Light Pollution- Luminous Restrictive Measures

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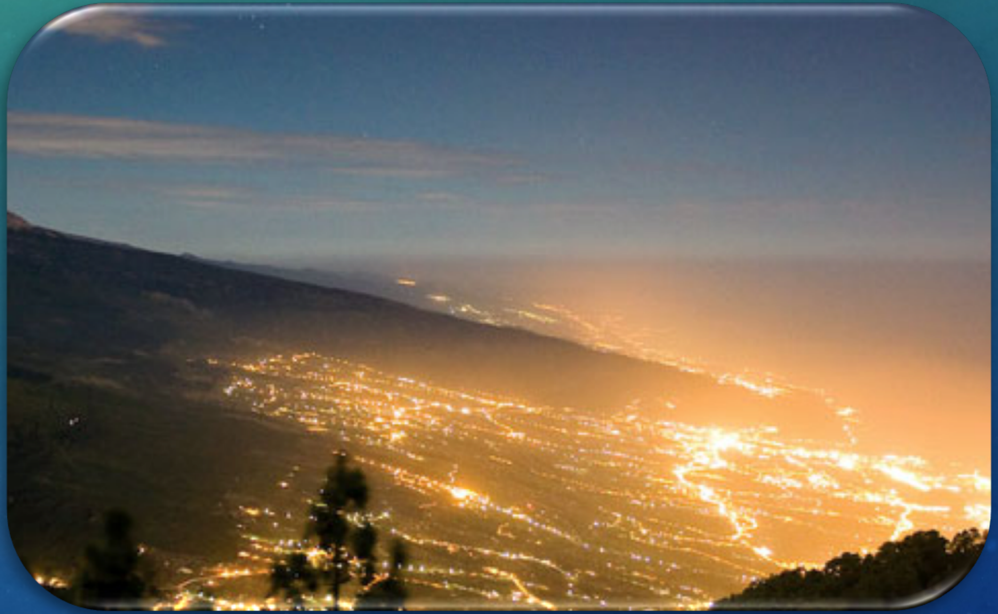
ROAD LIGHTING - NEED FOR BALANCE

On the one hand….

One the other hand….



Visual Comfort, Road safety

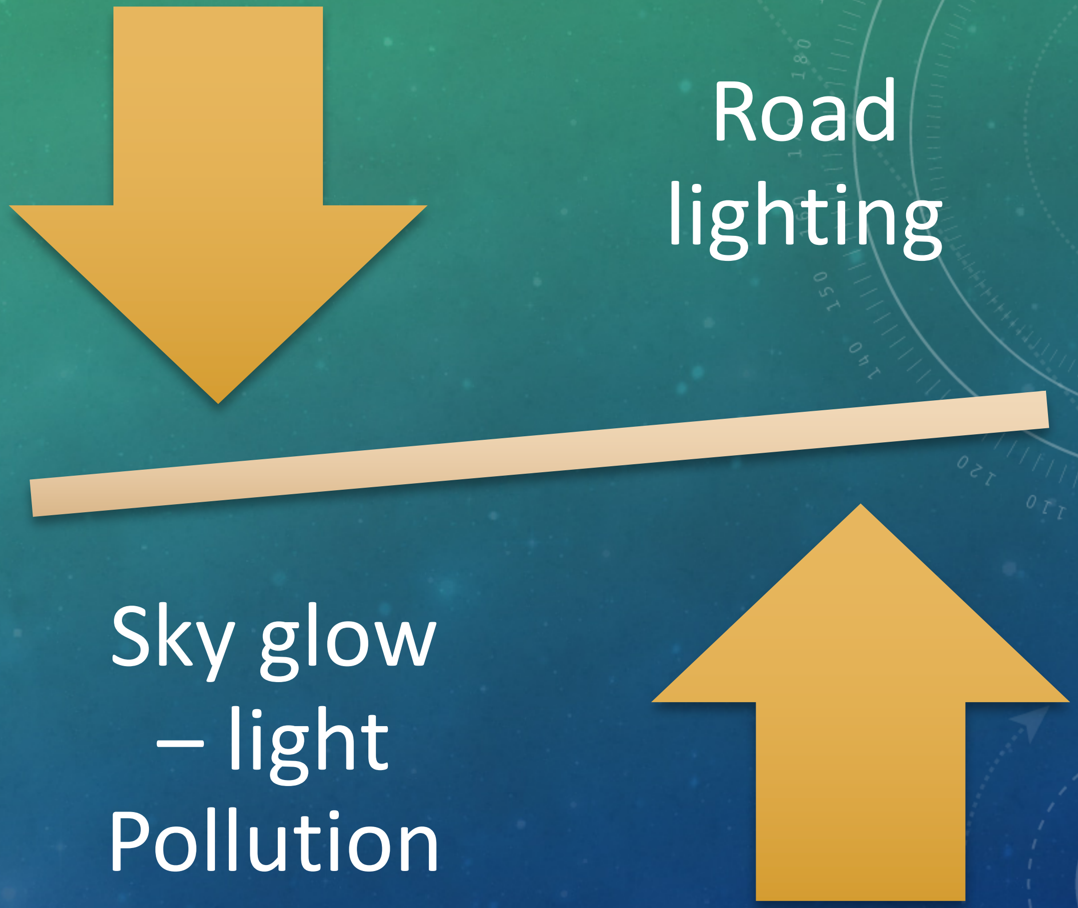
Wildlife Disturbance, Sky Glow

Technical Contradiction

or

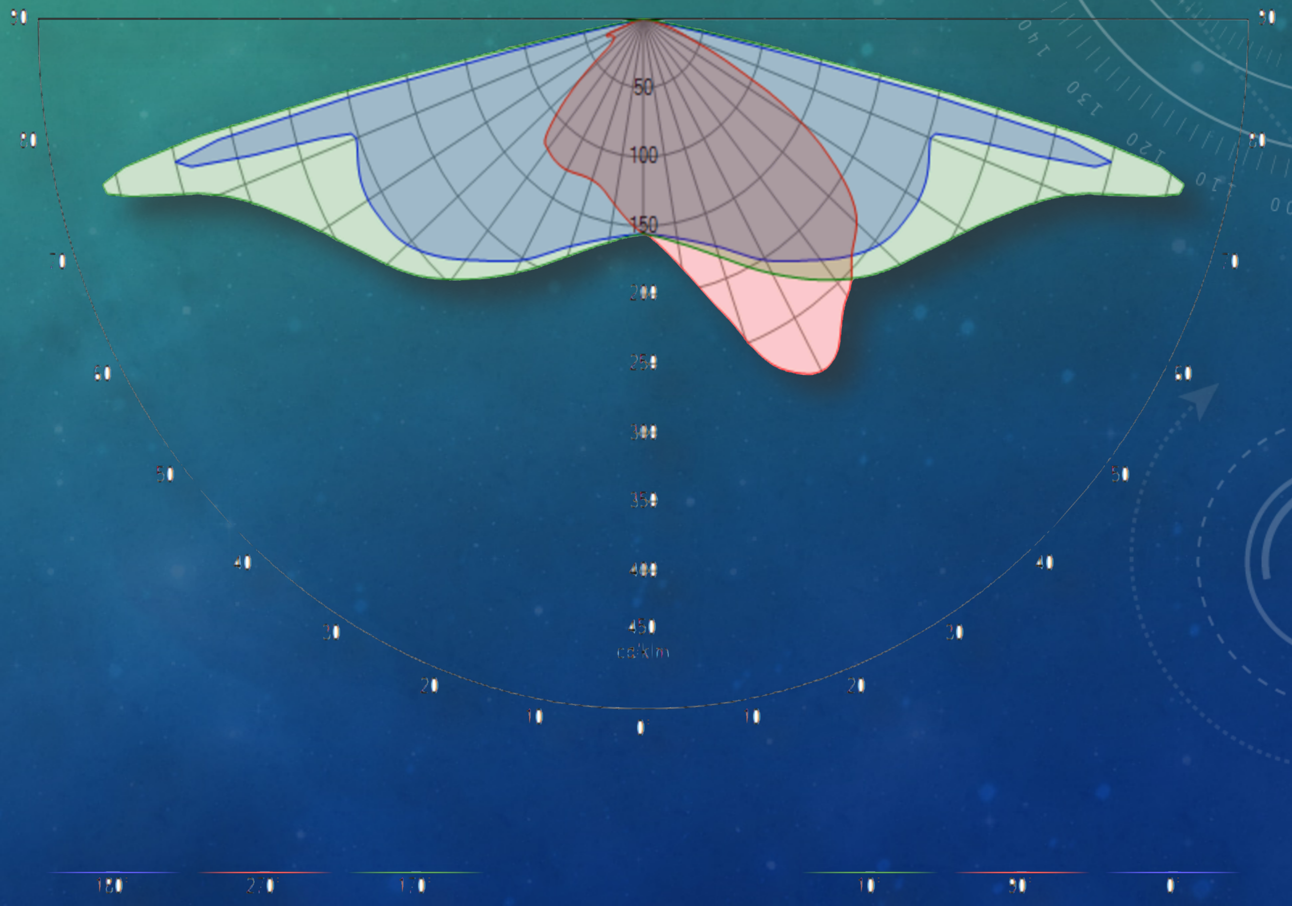
Poor Lighting Design

?



LUMINOUS INTENSITY DESIGN PARAMETERS

- EN 13201-2: 2015 – G classification System
- A glare control oriented system where TI% is not calculated
- Restricts luminous intensity in certain gamma angles



CLASS	Maximum luminous intensity in directions below the horizontal in cd/klm of the output flux of the luminaire			Other Requirements
	at 70° and above	at 80° and above	at 90° and above	
G1		**200**	**50**	None
G2		**150**	**30**	None
G3		**100**	**20**	None
G4	**500**	**100**	**10**	Luminous intensities above 95° to be zero
G5	**350**	**100**	**10**	Luminous intensities above 95° to be zero
G6	**350**	**100**	**0**	Luminous intensities above 95° to be zero

Luminous intensities are given for any direction forming the specified angle from the downward vertical with the luminaire installed for use.
Any direction forming the specified angle from the downward vertical, with the luminaire installed for use
Luminous intensities up to 1cd/klm can be regarded as zero

G CLASSIFICATION

G1 → G6

More control over critical design angles

AMERICAN INFLUENCE

- The IESNA’s BUG Rating System

EN 13201-2 IMPLICATION

G classification – a sky glow preventive measure (?!)

Higher installed G class distribution types (G4, G5, G6)

What would their impact be on affecting ***Sky Glow*** and ***Energy Efficiency*** ?

CIE RECOMMENDATIONS

Upward Light Ratio – ULR

- **Only Direct** light emission into the sky
- Calculation – Installation’s Tilt taken into account

Upward Flux Ratio – UFR

- Accumulative light emissions
- Direct emissions + Reflected emissions
- Reflection occurs by :
    1. Area to be lit
    2. Surroundings
- UPF = Max total installation emissions in lm

LIGHT DISTRIBUTION

- ✓ Maximize Utilization Factor for the Area to be Lit
- ✓ Reduce light in the Surrounding Area
- ✓ Different Reflection Factors in each area eg. Asphalt, Grass, Concrete, Stone etc.

DIRECT EMISSIONS – ULR %

Case Study

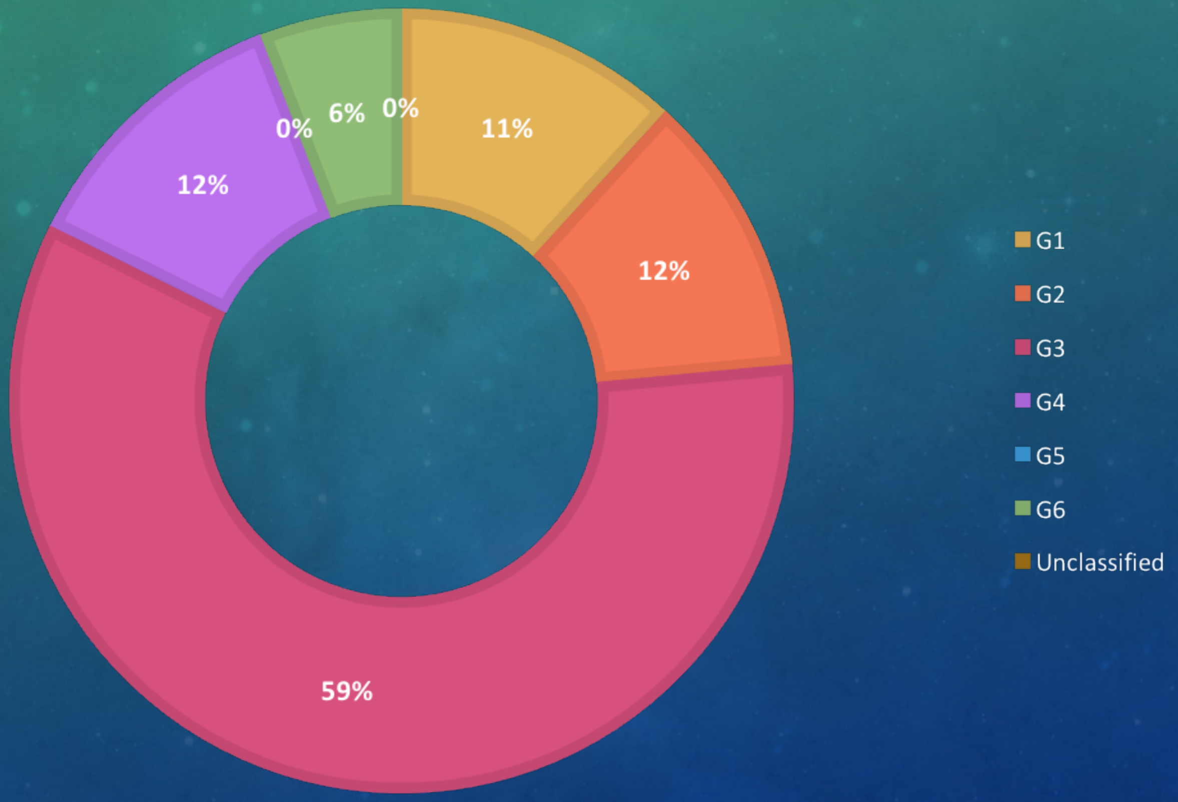
- Three European LED luminaire manufacturers
- Commercialized Street Light Optics
- Absolutely Photometry
- How Tilt affects ULR % ?
- How and if G is related with ULR % ?

Results

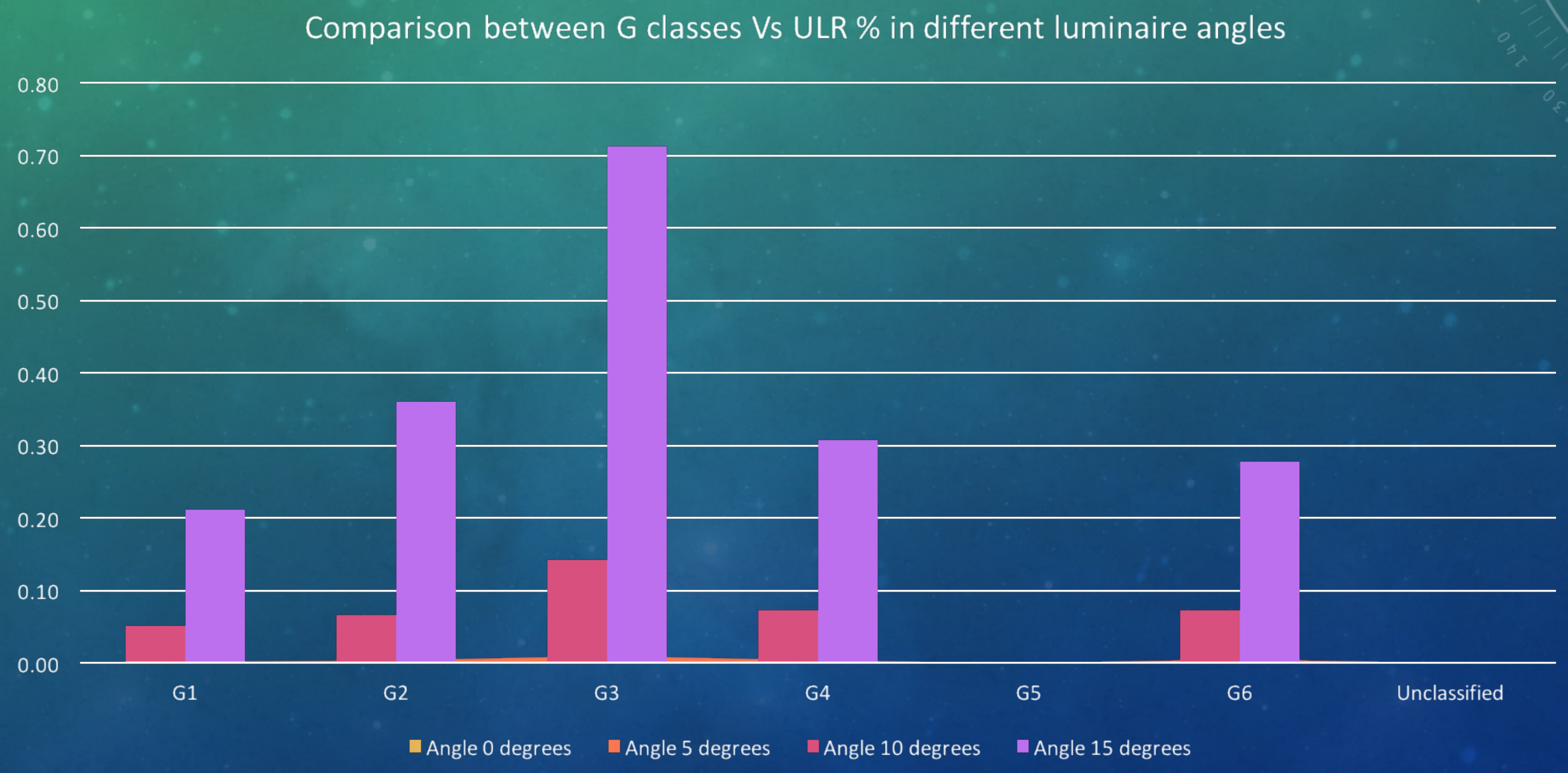
- Compliance with ULOR = 0% and FULL CUT OFF
- ULR % @ (0,5,10,15 tilt) not connected with drastic reduction with the choice of G higher installed class
- ULR % similar in all G classes
- Maximum noticed ULR 1,4% @ 15º Tilt

DIRECT EMISSIONS – ULR %

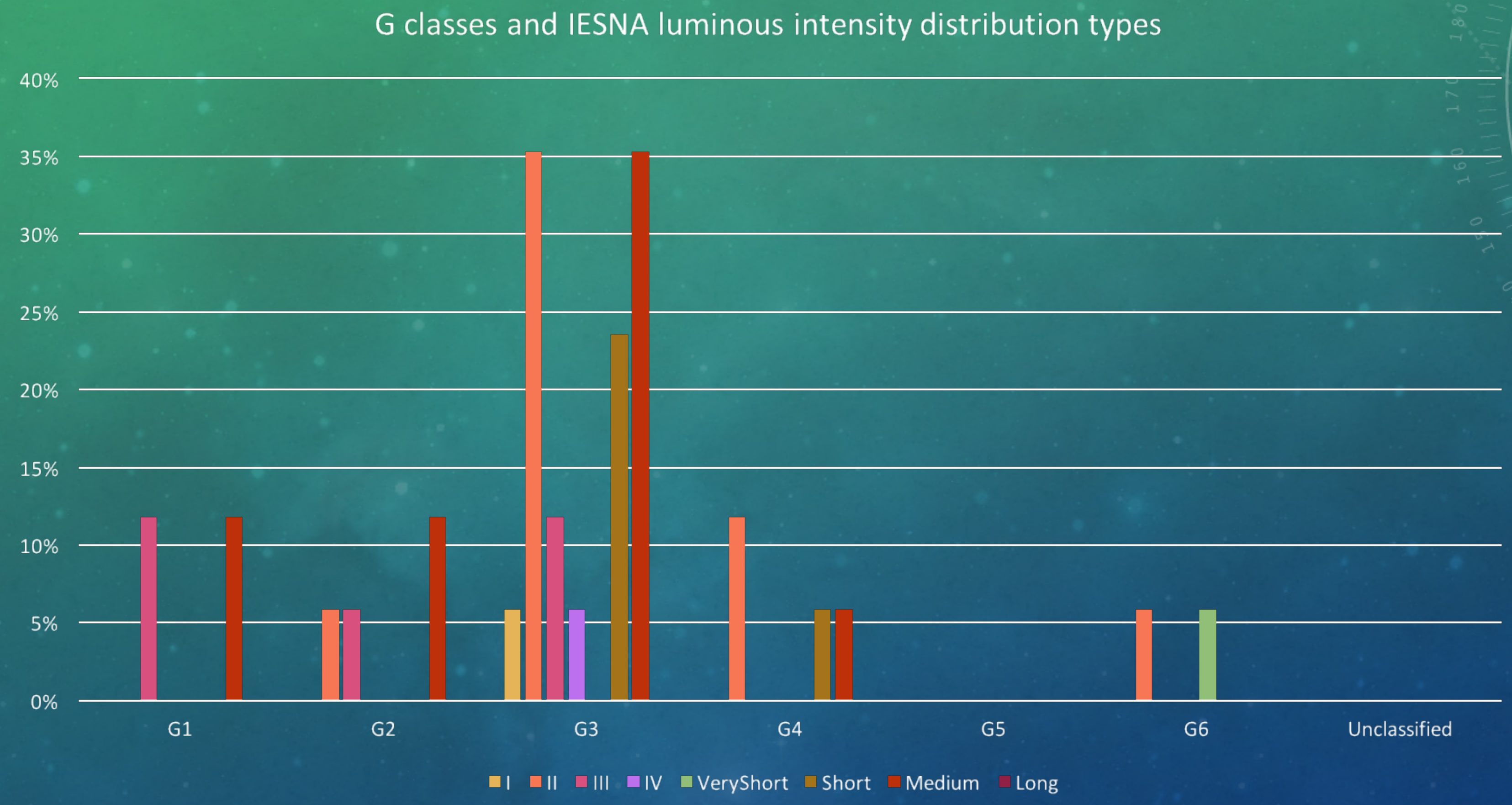
G CLASSES – ABSOLUTE PHOTOMETRY



DIRECT EMISSIONS – ULR %



DIRECT EMISSIONS – ULR %



- ✓ A restriction in G classes would affect critical design angles
- ✓ Shorter and less wide distributions

TOTAL CONTRIBUTION

CASE STUDIES WITH CIE’S EVALUATION METHODS

ZERO TILT NOT ALWAYS THE SOLUTION

Tilt restriction : 11% Power Density Increase
Light Pollution increased by 15%
Competent design for the correct choice of LED optic.

Case study 1

- M3 lighting class
- Height = 8m
- Width of carriageway = 8m
- Adjacent areas to be lit = as requested by EN 13201

Spacing	Power Density (kW/km)	Tilt	Lave (cd/m²)	EIR	Luminaire flux	ULR	DLOR	UPF max	Contribution L.Pollution per km
40	**2,68**	10	1,05	0,4	11500 lm	0%	100%	1204 lm	**30,1 klm**
39	**2,74**	5	1,12	0,3	11500 lm	0%	100%	1189 lm	**30,3 klm**
39	**2,74**	15	1	0,5	11500 lm	0,2%	99,8%	1243 lm	**31,9 klm**
36	**2,97**	0	1,02	0,5	11500 lm	0%	100,0%	1249 lm	**34,7 klm**

COMPETENT DESIGN – KEY FOR BALANCE

Case study 2

- M3 lighting class
- Height = 10m
- Width of carriageway = 7,5m
- Adjacent areas to be lit = as requested by EN 13201

Again Competent design for the correct choice of LED optic
Proper use of EN 13201 with optically efficient luminaires – Light pollution control

Spacing	Power Density (kW/km)	Tilt	Lave (cd/m²)	EIR	Luminaire flux	ULOR a	DLOR	UPF max	UFR
30	**2,1**	10	1,08	0,3	7328 lm	0%	100%	751 lm	**2,28**
30	**2,1**	15	1,02	0,5	7328 lm	0,2%	99,8%	768 lm	**2,36**
30	**2,5**	0	1,06	0,4	8889 lm	0%	100%	956 lm	**2,76**
30	**2,5**	0	1,04	0,5	8801 lm	0%	100,0%	946 lm	**2,76**
30	**2,5**	0	1,07	0,5	8856 lm	0%	100%	952 lm	**2,76**

REFLECTION AND OTHER PROPERTIES

Luminance design schemes:

- Higher P_{area}% leads to lower pollution

Case study 2

- Most photometrically efficient i.e maximum Utilization Factor (μ)

P_{area}%	Spacing	Power Density (kW/km)	Tilt	Luminaire flux	ULOR a	DLOR	Upward flux/luminaire	UFR
R3, 7	**30**	**2,1**	10	7328 lm	0%	100%	751 lm	**2,28**
R3, 8	**30**	**1,8**	10	6419 lm	0%	100%	692 lm	**2,19**
R3, 10	**30**	**1,5**	10	5349 lm	0%	100%	634 lm	**2,04**

MF

$$UFR = \left\{1 + \frac{ULOR}{P_{area} * \mu} + \frac{P_{surrounds}}{P_{area}}\left(\frac{DLOR - \mu}{\mu}\right)\right\}\frac{L_{av,initial}}{L_{av,maint}}$$

- $P_{surrounds}$%: As low as possible
- Reasonable use of Maintenance Factor leads to lower overlighting and light pollution

HIGHER G CLASS – NOT NECESSARILY A SOLUTION

Power Density was increased by 14% and UFR by 3%
G4, G5, G6 less efficient due to restrictions in critical angles

Case study 2

- C3 lighting class
- Height = 6m
- Width of carriageway = 6m

Intensity Class	Power Density (kW/km)	Tilt	Eave (cd/m²)	EUo	Luminaire flux	ULOR a	DLOR	UPF max	UFR
G3	**1,4**	15	15,6	41	4279 lm	0,2%	99,8%	406 lm	**2,53**
G4	**1,6**	0	16,1	46	4570 lm	0%	100%	432 lm	**2,60**

CONCLUSIONS (1/2)

- ***The restrictions in G or BUG classes*:** Can not help drastic sky glow reduction. *EN 13201-2 implication must not be misinterpreted.*
- ***Excluding G1 to G3*:** Causes increase in Power Density by 14 % in C class, 25% in P classes and even 38% in M classes.
- ***Light Pollution impact***: Not exclusively a matter of a distribution type, G type but rather an issue of photometrical efficiency. ***Assessment is per case, no general rule***
- ***Optimized optical system – layout*:** Generates the least amount of upward flux. *An installation that uses the least flux to create an amount of luminance with maximum utilization factor. The higher the photometric efficiency the less the spilled light*

CONCLUSIONS (2/2)

- ***Edge Illuminance Ratio***: Need to be maintained within reasonable values depending on the lower limit eg. Up to +10% of the minimum EN required value
- ***Maintenance Factor***: Reasonable use, related to new technological advances reduces excessive luminous flux
- ***Zero ULR** installations*: can be more polluters than less tightly controlled ones.
- ***Light absorbing materials***: for the surroundings e.g. Grass reduce light pollution
- ***Adoption of ULR and UFR limits***: for each lighting class and geometric scheme

Thank you for your attention!!

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