



## Measuring Light: The important differences between PPF and PPFD

There exists some industry inconsistencies between how PPF and PPFD is used when describing their lamps output. For those basing their decision on which lamp is best suited their garden it's important to know what these different terms mean.

**PPFD (Photosynthetic Photon Flux Density)  $\mu\text{Mol}/\text{M}^2\text{S}$  is certainly well defined, accepted and consistently used. However, PPF is used inconsistently by nearly every source referencing it. We have seen a quantum sensor manufacturer indicate that the terms PAR, PPF, and PPFD are all the same having units of  $\mu\text{Mol}/\text{M}^2\text{S}$ . We have also seen many refer to PPF in various ways having units of  $\mu\text{Mol}/\text{M}^2\text{S}$ . We have seen industry leading light manufacturers refer to PPF as the total radiant light output in the PAR region of a lamp in units of  $\mu\text{Mol}/\text{S}$ . So the question is: If PPFD is well defined and uniformly accepted, why then are so many within the industry using PPF to have the same meaning?**

The likely answer is that there is no good solid standard for the industry to work within. So taking a look at area lighting and their value definitions the best conclusion we can draw is **that the units for PPF should be  $\mu\text{Mol}/\text{S}$** . We think the reason for this confusion results from a disconnection between the lamp and sensor manufacturers, particularly since **lamp specifications should be based on PPF and field measurements based on PPFD**. Another issue contributing to the confusion is that so many manufacturers, both lighting and measurement, do not consistently show the complete proper engineering units in their marketing, operating, and specification documents.

PPF as  $\mu\text{Mol}/\text{S}$  is the value that a grow lamp should specify for its total light output (Radiant Watts would also be appropriate), this would be similar to using Lumens for a regular area light. PPFD is the primary measurement taken by a Quantum PAR meter and is expressed as a density over a unit of area, this would be similar to using Lux or Foot-Candles on a regular light meter. We do believe these to be the proper definitions as originally intended, but have been unable to find any industry standard or document to substantiate that.

For your consideration:

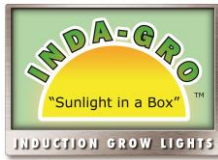
**PPF** (Photosynthetic Photon Flux) issued by (or should be) manufactures as the lamps total emitted number of photons per second in the PAR region. **Units of measure:  $\mu\text{Mol}/\text{S}$**

**PPFD** (Photosynthetic Photon Flux Density) represents a field measurement and is defined as, the number of photons in the PAR region emitted per  $\text{M}^2$  per Second. **Units of measure:  $\mu\text{Mol}/\text{M}^2\text{S}$**

In standard commercial/industrial lighting terminology the use of the term "flux" generally applies to the light energy on a per time basis which in grow lamps would be the lamps PPF value. By definition, **Energy per time** or energy transfer rate is defined as **Power**. In lighting terms, light power is generally defined in terms of **Radiant Flux** or **Luminous Flux**.

The point of this discussion is that the term "flux" used in the absence of density applies to energy or power emitted, **but not over a specific area**. The term "Density" generally applies to the energy or power per a volume of space, in the case of lighting, it generally applies to an area rather than a volume, since light striking a surface area is more applicable than light within a volume.

Lamp manufacturers should rate the lamps overall output in PPF ( $\mu\text{Mol}/\text{S}$ ) or PAR radiant Watts rather than Lumens which are strictly for human vision. Ideally in the future we may have a generally accepted PAR sensitivity standard that can be applied to give results as Yield PPF or Yield Radiant Watts which would be a more equivalent measurement to Lumens, but would be plant specific.



If a lighting manufacturer, not a lamp manufacturer, were to use PPF as a specification for a particular fixture/lamp combination they would need to include all of the following information for the user to properly interpret the information being given:

1. Provide the height from which the measurement was taken.
2. Provide multiple locations across the illuminated footprint at meaningful points allowing for interpretation of consistency of intensity and footprint limitations.
3. Provide multiple sets of PPF measurements at different heights.

To publish in a PPF value various considerations with this approach would be:

1. Measurements must be taken with reflectors in place to achieve accurate results.
2. For HID lamps since the lamps are sold separate from the reflectors there can be many different combinations of lamps and reflectors. Any measurements taken need to be specific to a particular lamp/reflector combination.
3. At the close height that grow lamps are used their light distribution patterns will not change in a regular expected manner. The use of a reflector in the design requires that a certain minimum measurement distance is used for values to stabilize and act with an expected regularity for varying heights. This height in many cases will be greater than the typical height used for an indoor grow, but would likely be good for a greenhouse supplemental application. Basically we are referring to relationship of Light Intensity as a function of  $1/d^2$ , where  $d$  is the measurement distance from the light source. Until this certain height is achieved, you will not see measured values following this rule at all.
4. As for LED panels, these measurements will not stabilize until a height is reached for which the beam patterns of the LEDs have interlaced enough to be somewhat homogenous, both with respect to intensity and mixture of different LED wavelengths.
5. Interpreting the results of overlapping light from adjacent lamps in multiple lamp systems can be a difficult task, but would be necessary to determine the true quantity of light intensity at any particular point.
6. It will likely still take some field experimentation with proper measurement equipment and different configurations of the lamps to come to the optimal lamp placement, particularly in a multiple lamp system.

### **This is all great information but how do I use it in the field?**

As indoor gardeners we are trying to optimize all the conditions in the garden which include an even spread of light at enough intensities to meet our crops daily light needs. It's important to have accurate canopy values as it relates to the amount of  $CO_2$  that is necessary to meet crop flowering demands. So while this may seem like a lesson in advanced mathematics, it's really good for the gardener to approach how much light they expect to see at the canopy based on this approach:

1. Take the PPF value that the manufacturer provides for total PPF output.
2. Reduce that output by ~20% as a reasonable loss associated with light not making it to the canopy.
3. When you have that number divide it by the canopy surface area in  $M^2$  and that would represent what intensity you would expect over that surface area.
4. Use that value to calculate how much  $CO_2$  your plants would require based on RH between 50-70%.



This is an example of how you would use the PPF to get an expected PPFD value;

Lamp PPF Output: 1,100  $\mu\text{Mol/S}$   
Grow Area:  $4' \times 4' = 16 \text{ sq-ft} = 1.49 \text{ M}^2$   
Grow Losses off Canopy: 20% = 80% used  
Light Actually Used =  $1,100 \times .8 = 880 \mu\text{Mole/s}$

**Sample Average PPFD Formula:  $880 \mu\text{Mole/S} \div 1.499 \text{ M}^2 = 591 \mu\text{Mole/M}^2\text{-S}$**

**Summary Conclusions:** PPF and PPFD certainly have their place when discussing grow lamp output values and how those values may then be measured in the field. However, there does exist inconsistencies on how lamp and sensor manufacturers use these terms and for the average gardener who may lack advanced degrees in Physics and Engineering, these are not going to be terms they can easily come to grips anyway. As such we felt introducing an alternative method, which was easier to comprehend, would be in order.