SMART LIGHTING ENGINEERING

smart lighting engineering

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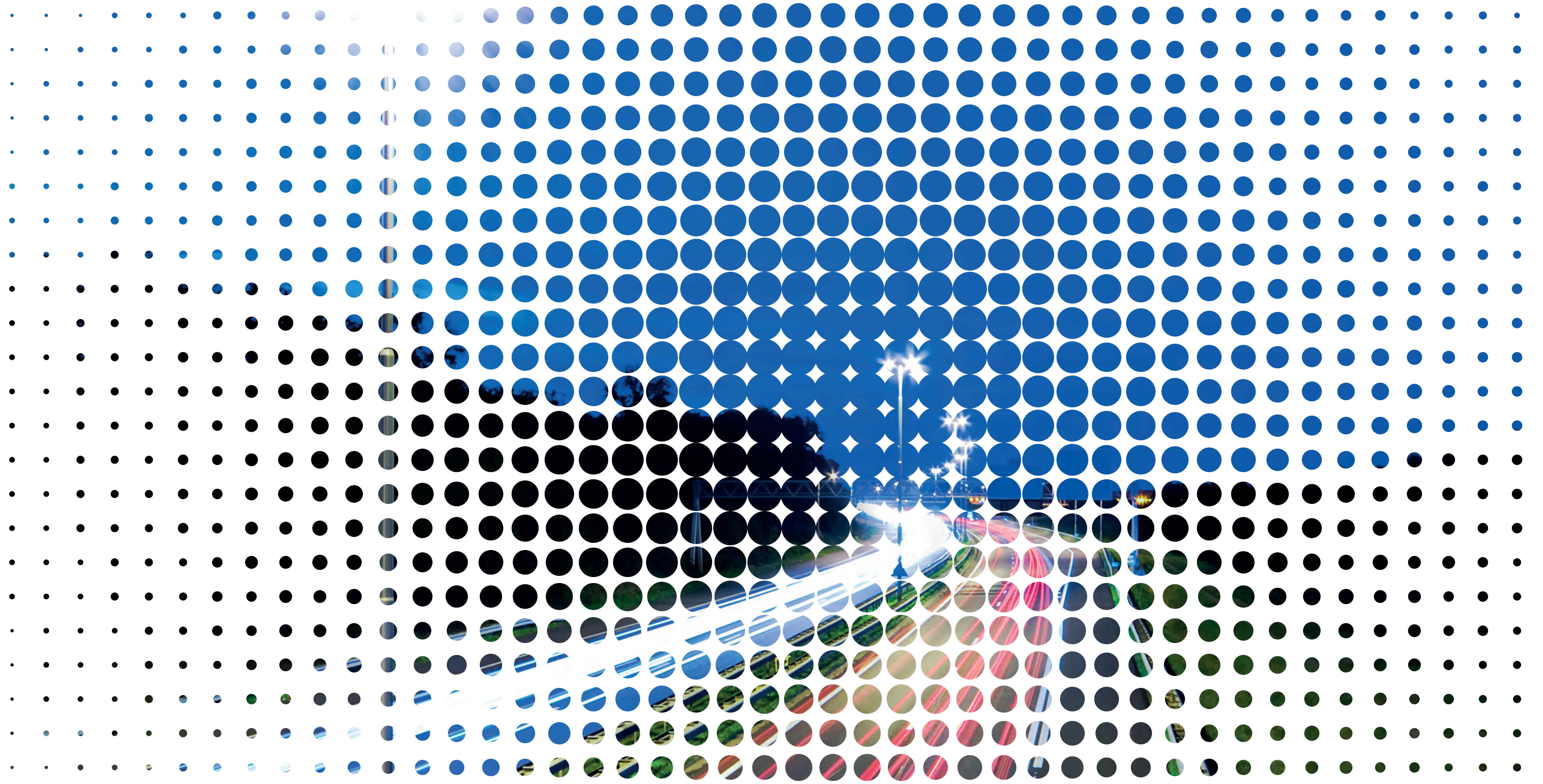


LIGHT AND SAFETY

A NEW DIRECTION
IN STREET LIGHTING

smart lighting engineering

A new way of thinking about the safety, security and efficiency of our streets

INTRODUCTION

Public lighting systems need no longer be defined by the yellow light of high-pressure sodium lamps, which were chosen purely based on their efficacy. Now there is another option, one that is simply better.

Advancements in light source technology now allow us to introduce a new light to our public spaces, a light that combines properties of daylight with energy efficiency. That light is high quality white light, which is perceived as brighter and more natural than the light emitted by conventional light sources. White light sources have comparable or better efficacies than high-pressure sodium lamps, with another benefit being that the light emitted is more visually effective.

Current standards for public lighting, with a focus especially on the illumination of roads, do not fully implement the findings of modern research and understanding of light. In order to achieve the greatest energy savings it is important that all involved in the creation of standards and the manufacture of luminaires and light sources use the available knowledge to make our streets safer and more efficient.

CONTENT

WHITE LIGHT

The yellow light of many older street lighting luminaires enables very poor colour rendition, which limits visual acuity. Another disadvantage is that the light is emitted in all directions, including into the night sky causing light pollution. White light, in combination with modern luminaires, ensures that the light is emitted onto the roads and pavements and not wasted where it is not needed. This minimises light pollution and helps to reduce the incidence of traffic accidents as well as criminal activity, making our streets look better and feel safer.

Figure 1
Low quality yellow light

Figure 2
High quality white light

These two photographs show similar streets. Figure 1 shows a street illuminated by an old lighting installation and Figure 2 shows another street after the lighting was renovated using modern luminaires and white light sources. The white light is more focused where needed and appears brighter and more natural, promoting safety. The new installation is also much more efficient than the original one.

SECURITY, CRIME AND ACCIDENT PREVENTION

The main function of public lighting in the darker hours is to provide high enough levels of illumination to enable the detection and identification of objects and people, as well as escape routes in the event of an emergency. There is clear quantitative evidence suggesting that vertical illumination at a level of 10–30 lx enables those whose vision is fully adapted to the light level to easily detect and recognise objects and approaching people, cyclists and vehicles.

Another function of public lighting is property protection. The most commonly used security lighting technique involves illuminating a guarded area with at least twice as much light as adjoining areas, which enables easy recognition of any activity in the area as well as reducing shadows and dark corners where criminals could lurk. An alternative technique could be to illuminate only key areas using luminaires directed outwards to brightly illuminate such weak spots as entrances and deter criminals from attempting to break in or damage property. Furthermore, public lighting also enables CCTV cameras to clearly record the events in monitored locations.

White light is highly beneficial with regard to all the demands placed on public lighting, as it is perceived as brighter and provides superior colour rendition compared to the yellow light so commonly found. This greatly improves the visual acuity of those in our streets and public spaces, encouraging people to enter areas and stay longer, which in turn acts to invite more people, ultimately leading to increased safety and security. In addition, white light also improves the clarity of images recorded by CCTV cameras, helping in the identification of people and vehicles as well as providing reliable evidence in the case of recorded criminal activity.

Figure 3
White light enables the police to better guard our streets

Figure 4
With white light is easier to find and identify criminals

SAFETY AND ATMOSPHERE

It goes without saying that better visibility improves road safety. White light enables higher levels of peripheral visual acuity, helping drivers to notice roadside movement sooner and from a greater distance. This gives them precious extra time to stop in the case that a child, pedestrian, cyclist or animal unexpectedly crosses their path, reducing the incidence of accidents and fatalities.

Figure 5
White light enables higher levels of visual acuity for pedestrians and road users, reducing the incidence of accidents

Increased visibility is just as beneficial to pedestrians as for road users, helping them to see and react to oncoming traffic sooner. There is also evidence that higher levels of visual acuity act to prevent pedestrian accidents as obstacles are more clearly seen and avoided.

Figure 6
Our homes and communities feel safer and are more secure with the right lighting

White light is ideal for the illumination of roads and public areas not only because of its ability to improve visual acuity, but also thanks to the ambience it creates. The properties of white light are similar to those of daylight, making it preferred over the unnatural poor yellow glow of high-pressure sodium lamps. The natural atmosphere created by white light promotes feelings of safety, making our public spaces more livable and enjoyable.

White light is also perfect for illuminating architectural areas as it highlights details that would normally be lost during the night hours. People react positively to the new life this breathes into parks, city squares and streets, encouraging them to spend more time celebrating the beauty of their towns and cities and instilling a feeling of civic pride.

From a practical point of view, by encouraging increased activity in our public spaces, white light also indirectly improves safety and security as increased numbers of people automatically make a space safer. It discourages criminal activity such as vandalism and aggressive behaviour and in turn makes it even more appealing for residents to spend time outside. The effects support and strengthen each other, bringing a hole new lease of life to our hometowns.

AESTHETICS AND DEVELOPMENT

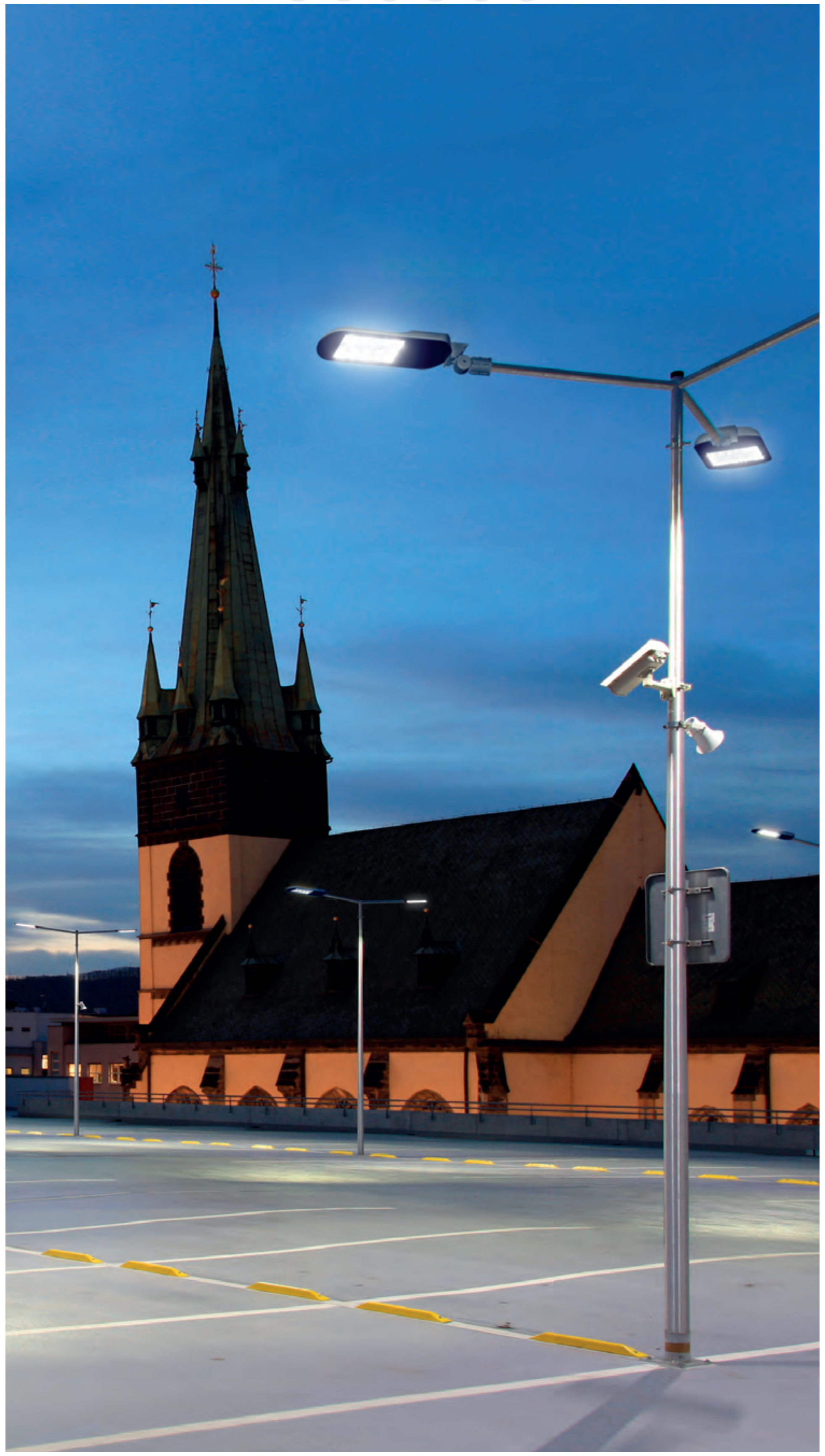
Well designed public lighting can support the economy of communities and cities by attracting visitors to all matter of outdoor activities such as markets, concerts and cultural events. It is therefore important that key buildings, monuments and parks are well illuminated to be appealing to those passing through.

Figure 7
City centres feel bright and airy even during the night

Figure 8
Parks and squares can now be full of life at all times of the day

Figure 9
The details of architectural buildings and monuments need no longer be lost in darkness

Higher levels of illumination should always be used for paths, signs, building facades and landscape features. The choice of light colour and the ability of a light source to render colours well should be key factors in a lighting designer's concept.



VISIBILITY AND COMFORT

Visual acuity is determined by brightness level, lighting uniformity and distribution, contrast and glare. It is important that public lighting be designed to illuminate areas as uniformly as possible so as to minimise the need for our eyes to adapt to changes in brightness. It is also vital to maintain sufficient levels of contrast between objects and their background to aid perception and recognition. However, visually detrimental excessive contrasts should be avoided at all times.

Figure 10
Uniform illumination

Figure 11
Contrast aids perception and recognition

Contrast is defined by calculating the difference between the luminance of an object and its background. The illumination level need not be enough to enable easy perception of colour or detail.

The contrast provided by white light makes it easier to identify objects as well as increasing the perception of colour and detail. This leads to safer roads for all users and pedestrians as they can more clearly see what is happening around them.

ENERGY SAVING POTENTIAL

In modern street lighting installations, there exist ways by which to save significant amounts of energy while guaranteeing that the provided light is of an appropriate quality and quantity for the given road conditions in accordance with standards.

One way is through the use of a Lighting Management System (LMS) that regulates the lighting according to estimated or real-time traffic flow, and/or according to real-time weather conditions. In both cases, it is possible to achieve this energy saving based on the idea that when the illumination of a road exceeds that defined by standards for the given conditions, it is possible for the LMS to reduce the output accordingly without it falling below standard or compromising road safety. This functionality can be supplemented by the Constant Lumen Output feature programmed into many LED drivers, which compensates for the inherent lumen decrease of light sources throughout their lifetime.

A further energy saving method involves the use of light sources with high S/P ratios, which emit higher quality light that provides the same level of visual acuity from less energy when compared to conventional light sources with lower S/P ratios. Furthermore, the use of high performance optics can improve energy saving potential due to the luminous output being better distributed and losses minimised. In order to benefit from these energy saving methods, the luminaire design must be factored into the overall system design from the beginning of the planning process.

Each of the mentioned methods can be used independently or in connection with others. In all cases, we can rest assured that at no point will the road illumination be insufficient, and that savings are always possible.

WEATHER CONDITIONS

The photometric parameters recommended for lighting a road strongly depend on the reflectivity of its surface, which, along with the performance of the lighting installation, is greatly influenced by the prevailing weather conditions of any given time.

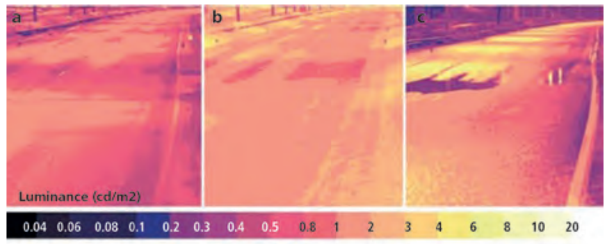


Figure 12
Luminance distribution of the observed MEW3 class road in different weather conditions

EUROPEAN STANDARD EN 13201-2 REQUIREMENTS FOR THE ILLUMINATION OF MEW3 CLASS ROADS

L_{av} = 1 cd/m²	
U_0 = 0.4	dry conditions
U_0 = 0.15	wet conditions
U_L = 0.6	the application of the criterion is voluntary but recommended for application on high class roads and motorways

L_{av} – Average luminance
U_o – Overall uniformity
U_L – Longitudinal uniformity (lowest of the longitudinal uniformities of all driving lanes)
$U_{L,left}$ – Longitudinal uniformity of the left driving lane
$U_{L,right}$ – Longitudinal uniformity of the right driving lane

DRY SURFACE

L_{av} = 1.11 cd/m²	
U_0 = 0.74	
$U_{L,left}$ = 0.782	
$U_{L,right}$ = 0.814	

The luminance of the observed road in dry weather conditions. In this case, all recommended photometric parameters are fulfilled. The luminance level is slightly higher than required due to planned over-dimensioning of the system to compensate for deterioration of light output as the lighting system gets dirty and ages.

SLIGHTLY SNOWY SURFACE

L_{av} = 1.66 cd/m²	49 % higher than in dry weather conditions
U_0 = 0.639	14 % lower than in dry weather conditions
$U_{L,left}$ = 0.808	3% higher than in dry weather conditions
$U_{L,right}$ = 0.756	7 % lower than in dry weather conditions

WET SURFACE

L_{av} = 2.37 cd/m²	113 % higher than in dry weather conditions
U_0 = 0.22	71 % lower than in dry weather conditions
$U_{L,left}$ = 0.398	50 % lower than in dry weather conditions
$U_{L,right}$ = 0.618	24 % lower than in dry weather conditions

Figure 12A
Dray surface

Figure 12B
Slightly snowy surface

Figure 12C
Wet surface

The luminance of the observed road in slightly snowy conditions. In this case, all recommended photometric parameters are fulfilled but the values are not optimal. The average road surface luminance is 49 % higher than in dry weather conditions.

The luminance of the observed road in wet weather conditions. In this case, recommended photometric parameters are fulfilled with the exception of longitudinal uniformity, the criteria of which is for voluntary application. The average road surface luminance is 113 % higher than in dry weather conditions and the overall uniformity has decreased by 71 % but still fulfils standards.

What these findings show us is that weather conditions can have a significant impact on the luminance of a road surface. As the human eye registers luminance and not illuminance, it means in practice that lighting levels can be greatly decreased in certain weather conditions while still fulfilling the recommended visual needs of road users. This converts into a considerable potential to save energy when weather conditions are factored into road lighting. It is possible to also apply this kind of energy saving on lighting installations used on ME class roads in drier countries where roads are not often damp or wet during the night hours. However, as energy savings depend on weather conditions the overall saving potential will be less.

TRAFFIC FLOW

The required lighting parameters for one road can vary greatly depending on traffic flow, especially in terms of required luminance levels. When traffic flow is lighter, predominantly during the early morning hours, it can be appropriate to reduce levels of luminance without compromising safety. It is necessary to classify the road for every reference point of time according to the tables found in Annex A of EN 13201-1 and in accordance with the appropriate road authorities. However, standards only classify traffic flow according to the number of cars using a road per day, not taking into consideration rush hours and times of little activity. In this case it is necessary to use a little common sense to identify the times when traffic flow is greater or lesser and to adapt the road lighting requirements accordingly.

It is necessary to use dynamic road lighting to achieve the desired reduction in illumination according to traffic flow, as well as according to the time of day and weather conditions. However, it is possible to use a common Lighting Management System to adapt lighting conditions to expected traffic flow and times of day even if not according to weather conditions, an option that is easy to implement and still provides significant saving potential.

S/P RATIOS AND MESOPIC VISION

Further energy savings can be provided by using light sources with high S/P ratio – the ratio between scotopic and photopic vision. This is based on understanding and utilising the basic physiology of the human eye and its receptors. There are three types of receptor, two of which are responsible for basic vision. Cones are most active in well-lit conditions and therefore act as the base for photopic vision. Rods are most active in poorly-lit conditions and therefore act as the base for scotopic vision. Mesopic vision lays somewhere between photopic and scotopic vision and is facilitated by both cones and rods. Cones and rods have increased sensitivity to different parts of the light spectrum. In darker conditions our vision is more acute under light that is strong in lower wavelengths (green/blue) and less acute under light that is strong in higher wavelengths (yellow/red). By taking advantage of this we can provide light that is literally more effective at the given brightness levels. For example, under the light emitted by a high-pressure sodium lamp the S/P ratio is a very low 0.65 with brightness perception reduced by 35 % in scotopic conditions when compared to photopic conditions. Figure 14 compares mesopic with photopic vision at various luminances and using different light sources with different S/P ratios.

Figure 13
Vision types and luminance

	LUMINANCE
Photopic vision	>5 cd/m²
Mesopic vision	0.005 – 5 cd/m²
Scotopic vision	<0.005 cd/m²
Used luminance on road	0.3 – 2 cd/m²

Figure 14
Differences between mesopic and photopic luminance (%) calculated with the recommended mesopic system for a range of light source S/P ratios (CIE 191)

	S/P	Photopic luminace (cd/m²)									
		0.01	0.03	0.1	0.3	0.5	1	1.5	2	3	5
LPS~	0.25	-75 %	-52 %	-29%	-18%	-14%	-9%	-6%	-5%	-2%	0%
	0.45	-55%	-34%	-21%	-13%	-10%	-6%	-4%	-3%	-2%	0%
HPS~	0.65	-31%	-20%	-13%	-8%	-6%	-4%	-3%	-2%	-1%	0%
	0.85	-12%	-8%	-5%	-3%	-3%	-2%	-1%	-1%	0%	0%
	1.05	4%	3%	2%	1%	1%	1%	0%	0%	0%	0%
WWMH~	1.25	18%	13%	8%	5%	4%	3%	2%	1%	1%	0%
	1.45	32%	22%	15%	9%	7%	5%	3%	3%	1%	0%
	1.65	45%	32%	21%	13%	10%	7%	5%	4%	2%	0%
	1.85	57%	40%	27%	17%	13%	9%	6%	5%	3%	0%
	2.05	69%	49%	32%	21%	16%	11%	8%	6%	3%	0%
CWLED~	2.25	80%	57%	38%	24%	19%	12%	9%	7%	4%	0%
CWMH~	2.45	91%	65%	43%	28%	22%	14%	10%	8%	4%	0%
	2.65	101%	73 %	49%	31%	24%	16%	12%	9%	5%	0%

Figure 15
Examples of the S/P ratios of various light sources

LIGHT SOURCE	S/P RATIO
Incandescent	1.36
Fluorescent (3500 K)	1.36
Fluorescent (5000 K)	1.97
Metal-halide (warm white)	1.20
Metal-halide (cool white)	2.4
Hight-pressure sodium	0.65
Low-pressure sodium	0.25
LED (3500 K)	1.39
LED (6000 K)	2.18

A real example: ME3 class roads are required by standards to have a luminance of 1 cd/m². Compared with photopic conditions, in mesopic conditions we perceive 4 % less light from a high-pressure sodium lamp and 11 % more light from a cool white LED light source. This means that the use of the right kind of LED light source for the illumination of such a road translates into a 15 % improvement in perception when compared to the use of conventional yellow light.

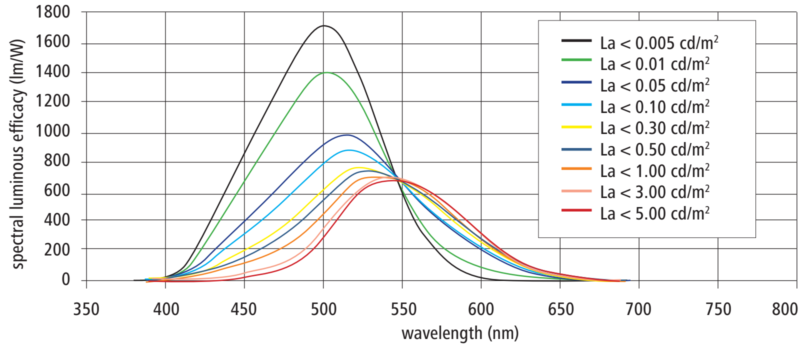


Figure 16
Spectral luminous efficacy of radiation for selected luminances

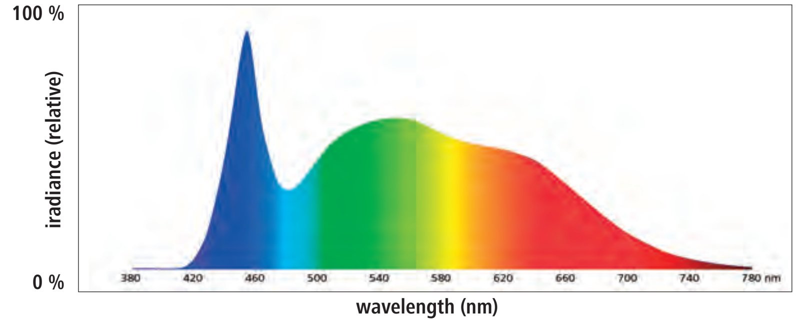
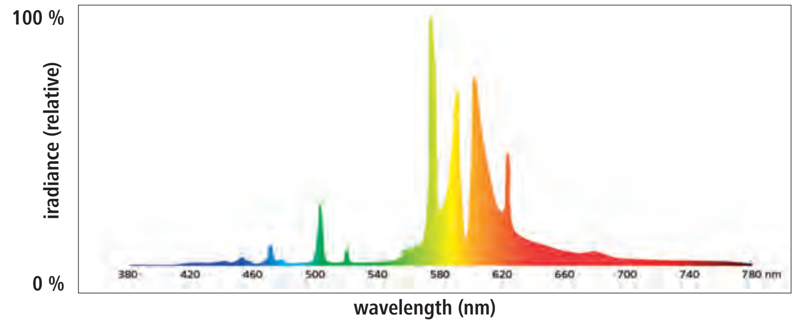


Figure 17
To have highest possible S/P ratio and the best visible conditions, must be spectrum the most similar as possible like curve from Figure 16 for actual luminance value

LED 6000 K
S/P = 2.18



High-pressure sodium,
S/P = 0.65

LUMINAIRE OPTICS

Figure 18 shows how luminaire optics can be developed to minimise the amount of light falling outside of the target area and ensure 100 % illumination uniformity of the road surface. This reduces the amount of light being emitted to where it is not needed, and therefore wasted, which results in a decrease in energy consumption whilst still fulfilling the recommended visual needs of road users. This feature has the added benefit of limiting light pollution.

Figure 18A
An installation using conventional luminaires that allow a large proportion of light to fall outside of the target area and be distributed into the sky as light pollution

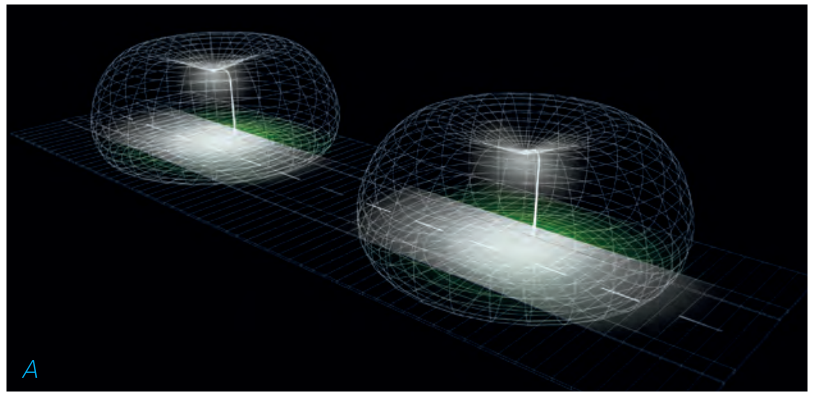
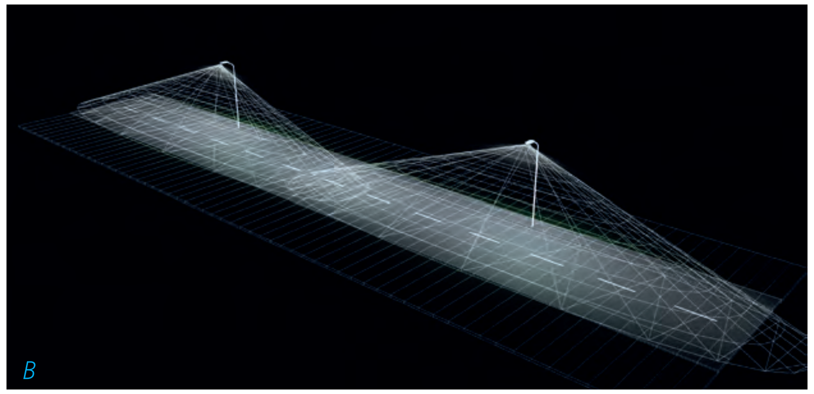


Figure 18B
An installation using luminaires with high performance optics that minimise the amount of light falling outside of the target area



The use of LED light sources for road lighting has several energy saving advantages additional to the positive effect of their S/P ratios.

Firstly, they emit light in a direct way as opposed to conventional light sources that emit light in all directions, providing a more effective and therefore efficient distribution of the light falling in the target area. This results in the need for fewer and less powerful light sources to fulfil the recommended visual needs of road users when compared to conventional light sources.

Secondly, they provide more uniform illumination and less glare, which contributes to better visual comfort and acuity for drivers and other road users.

Thirdly, luminaires using high performance optics can laterally project light more then five times the distance of the mounting height, as illustrated in Figure 19, for lower class streets the ratio of height to distance between luminaires can be as high as 1:9. This results in fewer luminaires being needed to fulfil the recommended visual needs of road users, which in turn reduces energy consumption, and installation, labour and maintenance costs.

Figure 19A
An installation using conventional luminaires that illuminate unevenly, creating 'hot spots' that reduce visual acuity

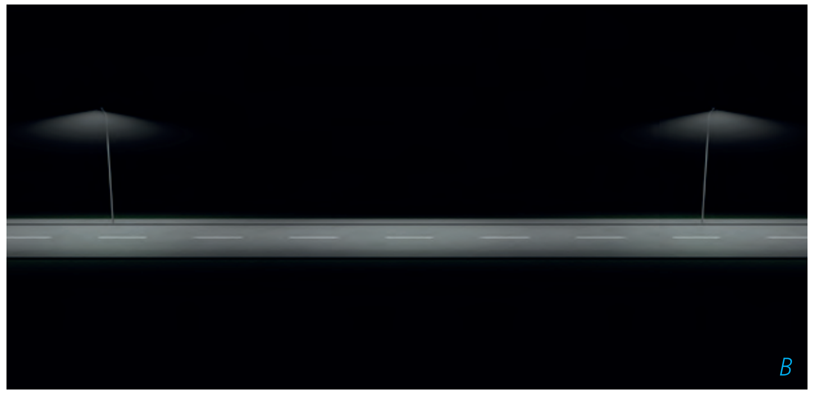


Figure 19B
An installation using luminaires with high performance optics that emit light laterally over a large distance, ensuring that the road is evenly illuminated and visual acuity maintained

Figure 20 shows how much of the light emitted falls in the target area. This is referred to as the Utilisation Factor (UF), calculated by multiplying the average maintained illuminance (lux) by the target area to be illuminated (in m^2), the product of which is divided by the total installed lumens (lm) and multiplied by 100.

$$UF = \frac{\text{average maitained illuminance * area of the target illuminated}}{\text{total installed lumens}} * 100$$

Figure 20
Comparison between a higher powered conventional light source and LED

LIGHT SOURCE	METAL-HALIDE 250 W	LED
Net power consumption of the luminaire (W)	265	123
Lamp power (W)	250	123
Output of the light source (lm)	19,000	10,800
Light Output Ratio (%)	70.5	85
Net lumen output (lm)	13,400	9,200
Utilisation Factor – UF (%)	54	78
Light falling in the target area (lm)	7200	7200

We can see from the calculated UF value for the conventional light source luminaire that 46 % of the light emitted is wasted. However, the LED luminaire utilising high performance optics ensures that only 22 % of the emitted light is wasted, an improvement of 24 %. This equates to a 46 % reduction in energy consumption whilst still fulfilling the recommended visual needs of road users.

CONCLUSION

The difference between safety and danger is if and how quickly we see potential risk. For this, it is necessary to have the best lighting. No light is more natural for us than daylight. The innovation of LED light sources that emit white light, which closely copies the properties of natural light and, therefore, provides improved visual acuity, allows us to reduce the lumen output of a light source while still ensuring the same perceived levels of illumination as a conventional light source that emits very unnatural light.

Effective security lighting enables building occupants to see the forms and faces of those visiting as well as helping the police to secure reliable information and credible evidence by means of CCTV cameras, and to better perform their job in the streets. Furthermore, white lighting actively deters criminal activity thanks to the perceived brightness and clarity of the illumination.

So, before making a final decision about how best to update your street lighting, be sure to assess the advantages and disadvantages of all available light sources, optics and control systems, to ensure that you fully understand the options and in turn receive the greatest benefits possible.