Updated as of Apr 2024

TIPS FOR CHOOSING THE RIGHT LIGHTS

LED grow lights are investments with long-term impact to your operations. Here are some tips on how you can choose the right LED for your farm. Technical details can be found in the next pages.

Understand Terminologies for Crop Needs

- **P**hotosynthetic **A**ctive **R**adiation (PAR): light spectrums crops need for photosynthesis.
- **D**aily **L**ight **I**ntegral (DLI): total PAR delivered to crops in a day.
- **P**hotosynthetic **P**hoton **F**lux (PPF): intensity of light from source.
- **P**hotosynthetic **P**hoton **F**lux **D**ensity (PPFD): intensity of light in an area.

Different combinations of spectrum and intensity affect yield, height, leaf sizes, and much more.

Page 2

Request for the Specifications

- Ask for details about how PPFD are measured such as distance from light source and distribution.
- Ask for photon efficacy, higher figures indicate better performance at converting electricity to PAR photons.

Page 2

Calculate Energy Efficiency

- Relate PPFD, PPF and photon efficacy. Look out for efficacy claims that seem too good to be true.
- Consider the total OPEX and CAPEX over the expected lifespan of lighting systems.

Page 3

Check for Reliability and Quality

- Consider the warranty and the equipment degradation rate.
- For indoor vertical farms, locate external LED drivers separate from growing spaces to reduce air-conditioning cost.
- Request for some light fittings to conduct growing trials before making bulk purchases. Compare energy consumption and light quality measurements with the manufacturer specifications.

Page 4

Local farms can tap on the Agri-Cluster Transformation (ACT) Fund with the enhanced Energy Efficiency Programme (EEP) to build capabilities and capacities that help farms drive towards higher productivity in a sustainable and resource-efficient manner. Farms can tap on co-funding under the EEP to undergo an **energy efficiency audit** which would establish their baseline energy consumption and identify potential areas for improvements. Farms can also leverage the enhanced Capability Upgrading component to **adopt resource and energy-efficient equipment and technologies** from SFA's pre-qualified list. All licensed farms can apply for co-funding under the EEP.

Find out more!

UNDERSTAND TERMINOLOGIES:
Quality and Intensity Specifications

Photosynthetic Active Radiation (PAR)[3]

Light (made up of elementary particles call photons) within the 400-700nm wavelength spectrum (visible to human eyes) that are most required for photosynthesis. Different crops at various stages of its life cycle require different combination of spectrums to achieve optimal yield and health.

Daily Light Integral (DLI)[3]

Expressed in mol/d·m², DLI measures the total amount of light in the PAR range that is delivered to plants in a day. Different crops require different DLI. Use DLI with PPFD to determine sufficient lighting system and operating hours (photoperiod).

Photosynthetic Photon Flux (PPF)[3]

Expressed in µmol/s, PPF measures how many photons in the PAR range is produced by a lighting system per second. Ratio of different spectrums' PPF (e.g., blue to red light) determines your 'light recipe' as it tells how much photons for various spectrums are produced. This parameter is best used to compare light fittings.

Photosynthetic Photon Flux Density (PPFD)[3]

Expressed in µmol/m²·s, PPFD measures PAR photons landing per unit area. PPFD are typically an average of many measurements. Values can differ depending on distance from the lighting source and number of measurements. It is important to know these specifications to make fair comparison between lighting systems.

Generic Light Requirements

Type of crops	PPFD	DLI
Leafy Vegetables	200-300	12-17
Microgreens	100-200	6-12
Fruited crops (e.g., tomatoes)	260 – 600	15-40

Note: DLI for leafy vegetables and microgreens are calculated from PPFD, assuming photoperiod of 16 hours. The upper bound for fruited crops of 600 PPFD and 40 DLI is calculated using photoperiod of 18 hours. Requirements for various crops vary greatly.

Conversion between PPFD and DLI

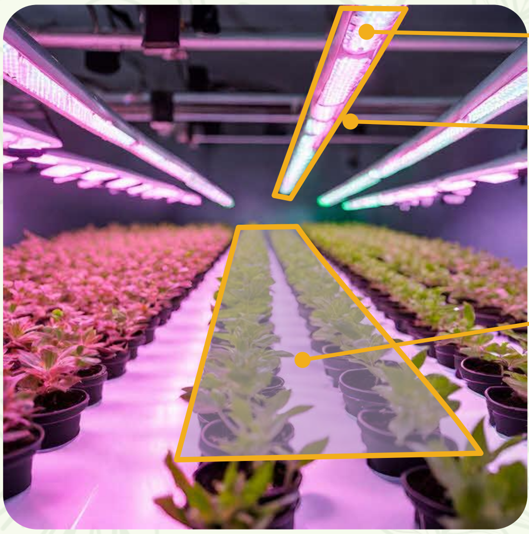
From PPFD to DLI:

$$DLI(mol/d \cdot m^2) = \frac{photoperiod \times PPFD \times 3600}{1{,}000{,}000}$$

From DLI to PPFD:

$$PPFD(\mu mol/m^2 \cdot s) = \frac{DLI \times 1{,}000{,}000}{photoperiod \times 3600}$$

If your lighting system has slightly higher/lower PPFD than desired, adjusting the photoperiod can achieve your desired DLI. Optimal photoperiod saves energy and achieves desired yield.



Created using Canva (Magic Studio™)

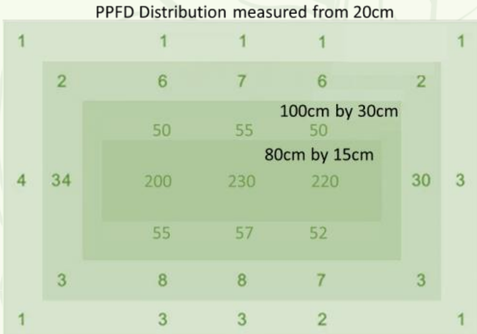
PAR: We see different spectrums as different colours. Blue (400-500nm) and red (600-700nm) spectrums produce the common purple seen in indoor vertical farms.

PPF: number of photons generated by a light source per second. Dense configurations of LED cells and high-quality LED cells generate more photons.

PPFD depends on PPF and optical control such as light fittings' diffuser and reflector. Ask for the PPFD distribution (right image) as the values under adjacent lightings are not simple additions.

PPFD values are average of multiple readings. Request for maximum and minimum values to evaluate uniformity.

PPFD Distribution measured from 20cm



Green figures are measured PPFD values.
Black figures are dimensions of sampling area.
For illustration purposes only.

Singapore Food Agency

CALCULATING ENERGY EFFICIENCY

Photon Efficacy (PE)

Expressed in µmol/J, PE measures how efficient a lighting system is at converting electrical energy (Joules, J) into photons of PAR. Photon efficacy can be calculated with the PPF and the input wattage (see formula and table below).

LED lights efficacy cannot exceed the theoretical maximum, determined by the characteristics of photons (wavelength and frequency). LED light systems that are predominantly red can achieve higher efficacy compared to ones that are predominantly blue.

For example, for a light system that is 80% red and 20% blue, the theoretical maximum efficacy is ~5.1 µmol/J

Theoretical Maximum Efficacy

Spectrum	Wavelength (nm)	µmol/J
Blue	~450	3.76
Green	~550	4.60
Red	~650	5.43
Far red	~750	6.27

Converting PPF, PPFD to Energy Consumption

$$Watt(W) = \frac{PPF(\mu mol/s)}{Photon\ Efficacy(\mu mol/J)}$$

Used to determine energy usage

Where Watt is the energy consumption of a lighting system. PPF and Photon Efficacy can be obtained from the supplier.

$$W/m^2 = \frac{PPFD(\mu mol/m^2 \cdot s)}{Photon\ Efficacy(\mu mol/J)}$$

Estimate energy usage based on growing area

Where W/m^2 is the average energy consumption per m^2 of growing area and PPFD is the average at the growing plane.

Current LED Fixtures Efficacy[2]

Spectrum	µmol/J	Efficiency (%)
Blue/red	2.55 - 3.0	50-60%
White/red	2.59 - 2.78	~50%
White (5000K)	~2.4	~60%

Efficiency (%) is a light systems' photon efficacy divided by the theoretical maximum efficacy.

Light Efficacy is improving rapidly with some brands reporting ~3.5µmol/J (~68%) at the B/R spectrums.

Relationship between PE, PPF, PPFD and Energy Consumption

Photon efficacy (µmol/J)	PPF (µmol/J)	PPFD (µmol/m²·s)	W/m² of growing plane	W / light fitting
1.5	140	230	153	93
2.0	140	230	115	70
2.5	140	230	92	56
3.0	140	230	77	47

Light fittings with better photon efficacy uses less energy (W) at similar PPF and PPFD levels

Grow light energy consumption can be calculated,

$$Total\ energy\ consumption\ (kWh\ /\ day) = W\ /\ light\ fitting \times no.of\ light\ fittings \times photoperiod\ (Hours) \times \frac{1}{1000}$$

Or estimated,

$$Total\ energy\ consumption\ (kWh\ per\ day) = W\ /\ m^2 \times total\ grow\ area \times photoperiod\ (Hours) \times \frac{1}{1000}$$

LED LIGHT RELIABILITY & QUALITY CHECKS

Expected Lifetime

Light fittings should be tested according to recognised standards such as IES LM-80[1]

50,000 hours – L80B10

L80 of 50,000 hours: the tested product can generate 80% of the initial PAR for 50,000 hours. Higher percentages indicate better products.

B10: 10% of tested products failed to meet 50,000L80. Lower values indicate better uniform quality.

LED Drivers[4]

LED drivers deliver the suitable current and voltage to power LED lights. It typically includes safety features that prevent overprovision of current and short circuit protection.

Some drivers feature dimming and communication protocols. Dimmable lights offer flexibility during operations and enable OPEX savings. Communication protocols enables advance functions such as remote control, monitoring and programmable lighting.

Consult with electrical/lighting engineer early to achieve energy efficiency.

Power and Light Quality Meters

Power meters use current transformers (CT) to measure energy consumption. Different power sources (single/three-phase, 2/3 wire configurations) require different number of CTs.

Light meters can be used to measure PPFD, quantify the various spectrum (e.g., red, blue etc.) and calculate the spectrum ratios.

Contact us via the feedback form (QR code, right) to enquire about using light meters.

Let us know your thoughts

About the author

LAN Yi Chieh is from the Agri-Technology and Food Innovation Department of the Urban Food Solutions Division. An environmental engineer by training, his current research interest includes climate control and energy efficiency for controlled environment agriculture.

References

1. Illuminating Engineering Society approved method for measuring luminous flux and color maintenance of LED packages, arrays and modules. (2015).

2. Kusuma, P., Pattison, P. M., & Bugbee, B. (2020). From physics to fixtures to food: current and potential LED efficacy. Horticulture Research, 7(1). https://doi.org/10.1038/s41438-020-0283-7

3. Sípos, L., Boros, I. F., Csambalik, L., Székely, G., Jung, A., & Balázs, L. (2020). Horticultural lighting system optimalization: A review. Scientia Horticulturae, 273, 109631. https://doi.org/10.1016/j.scienta.2020.109631

4. The Ultimate Guide to LED drivers. (accessed Mar 2024). Lighting Style. https://www.lightingstyle.com.au/led-drivers.html