LED iBOND

Indoor Farming White Paper

December 2023

7 THINGS TO CONSIDER WHEN BUYING GROW LIGHT FOR GREENHOUSES

High performance top lighting lamps for commercial greenhouses based on second generation horticulture LED technology is available now.

In this paper we discover how to select the right and most cost-effective top lighting solution for your greenhouse with optimal performance and low energy consumption.

LED Grow light - Buyer's Guide and Benchmark

Light emitting diodes (LED lights) were first introduced to the market to replace the traditional incandescent and fluorescent lights for a more sustainable and energy saving solution. With LED becoming a standard for lighting in homes and offices, the horticulture industry is now looking the same way to benefit from this technology.

Highly developed LED grow lights have made a unique niche of its own and have become extremely competitive versus the old traditional grow lights that use HPS (high-pressure sodium) or CMH (ceramic metal-halide).

There are five essential advantages of new and improved LED grow lights:

Energy saving
LEDs use far less energy to produce the same amount of light when compared to HPS or CMH. LED lights consume up to 65% percent less power than HPS grow lights which mean significant savings on electricity bills. LEDs are the most power efficient lighting technology in the world.

Customized spectrum
A light spectrum is the range of wavelengths produced by a light source. These wavelengths are expressed in nanometers (nm) and correspond with a specific color. Plants use the photon energy that light provides for photosynthesis and photomorphogenesis, or growth and development. The frequencies of light that is most important to plants lies within the range of 400-700nm, also referred to as Photosynthetically Active Radiation (PAR).

LED technology allow top lighting lamps to be constructed with any spectrum desirable and best fitted for the specific type of crops to enhance growth and quality at minimum power consumption.

Longer Lifespan
In comparison to HPS lights, LED lights have a longer lifespan. With time, HPS bulbs may become dimmer (become black) and lose efficiency, once the issue appeared, need to replace the whole light bulbs which is costly and time consuming. LED grow lights can typical last more than 50,000 hours before its light output is significantly reduced.

Produces Less Heat
Another benefit of LED grow light is that they produce less heat than any other type of lamp. The low heat dissipation means that active cooling in most cases can be eliminated leading to a simpler construction and installation with lower overall cost.
The lower temperature of the light panel at which the LED is mounted, the longer the LEDs will last and the higher its energy efficiency will be. In short, it is highly desirable to use a design for the light panel that will keep the temperature of the build-in LEDs as low as possible.

Dimmable and advanced light control
LED lights are dimmable and allow for more advanced light control both in terms of intensity but also across zones of a greenhouse. Support for advanced light control allows for even more optimized use of the light with increased yield and even lower energy consumption as an outcome.

LED outperforms traditional top lighting solutions

LED technology has been available for decades, but older LED technology and older first-generation grow light lamps often had issues with limited lifetime and questionable performance simply due to the massive heat generation in high-power lamps. LEDs biggest enemy is too high temperatures that eventually will kill them.

The advancement in development of the LED technology used for grow light has been significant in the last 2-5 years and second-generation top lighting solutions are now available and outperformances any traditional HPS lamps on several parameters including energy savings.

This means that LED based grow light lamps today are highly suitable as grow light for indoor farms to grow more plants at reduced expenses. The quality issues from the past have been eliminated for most manufacturers of high quality LED top lighting lamps.

As a greenhouse operator you may likely be ready for transition from old HPS lamps to new LED lamps, but it is very important that you know what to look for when selecting your next top lighting solution.

What to consider when selecting LED grow light lamps

There are several factors to consider when choosing a growth top lighting panel. The following list of seven factors are of very important when benchmarking different LED lights panels:

1. Light Spectrum
2. Light Intensity (Density)
3. Wattage Draw (Power consumption) and Energy Efficiency
4. Coverage Area and Homogeneity
5. Lifespan
6. Maintenance costs and Ease-of-cleaning
7. Price and Installation Cost

1. Light Spectrum

When choosing a spectrum of light for growing plants, the following two main processes in plants must be stimulated with light photons of different colors:

> **Photosynthesis:** a process used by plants to convert light energy into chemical energy that, through cellular respiration, can later be released to fuel the organism's activity
>
> **Photomorphogenesis:** ‘Photo’ means ‘light’, ‘morpho’ means ‘shape,’ ‘genesis’ can be translated as ‘creation of.’ So, it’s using light to create a certain plant shape.

Light can do a lot more than just change the growth pattern of a plant, though. It can trigger or delay flowering and fruiting, change chemical composition and taste, among other diverse reactions.

Different regions of the wavelength in the illuminaton spectrum have different effects on the plants:				
Wavelength range [nm]	**Photosyntesis**	**Further Effects**	**Further Effects**	**Further Effects**
200 – 280		Harmful		
280 – 315		Harmful		
315 – 380				
380 – 400	Yes			
400 – 520	Yes	Vegetative growth		
520 – 610	Some	Vegetative growth		
610 – 720	Yes	Vegetative growth	Flowering	Budding
720 – 1000		Germination	Leaf building and growth	Flowering
> 1000		Converted to heat		

Choosing the right spectrum for specific plant is essential for crop yield but it is also a question of ensuring that the electrical energy used to drive the grow light panel is used optimally by generating light photons with the highest impact on plant growth and thereby crops produced with the right quality. The optimal spectrum will increase the yield and reduce production cost.

Figure 1 shows the spectrum from a traditional HPS lamp with significant amount of energy concentrated around 600 nm at wish the Photosynthesis effect is limited. For comparison, Figure 2 shows LED iBond's customized supplement spectrum specifically designed for optimized photosynthesis in greenhouses.

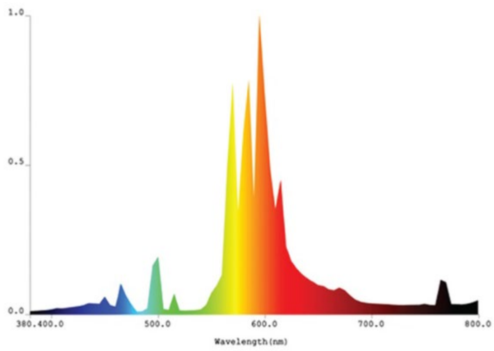


Figure 1 Standard spectrum HPS lamp

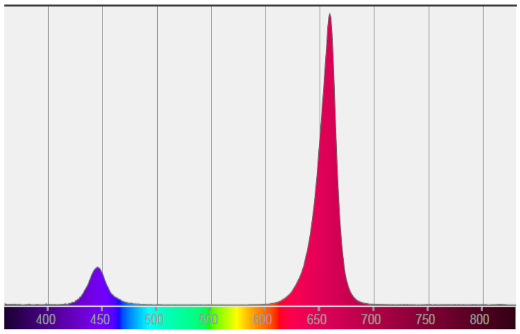


Figure 2 LED iBond - Supplemental spectrum

The optimal spectrum for a specific type of crop can be selected based on knowledge and experience but more accurately by conducting controlled growth experiments using different spectra for comparison of crops produced and its quality.

Even small changes in the composition of a spectrum can led to significant changes in yield (as up to 50%). Moreover, most plants and yield will benefit from using different spectra during the life cycle of the plant from nursery phase to full grown plant ready for harvest.

Remember to ask you lamp supplier about which spectrums that is offered.

While there is no doubt that grow light spectrum is important, accurate and optimum light intensity is also crucial.

2. Light Intensity (Density)

PPF (Photosynthetic Photon Flux) measures the total amount of light produced by a grow light lamp in terms of micromoles of photons produced per second, µmol/s.

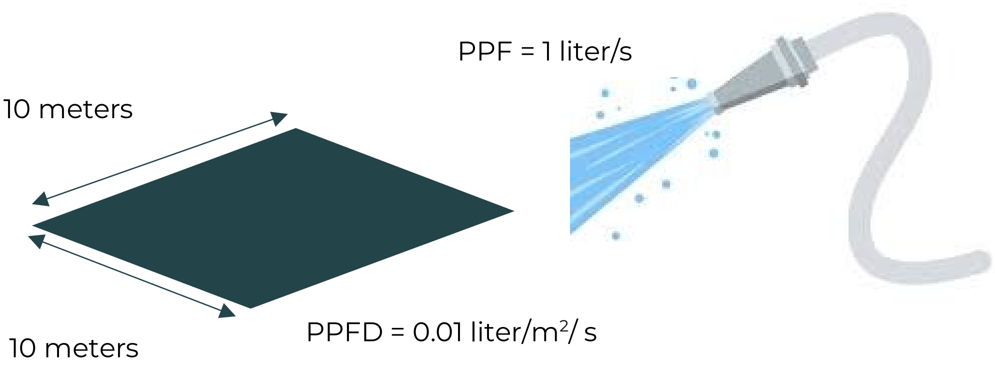
1 µmol/s = 6.022 x 1017 light particles (photons) hitting an area in one second

This is an important number because unlike PPFD (which will be explained below) it can't be manipulated and tells you the full amount of light energy coming from the LED grow light. For comparison you can think of a water hose with water flow: the photon Flux (μmol/s) would then correspond to liters of water per second (liter/second) coming from the hose.

PPFD (Photosynthetic Photon Flux Density) on the other hand measures the amount of micromoles of photons striking a square meter per second, μmol/m2/s.

1 μmol/m2/s = 6.022 x 1017 light particles (photons) hitting a m^2 area in one second

With the example of the water hose, the Flux density becomes 0.01 liter/m^2/s if all the water (1 liter/s) from the hose is distributed equally over a 10x10 meter (100 m2) large lawn.



Full daylight sun at noon in the summer is around 2000 μmol/m^2/s but plants need far less, because the Sun's intensity is only that bright for a small portion of the day and because the angle of that intensity changes throughout the day, providing that much light for an extended period of time would very likely be damaging to plants.

Depending on the type of plant, at levels greater than 800-1000 μmol/m^2/s the plant can't absorb the light anymore and energy is lost. This means that plants can be exposed to more light than this, but it likely not leads to a huge change in outcome (grow of the plant/yield) and may even damage the plants. In reality and due to practical constrains, typical optimal levels for light applied in Greenhouses is typically 50-120 μmol/m²/s for many plants. There are, however, some type of plants like cannabis that need levels of up to 600-800 μmol/m²/s.

Measurement of PPFD is highly depended on how close to the grow light panels the measurement is performed.

A grow light manufacturer should therefore always report what distance the PPFD numbers were measured at (e.g., 200 cm) below the grow light and should be an average number measured across the grow area as the homogeny of the light can be low.

For indoor farming it is important to ensure that all light from the light panels will reach as much of the plants as possible to increase whole photosynthesis of the plants. Traditional HPS lamps use a reflector to distribute the light more evenly and increase some homogeneity across the grow field. Unfortunately, such reflector can't be used with LED technology, and the creation of homogenic light from LED based lamps is in practice very challenging.

Despite the use of a reflector, even HPS lamps produce uneven light distribution across the grow bed. Figure 3 shows an example for the typical light distribution across a grow bed being 670 cm wide and illuminated with two rows of HPS.

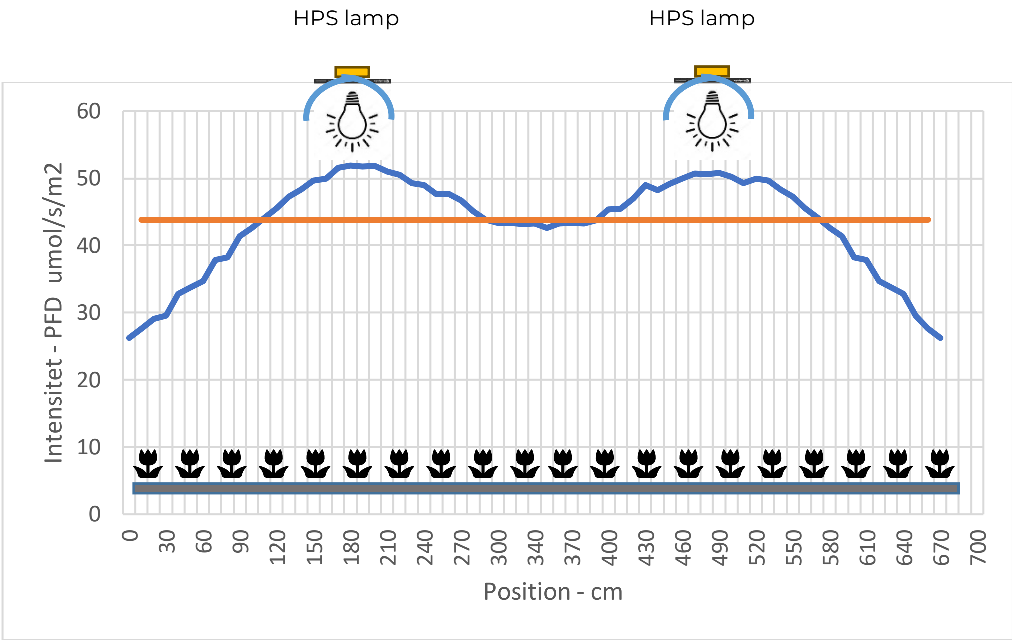


Figure 3 PFD (light intensity) across a 670 cm wide grow bed.

As different grow light lamps have different form factors and spreads light differently, it is vital that intensity (PPFD) is determined and benchmarked at the same distance from the lamp or the electrical power to the light panel is adjusted so the PPFD becomes identical when measured at the plant's position.

As most traditional lamps as placed in a grid across the grow bed, the homogeneity must be measured and benchmark across a larger area of the grow bed. The PPFD must be measured at the location of the plants below the light panels for a benchmark to be valid.

Figure 4 shows an example of a high degree of light homogeneity achieved using a very linear formfactor and smart lens design for the LED lamp (HORTISABER). The result is a very homogenic light distribution.

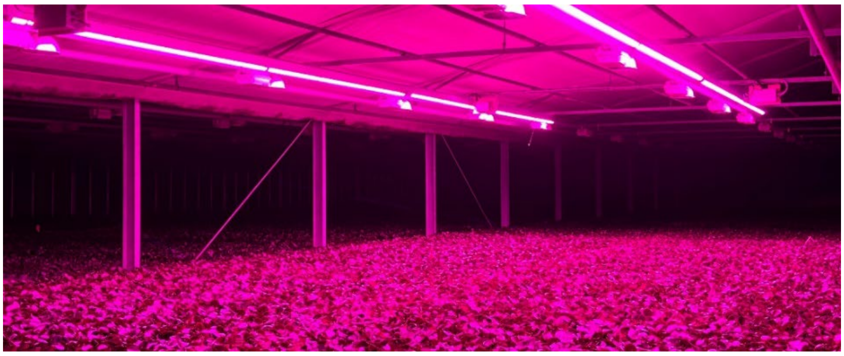


Figure 4
Light distribution from 4 HORTISABER lamps (6m long) – grow bed covered is 12m long and 6.7m wide.

3. Wattage Draw (Power consumption) and Energy Efficiency

The power consumption should be minimized and is very important as a light panel normally are powered on for up to 8-12 hours per day in the wintertime.

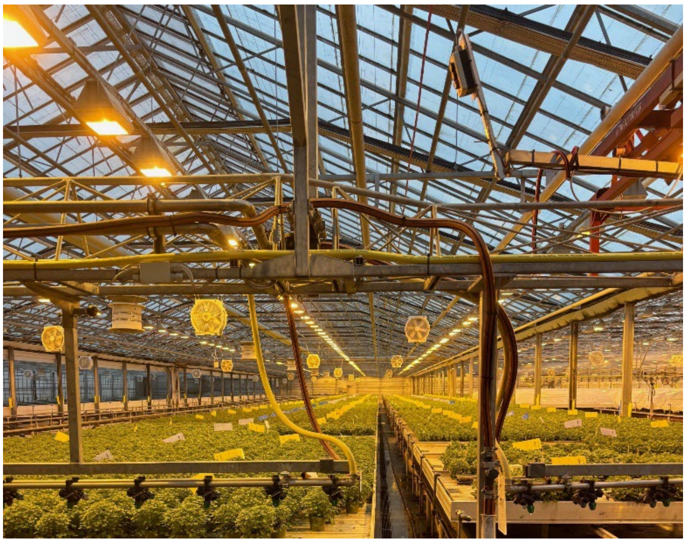
The power consumption to be considered shall be wall-plug-consumption and shall therefore include any electrical driver (power supply) as the energy loss in a LED driver is typically 7-10%.

The quality and energy efficiency of the LED is an important metric. For top lighting lamps the energy efficiency is often expressed in µmol/W. Good lamps with the highest energy efficiency is up to 3.6-3-7 µmol/W whereas lower quality may be as low as 2.2-2.5 µmol/W.
In order to compare two different types of grow light lamps, it is best to measure the power consumption required to produce the exact same amount of PPFD (Photosynthetic Photon Flux Density). The PPFD must be measured at the location of the plants below the light panels for a benchmark to be valid.

4. Coverage Area and Homogeneity

Each top lighting lamp can be used to illuminate a certain grow area. Most lamps are designed to be used together and placed in a row or a matrix to increase the light homogeneity and more efficiently use all the light energy from the lamps.

An important metric is therefore how many light lamps are required pr square meter (m2) of growth area - or how many square meters one lamp can cover.



More light lamps required will mean more initial cost (capex), higher installation cost, and more service time.

The homogeneity is also important to considered when the number of lamps is considered as low homogeneity will lead to an uneven growth of the plants across the illuminated growth area.

Always ask your supplier for measurements of the homogeneity for the type of lamp you are considering.

5. Lifespan

The lifespan of the top lighting lamps is an extremely important metric. Typical lifespan is claimed to be many years and is often based on the expected lifespan of the specific light emitting diodes used in the light panel construction.

The lifespan is, however, highly effected by the actual temperature of the light panel (lower temperature leads to longer lifespan) and the harsh environment in an indoor farming facility will lead to lifespan degradation and in some cases compete failures after few years of operation.

A long lifespan for a light panel in a harsh environment with high humidity requires a light panel design for which the LED diodes are encapsulated Open structures will not last long in practice as the LED and electronics are exposed to moisture due to high humidity and water from cleaning processes.

You should expect a lifetime of more than 50.000 hours.

6. Maintenance costs and Ease-of-cleaning

Most top lighting lamps do in general not require any specific maintenance or parts that needs to be replaced over its expected lifespan. Some type of high-power light lamps may, however, include active cooling that could need service regularly.

It is necessary to clean the top lighting lamps occasionally to keep the grow area facility free from, e.g., fungus. The cleaning process needs to be considered as cost of maintenance. Some grow light lamps may have to be demounted for cleaning whereas others can be sprayed using a water hose while the light lamps remain in place.

Consider how smooth the surface of a lamp is and how easy will be to clean using hose.

7. Price and Installation Cost

The price and installation cost of a top lighting lamp is an initial investment and an important metric to consider and shall be included in a total-cost-of-ownership analysis together with all the other 6 factors listed above.

Some lamps cover only 10 m2 of grow area were as other type lamps, such as the HORTISABER, covers up to 30 m2 – as an example this will mean that 66% of the installation cost can be saved by using the HORTISABER lamp.

Also consider if you need to install new metal bearings to mount the new top lighting lamps on to – in some case it may not be installed where the old HPS lamps are mounted but needs to be installed in a new position in the greenhouse to optimize.

Conclusions and recommendations

Benchmark of different types of grow light lamps requires a structed and detailed comparison of several important metrics including light Intensity, power consumption, coverage area, homogeneity, lifespan, maintenance costs and ease-of-cleaning, price, and installation cost, and at the end production yield.

It is important that any comparisons are made under the same comparable conditions. If for example power consumption for two different light panels are compared, the consumptions must be determined and calculated pr square meter of grow area with a predefined specific light intensity (PPFD) at the crop's locations below the lamp. Only under such equivalent conditions a benchmark can meaningful be made.

It is also our recommendation that detailed growth experiments are conducted to validate the grow light manufacturers specifications and determine yield under specific and comparable conditions using an optimal spectrum. If not done in a structured way, there is a high risk that any conclusions may be completely wrong.

For more information about light solutions for indoor farming or advice on lighting options to construct an indoor farm, please visit ledibond.com or send an email to sales@ledibond.com.