

A guide to the green public procurement of road lighting

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- Have light levels As Low As Reasonably Achievable.
- Know the benefits with LED, but also the risks.
- The triple win if you dim LED.
- The factors you need to know in order to minimise energy costs.
- Skyglow and reduced star visibility – relevant design factors.
- The trade-off between blue light, CRI and ecological health effects.
- Life cycle costing.
- How to overcome high up-front costs of LED-conversion.

Know your lighting assets!

"if you can't measure it, you can't manage it"

This common business phrase is absolutely applicable to road lighting. First you need to know how many light points you have and where exactly.

Then you need to know how much electricity they consume.

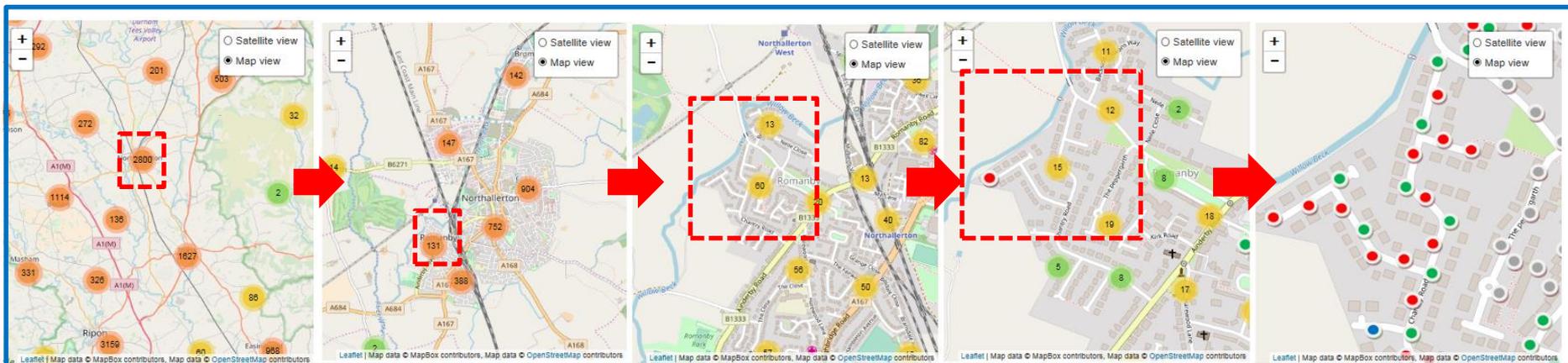
Only then can you properly assess what possibilities exist to reduce costs and environmental impacts.

One good example of asset management is North Yorkshire, who have published their own asset management plan and have an online map of their light points which residents can use to report faults.

See:

[https://www.northyorks.gov.uk/sites/default/files/fileroot/About%20the%20council/Strategies,%20plans%20and%20policies/Street_lighting_g_asset_management_plan_\(May_2016\).pdf](https://www.northyorks.gov.uk/sites/default/files/fileroot/About%20the%20council/Strategies,%20plans%20and%20policies/Street_lighting_g_asset_management_plan_(May_2016).pdf)

<https://www.northyorks.gov.uk/report-street-light-problem>



Map key

- Street light is on all night;
- Street light is a part night light;
- Street light is not maintained by us;

Map key

- Street light has already been reported as faulty;
- A group of street lights. Select a group to zoom closer until you find the required street light.

ALARA (As Low As Reasonably Achievable) light levels

EN 13201 recommendations

Luminance		Illuminance			Illuminance		
= see road		= see objects			= see objects		
view point: car driver		view point: any			view point: any		
EN 13201	L,m	EN 13201	E,m	E _{min}	EN 13201	E,m	E _{min}
Class	Cd/m ²	class	lx	lx	class	lx	lx
		C0	50				
M1	2	C1	30				
M2	1,5	C2	20				
M3	1	C3	15		P1	15	3
M4	0,75	C4	10		P2	10	2
M5	0,5	C5	7,5		P3	7,5	1,5
M6	0,3				P4	5	1
					P5	3	0,6
					P6	2	0,4
Mesopic vision(max)	0,1				Moonlight	0,3	

M-class roads are used only by motorised vehicles (**need to light?**).

C-class roads are where conflict areas exist, i.e. where motorised vehicle roads or other roads interact.

P-class roads are used by pedestrians or low speed vehicles.

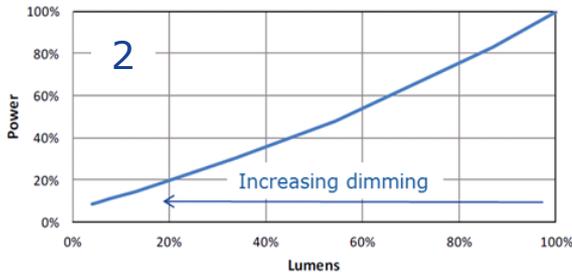
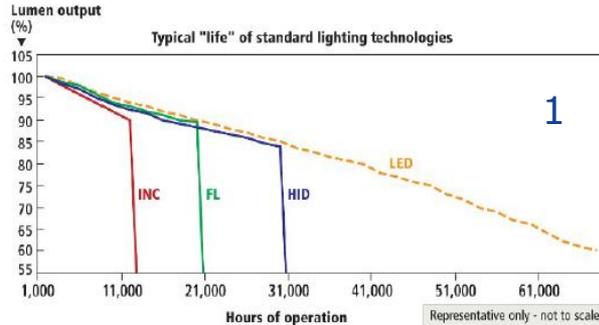
Higher classes (i.e. 6→0) are associated with higher traffic flows.

- The EN 13201 light levels are **much higher** than many existing roads across Europe (not ALARA).
- These levels are recommendations - **not obligatory in most of Europe**.
- Do not light roads any more than the legal minimums in your region.
- Road class is linked to number of users (a dynamic thing) so make lighting levels change with use patterns (**i.e. curfew dimming**).
- If converting to LED, have a **pilot demonstration** first that includes **public consultation**.

The benefits of LED

Lifetime of LED:

LED light sources do not suffer abrupt failures but rather a gradual decrease in lumen output.



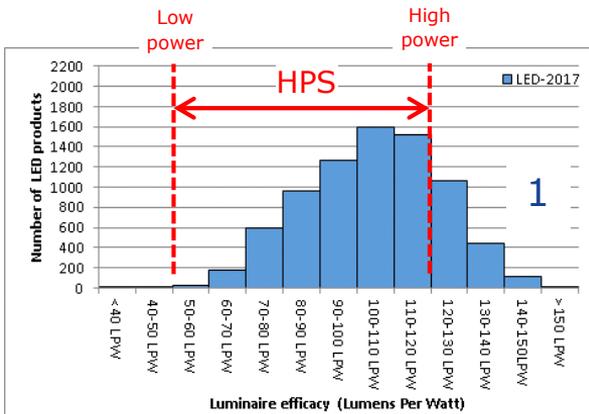
Almost proportional relationship between dimming and power consumption when dimming down to 10% of max. power.

- More energy efficient than HPS.
- Efficiency improving each year.
- Lots of dimming possibilities.
- No flickering.
- More possibilities with optics.
- Range of colours (CCT) possible.
- Last much longer than HID light sources (x2 to x5 or more).
- No abrupt failure of LED.
- No Mercury.



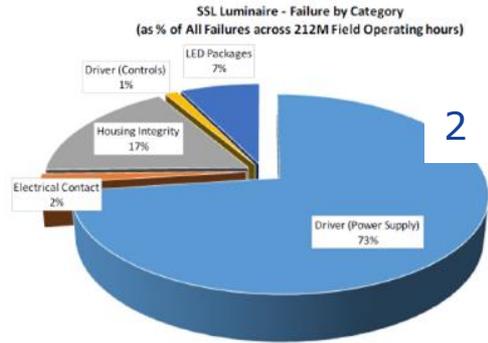
The risks with LED

HPS efficacies range from 50-120 LPW, rising as power rating rises. LED efficacies are much less dependent on power rating for efficacy but not all products are clearly superior to HPS...



Lifetime predictions **must** be reported in accordance with standards (e.g. IESNA LM80-TM21 in US or IEC 62722/63013 in EU).

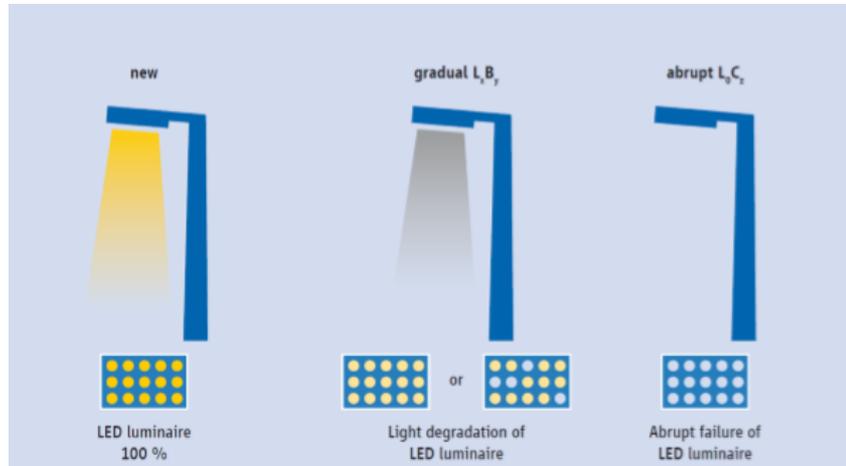
Increased risk of overheating in cheaper luminaires with poorer heat sinks. Increased risk of failure in hot climates and when operating for long periods at maximum power output. **Easiest way to reduce risk is to dim LED!**



- Wide range of LED efficacies.
- Range of qualities for chips, drivers, optics and heat sinks.
- Higher capital costs = higher losses when things go wrong.
- Rapid evolution + long life = high risk of obsolescence
- Concerns with glare & blue light
- **Need to verify lifetime claims.**
- Even if light source doesn't fail abruptly, driver can - overheating is biggest cause of premature failure.

A closer look at lifetime claims

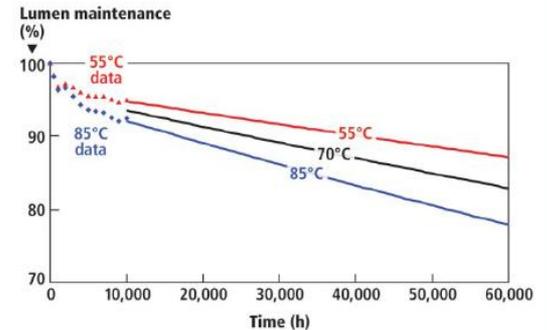
- Lifetime claims with LED lamps are completely different to HID lamps.
- LxBy and LxCz concepts.



- LxBy refers to gradual lumen depreciation of light source.
- Linked to a specific operating time (h).

- E.g. L₇₀B₁₀ at 50000h means that after 50000h operation, the total light output will still be at least 70% of the initial performance and that no more than 10% of the LED modules shall fail to meet 70% of their initial performance.
- E.g. L₀C₁₀ at 50000h means that after 50000h, less than 10% of the LED modules shall have suffered abrupt failure (equivalent to 0.2% per 1000 hours).
- Be aware that all data is **projected** based on initial test results and is strongly dependent on test conditions (**especially temp.**).

- **Make sure claims are linked to the actual luminaire to be purchased, to accredited laboratories and that the conditions are communicated.**



The triple win if you dim



Less electricity consumption (easy to reduce electricity costs by 25-40% → reduced environmental impacts associated with electricity production).



Less light pollution (less skyglow, less glare, less intrusive light, less effect on nocturnal species).



Lower risk of overheating (and thus premature failure) – LED lifetime may be extended even beyond normal manufacturer claims.

A wide range of dimming controls are available which can be broadly split into timers, photocells and motion sensors. **Timers are the simplest and cheapest option, based on an astronomical clock.** For ease of adjustment, dimming controls should ideally be able to be accessed and reprogrammed at ground level or remotely.

The factors that affect energy costs

(And it is not all about luminaire efficacy only)

$$\begin{array}{c}
 \text{Annual Energy Consumption Indicator} \\
 \mathbf{AECI} = \mathbf{PDI} \times \mathbf{E_m} \times \mathbf{F_D} \times \mathbf{T} \times \mathbf{0.001} \\
 \text{kWh.m}^{-2}.\text{yr}^{-1} \qquad \qquad \qquad \text{W.lx}^{-1}.\text{m}^{-2} \qquad \text{lx} \qquad \qquad \text{h.yr}^{-1} \qquad \text{kW.W}^{-1}
 \end{array}$$

\uparrow Reciprocal of product \uparrow \uparrow \uparrow

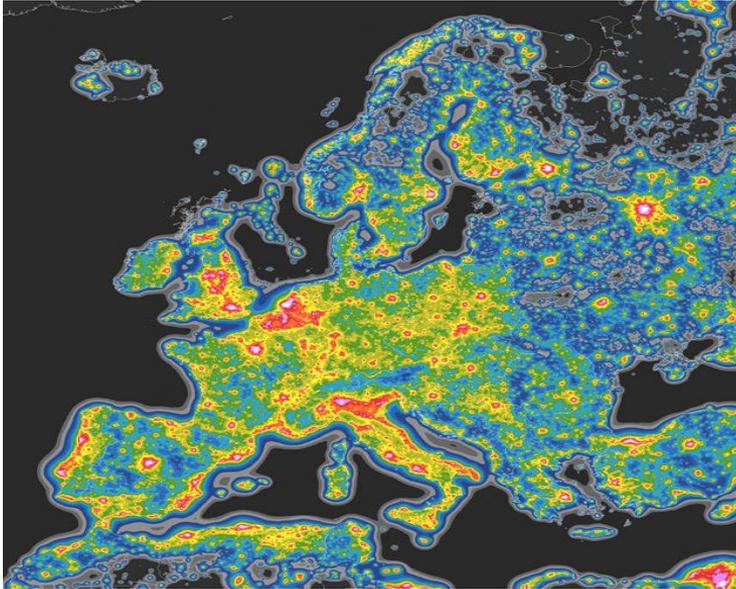
Luminous efficacy (lm/W) Maintenance factor Utulance factor Light level Dimming factor

- Luminous efficacy for LED luminaires is still improving each year (a conservative estimate is +5-7% per year). According to 2017 US data, 50% of LED roadway lighting is centred in the range 90-120 lm/W (LPW) (25-30% of PDI).
- The maintenance factor (MF) is poorly understood, assumptions may range from 0.80 to 0.97 (i.e. 17% influence on PDI). Lower MFs may result in over-designed lighting and more light pollution.
- The utulance factor is improving with LED but may require special optics to achieve a good factor in narrow roads <5m wide. Typical range is 0.35 to 0.70 (i.e. 50% potential reduction of PDI).
- The light level is hugely significant and impacts directly on AECI. Going down just 2 light classes in the design can reduce AECI by 50% (although some limited trade-off expected with lower luminous efficacy for lower power LED).
- The dimming factor, via curfew dimming to 50% / 10% can achieve AECI reductions of 25-40%.



Skyglow and reduced star visibility

Below is a map measuring artificial sky brightness in the V-band based on satellite data.



Even if light levels do not increase in terms of lumens on the road, replacing HPS lights with LED could result in a significant increase in sky brightness.

Why? Because blue light (from LED) scatters more in atmosphere (the same reason why the sky is blue during the day).

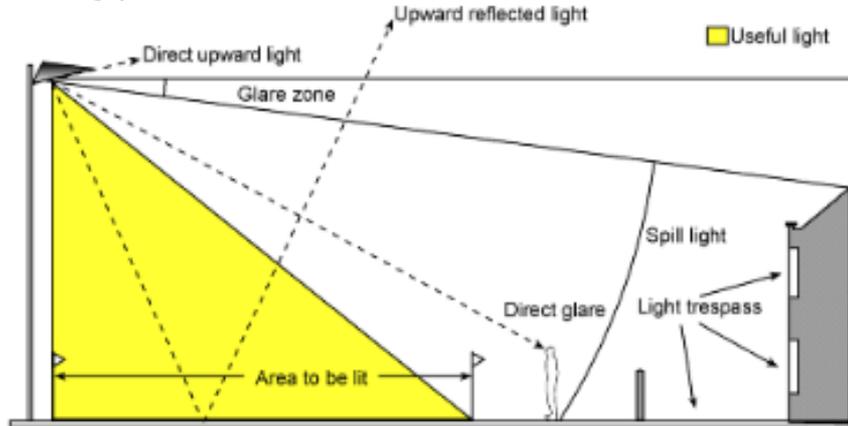
The loss of star visibility is difficult to appreciate because the lighting patterns tend to be the same every night in a given place and are influenced by light from up to 100km away.



Occasionally the opportunity arises (in this case when the Eastern power grid from Ontario to New York failed) it was possible to see just how much star visibility is reduced every night.

Glare and intrusive light (and skyglow again)

The diagram below explains the distinction between skyglow (combination of direct upward light and upward reflected light), glare (direct and indirect) and intrusive light (light that spills into areas not intended to be lit – especially intrusive in residential buildings).

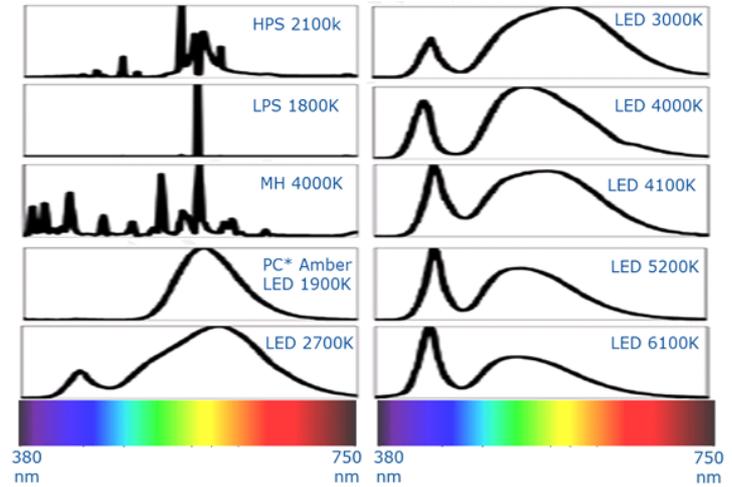


Upward reflected light cannot be controlled by the lighting engineer if they have no control over the surface. However, it should be noted that reflectivity coefficients vary greatly depending on the surface.

E.g. asphalt = 0.07 while concrete can easily be 0.10 (i.e. 30% more luminance for the same luminous flux from the luminaire).

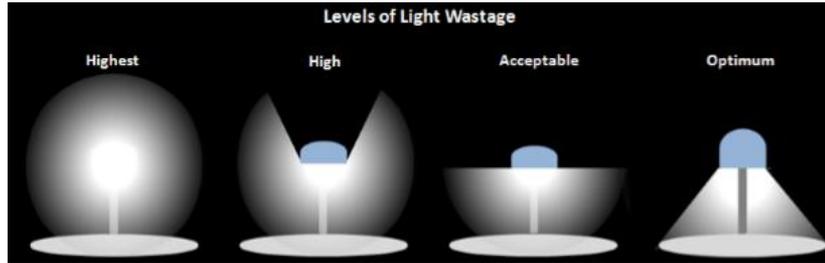
Know your real surface reflectance to avoid overlighting.

- Once going upward, blue light contributes much more to skyglow.
- Because it scatters more – LED typically has more blue light than HPS.
- *Scattering is a function of $= \frac{1}{\lambda^4}$*



Specifications to limit skyglow

- Skyglow = waste energy / money

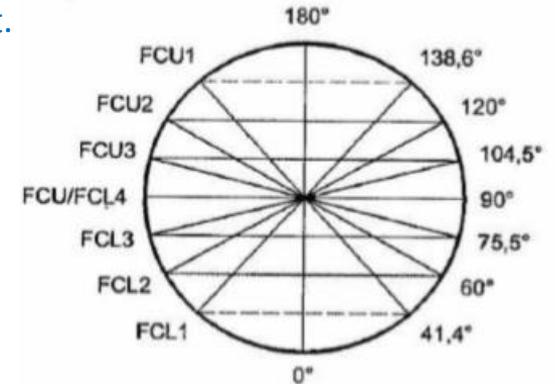


- Important to specify the luminaire and shielding.
- Not only important for skyglow, but also glare and intrusive light.
- However, be aware that too much shielding might lead to spot-lighting...
- Strike the right balance between uniformity, cost and light pollution



Luminaire specs that can reduce light pollution:

- Lower light levels.
- **CIE flux codes.**
- RULO 0.0% (i.e. CIE flux code #4).
- Less blue light.

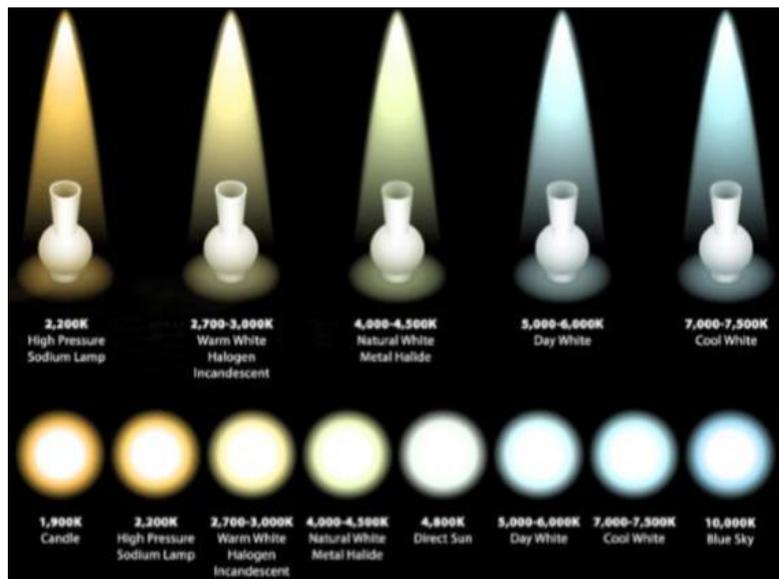


CIE flux code of: **45 65 95 100 68**

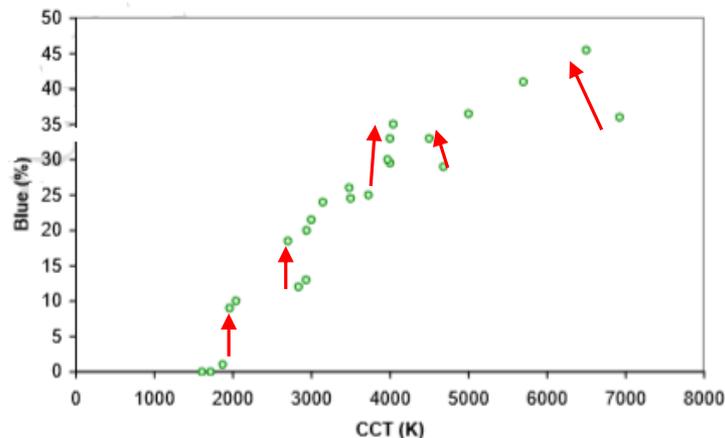
Of all the light generated by the light source, **68%** comes out from the luminaire.
45% of all the light coming out of the luminaire falls within 41° of the vertical.
65% of all the light coming out of the luminaire falls within 60° of the vertical.
95% of all the light coming out of the luminaire falls within 75.5° of the vertical.
100% of all the light coming out of the luminaire falls within 90° of the vertical.

Blue light and related specifications

- Correlated Colour Temperature (CCT) is a way of describing the appearance of light to the human eye.
- Higher values mean a “colder, whiter light” (typical of LED and MH lamps) while lower values represent a “warmer, redder light” (typical of HPS lamps).



As a light source becomes whiter (higher CCT) it typically contains more blue light.



But the relationship is not perfect (look at the arrows where CCT is similar but blue light content is up to x8 higher).

Which is why, if you really want to limit blue light, we recommend to use a more accurate specification:

e.g. the C-Index.

How to finance major lighting conversions?

Golden Rule: Need to shift from “lower initial cost” to “lowest total cost of ownership” mentality, i.e. a lower life cycle cost. Consider 3 main aspects:
(i) Capital costs, (ii) Energy costs and (iii) Maintenance costs.

Self-financing (traditional) model:

Public authority procures the design, equipment, installation and maintenance of the lighting installation (possibly being directly responsible for the maintenance).

Problems:

Major obstacle is initial investment cost.

Tips:

- Buy in bulk (joint procurement with other public authorities – especially important for small municipalities).
- Check for national or European subsidies.
- Check for low interest loans linked to sustainable development and/or smart city goals.

Leasing:

Public authority does not pay any upfront investment costs and rents the lighting installation until the costs (incl. agreed interest) have been paid back. The public authority should pay the energy costs as normal (which should be lower than before and these savings can help pay the “rent”).

Public Private Partnerships:

Public authority signs a contract with a private Company/consortium. The private partner brings the capital finance and technical expertise and assume the financial and performance risks.

Performance contracting:

Typically the public authority will work with an ESCO (Energy Savings Company) which provides most of the capital while money saved due to lower operational costs is shared between both sides according to an initial agreement.



Hope this helps!

Any questions?

You can write to us at jrc-b5-roadlighting@ec.europa.eu

Project website:

[http://susproc.jrc.ec.europa.eu/Street lighting and Traffic signs/documents.html](http://susproc.jrc.ec.europa.eu/Street_lighting_and_Traffic_signs/documents.html)

Stakeholder platform:

<http://eippcb.jrc.ec.europa.eu/batis/>

The right light levels for the light source used

"Photopic" versus "pupil lumens"

Lamp	Watts	Photopic Lumens	Photopic Lumens/Watt	(S/P) ^{0.78} Correction Factor	Pupil Lumens	Pupil Lumens/Watt
LPS	250	32,500	130	0.2	9,250	37
HPS	365	37,000	101	0.62	25,530	70
MH	455	36,000	79	1.49	48,960	108
T8 Fluorescent (3000 K)	36	2,800	78	1.13	3,080	85
LED Light	15	1,500	90	1.9	2,475	165
5000 K Induction	80	6,400	92	1.62	10,368	130

Very different light levels depending on which type of lumens you count!

Very different energy efficiencies depending on how you define your light level!

Question to stakeholders: How are photopic/scotopic vision differences currently accounted for in the determination of road lighting levels and road classes exactly?

- Light is basically radiation that is visible to the human eye (lumens).
- It covers radiation in the wavelength range 380-780nm.
- But human photoreceptors are **more receptive** to some wavelengths more than others within this range.
- Different during day and night.
- Different light sources have different spectra (see slide 10).
- Basically if converting from one light source to another (i.e. HPS→LED) do not keep the total lumens the same, consider "**pupil lumens**".