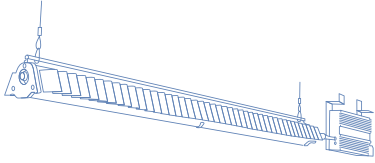
The real question is, why not? Controlled environments bring a wide range of benefits, including:

- The ability to grow crops 365 days a year, no matter the climate, weather, season or geography.
- The ability to enhance the natural output of every harvest.
- Removing barriers to new growers—you don't need 100 acres to develop a successful farm.
- More food can be produced locally, a trend that's attracting interest in many urban markets.

Current believes the future of farming is controlled—[download our white paper](#) for more insights on growing your business.

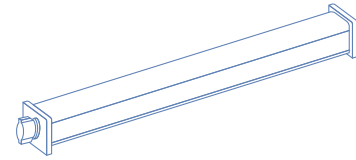
## TYPES OF LED Grow Lights

LED grow lights come in many configurations to meet different needs. Options commonly include:



### TOP LIGHTS

that can be a one-to-one replacement for 400W, 600W and 1000W HPS fixtures, becoming the workhorses of your greenhouse or indoor farm.



### LIGHT BARS

that fit neatly in growth chambers, grow racks, vertical farms and all manner of hydroponic, aquaponic and aeroponic environments.



### LAMPS

that facilitate photoperiod control, enabling you to manage vegetative growth or rapid flowering throughout the year by extending or shortening day length.



### TUBES

that replace fluorescent lamps so that you can stop changing lights so often; ideal for tissue culture laboratories.

## OTHER IMPORTANT FEATURES

Many lighting products can support photosynthesis, but not all are built to last or to maximize your investment. Beyond light quality, consider these key factors when selecting LED solutions for your indoor farm.



### Durable Construction

LED fixtures should be stamped from high strength-to-weight aluminum alloys or other suitable materials of construction, feature a sufficiently large heat sink and remain tightly sealed against the elements over time so that water, dust and debris do not damage sensitive internal components. Before you buy, ask your lighting advisor to point out potential design flaws.



### Ease of Installation

One of the first questions growers ask is if lights are easy to install. Opt for products offering multiple lengths, a range of mounting options and that can be installed in seconds, giving you maximum flexibility to create the optimal setup. This also makes it much simpler to alter your lighting layout as your setup changes over time.



### Advanced Optics

Some lenses simply outperform others. It takes true application expertise and stringent quality control to engineer optical systems that create the desired lighting effect and aim light precisely where it is needed. You may never see the difference, but your plants will know. Your trusted expert can answer questions about optical design and how to best lay the fixtures out in your farm.



### Reliability

Remember that a lower sticker price often comes with a higher cost of ownership. For instance, an LED grow light rated for a 36,000-hour lifetime (L90)—that is backed by a multiyear warranty, has been tested to actual application temperatures (many products are not), and is also IP66 and UL wet rated—is more likely to provide years of top performance in tough environments compared to cheaper alternatives that cannot make the same claims.

*Note: Certain lighting products may be unavailable or restricted to use in North America. [Contact us](#) for the latest details.*



# Advice to Grow On

Current fields a wide range of questions from growers every day. Here is more expert advice for your indoor farm.

## THE FACTS ABOUT FULL SPECTRUM

“Full spectrum” is a term used to describe the composite of many bandwidths of light that to the human eye can be interpreted as white light (lights marketed as full spectrum emit wavelengths across the entire PAR range). However, there is no single agreed upon definition of full spectrum—the term is often misapplied and can mean different things to different manufacturers.

It is also important to note that white light is not necessarily better for growing plants compared to pink, purple or “burple” hues. The confusion stems from the notion that “white” sunlight is the natural and preferable choice. Of course, white light is merely a composite of the full color spectrum—violet, indigo, blue, green, yellow, orange and red all merged smoothly together.

The truth is the optimal light for your crops depends on many factors and tends to require ample reds and blues. That’s to say, there is good reason (and science) behind the continued popularity of pink and purple(ish) grow lighting.

Be wary of full-spectrum solutions asserting the advantages of white light. While technically accurate, these claims can be misleading.

## MANAGING HEAT AND HUMIDITY

Heat and humidity have the potential to boost your harvest or ruin crops completely. In all cases, growers are challenged to strike the perfect balance between air temperature, relative humidity and light level.

Temperature has a significant impact on the speed of growth as well as the physiology of plants. Additionally, the ability of a plant to retain water is determined partly by humidity, which impacts the ability of stomata to draw in carbon dioxide and release oxygen and water.

As rows of lights begin to fill indoor facilities, they can become a major heat source, meaning airflow solutions are crucial to reducing cases of tip burn and wilt. LED fixtures that emit less heat than legacy lighting systems can also help achieve the best outcomes.



*Many growers have invested in full-spectrum lighting with mixed results—cut through the claims before the wrong choice costs more than you bargained for.*

## WHY WHITE LIGHT IS WASTEFUL

Some LED fixtures use phosphor materials (such as a coating applied to blue diodes) to make the light that is emitted appear white. However, this comes at the cost of light output efficiency that can suffer by 30% or more. Coatings can also degrade over time causing a shift in light color. A better approach is to look for products that combine blue and red diodes to create a desirable spectrum.

## DID YOU KNOW?

Different light recipes can be employed at the end growth stage to increase anthocyanin synthesis and pigmentation in produce such as red lettuce, whereas a “greener,” less red-pigmented plant may be less appealing to shoppers.

## EVOLVING ON FROM

## Sodium

High-pressure sodium lights have long been a fixture in CEA, but this is changing. LED products offer far more control when it comes to tailoring light recipes to optimize plant growth and increase yields. LEDs can also last over 50,000 hours while traditional HPS light sources tend not to exceed 10,000 hours. Rather than replace lamps routinely, growers can focus on perfecting their operation. LEDs also reduce cooling demands by radiating less heat.

When you stack the advantages, it’s little wonder LEDs are springing up everywhere.

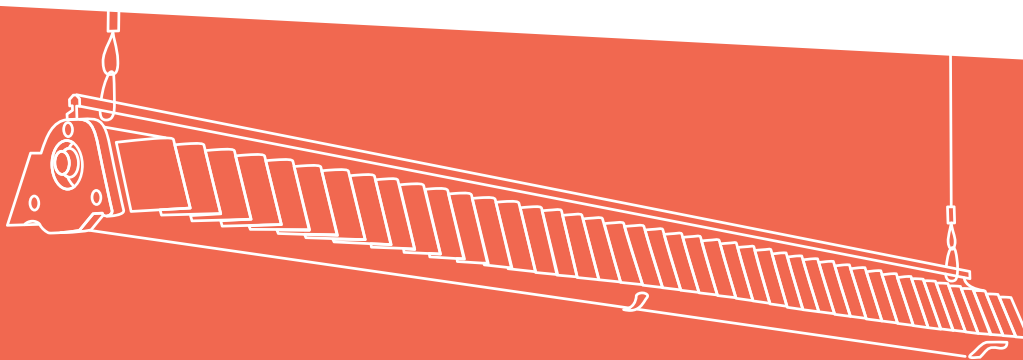
CALLING ALL  
AG EXPERTS

Current, in conjunction with Hort Americas and Urban Ag News, hosted the first annual Great Lakes Ag Tech Summit at The Institute at Nela Park. The event featured keynotes and panel discussions from leading researchers and innovative growers, including representatives from Purdue University and The Ohio State University. Attendees learned about optimizing plant production, how to vertically farm different crops and why technology is changing everything, among other key takeaways.

Keep an eye out for the next opportunity to connect with growers, scientists, researchers and entrepreneurs as we work together to shape the future of controlled agriculture.

“We are testing our first round of crops, and the lighting is my last concern. I recently delivered some garnishes to a very discerning chef, and he looked and said, ‘These are beautiful.’ Our opinion is that LED was the right answer, absolutely.”

-Adam Green, President, AGreen Farms

MEET THE WORLD'S  
MOST ADVANCED GROW LIGHT

Current has developed the industry’s first **one-to-one LED replacement** option for double-ended, 1,000-watt HPS fixtures. We worked closely with growers to design a top light with efficacy levels up to 3.5 micromoles per joule—making the Arize Element™ L1000 the most efficient and flexible grow light available. The L1000 supports universal installation, enabling users to grow more crops and consume less energy in any type of facility.

# LEDs in Action

Businesses across the world are using LEDs to grow a bigger bottom line. Here's an inside look at some highly successful indoor operations.

## FEEDING THOUSANDS IN TEXAS

**Big Tex Urban Farms** is using Arize LED grow lighting to serve up more fresh greens for Dallas residents. Arize provides optimal light spectra for plant growth. On one spectrum, higher red content promotes flowering and fruit generation while on another, higher blue content helps produce thick, healthy leaves. A third spectrum, balanced red to blue, encourages overall growth. Big Tex is now on pace to produce 11,000 pounds of food this year that will be donated to local communities, equating to over 140,000 healthy servings.



## BUSINESS IS BLOOMING IN COLORADO

**Fantasy Orchids** operates from a large greenhouse in Louisville, Colorado, where business is always "blooming" amid an assortment of 70,000 exotic flowers that are fragrant and colorful, thanks in part to Arize LED lighting that makes growing season a year-round proposition. By shortening the time plants spend in the greenhouse, this botanist boasts, "It's like having 5,000 square feet of grow space we didn't have to build." For Fantasy Orchids, it means a lower cost per plant and the flexibility to adjust to changes in consumer preference that can be hard to predict.



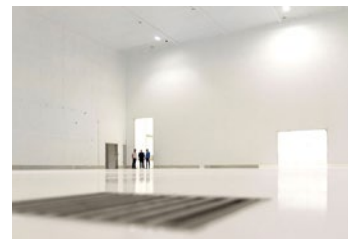
## GROWING YEAR-ROUND IN CANADA

**Lufa Farms** in Montreal grows more than 70 types of vegetables sold directly through a subscription-based service to over 10,000 customers. When the farm needed a three-tier lighting system for a new greenhouse, it installed Arize LEDs across 7,000 square feet of grow space. Nearly two years later, Lufa has reported zero issues with its 430 fixtures and has seen 15% faster seedling production. Canadian Prime Minister Justin Trudeau even visited the site to show support for sustainable farming technology.



## INDUSTRIAL-SCALE PRODUCTION IN THE UK

**Jones Food Company Ltd.** is a vertical farm in the North Lincolnshire countryside with commercial-sized ambitions. Featuring a grow area of 5,120 square metres (about 26 tennis courts) and racks stacked 11 metres high, Jones Food is passionate about raising an abundance of excellent produce. When the farm needed a solution to ensure every plant received optimal light, it found its answer using thousands of Arize LED fixtures that, stretched end-to-end, span 12.3 kilometres. Jones Food expects to turn out 420 tonnes of leafy greens per year as it strives to meet booming demand for premium natural ingredients featured in food, pharmaceutical and cosmetic products.



## DID YOU KNOW?

The average yield per acre of vine crops, such as tomatoes and greens grown in indoor farms, is over 10 times higher than that of outdoor farms.



## LIGHTING THE WAY FORWARD

Current is excited to help growers navigate the indoor farming revolution, optimize production and drive costs down with LED-lit operations. Combining world-class lighting expertise with years of research by plant scientists and acquired knowledge from our customers, we enable efficient growth at an industrial scale while curbing energy costs.

When Edison invented electric light, his challenge didn't end there—he next had to figure out how to scale and optimize his creation. Well over a century later, Current is revisiting this challenge with LED technology to explore how greenhouses and vertical farms can thrive.

### READY TO LEARN MORE?

THE ROAD TO THE RIGHT LIGHT STARTS WITH A PROFESSIONAL AUDIT OF YOUR GROW SPACE.

Contact GE Current, a Daintree company, to explore the best options for your indoor farm.

[www.gecurrent.com/contact](http://www.gecurrent.com/contact)

For EU inquiries, email [horti.info@gecurrent.com](mailto:horti.info@gecurrent.com).

#### ADDITIONAL REFERENCE

MarketsAndMarkets; "[Vertical Farming Market by Growth Mechanism \(Hydroponics, Aeroponics, and Aquaponics\), Structure \(Building Based and Shipping Container\), Offering \(Hardware, Software, and Service\), Crop Type, and Geography—Global Forecast to 2022](#)"; June 2019

ResearchAndMarkets.com; "[Indoor Farming - Global Market Outlook \(2017-2026\)](#)"; July 2019

Market Research Future; "[Vertical Farming Market Research Report - Global Forecast till 2024](#)"; October 2019