



How to save energy with the latest horticulture LED lighting and sensor solutions

<https://ams-osram.com/de/applications/lighting/agriculture-horticulture>

By Florian Lex, Heidi Binder, Thomas Grebner, Markus Hofmann, Una Forgic, Sebastian Czernetzki

Sensing is life

am^{UN} OSRAM

Introduction

Energy efficiency is a critical factor in the success of controlled environment agriculture (CEA). With energy costs rising rapidly, minimizing power consumption in greenhouses and vertical farms is essential not only for achieving high yields but also for maintaining profitability. Among all operational inputs, horticultural lighting accounts for a significant share of energy use, making the adoption of highly efficient luminaires a key priority for growers.

Advancements in LED technology have transformed the possibilities for horticultural lighting. Modern LED fixtures can now replace traditional systems such as high-pressure sodium (HPS) lamps, offering superior efficiency, longer lifetimes, and greater reliability. Beyond energy savings, LEDs provide an additional advantage: the ability to fine-tune the light spectrum to meet the specific needs of different crops, thanks to the wide range of LED components available on the market.

LED Luminaires vs. Traditional Luminaires

In the diagram below, the Total Cost of Ownership (TCO) of a traditional horticulture fixture is compared to the TCO of an LED fixture that offers the same performance. The assumptions for the TCO calculation have been simplified: only the initial fixture costs and the energy costs have been considered. The traditional fixture has lower initial costs than the LED fixture. After a certain operating time, the LED fixture will reach a lower total cost than the traditional fixture because of its higher efficiency and lower power consumption. The top performing LED fixtures can reach break-even point after as little as one year, as shown in the graph.

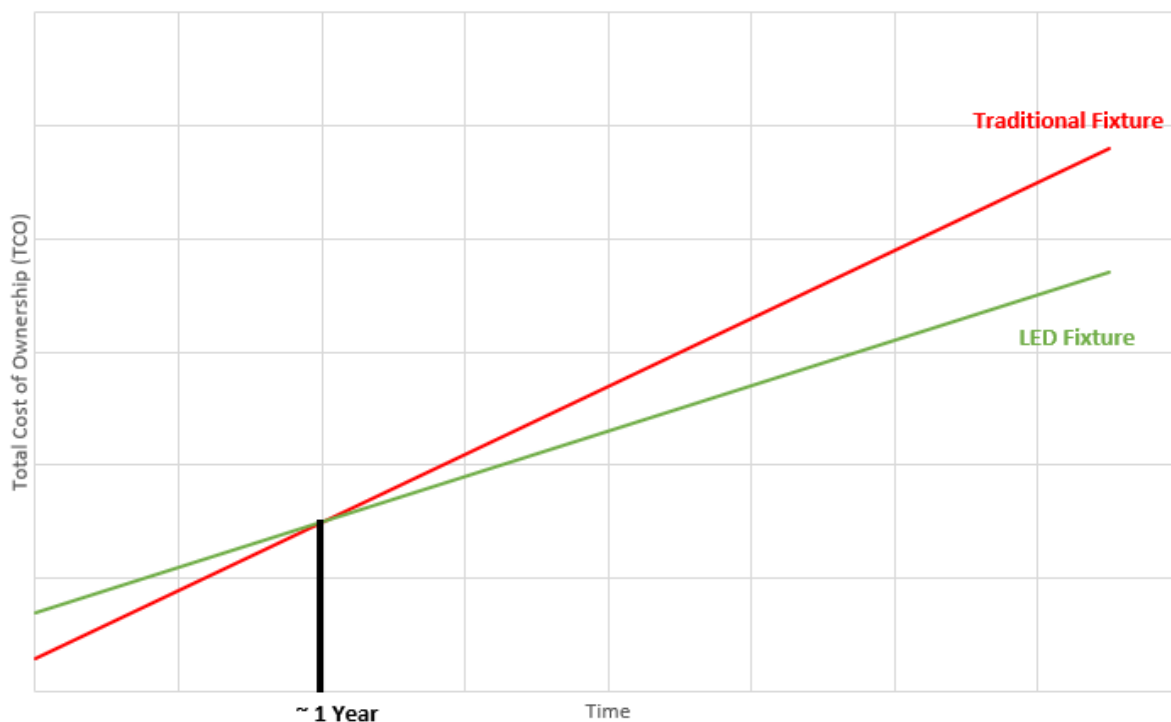


Figure 1: Comparison of traditional horticulture fixture versus LED fixture!

LED efficacy

The main reason for the higher efficiency of horticulture LED luminaires is the LED itself. An LED consists of a light-emitting semiconductor chip, a package or housing in which the chip is mounted, and – in the case of white LEDs – a phosphor converter applied as a coating on the LED chip. The careful design and production of each of these sub-components can minimize total losses in the LED.

In the chip, the goal is to generate as many photons as possible, and to design it so that as many of these photons as possible can exit the chip, while at the same time keeping electrical losses to a minimum. The design of the package should allow as much light as possible to be extracted, for instance by minimizing internal reflections. In white LEDs, conversion losses reduce light output. Colored LEDs do not need a converter. This is a fundamental advantage: since they have no conversion losses, they gain a marked improvement in efficiency.

compared to white LEDs. In plant illumination, Hyper Red LEDs (660nm) are particularly important. A Hyper Red LED such as the GH PUSRA2.25, which offers best-in-class efficacy of 4.63 $\mu\text{mol/J}$ at 85°C junction temperature, is more efficient than white LEDs, at $\sim 3.0 \mu\text{mol/J}$.



White Spectral content

So, what is the effect of the higher efficiency of Hyper Red LEDs on the operation of a horticulture lighting system as a whole? The calculation shown in the graph below reveals the impact of changes to the ratio of red to white LEDs on system costs. This is a useful consideration for growers of crops which produce good yields under light which has more red content in its spectrum than white LEDs alone emit. In this calculation, the photon flux and the efficiency of the system are constant for all ratios of red to white light, so the efficiency advantage of increasing the Hyper Red content affects system costs rather than the efficiency of the fixture. From left to right, the share of Hyper Red LEDs is decreased from 100% to 0%, while the share of white LEDs is increased from 0% to 100%. The total cost (cost to buy the LEDs + energy cost) increases exponentially as the ratio of white LEDs rises. This shows that implementing a design with a higher share of white LEDs results in higher LED costs for a fixture with the same efficacy as a fixture that has a higher share of Hyper Red LEDs. Of course, the freedom to increase the share of Hyper Red LEDs in a fixture might be limited by the spectral requirements of the intended crop. But for instance, reducing the share of white LEDs in a fixture from 80% to 60% produces a double-digit system cost saving.

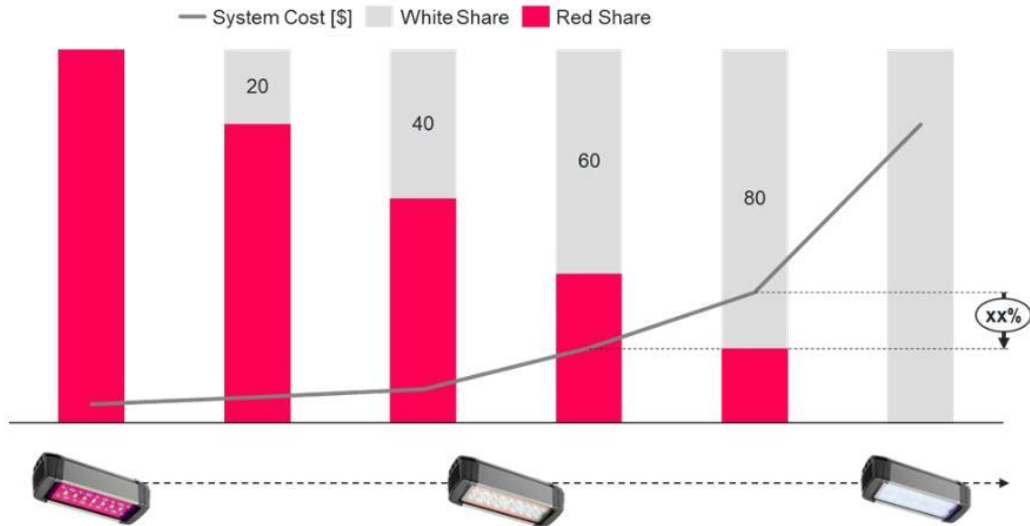


Figure 2: How the share of red and white LEDs affects the system costs!

Comparing different Spectra

Another way of studying the effect of adjusting the proportion of white content in different spectral power distributions is to compare the spectra for different LED combinations that all offer the same photon flux. The table below shows the different spectral outputs of various combinations of LEDs. All these combinations produce a photosynthetic photon flux (PPF) output of 2000 $\mu\text{mol/s}$.

Variants	Name and Composition	LEDs	Spectra
Variant 1	90% 660nm + 10% 450nm  	OSCONIQ P 3737 ▪ GH PUSRA2.25 ▪ GD PUSRA2.15	
Variant 2	80% 660nm + 20% White  	OSCONIQ P 3737 ▪ GH PUSRA2.25 ▪ GW PUSRA2.HW	
Variant 3	30% 660nm + 70% White  	OSCONIQ P 3737 ▪ GH PUSRA2.25 ▪ GW PUSRA2.HW	
Variant 4	10% 660nm + Mid Power White  	OSCONIQ P 3737 + OSCONIQ S 3030 ▪ GH PUSRA2.25 ▪ GW QSLMS3.EM	
Variant 5	10% 660nm + White Low Cost  	OSCONIQ P 3737 + DURIS E 2835 ▪ GH PUSRA2.25 ▪ GW JTLPS1.EM	

Figure 3: Different spectra comparison!

The graph below shows the difference in efficiency between the five variants.

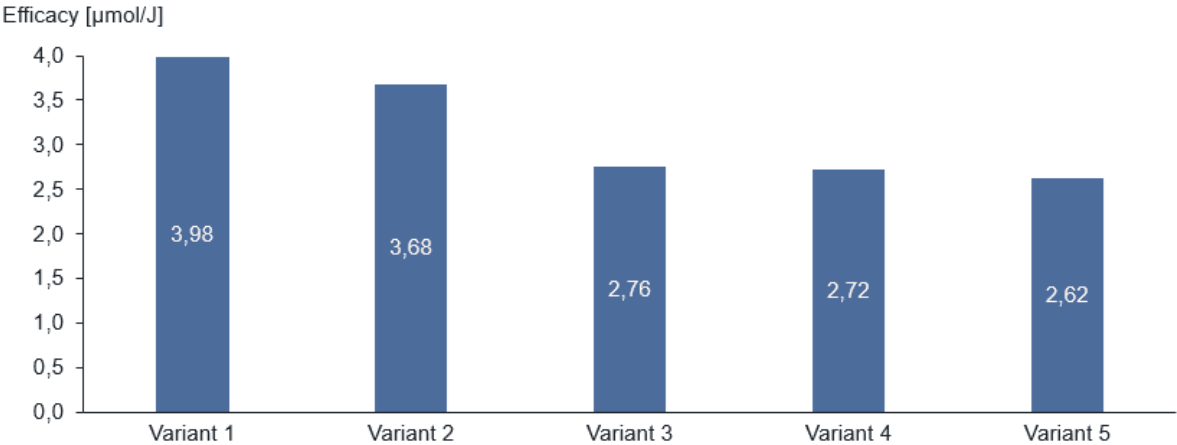


Figure 4: Efficacies simulated at 95% opt., 95% el. efficiency, Tj = 70°, high power LEDs at 700mA, mid power at 120mA

With this information, the TCO of each variant can be plotted as shown in Figure 5.

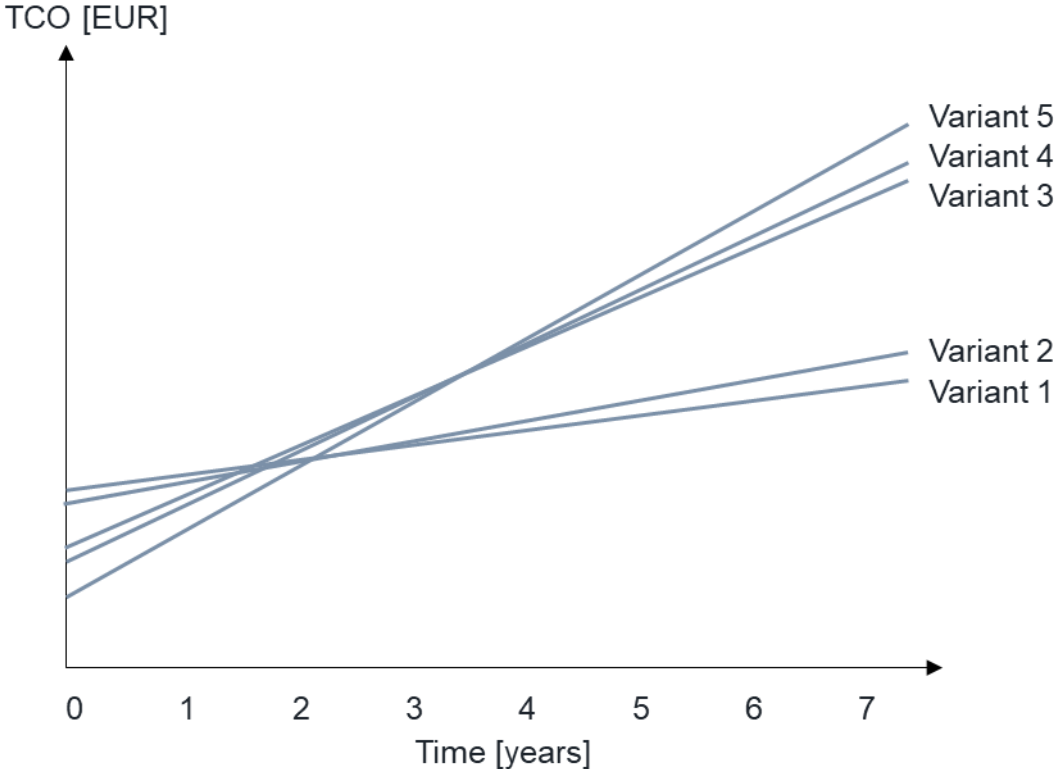


Figure 5: Comparison of the TCO of five different combinations of LEDs!

This graph shows that Variant 1, a combination of Hyper Red with Deep Blue LEDs, offers the lowest TCO followed closely by Variant 2, which is a combination of Hyper Red with a low white content. Increasing the white content, as shown in Variants 3 and 4, increases the TCO, and the effect is even more pronounced in Variant 5.

Quantum Sensing with Spectral Sensors: The Value of PAR Monitoring



The term Photosynthetically Active Radiation (PAR) refers to light at wavelengths in the visible range (VIS) between 400 nm and 700 nm. A plant needs PAR to perform photosynthesis. Growers can optimize plant yields and health by controlling the lighting conditions to maintain important levels of PAR using artificial light. By measuring the PAR value of natural light, growers can adjust light sources to the appropriate settings to achieve the target level for total PAR. The simplest method of control is to turn the lights on or off, a process which can be automated with smart luminaires. But changes in the environmental conditions make the adjustment of artificial lighting more complicated: cloud cover, the cycle of night and day, smudged or dirty glass and other external conditions affect the intensity and color of artificial light required to produce ideal growing conditions for the plants in a greenhouse.

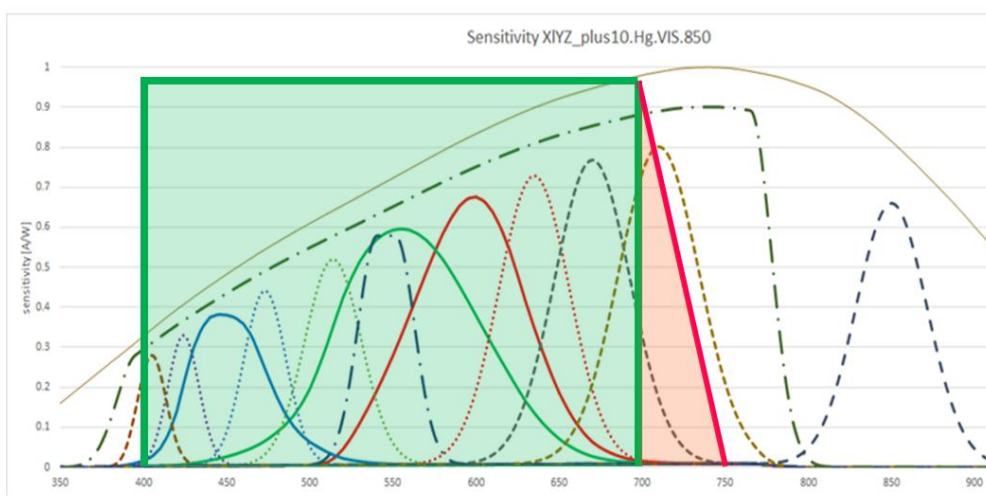


Figure 6: The spectra sensitivity of the TCS3448 sensor at PAR wavelength!

Why TCS3448 is ideal to measure PAR?

The TCS3448 is a 14-channel, miniature chip-scale spectrometer. Based on semiconductor technology that is proven in high-volume production, the TCS3448 enables the implementation of designs for an accurate PAR meter that use just a single sensing component. The provision of multiple channels in the TCS3448 enables spectral matching of the PAR curve. Using the TCS3448, monitoring equipment can perform highly accurate metering of photosynthetic photon flux density (PPFD). A full spectral reconstruction provided by an TCS3448-based system enables accurate PAR metering with spectrometer-like features. Using detailed PAR metering data, horticulture lighting equipment manufacturers can implement a complete, multi-channel supplemental light tuning solution.



Figure 7: The TCS3448 spectral sensor!

The TCS3448 can measure both the intensity and spectral power distribution of sunlight. An LED/TCS3448 sensor closed-loop control system makes it possible to control total light intensity to the PAR value required by the plant.

What are the advantages of this solution based on the TCS3448 spectral sensor?

1. Active PAR sensing can be implemented in a low-cost system installed in the greenhouse, rather than using laboratory equipment
2. Automatic adjustment of supplementary lighting
3. By avoiding the unnecessary use of artificial lighting when there is enough sunlight, growers can reduce energy consumption. This reduces a greenhouse's operating costs, as well as its carbon emissions.
4. Optimization of lighting conditions improves crop yields Studies show that switching from conventional lighting sources to LED-based systems with active control can reduce electricity consumption by up to 40%. Yields are between 20% and 30% higher than in non-illuminated greenhouses.¹

¹Energy savings in greenhouses by transition from high-pressure sodium to LED lighting – ScienceDirect

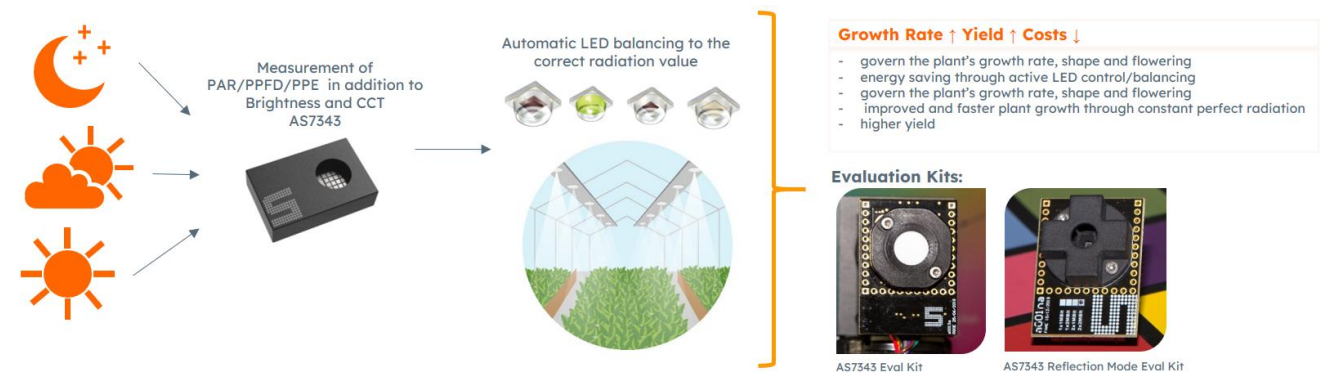


Figure 8: PAR measurement performed with the TCS3448/TCS3448!

Additionally, the TCS3448 can measure back-scattered light from the canopy to assess plant health. It can also check whether the specified light spectrum emitted by fixtures reach the plants. Using spectral sensing, the combination of daylight and artificial light may be actively measured. This enables daylight harvesting, which saves energy and reduces carbon emissions. Provided the PPFD or photosynthetic photon efficacy (PPE) values required by the plants are known, the control mechanism can be as simple as dimming lights to the level required to produce the exact values for light intensity and color at the plant level. Together, high-quality LEDs and spectral sensing pave the way to the future for horticulture lighting. This solution can reduce energy needs and improve plant growth with a control method as simple as dimming lights.

Conclusion and Outlook

With ams OSRAM, horticulture lighting fixture manufacturers and growers gain access to the latest innovations in professional horticultural lighting, from greenhouses-top- and inter-lighting systems, to advanced vertical farming designs.

The innovative approach to horticulture lighting enables more sustainable food production by addressing the global challenge of feeding a growing population, while simultaneously reducing CO₂ emissions and lowering energy consumption. Through cutting-edge lighting and sensor solutions, ams OSRAM empowers the industry to achieve higher yields, improved efficiency, and more sustainable future