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Designers Lighting Forum

Lighting the Way Responsibly: Safeguarding Your Well-Being

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March 20, 2024

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Introduction

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

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Learning Objectives

At the end of this course, participants will be able to:

1. Mitigate intrusive Lighting
2. Achieve optimal lighting results via photometry mixing
3. Understand how to Protect wildlife and human well-being at night
4. Consider Bio-based raw material alternatives

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Agenda

Introduction

Light pollution and intrusive Lighting reduction

Project optimization via mixed optics

Nature friendly Lighting solutions

Bio-based raw materials alternative

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Light Pollution reduction

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ARE YOU ONE OF THE LUCKY ONES?

ONLY 2 OUT OF 10 PEOPLE ON EARTH CAN SEE THE MILKY WAY

99% OF THE USA AND EUROPE

live under light polluted skies

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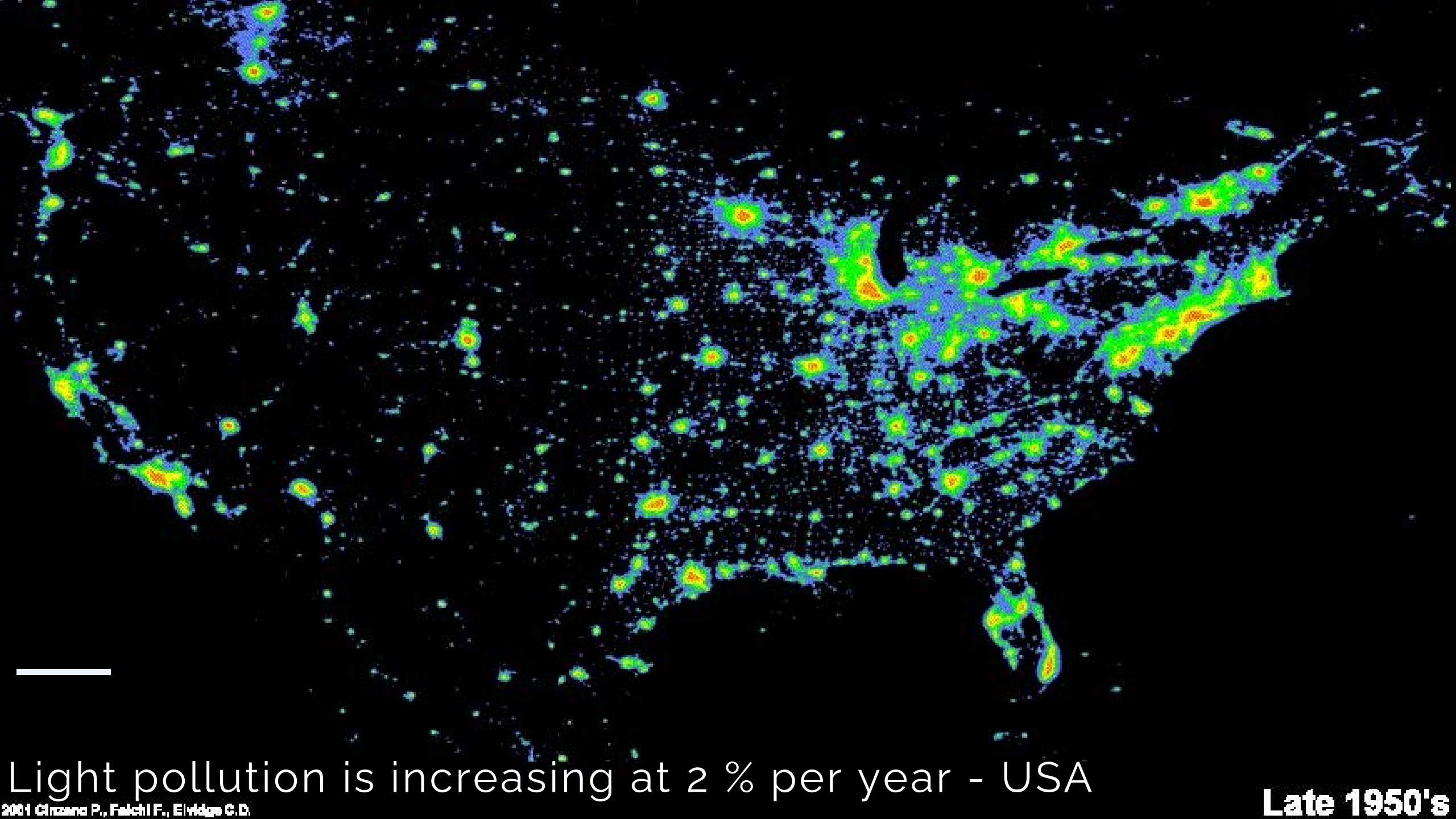
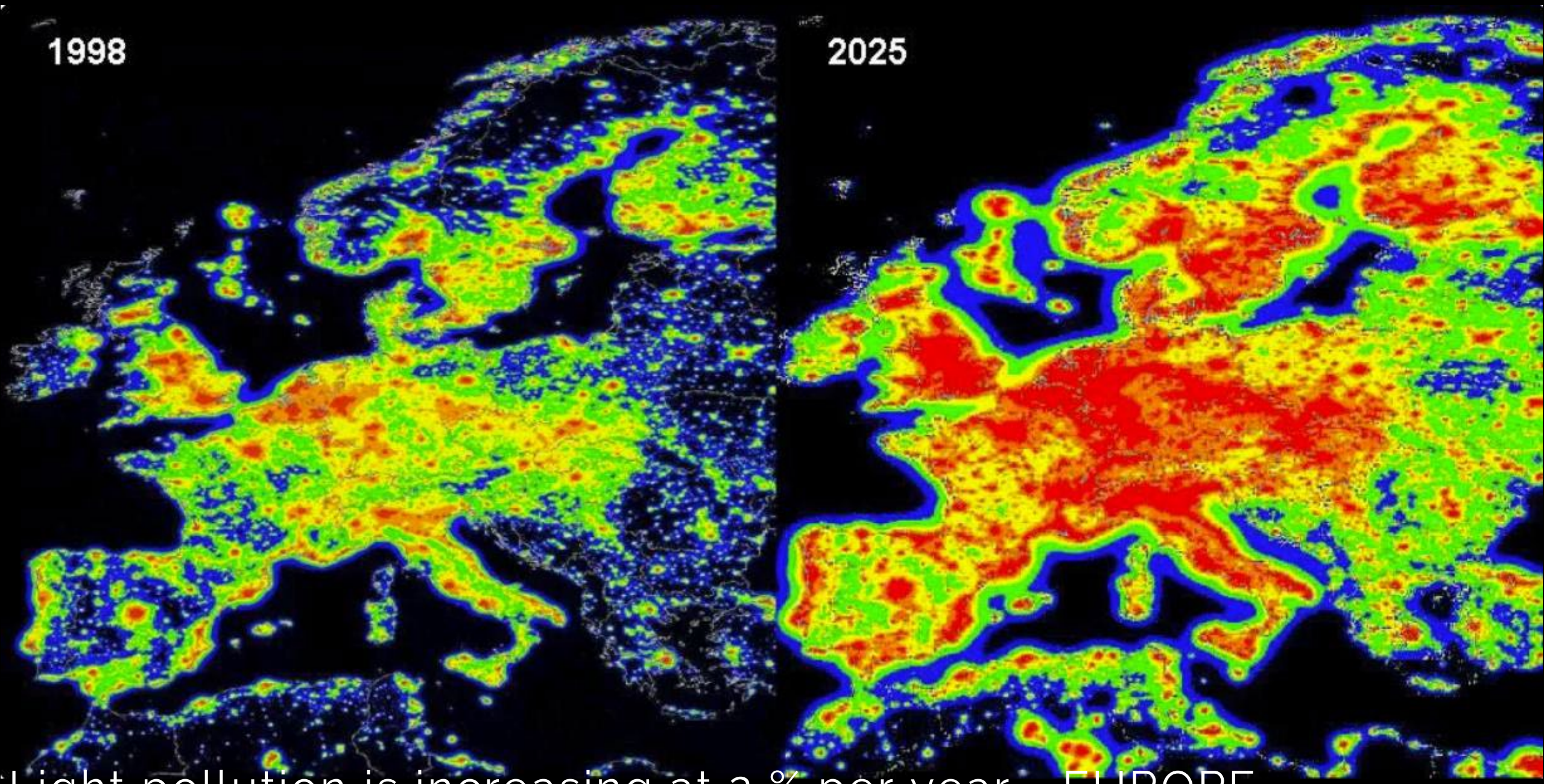

Light pollution is increasing at 2 % per year - USA
2001 Cinzano P., Falchi F., Elvidge C.D.
Late 1950's



Light pollution is increasing at 2 % per year - EUROPE

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Image: Mike Knell

LIGHT POLLUTION

Light pollution is the result of outdoor lighting that is not properly shielded, allowing light shine into the eyes and night sky.

It comes in 3 main forms:

- Skyglow,

- Glare,

- Light Trespass

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LIGHT POLLUTION CONSEQUENCES

- Ecological Impacts,
- Energy Waste,
- Human Health
- Safety

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FIND THE POTENTIAL STALKER

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MYTH:

More Lighting is Safer

REALITY:

Well Designed Lighting is safer

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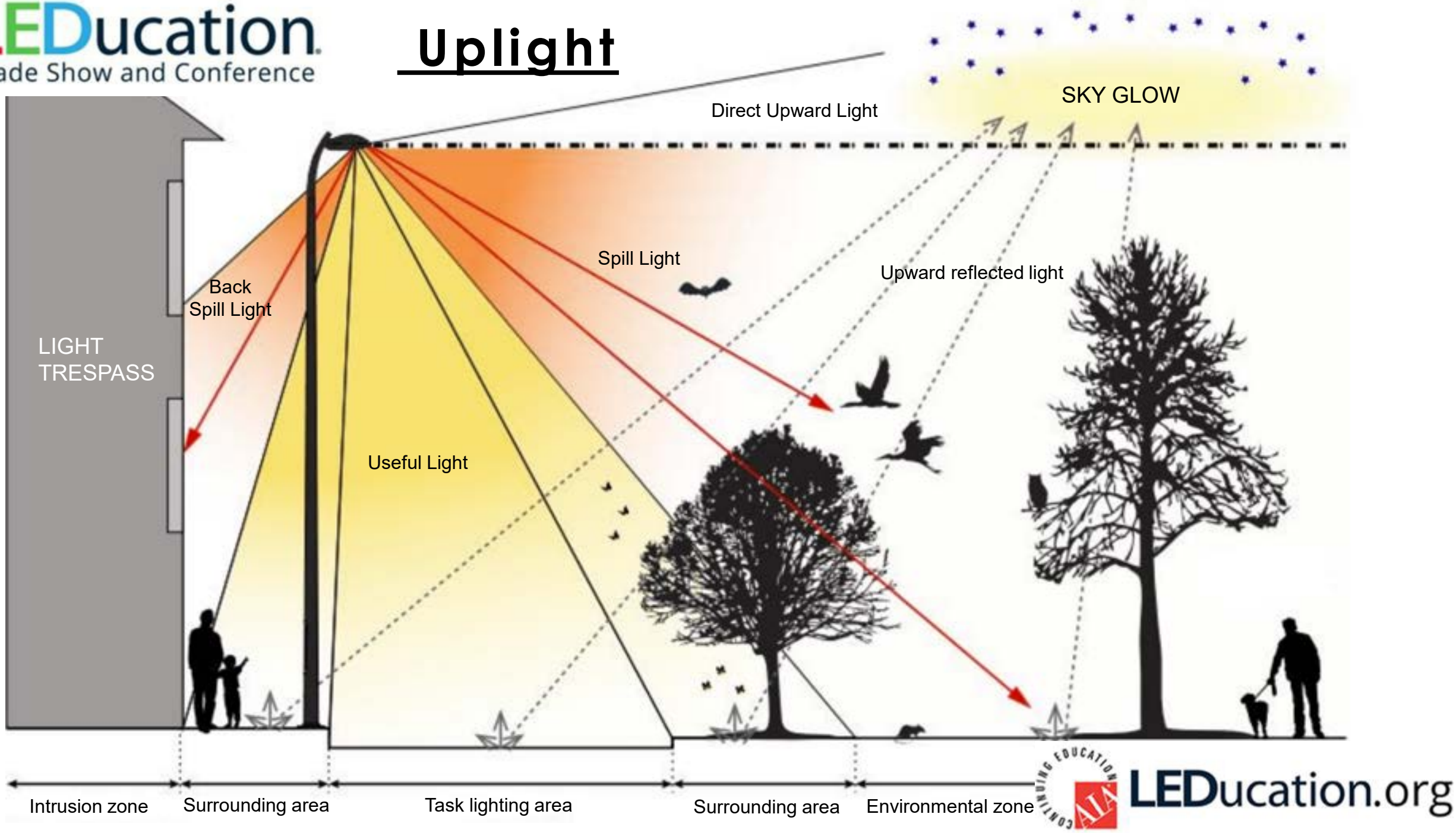
Uplight



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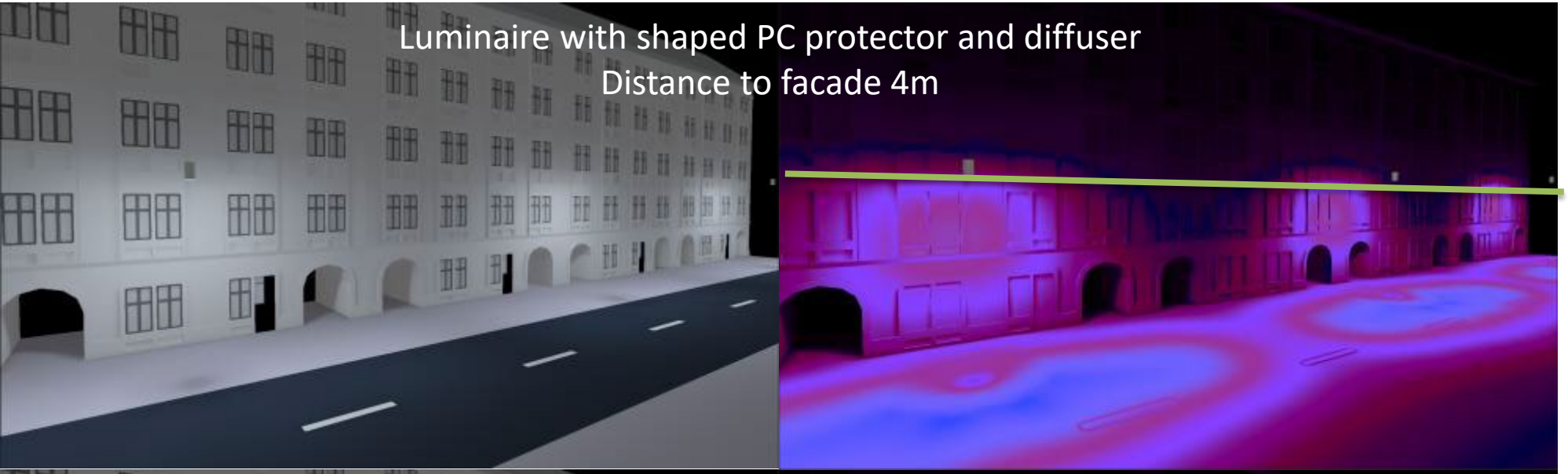
Uplight example



Diffuser

Flat glass

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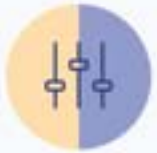
Five Lighting Principles for Responsible Outdoor Lighting

DarkSky

IES Illuminating

Responsible outdoor lighting is

1 Useful	**Use light only if it is needed** All light should have a clear purpose. Consider how the use of light will impact the area, including wildlife and their habitats.	
2 Targeted	**Direct light so it falls only where it is needed** Use shielding and careful aiming to target the direction of the light beam so that it points downward and does not spill beyond where it is needed.	
3 Low Level	**Light should be no brighter than necessary** Use the lowest light level required. Be mindful of surface conditions, as some surfaces may reflect more light into the night sky than intended.	
4 Controlled	**Use light only when it is needed** Use controls such as timers or motion detectors to ensure that light is available when it is needed, dimmed when possible, and turned off when not needed.	
5 Warm-colored	**Use warmer color lights where possible** Limit the amount of shorter wavelength (blue-violet) light to the least amount needed.	

DARKSKY APPROVED · Reduces light pollution ·

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Responsible outdoor lighting

- Meets the needs of people to see at night
- Conserves energy
- Avoids harmful effects on wildlife
- Protects our night sky

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Lighting distribution

Without intrusive light control

With intrusive light control

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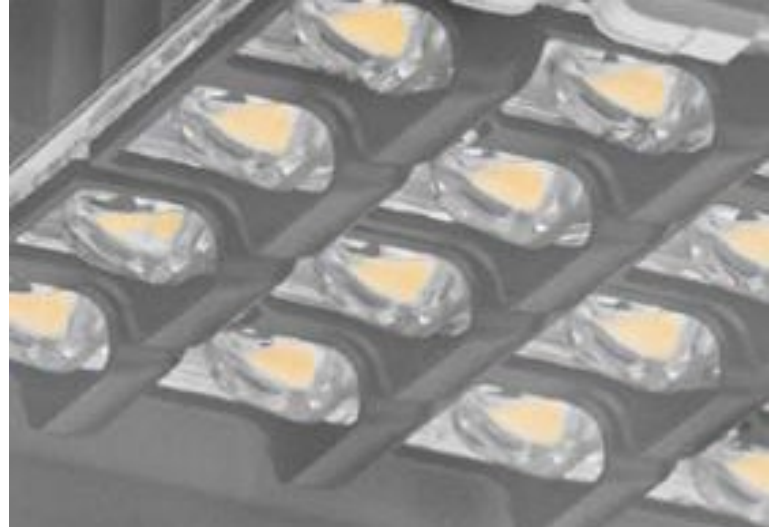
Light Shielding



Possible accessories:

- Internal - Backlight Cutters
- External - Visors

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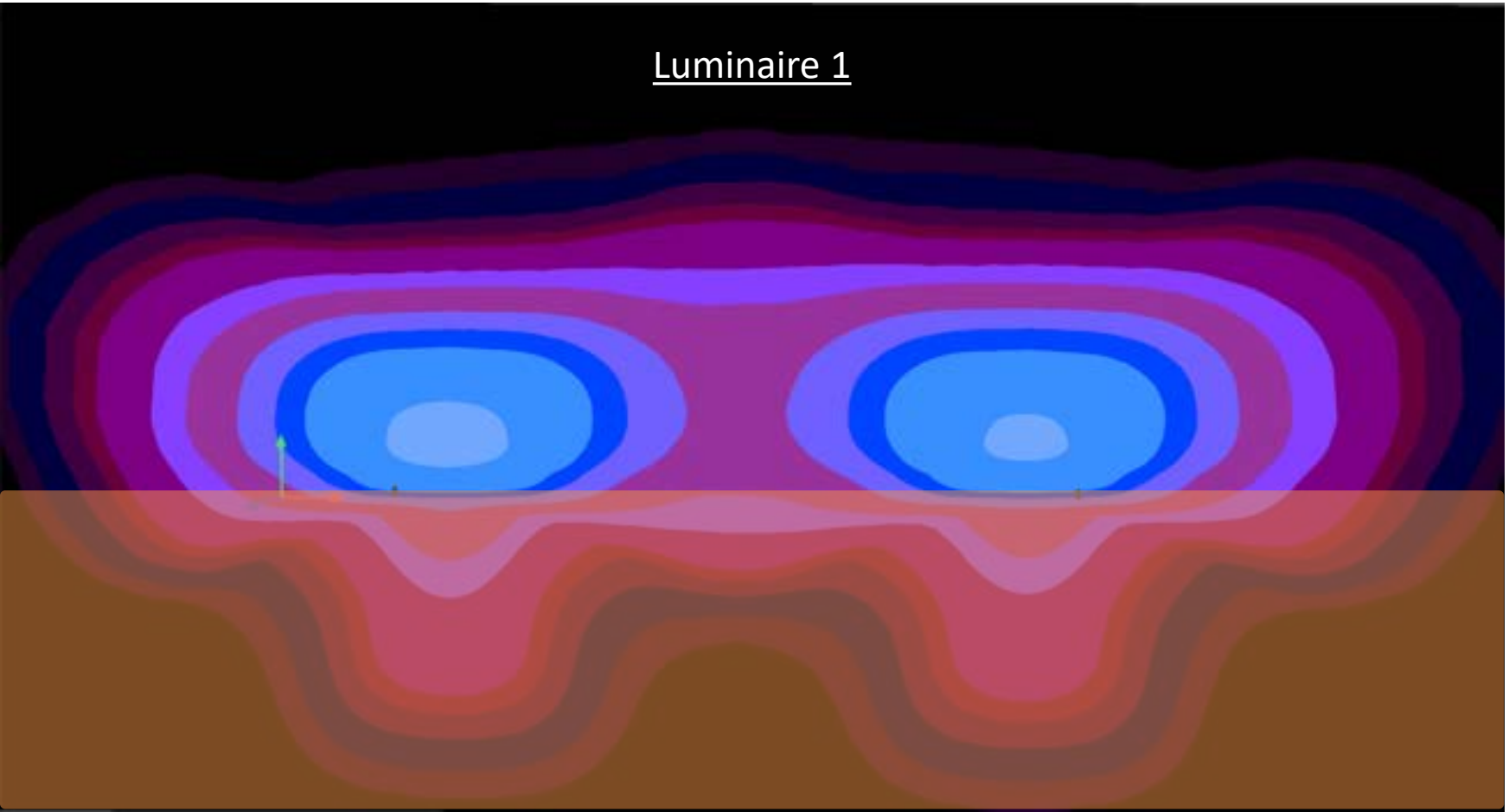
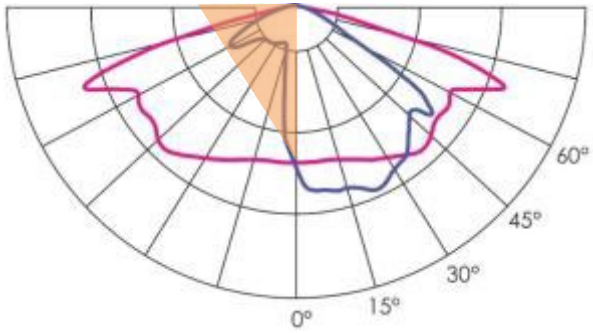
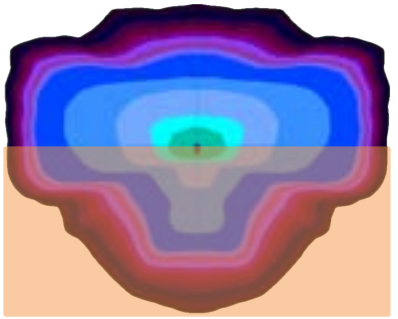
Application example

Luminaire 1







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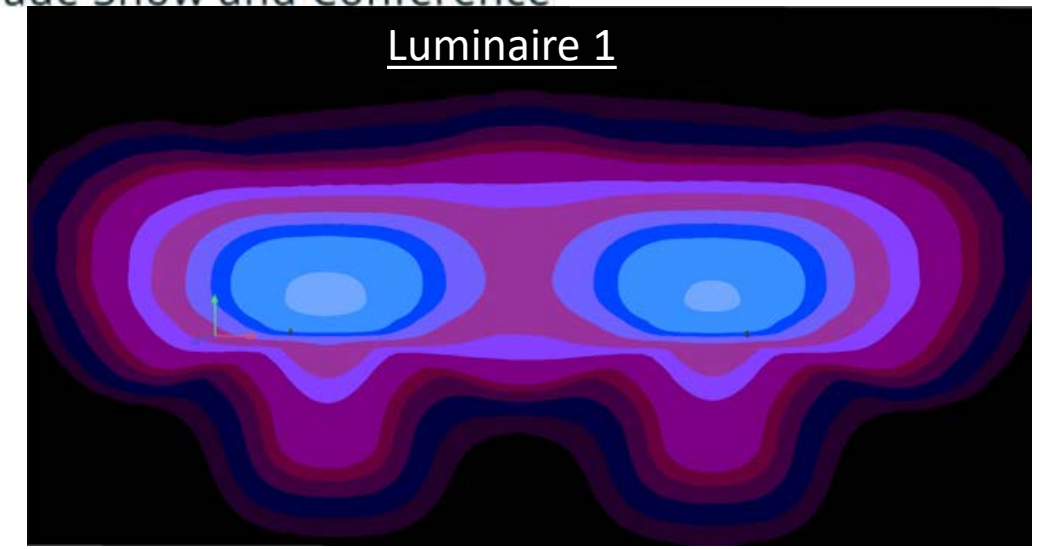
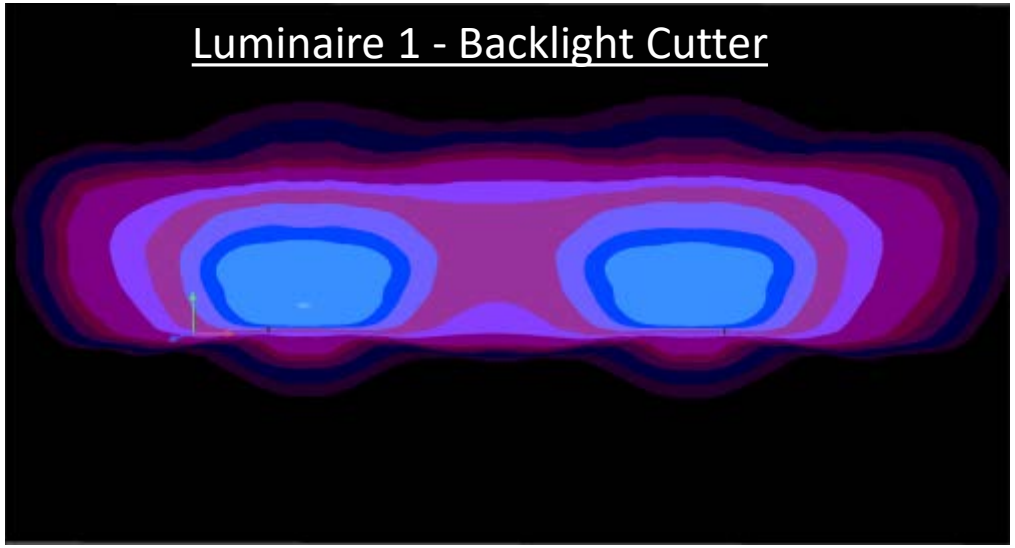
Visors vs Backlight Cutter

Luminaire 1

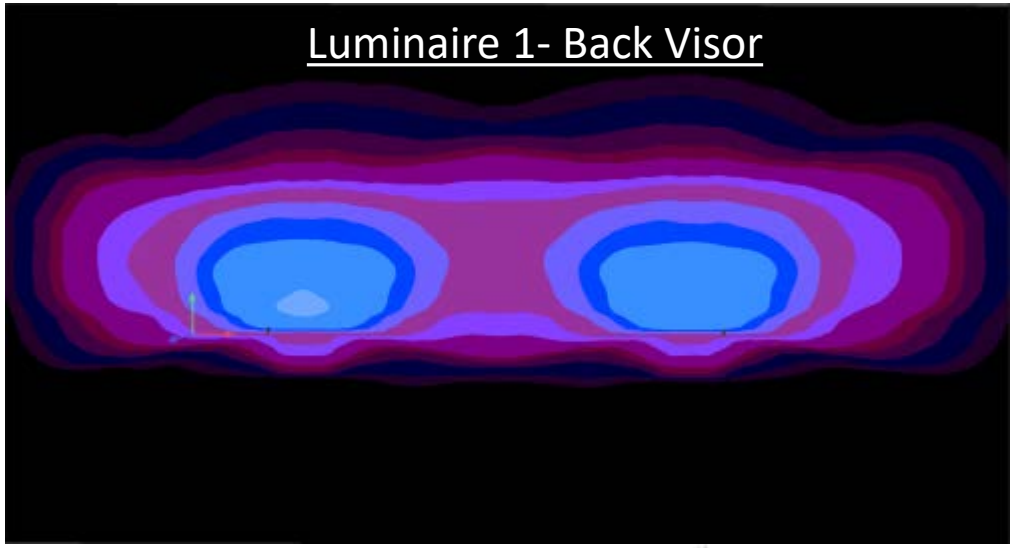


vs

Luminaire 1 - Backlight Cutter



Luminaire 1- Back Visor



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Visors/BLC – vertical impact

VS

Backlight Cutters are >90% Comparable Solution with the Back Visors

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LA light pollution

Los Angles' light pollution in 1908 (left) and 2017 (right). (UCLA)

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WE CAN MAKE A DIFFERENCE

LIGHT POLLUTION

Has a simple solution:

BETTER LIGHTING DESIGN

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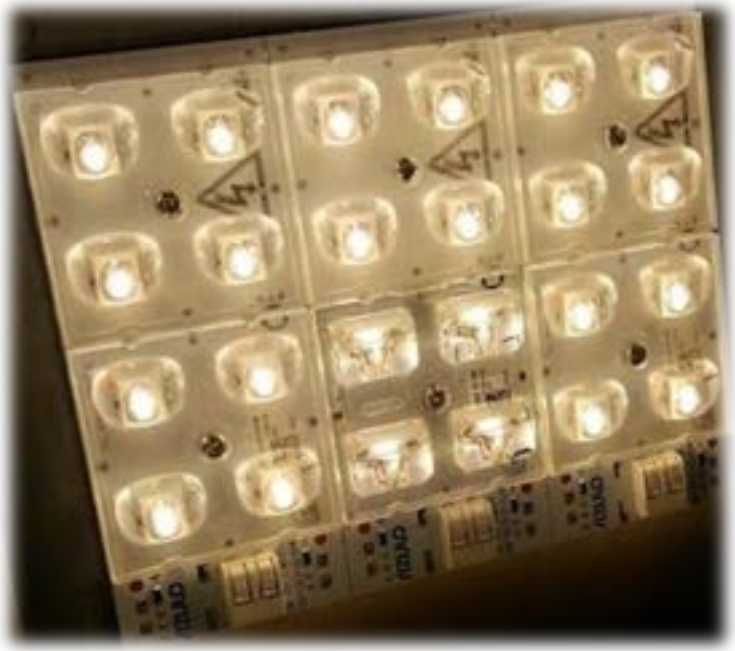
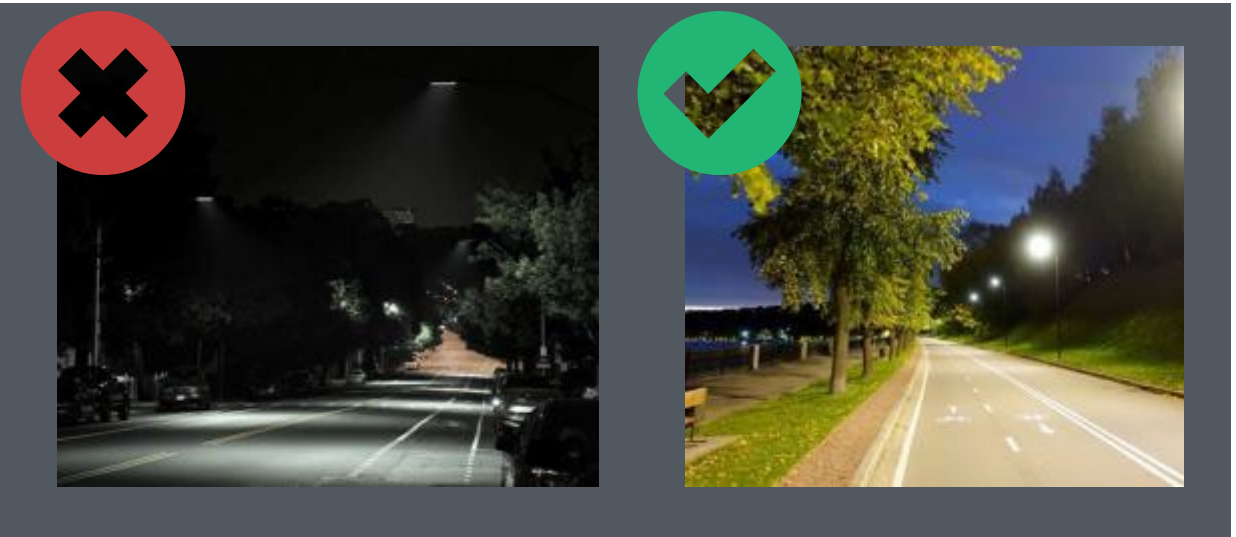


Photometry mixing



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WHY DO WE MIX OPTICS?

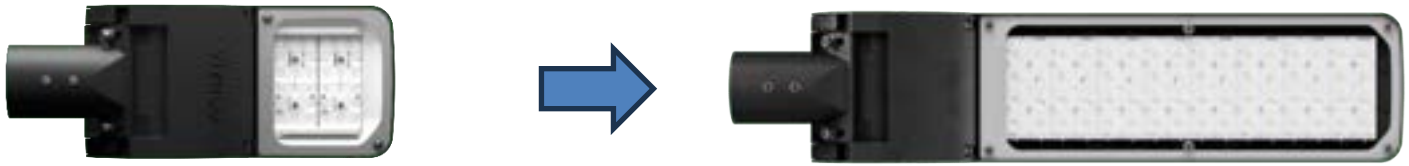
Not optimal Calculation results – **the edge of specification!**

Not possible in the project:

- Spacing / overhang change

- Luminaire Power increase

- Luminaire Size change



- Lighting class reduction

LIGHTING CLASS	dry			wet *	TI in %	SR
	L_{av} in cd/m²	U_o	U_l	U_o		
M1	2.0	0.40	0.70	0.15	10	0.5
M2	1.5	0.40	0.70	0.15	10	0.5
M3	1.0	0.40	0.60	0.15	10	0.5
M4	0.75	0.40	0.60	0.15	15	0.5
M5	0.50	0.35	0.40	0.15	15	0.5
M6	0.30	0.35	0.40	0.15	20	0.5

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PHOTOMETRY MIXING

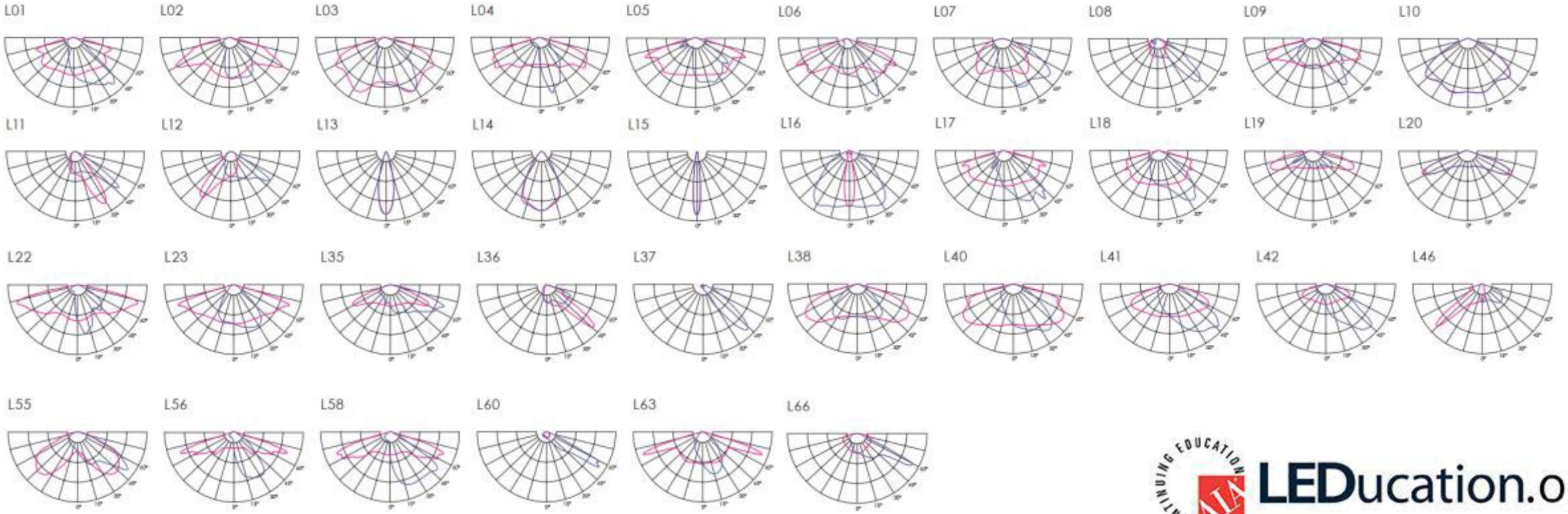
Step 1: Lighting Calculations – use more than one optic in the luminaire and divide lumen output accordingly (eg. 30/70%)

Calculate the correct proportions depending on the lens size

type 2x2
50x50mm

type 8
50x50mm

type 4x2
50x50mm



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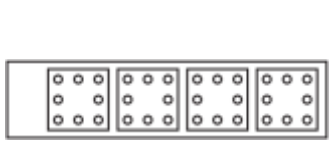
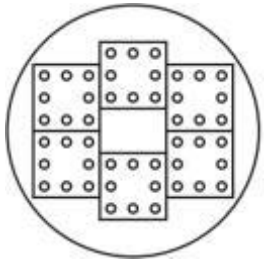
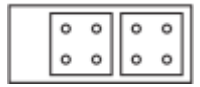
PHOTOMETRY MIXING

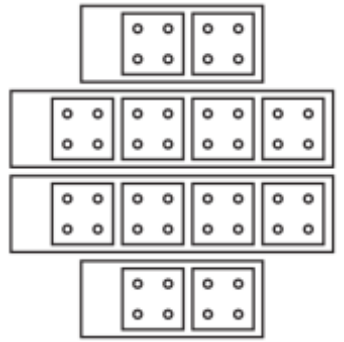
Step 2: Modelling – design the Lens matrix accordingly to calculated results,

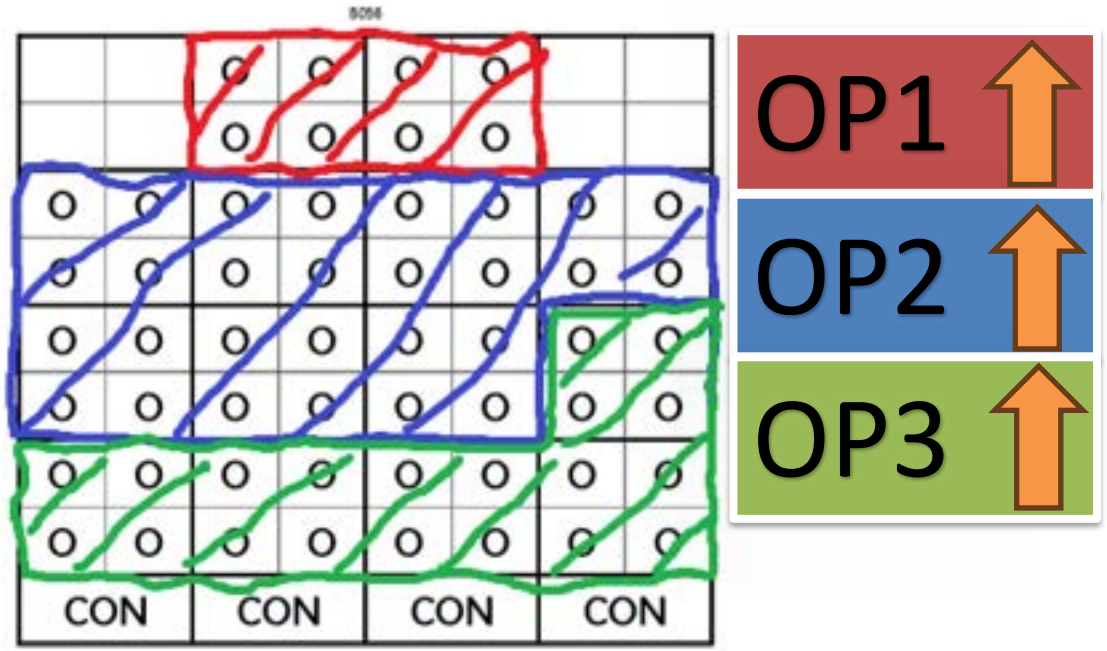
Take into account PCB size options

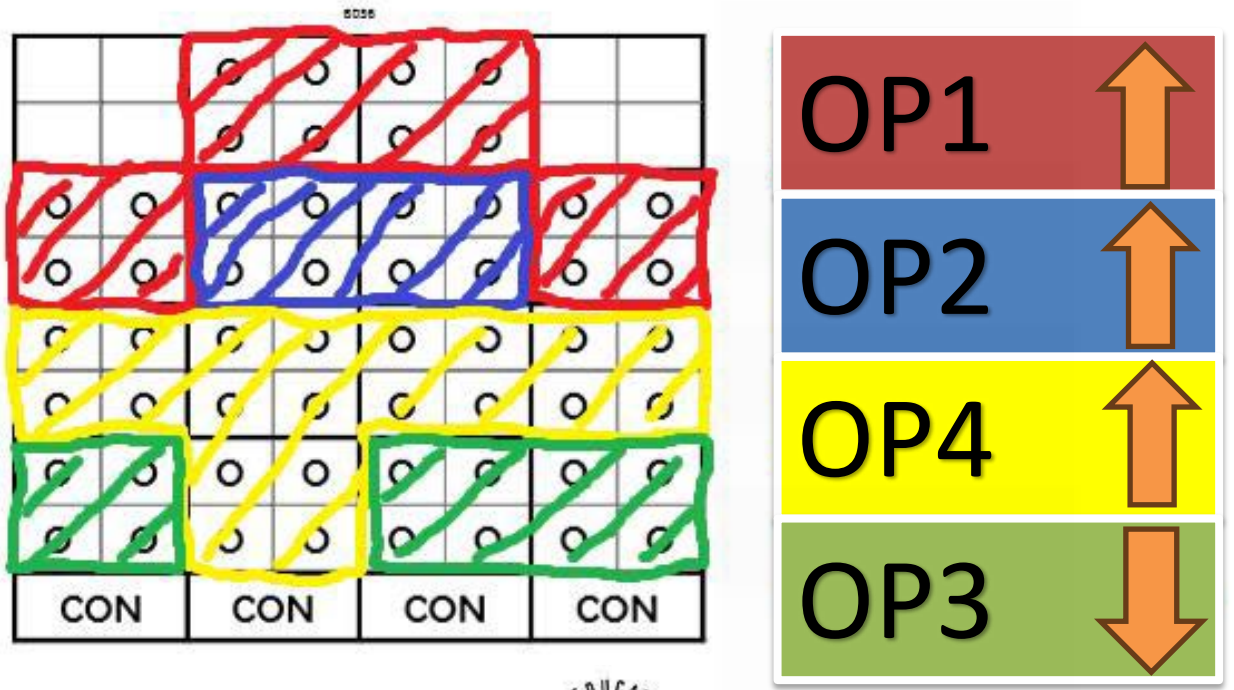












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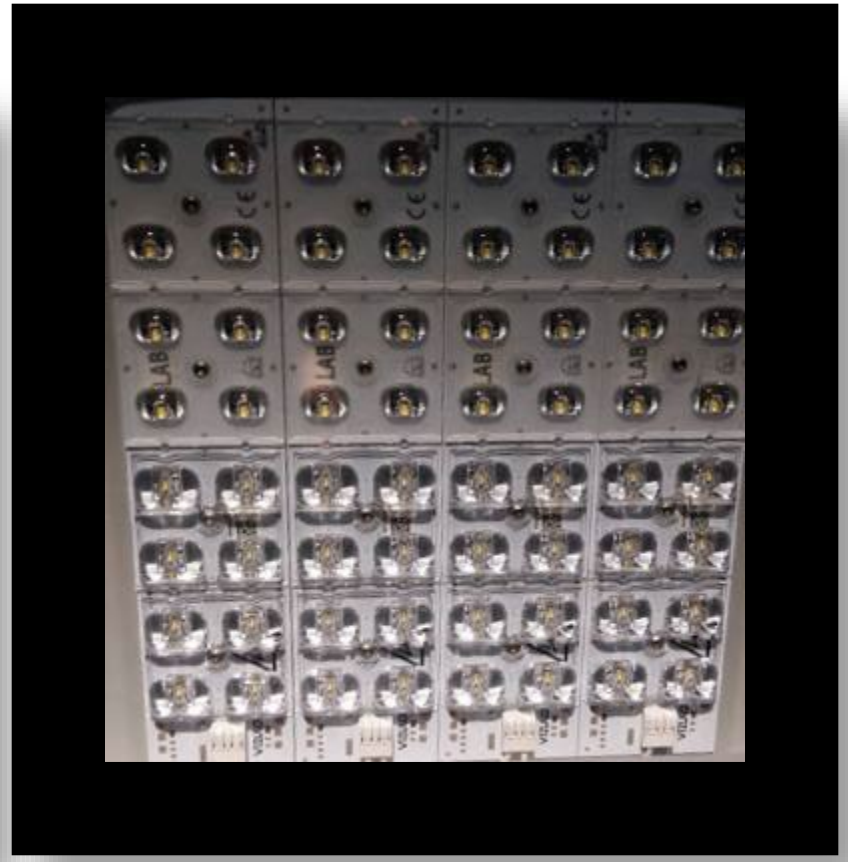
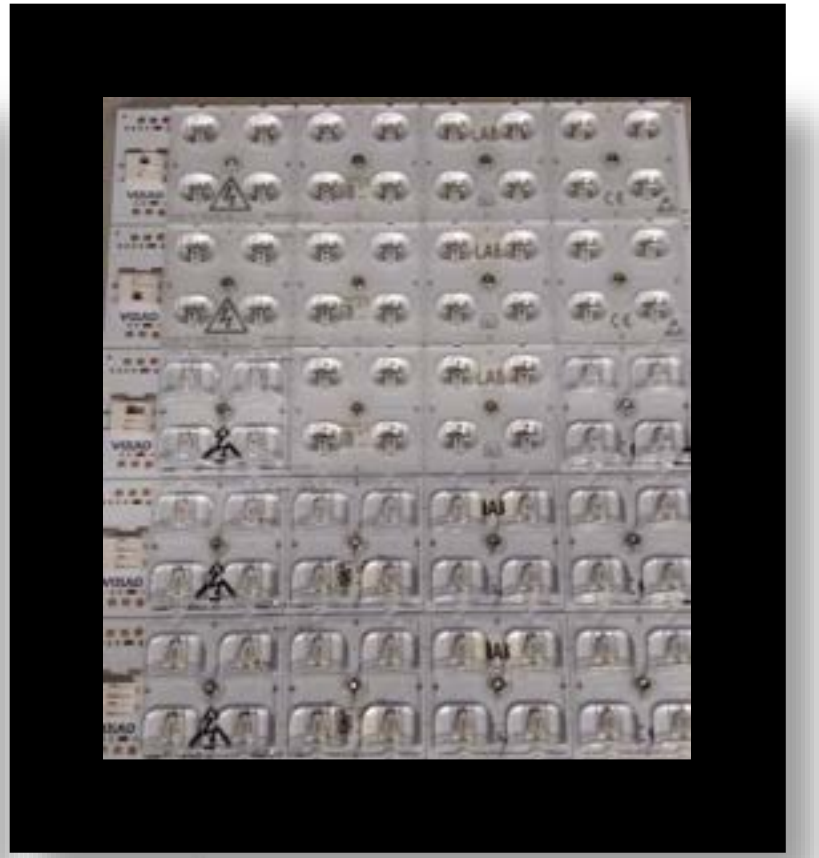
PHOTOMETRY MIXING

Step 3: Prototype – collect and arrange Lenses on PCBs

Durring assembly follow the correct lens arrow direction!





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PHOTOMETRY MIXING

Step 4: Lab photometry meassurement – mixed optic LDT/IES creation and lab test report

Use accredited laboraty to achieve sufficient results

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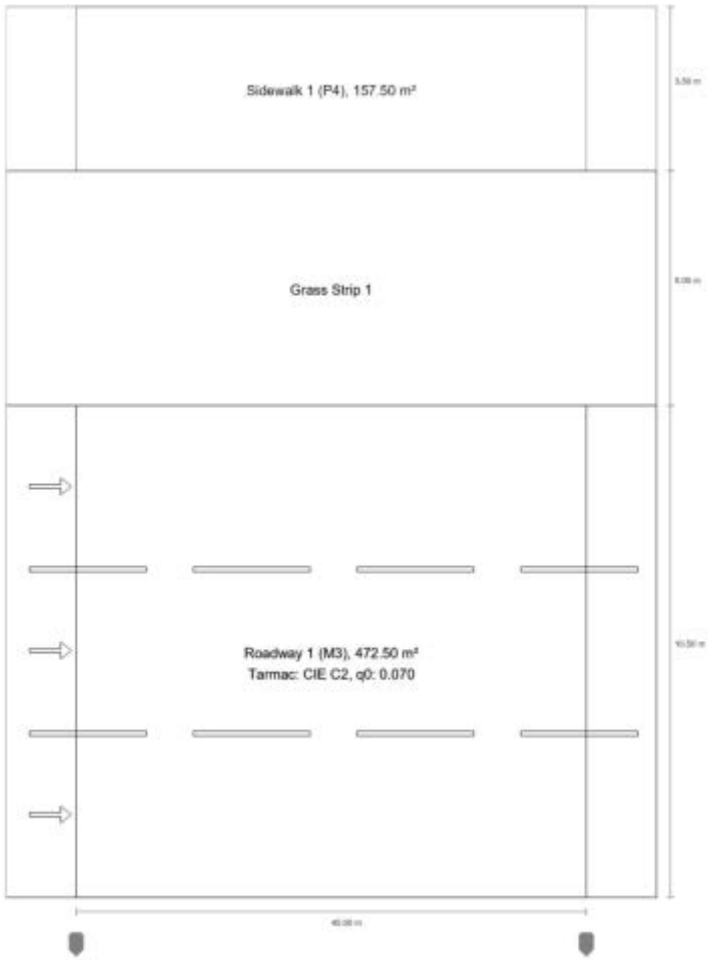
PHOTOMETRY MIXING

Step 5: Calculation comparison – compare results with innitially assumed and real meassured photometry

Project example



Tender specification demand:

- Spacing: **≤ 45m**
- Overhang: **-1m**
- Inclination: **≤ 5°**
- Pole height: **10m**
- Power: **≤ 140W**
- Efficacy: **≥130lm/W**
- Size /weight: **≤ 700 x 300 x 110 / 8kg**
- Lighting class: Roadway **M3** / Sidewalk **P4**

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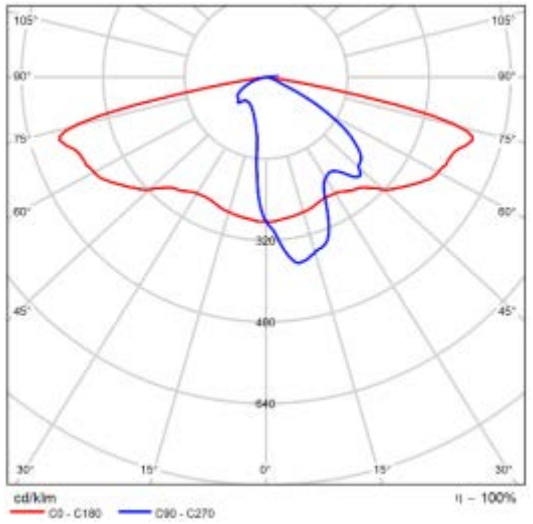
REGULAR OPTIC „OP1”

Article No.	6000102979 SRL 140 740
Article name	Stork Little Brother 140 W 64 LED
Fitting	1x 64 LED MOD AB

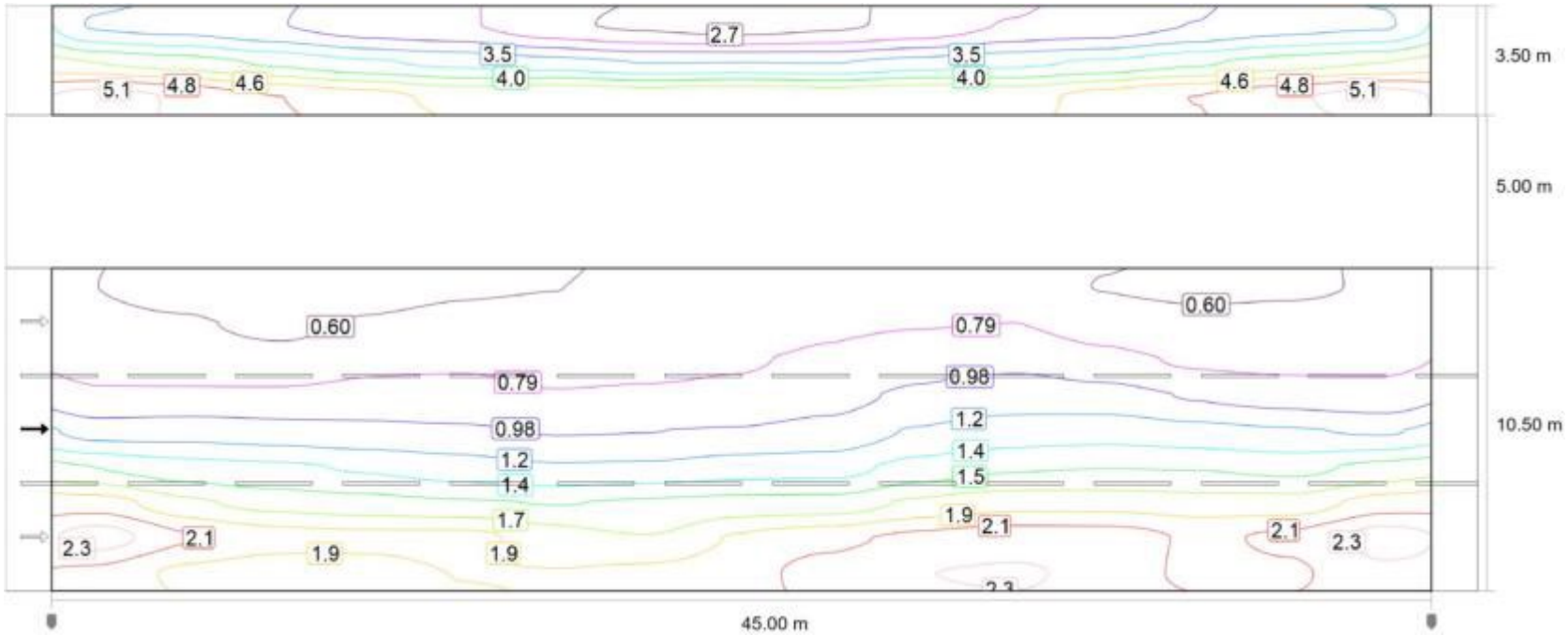
P	140.0 W
Φ_{Lamp}	18991 lm
$\Phi_{Luminaire}$	18991 lm
η	100.00 %



Results for valuation fields

A maintenance factor of 0.80 was used for calculating for the installation.

	Symbol	Calculated	Target	Check
Sidewalk 1 (P4)	E_{av}	3.86 lx	[5.00 - 7.50] lx	✗
	E_{min}	2.53 lx	≥ 1.00 lx	✓
Roadway 1 (M3)	L_{av}	1.15 cd/m²	≥ 1.00 cd/m²	✓
	U_0	0.40	≥ 0.40	✓
	U_l	0.68	≥ 0.60	✓
	TI	15 %	≤ 15 %	✓
	R_{EI}	0.58	≥ 0.30	✓



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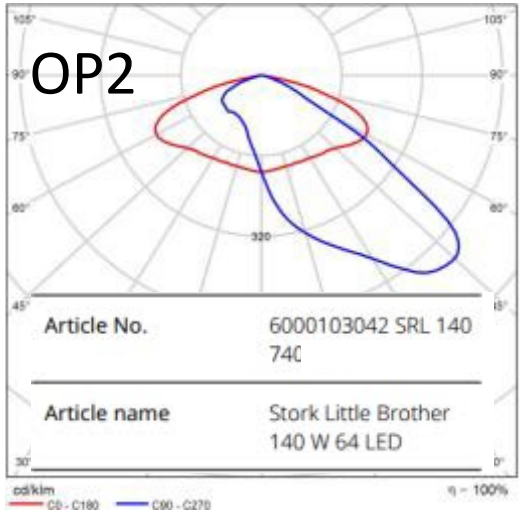
MIXED OPTIC „OP1+OP2” SIMULATION



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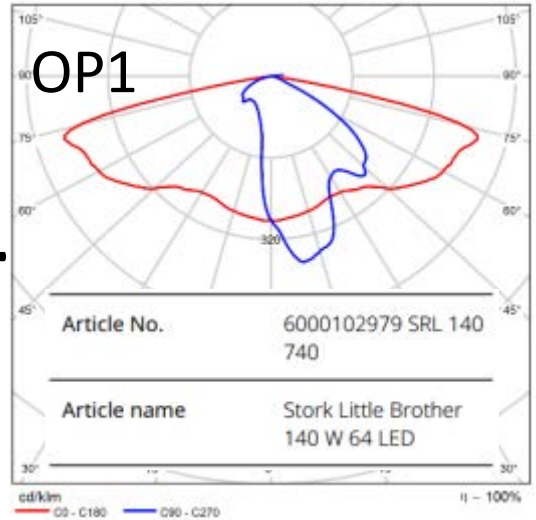

2x

P	70.0 W
Φ_{Lamp}	9496 lm
$\Phi_{Luminaire}$	9496 lm
η	100.00 %

Results for valuation fields

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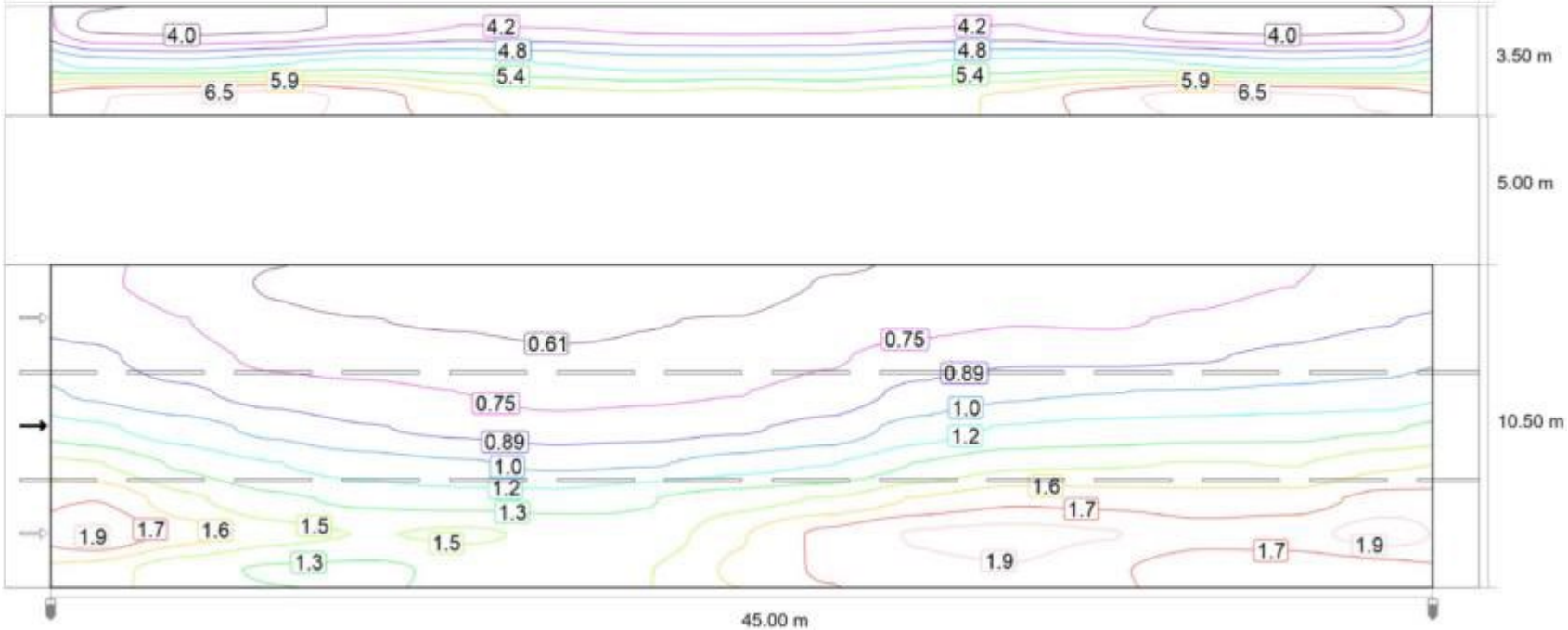
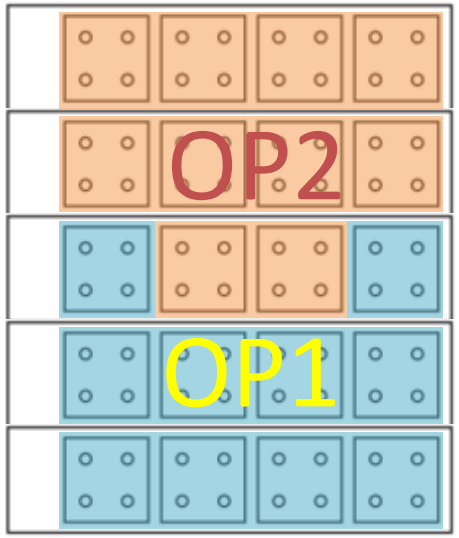
Sidewalk 1 (P4)	E_{av}	5.09 lx	[5.00 - 7.50] lx	✓
	E_{min}	3.82 lx	≥ 1.00 lx	✓
Roadway 1 (M3)	L_{av}	1.05 cd/m²	≥ 1.00 cd/m²	✓
	U_o	0.47	≥ 0.40	✓
	U_l	0.63	≥ 0.60	✓
	TI	12 %	≤ 15 %	✓
	R_{EI}	0.53	≥ 0.30	✓



50/50% proportion



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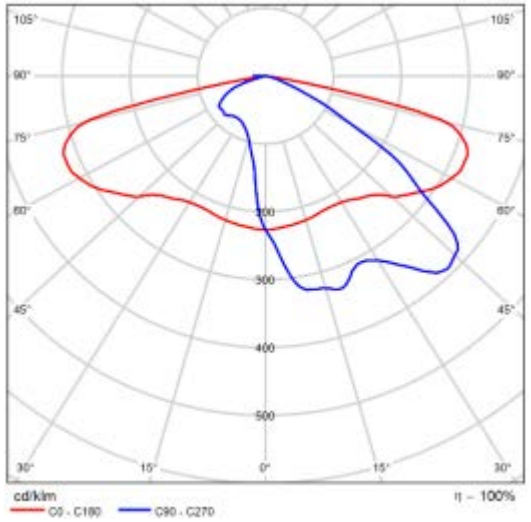
MIXED OPTIC „ OP1+OP2” MEASURED

Article No.	STORK LITTLE BROTHER 140 W 64 LED
Article name	SRL 140 740 B064 CSN DG1
Fitting	1x 64 LED

P	140.0 W
Φ_{Lamp}	18991 lm
$\Phi_{Luminaire}$	18991 lm
η	100.00 %



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	U_o	0.47	≥ 0.40	✓
	U_l	0.67	≥ 0.60	✓
	TI	13 %	≤ 15 %	✓
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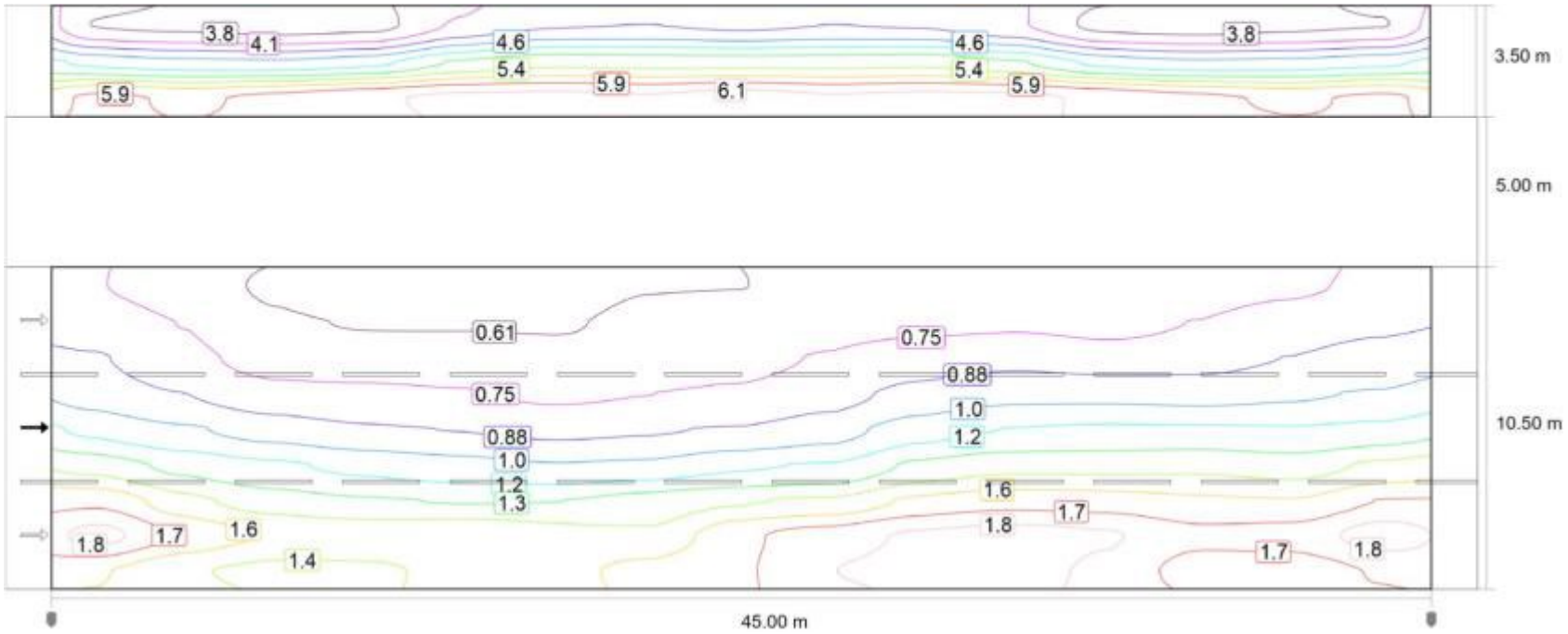

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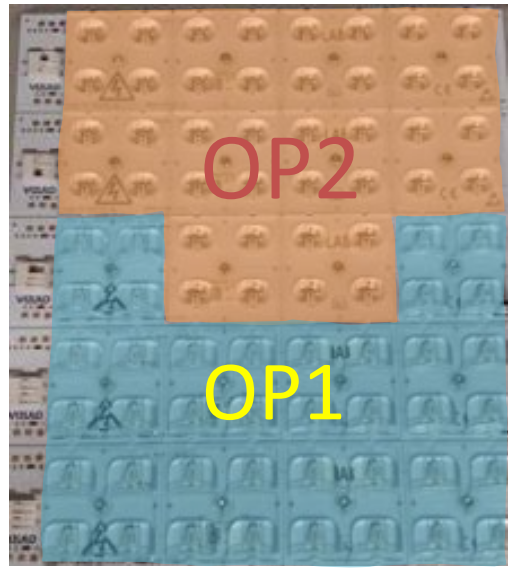

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RESULTS

REGULAR OPTIC „OP1”

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MIXED OPTIC SIMULATION

Results for valuation fields

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	U_l	0.63	≥ 0.60	✓
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MIXED OPTIC RESULTS

Results for valuation fields

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Nature Friendly Lighting

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What is Nature Friendly Lighting?

Nature friendly Outdoor Lighting – approach which reduces negative environmental impact disrupting our body clock and affecting wildlife or biodiversity.

This is NOT only a product or solution but a wide range of qualities that lighting product should have

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What is Nature Friendly Lighting?

Worldwide studies and tests conclusion is that **not only distribution and the brightness** level of artificial lighting at night that impacts the nature, but the **color temperature** also.

Nature Friendly Lighting must be **adaptative solution** controlling both the color temperature and brightness level of light in exterior environments.

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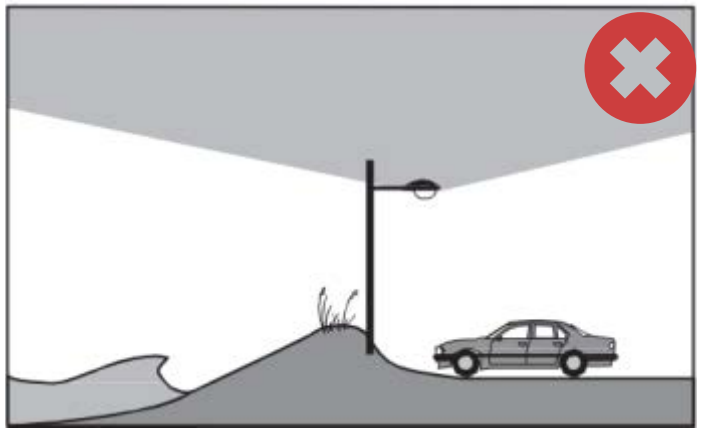
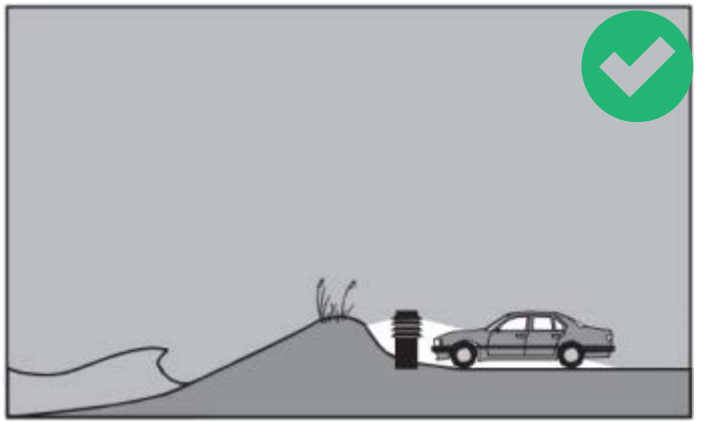
Lighting impact on wildlife

WHY do we need **TURTLE Friendly Lighting**?

A simple rule:

> *If light from an artificial source is visible to a person standing on a beach, that light is likely to cause problems for sea turtles that nest there*





The incorrect lighting at beach front developments:

- alters critical nocturnal behaviors prevents sea turtles from nesting
- disrupts their return path to the sea after nesting
- prevents hatchlings from safely reaching the ocean after emerging
- decrease the survival rate of sea turtles.

Source: Florida Fish and Wildlife Conservation Commission (FWC) Technical Reports

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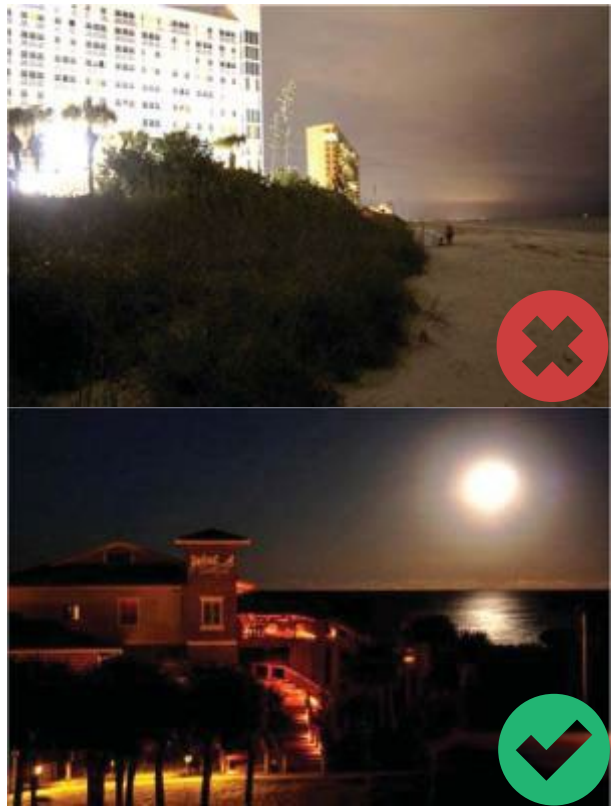
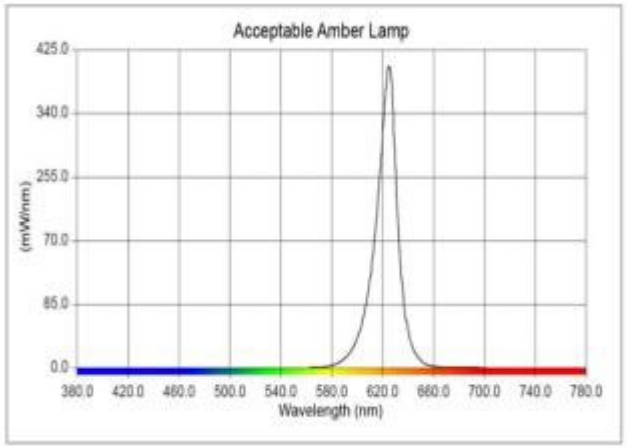
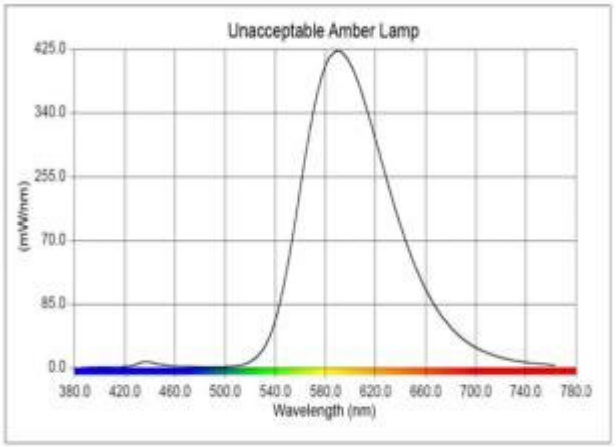
TURTLE Friendly Lighting

Beachfront Property owners should minimize all lights that may be visible from the beach, including all exterior, structural, decorative and landscape lighting following the three golden rules, "Low – Shielded – Long" when installing or modifying their lights:

1. Keep it **LOW** – mounting height and power
2. Keep it **SHIELDED** – full cut-off and only downward-directed light
3. KEEP it **LONG** - wavelength light (≥560nm – amber, orange, red)







Source: Florida Fish and Wildlife Conservation Commission (FWC) Lighting Guidelines

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Lighting impact on wildlife

How is conventional lighting harmful to bats?

Artificial lighting disrupts the feeding patterns of bats in following ways:

1. Bats shy away from bright artificial light at night, staying inside their roosts and missing the opportunity to hunt nocturnal insects, avoiding light due to light-dependant predation risk;

2. Insects are drawn to bright light sources, accumulating near them and creating a vacuum in darker places, where bats primarily hunt.

3. Therefore, when bats get to their usual feeding areas, they find them devoid of food. Bats being unable to hunt and feed themselves properly leads to a decrease in their reproductive ecology, such as slower growth rates and starvation of young

Why is the wellbeing of bats important to us??

Bats are a crucial part of the ecosystem, feeding on various insects and upkeeping the balance in the food chain of their local habitats.

- their numbers dwindle and the entire ecosystem loses its equilibrium
- bats play an essential role in pest control, seed dispersal and crop pollination
- humans can experience significant losses in agricultural industry due to damage to crops and pesticide costs

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Lighting impact on wildlife

What should be the Bat friendly Lighting?

1. Bats are sensitive to bright light, especially the green and blue component of it
2. Warm toned light with lower CCT, as well as red and amber noticeably less disturbs bats, since their retinas barely absorb wavelengths longer than 590nm
3. This kind of light also does not attract insects as strongly as blue and white light does
4. It ensures that insects are present in their usual habitats, reducing the vacuum effect that prevents bats from feeding.

Bat friendly Lighting **impact on humans**:

- As opposed to bats, humans perform better when the light color is cooler
- When the color temperature of light decreases, it is harder for humans to discern details and their reaction time to visual triggers increases.

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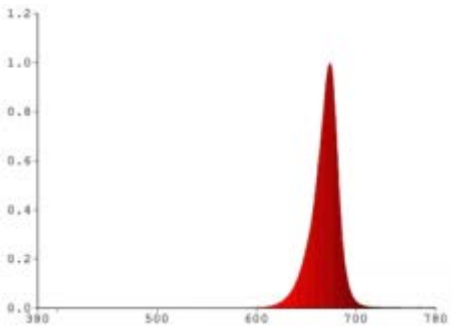
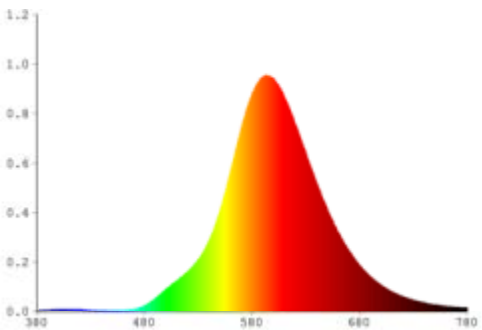
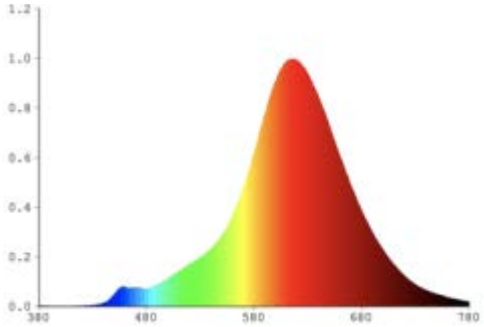
Bat friendly solution :



red



amber



1800 K

Bat Fan – maximal value placed on bat comfort:

- red color lighting – minimal disturbance to bats is achieved
- recommended together with the integrated dual-color technology with smart control

Bat Friend – slightly more disturbing for bats:

- the amber spectral emission peak being closer to blue
- more friendly to human eyes
- balance between being friendly to both humans and bats

Bat Associate

- a warm toned polychromatic illumination (1800 K)
- relatively comfortable to human eyes, while keeping the bats wellbeing
- more energy efficient than amber light yet more disturbing to bats

	Bat Fan *red light*	**Bat Friend** *amber light*	**Bat Associate** *1800 K light*
Relative energy efficiency	+30%	+0%	+15%
Comfort to humans	Low	Medium	Medium
Comfort for bats	High	Medium	Low
Necessity for dual-CCT smart control system	High	Medium	Medium

Please note that we **do not recommend** using this solution along highways and busy roads as, according to studies, red, amber and warm-toned lighting increases the time it takes for humans to react, causing potentially hazardous situations while driving at high speed.

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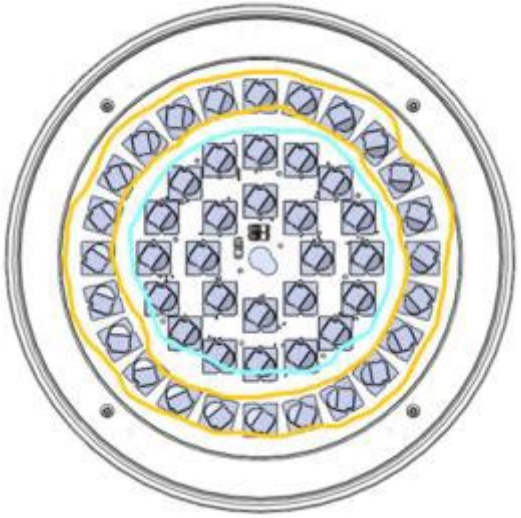
Lighting impact on wildlife

Solution Example 1 - Standalone

1. Double circuit 48 LED:
- Inner Circle - 24LEDs – 3000K, dedicated for street lighting – to keep the Lighting class, according to norm requirements
- Outer circle - 24LEDs – AMBER, dedicated for the Nature friendly application
2. Midnight dimming controlled dual channel electronic driver
3. No external Control system – standalone

Color change (PCB circuits switch) from 3000K to AMBER appears according to driver preprogrammed dimming / color change schedule.



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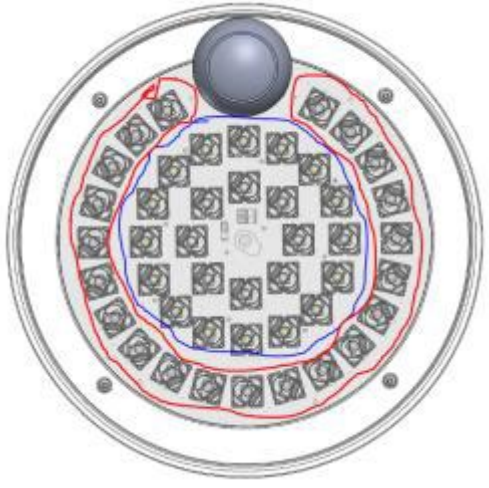
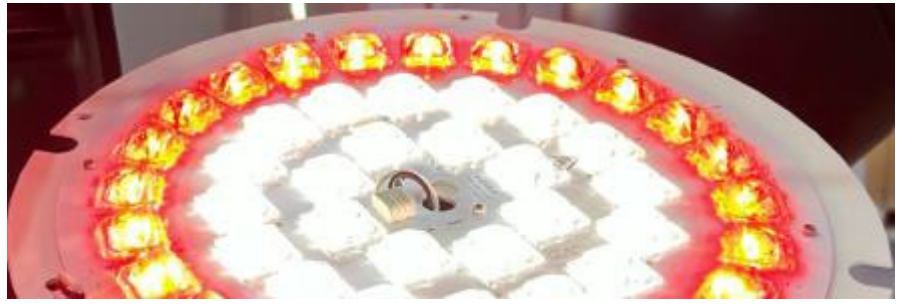
Lighting impact on wildlife

Solution Example 2 – Telemanagement system

1. Double circuit 48 LED:
- Inner Circle - 24LEDs – 3000K, dedicated for street lighting – to keep the Lighting class, according to norm requirements
- Outer circle - 24LEDs – RED, dedicated for the Nature friendly application
2. ZD4i Sensor, controlling dual channel electronic driver
3. Telemanagement Control system

Color change (PCB circuits switch) from 3000K to RED appears according to signal from the sensor. While no presence detection occurence, RED LED circuit stays ON, keeping notcurnal animals life easier





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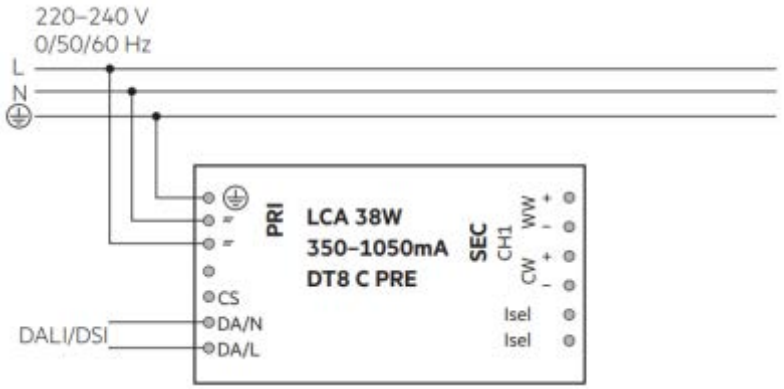
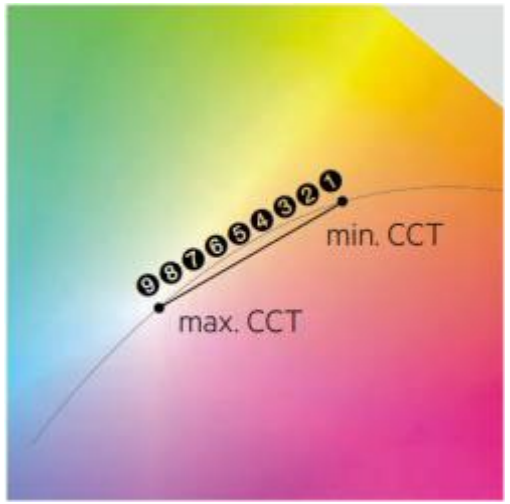
Nature Friendly – Building Blocks





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Standard for physical interface

Standardised communication protocol

Setting the color temperature via color SWITCH mode with 9 values between 2,700 and 6,500 K or via DALI device control system.

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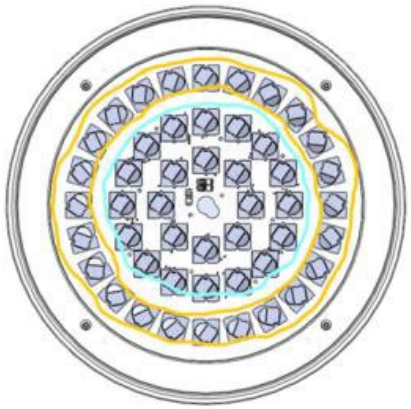

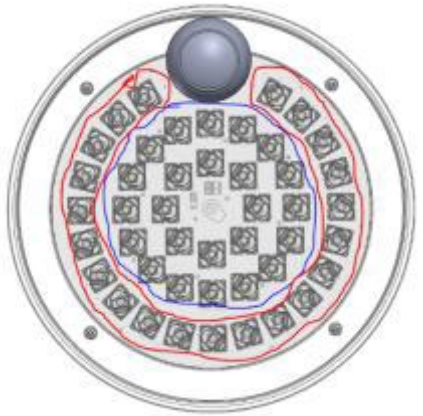

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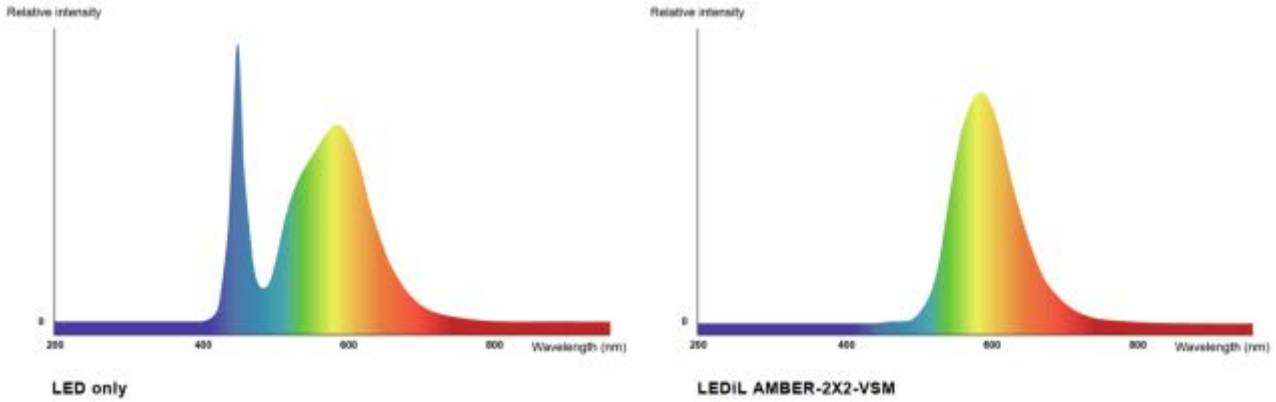
Nature friendly solution – TESTING PHASE

AMBER LENSES – Eliminate ~99% of the blue light from LED spectrum

Spectrum comparison LED vs AMBER



LED CCT	Amount of blue light (380 – 500 nm)
2200 K	0.19 %
2700 K	0.21 %
3000 K	0.32 %
4000 K	0.38 %
5000 K	0.40 %
5700 K	0.44 %
6500 K	0.45 %

Source: LEDIL

Lumen	CCT	CRI
1800 K -12% loss	1865 K change to 1550 K	71 CRI change to 51
3000 K -20% loss	3036 K change to 2101 K	72 CRI change to 44
4000 K -25% loss	4046 K change to 2394 K	71 CRI change to 42
5700 K -30% loss	5873 K change to 2722 K	71 CRI change to 38

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Conclusions (AMBER LENSES)

ADVANTAGES:

- Eliminate ~99% of the blue light from LED spectrum

DISATVANTAGES:

- Because the blue light from the LED is absorbed by the lens, it heavily affects on lens efficiency and temperature
- Max available power is limmited
- CRI drops below acceptable value
- Currently limmited variety of optics

Bio-based raw materials alternative

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The circularity of (bio)plastics suitable for light fixtures

Aluminum vs Plastic

- Aluminium was deemed more circular even when the mechanical recycling of polycarbonate requires less Energy.
- It's because of the loss in properties when polycarbonate is mechanically recycled due to the shredding and remelting.
- Since there have been many advancements in (bio)plastics and the chemical recycling of plastics, multiple (bio)plastics are reviewed to see if they are a better option for the aluminium die-cast regarding sustainability.

Plastic Luminaire design expected properties:

- Required lasting period of a minimum of 20 years
- Suitable to implement threaded holes for a tightening force up to 10Nm
- Same production procedure of casting for freedom in design and shape
- IP66 water resistance
- IK08 impact protection or higher
- Suitable for outdoor use(weatherproof + UV resistant)

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Which (circular) plastics are suitable as replacement for the aluminium die-cast?

1. It has to be as close to 100% recyclable as possible to be viewed as a circular material.

2. It cannot lose properties when recycled because this will mean it cannot be used in the same application.

Table1: Fossil-based Plastics suitable for fixtures: Polycarbonate(PC), Polybutylene terephthalate (PBT) , Polystyrene (PS), Polyvinylchloride (PVC), Poly(methyl methacrylate); plexiglas (PMMA), Acrylonitrile butadiene styrene (ABS), Acrylonitrile styrene acrylate en Polycarbonate (ASA+PC blend)

Plastic	Tg (°C)	Young modulus(E) (GPa)	Tensile strength, Ultimate(σ) (MPa)	Notched Izod Impact (J/m^2)[10] (ASTM D256 and ISO 180)	Price per ton (€)[11]	UV resistance	Suitable for casting
PC[3]	142 - 152	1.8 - 6	30.0 - 105	80.0 - 650.0	2500	+	+
PBT[12]	55 - 65	0.420 - 23.4	21.0 - 166	27.0 - 999.0	2000	+	+ (High shrinkage)
PS[13]	83 - 100	0.894 - 3.55	5.5 - 59	50 - 350	760	With UV stabilizor	+
PVC[14]	70 - 100	0.00163 - 3.24	1.47 - 59.0	20 - 110	520	+	+
PMMA[15]	112	3.2	76	10 - 25	1400	+	+
ABS[16]	105 - 109	0.778 - 6.10	2.60 - 73.1	200 - 215	2000	With UV stabilizor	+
ASA+PC[17]	100	1.86 - 3.10	45.0 - 65.0	600 - 900	2750	+	+

Table 2: Recyclability of selected plastics

Plastic	Recycability
PC[18]	depolymerization
PBT[19]	depolymerization + pyrolysis
PS[20, 21]	depolymerization + pyrolysis
PVC[22]	pyrolysis
PMMA[23]	depolymerization
ABS	mechanical
ASA+PC[24]	mechanical

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Bioplastics

Poly (isosorbide carbonate)(PIC) – is a non-biodegradable polymer made of sugar. The plant-based content is about 56%

Bio-Nylon 10-10 – is a bio-based polyamide 10/10 made from castor oil with a bio-renewable content of 100%

Bio-PVC – uses bioethylene which is produced using lignocellulosic biomass which comes from wood and straw and thus is not competing with the food chain.

Cellulose-based plastic

Bioplastics

1. For bioplastics there has to be made a distinction between biodegradable bioplastics and non-biodegradable bioplastics
2. Most biodegradable plastics are weaker and have a low glass transition temperature when compared with the fossil-based selection. Most of these plastics would thus be unsuitable for the fixtures.
3. A non-biodegradable plastic would be more appropriate for the fixtures. The fixture has to resist being outside for at least 20 years and non-biodegradable plastics typically last and maintains their strength longer
4. Bioplastics usually have a lower carbon footprint than fossil-based plastics

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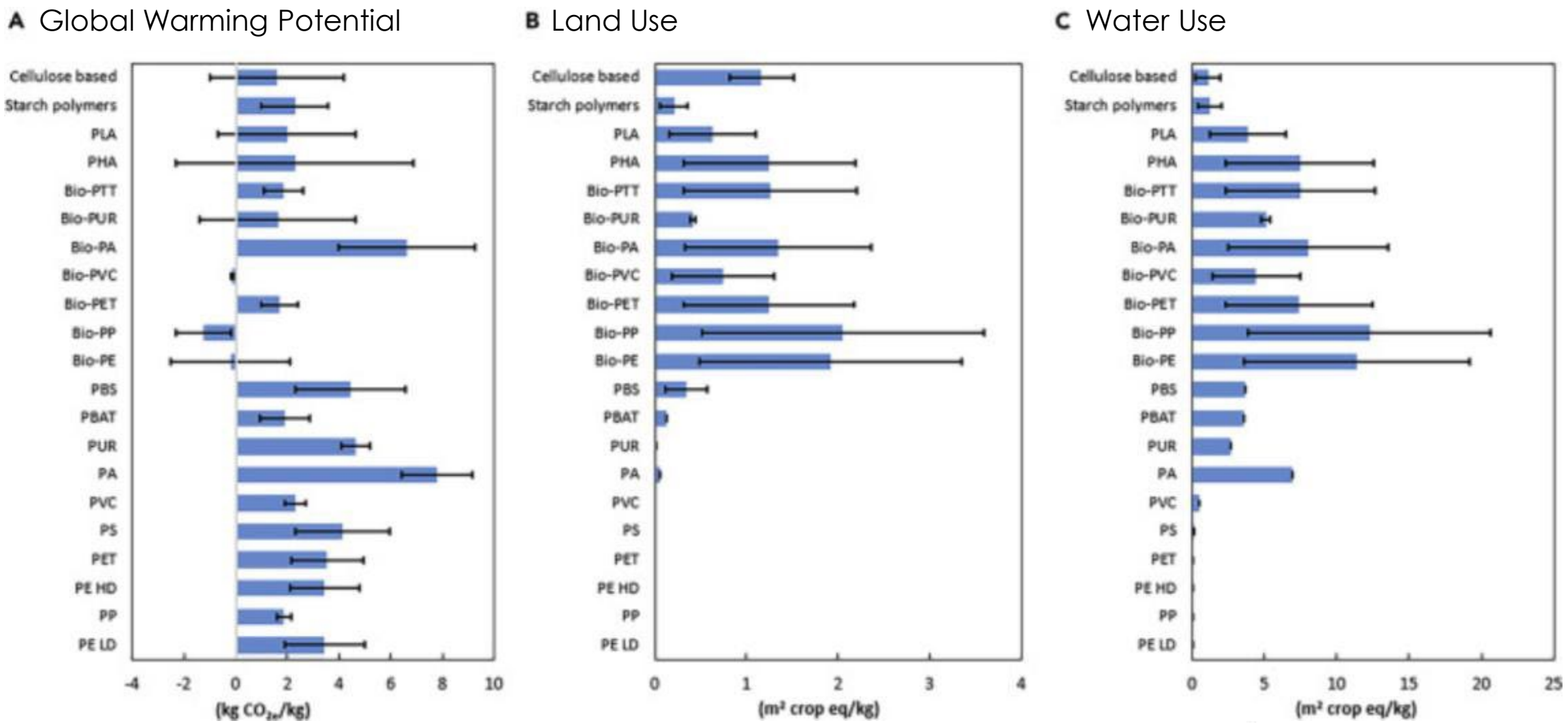
Remarks on the use of Bioplastics



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LCA of aluminium against bio(plastics)

- The primary production of aluminium cost a lot of energy thus has a high $kgCO_2$ eq.
- All fossil and bio-based plastics have a lower $kgCO_2$ eq. for the primary production.
- When only taking into account the primary production a (bio)plastic would seem more sustainable than aluminium.
- When aluminium is recycled it requires substantially less energy. Only about 5% of the initial energy is required thus the carbon footprint of secondary aluminium drops drastically.

LCA – Life Cycle Assessment

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Remarks on the use of Bioplastics

The LCA values of different bio-based and fossil-based plastics shows that the carbon equivalent of a bioplastic in most cases is lower but land and water usage will be increased.

EXAMPLE:

Globally 170 Mt of plastic is used for packaging. If all these fossil-based plastics would be replaced by bioplastics 61 million ha of land would be needed and 388.8 billion m^3 of water. Which is larger than France and more than 60% of the European Union's annual water withdrawal.

It is thus important to **make sure when using bioplastics that the production does not conflict with the food chain or water availability in the countries where the crops are grown**.

Conclusions

1. For a (bio)plastic to beat the currently used aluminium die-cast, it needs to have a lower $kgCO_2$ per recycling cycle equivalent.
2. The focused chemical recycling route for polymers is pyrolysis which is not very efficient regarding energy and thus will not be able to replace aluminium regarding sustainability when recycling and circularity are desired.
3. Currently available biodegradable bioplastics are too weak for the use in light fixtures.
4. Non-biodegradable (bio)polymers which can be recycled using a depolymerization process are likely more circular than aluminium. When the infrastructure would be present for these advanced biopolymers these would be more recommended due to the better physical properties.
5. When the High-impact polystyrene(HIPS) will have the infrastructure to be recycled by depolymerization then it can be considered more circular than aluminium recyclability.

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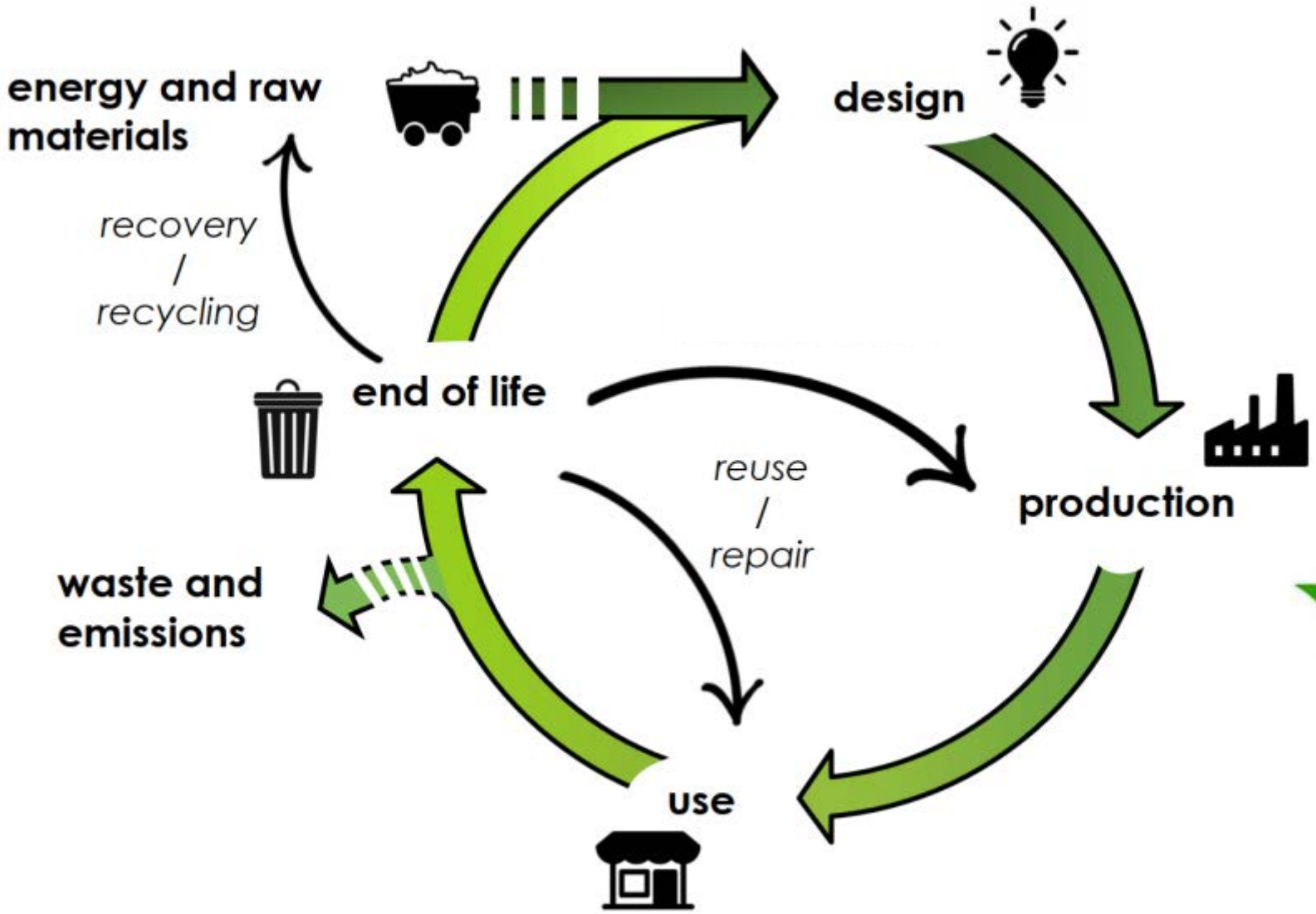
Our Sustainability

EPD®
THE INTERNATIONAL EPD® SYSTEM



Environmental Product Declaration (EPD)

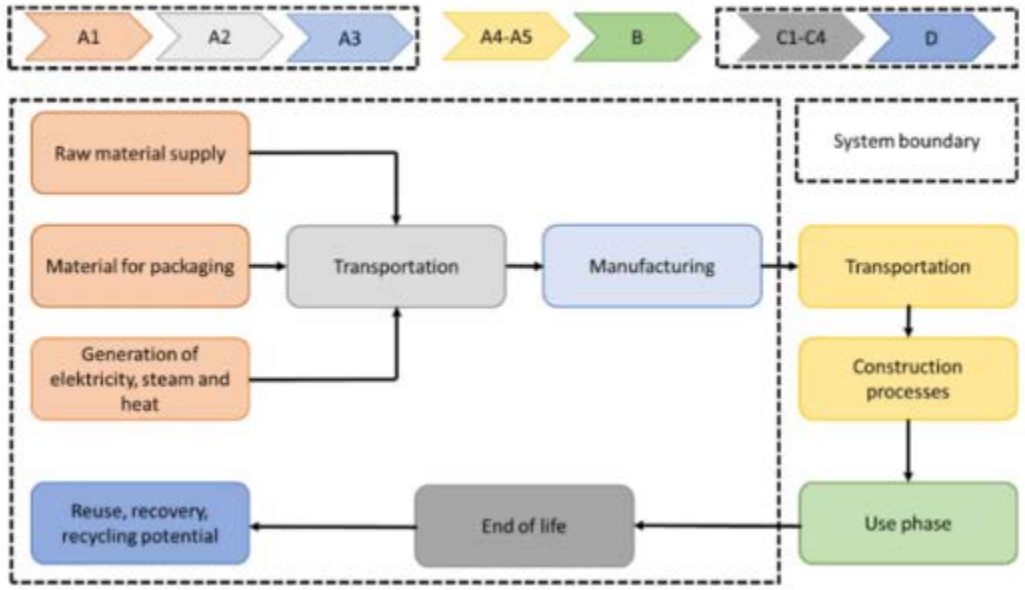


Figure 1 System Boundary of the LCA study conducted on Stork Little Brother luminaire produced by SIA VIZULO

Cut off rules:	The cut-off criterion was chosen based on the used PCR. According to the used PCR, more than 95 % of flows were included.
Allocations:	All material and energy flows were assigned to one product. Allocation was not necessary. No secondary fuels or materials are used in production. Generic process data for production of input materials and components were used.
Geographical scope:	Europe, Global

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Environmental Product Declaration

Content information

The luminaires consist of a die-cast aluminium case, tempered glass, protective rubber, LED diodes mounted on a printed circuit board (PCB), screws, wires and electronic controlgear. None of the materials of the luminaire that are exposed to public are listed on the list of Substances of Very High Concern (SVHC).

Table 2 Product content declaration

Material/Component	Stork Little Brother
Die-cast aluminium (kg)	4,1878
PMMA (kg)	0,0352
Epoxy resin (kg)	0,1052
Stainless steel (kg)	0,0208
Glass (kg)	1,0028
Silicone (kg)	0,0924
Polyester (kg)	0,0744
Polyamide (kg)	0,0132
Polyethylene (kg)	0,0218
Copper (kg)	0,0218
Nylon (kg)	0,0012
LED driver (pcs)	1

PMMA (Polymethyl methacrylate)

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Environmental Product Declaration

Environmental performance

Environmental indicators shown below are calculated according to ISO 14025 and EN 15804+A2:2019.
Results per declared unit – 1 piece of Stork Little Brother luminaire are presented.

Table 3 Environmental indicators by modules A1-A3, C1-C4 and D

Parameter	A1	A2	A3	C1	C2	C3	C4	D
Climate Change - total [kg CO2 eq.]	4,83E+01	1,37E+00	5,45E-01	0,00E+00	7,71E-02	4,27E-03	1,84E+00	-3,58E+01
Climate Change, fossil [kg CO2 eq.]	4,82E+01	1,37E+00	4,02E-01	0,00E+00	7,66E-02	4,23E-03	9,03E-01	-3,58E+01
Climate Change, biogenic [kg CO2 eq.]	9,98E-02	-5,35E-04	1,42E-01	0,00E+00	-9,83E-05	3,59E-05	9,32E-01	-5,64E-03
Climate Change, land use and land use change [kg CO2 eq.]	1,53E-02	7,58E-03	3,02E-04	0,00E+00	6,31E-04	5,98E-06	1,56E-04	-1,08E-02
Ozone depletion [kg CFC-11 eq.]	7,72E-08	1,54E-16	9,19E-12	0,00E+00	9,85E-18	1,01E-16	1,10E-15	-1,11E-13
Acidification [Mole of H+ eq.]	2,10E-01	2,65E-03	6,65E-04	0,00E+00	7,78E-05	8,79E-06	6,45E-04	-1,32E-01
Eutrophication, freshwater [kg P eq.]	2,06E-03	2,82E-06	1,13E-05	0,00E+00	2,29E-07	1,13E-08	1,02E-06	-1,61E-05
Eutrophication, marine [kg N eq.]	2,91E-02	1,07E-03	3,10E-04	0,00E+00	2,50E-05	2,09E-06	2,57E-04	-2,26E-02
Eutrophication, terrestrial [Mole of N eq.]	3,18E-01	1,20E-02	2,86E-03	0,00E+00	2,98E-04	2,19E-05	3,09E-03	-2,46E-01
Photochemical ozone formation, human health [kg NMVOC eq.]	8,98E-02	2,94E-03	6,24E-04	0,00E+00	6,76E-05	5,67E-06	6,73E-04	-6,76E-02
Resource use, mineral and metals [kg Sb eq.]	4,48E-04	8,52E-08	1,88E-07	0,00E+00	5,87E-09	1,24E-09	1,61E-08	-6,56E-05
Resource use, fossils [MJ]	5,60E+02	1,84E+01	4,94E+00	0,00E+00	1,03E+00	7,52E-02	1,16E+00	-4,81E+02
Water use [m³ world equiv.]	6,16E+00	8,61E-03	2,08E-02	0,00E+00	6,69E-04	6,78E-04	2,72E-01	-2,08E+00

Table 4 Resource use indicators by modules A1-A3, C1-C4 and D

Parameter	A1	A2	A3	C1	C2	C3	C4	D
Use of renewable primary energy (PERE) [MJ]	2,30E+02	7,02E-01	1,38E+00	0,00E+00	5,72E-02	3,46E-02	3,02E-01	-1,56E+02
Primary energy resources used as raw materials (PERM) [MJ]	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Total use of renewable primary energy resources (PERT) [MJ]	2,23E+02	7,02E-01	1,38E+00	0,00E+00	5,72E-02	3,46E-02	3,02E-01	-1,56E+02
Use of non-renewable primary energy (PENRE) [MJ]	6,88E+02	1,84E+01	4,95E+00	0,00E+00	1,03E+00	7,52E-02	1,16E+00	-4,81E+02
Non-renewable primary energy resources used as raw materials (PENRM) [MJ]	9,42E-01	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Total use of non-renewable primary energy resources (PENRT) [MJ]	6,25E+02	1,84E+01	4,95E+00	0,00E+00	1,03E+00	7,52E-02	1,16E+00	-4,81E+02
Input of secondary material (SM) [kg]	9,21E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Use of renewable secondary fuels (RSF) [MJ]	0,00E+00	0,00E+00	4,72E-10	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Use of non renewable secondary fuels (NRSF) [MJ]	0,00E+00	0,00E+00	5,54E-09	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Use of net fresh water (FW) [m3]	5,55E-01	8,13E-04	6,08E-03	0,00E+00	6,55E-05	3,37E-05	6,47E-03	-3,13E-01

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THANK YOU

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