BETTER OFF WITH LEDS

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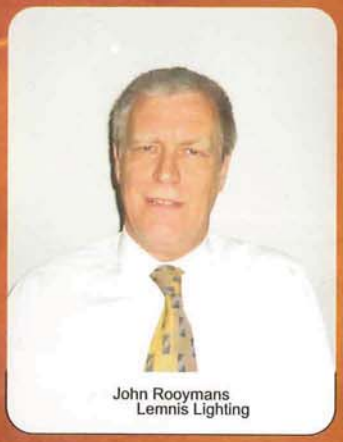

John Rooymans
Lemnis Lighting

LEDs are more and more considered the alternative for general lighting. There are however quite some aspects which are to be considered before the results will be satisfying. Many booby traps in the special features of LEDs make straight applying of what is common practice in lighting, worth to reconsider when using LEDs.

First a few very elementary lighting aspects for the energy bill savings with LEDs.

The efficiency of lamps is often overestimated. An incandescent lamp is in average only 1.5% efficient. One Watt is in the SI system 683 lumen. A lamp producing 10 lumen per Watt results therefore in an efficiency of 10/683 = 1.46%. When dimming incandescent lamps to 50% of the energy, the light output will drop to 1/5, which is only 20% of the nominal light output. When using dimmers the efficiency of incandescent lamps drops to 0.3%! So there is approximately 99% wasted as heat.

On the contrary, LED lamps get more efficient when dimmed than at nominal operation. For CFL's the average efficacy is 35 lumen per Watt. This results in 35/683 = 5.1% efficiency.

Good LED lamps nowadays reach 70 lm/W, which means LED lamps are 10% efficient. Generated heat is a very important aspect to consider in the B2B energy reduction. Cost of ownership or return on investment calculations should always contain the savings on air-conditioning energy reduction in tropical climates.

A hotel lobby 24 hours per week lighted with 50 pieces of 35W halogen lamps can be retrofitted with 50 pieces of 5W led MR16 lamps. The energy saving on the lamp replacement is 1.5 kWh. At an energy price of $ 0.15 kWh the annual saving on energy cost is 8760 hours x 1,5 kWh = $ 1.971,- The required energy to pump away the heat which is generated by the lamps is approximately 1/3 of the produced lamp heat. This means that 1/3 of the saved energy is also saved on cooling cost (0.5 kWh x 8760 x 0.15 = $ 657,-). The total annual energy saving is than $ 2.628- For a RIO of one year this would allow a price of $ 52.56 per lamp. Good LED replacements cost less than half of that price. With conventional halogens the lamps are in one operational year four times replaced.

Considering the energy savings, the cost of these lamps and labor cost to replace, the investment in LEDs should wait not a day longer. One thing should be strongly observed though. When choosing for LEDs for energy saving and a better world, one should also consider the CO2 footprint of the lamp. Some products have heavy casted aluminum casings which require enormous amounts of energy in production. This way the saving of energy is not in pace with the reduction of CO2 emissions. The product should have an as low as possible CO2 production footprint.

Uniformity of light

The relation between vision and light is often misunderstood. The general idea is that more light is more sight but this is not the case. Light is perceived by the human eye in a range of intensities up to 109, the range within the dynamics of artificial lighting is however only 103. We can define vision by what we see with the cones and at low light levels like outdoor streetlights and indoor domestic light, with what we see with cones and rods combined. This combined rod and eye vision is determined by the spectral composition of the light and can be expressed by S/P ratio. S stands for Scotopic rod vision and P for the Photopic vision with the cones. With approximately 120 million rods and five million cones the combined functioning of the rods and cones is very much dependent from the uniformity of the light, the intensity and the spectral distribution. These variables determine our vision. In 1997 Sam Berman, D. Jewett, B. Benson and T.M. Law of the Lawrence Berkeley National Laboratory concluded: "Our results measuring power and pupil size indicate that Photopic luminous efficacy is an inadequate metric by which to judge the efficacy of indoor illumination". This means there is a strong correlation between spatial brightness perception and pupil size. In contradiction to the general opinion this is also valid for most indoor lighting. LEDs opened a new element to lighting since they allow a great flexibility in spectral composition which affects the current methods of measuring light.

The uniformity of the light is a key element for good vision. Think of a full moon night outdoor in the field. Since moonlight is everywhere, so it is maximal uniform and we can see far and detailed despite the low light intensity. A single streetlight nearby our viewpoint will already disturb that uniformity and decrease the sight. The same effect applies indoor.

Studies by Lemnis show that the effect of the uniformity and spectral distribution are fundamentally different from conventional lighting and with the right spectral distribution the lamps are more effective than the conventional methods of measuring and judging light indicate.

A LED produces all of its light on a square millimeter or less. On top of that, most LED packages bundle the intensity of that light by a primary lens. When looking into the light, the bundling increases the candela intensity of the light source by the square root of the opening angle. With power LEDs the intensities cross quickly the biological safety limits for the human eye (fig 1). One would rather consider to virtually spread the light over a larger surface which will decrease the intensity of the point light source drastically. Indoor light bulbs should preferably have a large diffused glass bulb. This will also moderate the intensity of the light source whilst maintaining the same total flux.

S/P ratio

Another important value for good contrast and vision is the S/P ratio. This figure is the balance of vision between rods and cones in our eyes. The ratio stands for Scotopic / Photopic ratio. To get a high S/P ratio one can see that the Photopic range of output (at 555 nm) should be not too big since it will reduce the S/P ratio figure. There is a trade-off here at cost of lumen output to get a high S/P ratio. The importance of the S/P ratio is not yet well understood by everyone but it contains the major elements of the spectral distribution and outdoor and indoor lighting. Many scientists already discovered that light perception and measured values do not match with the reality.

Glare

The effect on the eye is that bright intensity light sources next to a uniform illuminated area disturbs the sight because the light adaptation system is affected and the light may cause glare on the eyeball. Glare is an effect you can often see as a reflected light point on the shiny lens of a camera (fig. 2). The same happens on our wet eye ball. Glare is mainly caused when light

fig. 1. Blinding beams (glare) by too high concentrated light source

fig. 2. Glare reflection (upside down mirrored lamps)

Fig. 3. No glare LEDs (foreground), conventional lamps (background)

sources are at eye height and within an angle of 25 degrees from the horizontal axis.

Directional light

The direction of the light is also affecting the measured result of light in lux. In figure 4 we see the various radiation patterns of various lamps. The lux values are measured at 1 meter above each lamp. A LED source is flat and radiates light in one direction whereas a tungsten in placed high in the bulb and radiates 360° around.

It's clear that the LED lamp will produce more light than an incandescent lamp when hanging above a table.

When placing a cap over the lamp as a standing table lamp, we will notice that the cap of the CFL will be brightest and the LED cap will have the lowest intensity. It's important to consider the required effect. When standing with the back to the lamps with caps on it, one will judge the LED lamp as the brightest.

Fixture efficiency

The current fashion is retrofit LED lamps. This means screw out the old incandescent lamp and place the new LED lamp in. The problem here is that many fixtures are well designed for tungsten lamps but lack any thermal management for LED lamps. Down lighters in the USA need to be air tight according to title 24. This automatically implies that LED down lighters will face thermal problems due to restricted convection. A similar problem occurs with MR16 fixtures with a closed cup. The efficiency of the lighting is very much determined by the way the light can escape from the source. Many fluorescent PL down lighters with round reflector meet hardly 50% efficiency. A measured sample of a

fig. 4. Radiation patterns of various lamp types

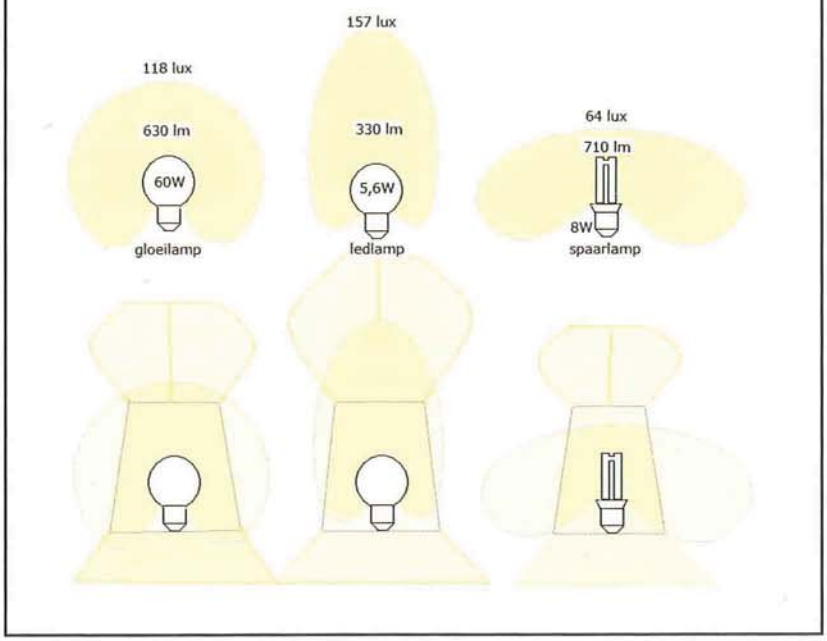

fig. 5. Buying 36W tubes of 3350 lumen means not 93 lm/W

parameter	measuring lamp	remarks
Color temperature	3927 K	Clear white (neutral white)
intensity	1791 Cd	
angle	88 deg	
Power P	88 W	
Power Factor	0,96	With this power factor there is for each 1 kWh of nett power, 0,3 kVAhr of reactive power
Flux	3362 lm	Osram reports that a single tube produces 3350 lm. In this case were there are two tubes in a fixture, there is not 6700 lm output but only half. The rest is lost by reflections and absorbtion. This is normal for standard fixtures
Efficacy	38 lm/W	
CRI_Ra	81	Color Rendering Index

3600 Watt replaced by 160W in total

standard fluorescent tube fixture is presented in fig. 5.

As can be seen is the efficiency of the dual tube system not 93 lm/W but only 38 lm/W. These are efficiency values which can easily be met by retrofit LED lamps with directional light.

To trickle curiosity and make one think, below is a picture of a tunnel with 250W sodium lamps on the left hand and ten times Lemnis 16W special spectral lamps on the right hand. We could say an indoor/outdoor application. The tunnel was equipped with a continuous row of dual 36W fluorescent tubes. The tubes were switched of and between every 10 tubes was placed a 16W LED streetlight. In total 3600W were replaced by 160W.

The question to the road authorities was "which side is brighter?" the collective answer was, "the left side." On the question why? They answered that the light intensities were measured and at the right hand it was 28 lux at the left hand was 6 lux measured. By the way, the measured CRI at the right side is 29.

What should we believe, our eyes or the meter?

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