DIY Warm white LED lamp PAR measurements, not so exciting after all!

If you read my last few posts about DIY LED lamps built using 150W warm white LED cobs (which do not require an independent driver) you might have been excited by some of my claims. I previously stated that you could probably get around a 1000W HPS equivalent using just two of these lamps, which meant an energy saving of around 60% relative to the HPS equivalent. However to really verify these claims I wanted to get new PAR and lux meters to perform proper PAR and lux measurements. The results my friends, are disappointing.

42	56	20
53	220	76
43	62	24

Previously I thought that these lamps were close to half of an HPS equivalent based on initial lux measurements. At the same distances, directly below the lamp, I could get around half the lux equivalent of your average HPS lamp, I thought from the warmer spectra of these white warm cobs that the PAR contribution would be significantly higher than that of a regular HPS but it seems that – due to the inefficient use of a white phosphor to produce the spectra – basically the PAR efficiency is equal to that of an HPS lamp.

The PAR (Photo-synthetically Active Radiation) basically measures the number of photons that can be used in photosynthesis that you get per square meter per second off a given light source. I will write a more in-depth post about PAR in the future, but it basically tells you the plant-usable photon flux you get. It is therefore measured in umol*s^{-1}*m^{-2}.

I performed classic PAR measurements with a 150W lamp 15 inches above a target center with measuring points around a 4 square feet area (to compare with the variety of HPS measurements you can find [here](#)). The results, in the first image in this post, show you the map of PAR values across the 2 feet by 2 feet area. This shows that the lamp is basically giving you 1466 umol*s^{-1}*m^{-2} per 1000W at its highest point, which is below the PAR/watt of even the poorest HPS models. With this lamp model using 150W cobs you will therefore need at least 7 lamps to reach the same equivalent of a 1000W HPS in terms of actual photo-synthetically active radiation.

Not only that but without any focusing or dispersing elements the PAR decay as a function of light distance is much more dramatic than for regular, reflector mounted HPS lights. **With all these information it now seems clear that these warm white light LED cobs are NOT a good HPS replacement.**

However the idea of the zip tie lamp is not dead! I found out that there are actually "full spectrum" LED cobs that are specifically designed to be grow lights (so basically a combinations of red and blue LED lights). These cobs come in 20, 30 and 50W formats and they should have a much more favorable PAR than the 150W warm white LED cobs. I have now ordered some of these cobs (here) to rebuild my zip tie lamp and see if I can indeed get a much better PAR/watt and watt/dollar compared with normal HPS lights.

Cheap DIY high power LED grow lights: Introducing the Zip-tie lamp

Make sure you also read this post, where I studied the PAR of these lamps and realized they are not as good as I thought!

Several months ago I wrote a post about using high power LED cobs that do not require an external driver in order to build a high power DIY LED lamp. However I hadn't built a practical lamp using these cobs at that particular point in time so I just gave a general idea of why I would use these diodes and how the particular lamp setup would work. Today I want to talk about how to build one of these lamps in practice using an aluminum heat sink, a 150W warm white LED cob, a fan and some zip ties. The setup lacks the use of any adhesives and should provide you with roughly a 40-50% equivalent of a 1000W HPS. With two of these lamps you should be able to run the equivalent setup to 80-100% of a 1000W HPS in terms of PAR with around 60% less power consumption.

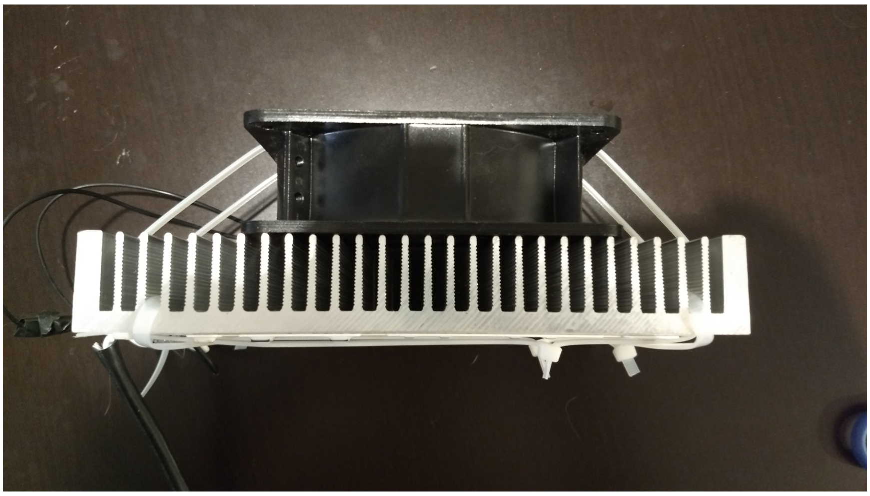
The idea of this post is to help you build a very affordable DIY lamp. However please note that this lamp involves work with mains voltages which are dangerous. Please familiarize yourself with all the precautions needed when working with high voltages. All the information herein in is provided as-is for educational purposes with absolutely no guarantee, either expressed or implied.

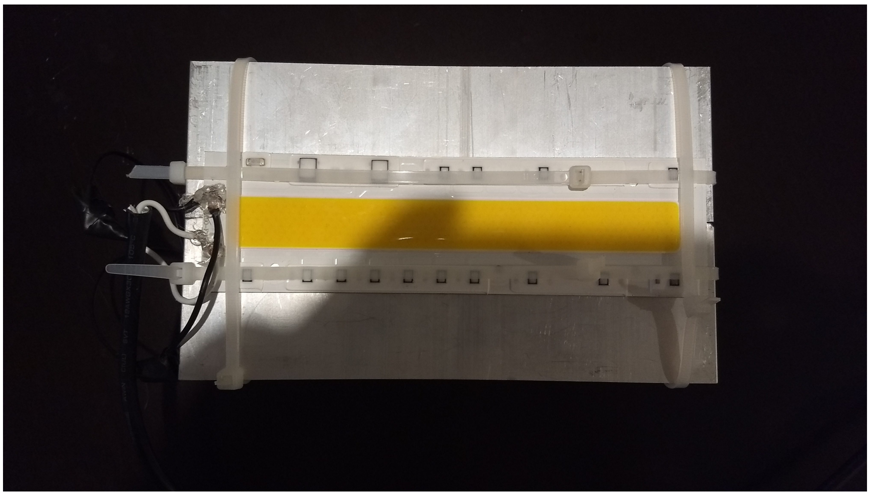
To build this lamp – showed above – you will need these materials (note that if your country uses another voltage you will need to buy the appropriate pieces for the voltage in your country):

- Warm white 150W LED cob
- 200x60x30mm aluminium heat sink (2 needed)
- 110V-120V AC fan
- Nylon zip ties 30cm
- Cable and wall connector
- Thermal compound (optional)

Initially I wanted to build a lamp using a high power warm white LED cob by gluing the cob to the heatsinks using a thermally conductive glue. However the problem with this is that these glues very permanently bind the cob to the heatsink so if for any reason the cob fails you would lose the heatsinks because the cob would be bound to them. For this reason I decided to use zip ties instead, which provide an easy way to secure the entire ensemble and allow you to easily replace any failing part rather quickly. I used nylon zip ties but you can also use stainless still ones if you want the setup to be more resilient (although things will be harder to cut if you make a mistake).

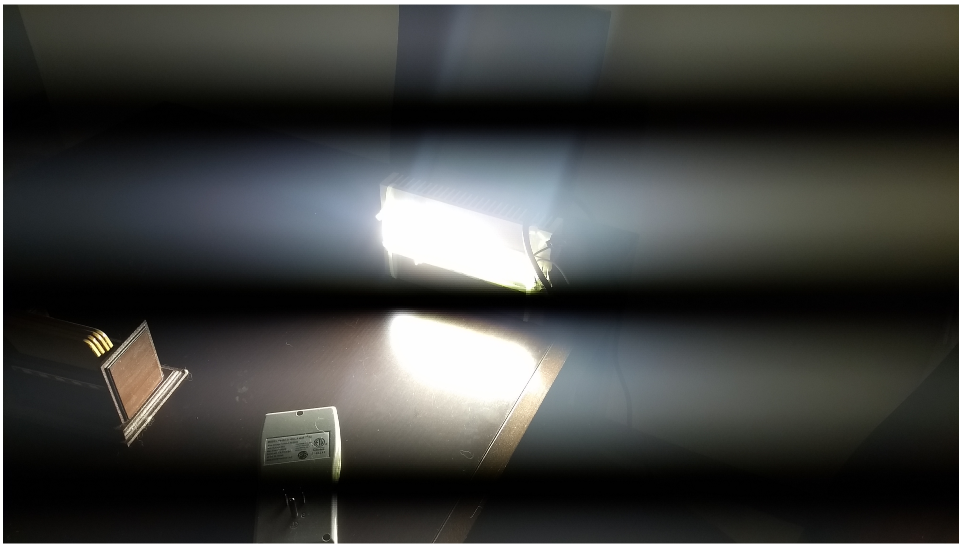
To assemble the lamp I basically used 4 zip tie lines two horizontal and two vertical. For the lines that go the width of the heat sink I just had to use one zip tie but for the other two lines – that also go above the fan – I had to use two zip ties for each line (you can connect one zip tie to another to have a larger zip tie). You need to tighten the zip tie very hard to ensure the cob is in direct contact with the aluminum along all its length, you can also use some thermal compound (like the one you use for CPUs) between the cob and the aluminum heat sink for maximum heat transfer. The pictures below show you a bit better how I performed the entire assembly. *When putting the fan on top of the heat sinks make sure the airflow is towards the heatsink (flow arrow in the case pointing down) and that the fan can spin freely).*





Finally I connected the cob directly to the AC line by soldering the appropriate live/neutral cables to the connectors at the left size of the cob (in the above picture). I then covered the soldered spots with silicon glue to ensure that the connections were as electrically isolated as possible. Make sure you solder as small portion of wire as possible and make sure the wire makes absolutely no contact with the aluminum heat sink or you will have a short. I also soldered the fan cables to the live/neutral as well since the fan can be driven directly by AC as well.

Since you have the zip ties you can also use them to hang the lamp, you can also add screws to the fan screwing ports and use those to hang the lamp from the ceiling. When I turned on this lamp its power consumption was around 220W – measured directly from the wall – meaning that it consumed a bit more power than what was advertised (which is not uncommon for these cobs). Since my voltage is a bit higher than 110V – which is the minimum rating for this cob – I actually get a slightly higher light/heat output than someone using it at a lower voltage. The fan – which takes around 12-15W on its own, also contributes to this consumption level.



When you power on this lamp – image above (sorry about the camera not being able to handle the light intensity) – you'll immediately notice how the heat sink starts to heat up. I have tested the lamp through 2 hours of continuous operation up until now and the heat sink reached a stable temperature of around the 120°C (~ 250F), the final temperature you reach will of course depend on your ambient temperature and how well you assemble the components. It is however very important for you to test each one of these lamps for 12/24 hours to ensure that they don't heat up excessively. *Nylon will melt at around 220°C so you definitely don't want your lamp to ever reach even close to that temperature (to be safer you can use stainless steel zip ties)*. However it is very likely that the LEDs will burn out way before this happens if your temperature rises too far. You can also add a second fan or use a larger heat sink if your temperature is too high.

In the end the setup is extremely simple to build and you can get roughly 40-50% of a 1000W HPS with one of these lamps. With two of these lamps you will run at around 450W which is 55% less power than an equivalent HPS setup. Although heat generation is no joke here, it is indeed much less than the comparable heat output of a 1000W HPS. With a cost of less than 80 USD per lamp you will be able to build these lamps at a far lower cost than the very expensive grow lights you can get online (which can often go for thousands of dollars for a single 1000W HPS equivalent). *If you read my earlier post you will notice that I previously thought you needed 4 cobs to reach the equivalent of a 1000W HPS, turns out you only need two 110V cobs running at 120V!*

I have made some PAR, lux and temperature measurements but I want to keep those for a future post where we will look at some of the spectral and thermal characteristics of this lamp vs other lamp types.

Building your own DIY high power LED lamp: Part One

It is no mystery that LED technology has evolved greatly during the past several years. We are now up to the point where anyone can buy LED lamps to replace HPS fixtures, with full spectrum LED configurations that have showed to be just as good – or sometimes even better – at growing crops (see here for a post about LED lights Vs HPS). However these lamps are often very expensive – most commonly around thousands of dollars to adequately replace a 1000W HPS. Within these series of posts I am going to talk about how you can build your own LED lighting to replace HPS lights for pennies on the dollar compared to commercial LED fixtures.

WARNING: Mains voltages (110-220V) can be extremely dangerous. Please make sure that you know what you're doing if you're going to follow these instructions. All of this information is provided "as-is" with educational purposes only. Make sure you follow all safety precautions when working on mains electricity.

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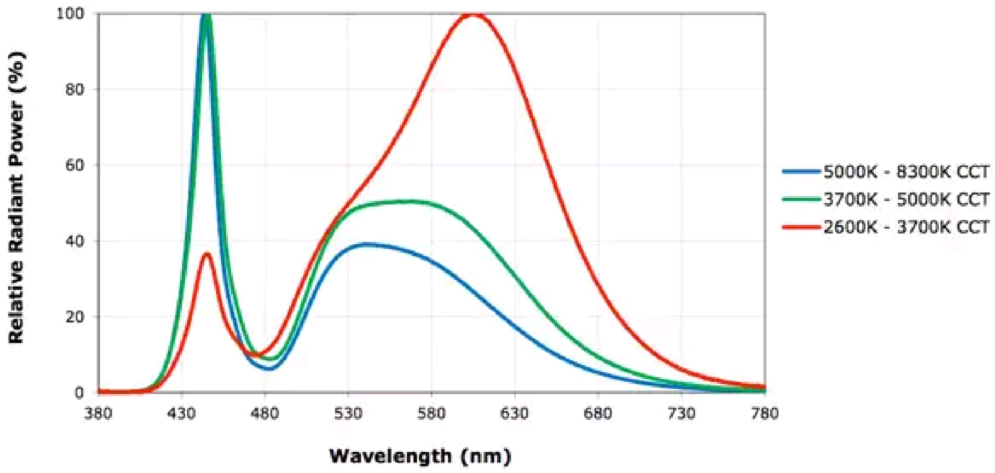

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There are several ways in which you could build your own LED lamps. This usually involves building an aluminium case with fans, putting an LED driver inside and then using that driver to power rows of different light emitting diodes. A driver is basically a transformer not unlike a computer PSU that takes voltage from the mains and dials it back down to a lower voltage that you can use across a row of diodes. Most commonly commercial lamps use combinations of 3W diodes with narrow focusing elements with sometimes higher wattage elements with wider focusing elements. Building a configuration like this can be done but it is a laborious that we can avoid using some of the latest advances in LED technology.

To make a simple high power LED lamp we should absolutely forget about putting together LED elements of different colors. This involves a lot of wiring and makes the lamp fundamentally more expensive. To replace them we can use white diodes instead which although far less efficient – as they are basically blue diodes whose light is absorbed and re-emitted by a phosphor – can give us all the different colors we need in the proportions we need them. The image above shows you the spectrum of different white diodes, as you can see we don’t want the 5000-8000K or 3700-5000K LEDs – which emit a lot of blue light we don’t need – but we need the much “warmer” 2600-3700K diodes which produce a lot of light in the red region of the spectra, with enough blue to provide us with close to a 1:3 ratio. Although this light spectra is still not ideal compared to what plants absorb it will easily able to replace a 1000W HPS.

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To make things very simple and avoid using a separate driver we can use 150W LED cobs that include their own driver and are fed directly with 120/240V electricity (like the ones here). As I mentioned we want the lower temperature spectra white diodes so go for the "Warm white" and make sure the temperature description says it is at least 3200K or lower (if you're looking at another source). The publication above contains 150W cobs that can do 2500-3200K so they can be considered ideal for this application. For every 150W cob you install you should also install a 2A AC fuse for that cob only to ensure that if anything bad happens the power will be cut almost instantly. *Since these cobs are wired directly to mains electricity you should be specially careful with having proper safety precautions (proper soldering of the wires, solders protected with isolating material (like silicon) fuses for each cob, etc).*

Of course the cobs are only half the setup. We need to place these cobs on top of an appropriate heatsink and then also ensure we have fans for it. You can buy a properly sized aluminium heat sink here. Since cobs measure 16×40 we can comfortably glue two cobs to the bottom of a heat sink of profile A (146x22mm) with a length of 400mm. To glue the cobs to the heatsink you should use proper arctic silver thermal adhesive (you can find it here). For fans you can place 2 12cm Fans on top of the above. There are several fans that work with 120-240AC that you can use, for example these fans work with 120V. This setup will give us a 300W LED lamp, with 2 fans that should be able to keep the heatsink temperatures in check. All of this for a total of around 83 USD, let’s call it 100 USD after adding fuses, cable and other parts you might require.

The above lamp will not replace a 1000W HPS on its own, for this you will need at least 4 cobs – meaning two of the above lamps – which should give you 600W of LED power that should be close to the PAR of a 1000W HPS light. This for the cost of only 200 USD (far less than the commercial LED replacement lights). I am in the process of making my own so I will be able to give you some additional details as soon as I get the parts and finish building my own setup. In part No.2 of this series of posts I’ll show you the results of my work and what it does in terms of photon flux and PAR.

Are High Pressure Sodium (HPS) Lamps better than LEDs?

Growers who use artificial lighting usually prefer high pressure sodium (HPS) lamps to do the job. Not only do HPS lamps have a very high photon flux but compared to metal halide (MH) lamps they have a much more prominent red spectral component and therefore a significantly larger dose of photosynthetically active radiation (PAR) per watt. However during recent years light emitting diode (LED) lamps have become much more efficient and have started to compete for the artificial lighting domain. However is there any advantage to using LED lights over HPS lamps? Are HPS lamps always going to be the winners? Today we are going to look at the science comparing HPS and LED lamps to see if there is currently a winner between the two.

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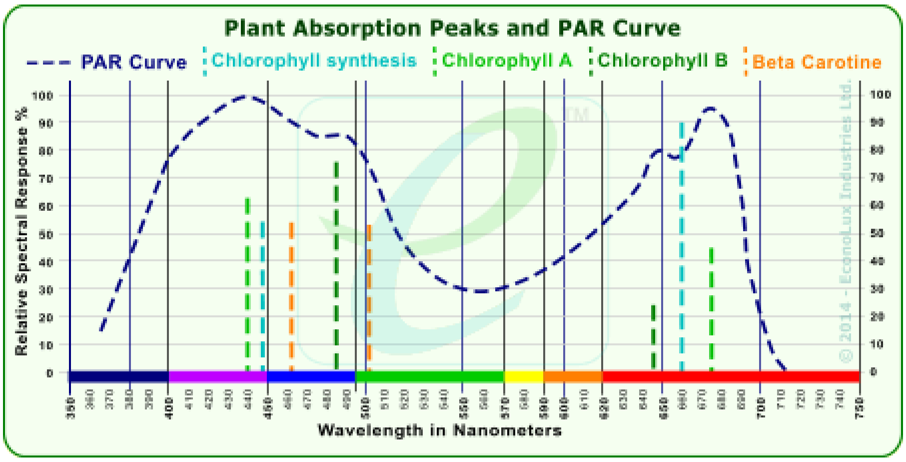

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The above graph shows you the PAR spectra. Basically this tells you which wavelengths of light are most prominently absorbed by plants. From this diagram it is clear that plants have peak absorptions around the blue and red parts of the spectra while the green section of the spectra is absorbed much less intensely and instead reflected (the reason why most plants look green). Ideally we would want lamps that have peaks in the regions of the spectra where the PAR peaks as well and we would like to have the highest peak in the red which is the region where we get the most efficient photons for the photosynthesis process.

In HPS lamps our spectra is basically fixed by the nature of the light source while in LED lamps we can tune the light source a lot. This is one of the reasons why there is such confusion when comparing HPS and LED lamps. Since LED lamps can be tuned so much it isn't surprising that there are a large variety of cases where growers have experienced worse results from LED lamps compared with their HPS counterparts. With HPS lamps you basically buy one 1000 W lamp and you're done while with LED lamps things such as the color distribution of the diodes being used and the focusing elements they have installed can make a tremendous different.

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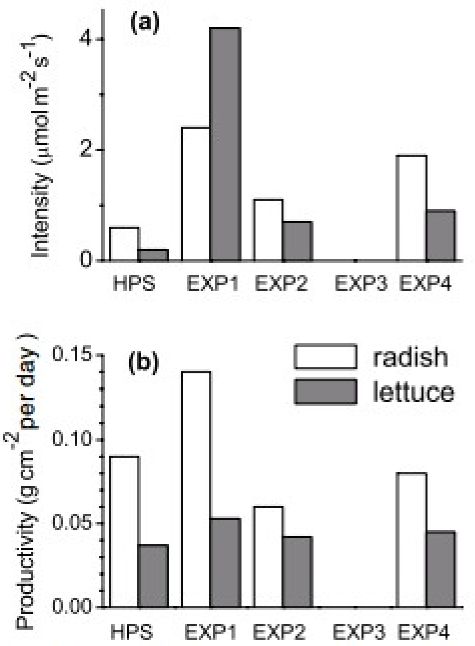

Figure 4. Net photosynthesis intensity (*a*) and photosynthetic productivity (*b*) of radish (white columns) and lettuce (dark columns) grown for two weeks under illumination by HPS lamps and under LED-based illuminator in treatments EXP1 to EXP4.

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Checkout [this study] comparing LED and HPS lights to grow lettuce and radishes. The picture above shows you the results they had with HPS lamps compared with 3 different experiments using different LED distributions. A person running setups 2 or 4 would have thought that LEDs are worse than HPS lights while someone using setup 1 would have concluded that LED lamps are simply much better. This is why some growers will tell you that LED lamps are the greatest thing on earth while others will tell you they are never as good as HPS – they simply have used different lamps. Notice that in setup 3 a complete breakdown of the photosynthetic process happened.

In the above experiment growers used 4 LED types, 455nm, 640nm, 660nm and 735nm LEDs in a roughly 10:120:10:1 ratio. In setup 2 the 640nm LED intensity was reduced by a factor of 1.5, in the setup 3 the 735nm component was changed to nighttime only and in setup 4 the 735nm LED was changed to only two hours during nighttime. You can see how the decision to change a light source that contributed less than 2% of the total light flux to nighttime had a very important effect. This is because the 735nm wavelength has a circadian rhythm effect that can substantially change how the plant responds. Just turning on 2% of the LEDs at the wrong time completely turned around the results.

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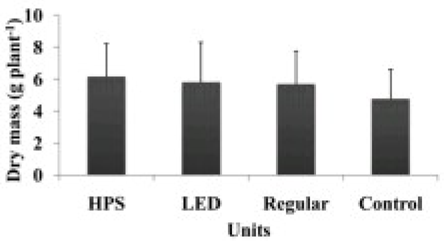

Fig. 5. Final average plant dry biomass for Boston lettuce (*Lactuca sativa* var. *capitata*) grown hydroponically under different treatments in a controlled environment. HPS = high-pressure sodium; LED = light-emitting diode; Regular = regular greenhouse HPS levels; Control = no supplemental artificial lighting. Harvest of 10 plants from each treatment averaged over two replications with SD bars.

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With the above it is not surprising that we find contradictory evidence in the scientific literature. Articles like this paper on cucumbers find that HPS provides better growing efficiency compared to LED lamps in line with other articles like this one on lettuce. However we should bear in mind that the LED lamps used are always different and the fact that a LED array provides worse results compared to HPS does not mean that this is true for all LED lamps overall. Since LED lamps can be tuned so much it is almost certain that for a given plant specie you will always find an LED combination that gives you at least the same results as an HPS lamp.

Nonetheless the power savings from LED lamps also need to be considered. In experiments where comparable photon fluxes are used LED lamps tend to provide savings of at least 30-40% in terms of power consumed from the lamps only while these savings can reach even higher values when considering the additional cooling needs of HPS lamps (that are often much lower for LED lamps).

Per the above LED lamps are definitely worth considering as a replacement for HPS lamps. However you need to properly build your LED lamps such that the photon flux and spectral composition does provide you with results that can surpass those of regular HPS. Building a lamp that is underpowered or that has an inappropriate spectral composition can indeed cause you to get results inferior to those of HPS lamps. This is most probably the reason why so many growers are so reluctant to move to this type of solutions when using either only artificial or supplemental artificial lighting.