

# Contemporary urban lighting and lighting of old city centres and historic sites

Vladimir Kocet  
Telektra d.o.o., Sesvete  
Green Building Council of Croatia  
Electrotechnical Society Zagreb

e-mail: Vladimir.kocet@telektra.hr

## ABSTRACT

In the history of lighting design, there are classic shapes that cannot possibly be suppressed, like the typical lighting poles with glass lanterns from the old photographs of every city, and they are present in personal memories and part of the urban décor itself.

With this paper we present the renovation of urban lighting, using new technologies to improve efficiency lighting and energy savings, in order to preserve the infinite charm of the old city centres, and facades of monuments and monumental architecture, using modern optics to reduce light pollution environment and protect the night sky, and Innovative **white light** and **LED** light lamps, thereby taking into account that the design of lighting installations remain inconspicuous, with maximum functionality.

## KEYWORDS

Urban lighting  
Illumination  
White light  
LED  
Lighting management systems  
Energy efficiency



Figure 1. Urban lighting installation on Forum in Zadar, Croatia

## **URBAN LIGHTING DESIGN**

As yet a fairly unconventional city marketing tool, lighting can significantly help boost a town's or city's image. Three factors are crucially important:

- Urban design lighting involves a great deal more than just illuminating an individual monument or church. Any lighting concept today needs to encompass an entire town or urban district, using the tools of architectural lighting to create a harmonious lighting design concordant with existing lighting structures.
- Imposing buildings, monuments or squares are not prerequisites for creating atmosphere with light. Even the humblest village or hamlet can be visually enhanced through the use of architectural lighting tools.
- Image-boosting lighting plans do not need to be abandoned because of budgetary constrictions. Small-scale and shortterm projects can also bear fruit, especially if designed for upgrading at a later date.

Of course, we must not forget the great contribution of Street lighting, lighting of Commercial Buildings and Public Spaces, to the formation of the city budget, just take the energy consumption, as well as ongoing maintenance costs.

One of the basic ideas in the design of contemporary urban lighting, is to use a unified designer line of lamps with different light-solutions, i.e. different light sources, optics (asymmetric, wide symmetrical, focusing optics or optics for street lights or bike lanes), and a variety of applications: single or dual beam, suspension, wall mounting bracket or mounting on the lamp post, in order to revive the decorated landscape, park, historic object or modern architecture.

Normal activities for outside needs require a lower level of illumination of interior lighting. Additional requirement that must be taken into account in outdoor lighting is that each illuminated area viewed from the aspect of the natural brightness of the sky and dark environments. Under these circumstances, good results are achieved with low luminance, resp. with only a few Lux.

The ability of the eye to adapt to various levels of brightness, is called adaptation. Adaptability of the human eye moves within the brightness ratio of 1:10 million. Duration of the adaptation depends on the brightness at the beginning and end of the process. Adaptation to lower gloss lasts longer than adaptation to a higher gloss. The adaptation process allows the complex network of ganglia-nerve cells that transmit information to the brain.

## **THE CRITERIA AND STANDARDS IN DESIGN OF URBAN LIGHTING**

### **Correct lighting design to reduce light pollution**

Contemporary European Standard EN 13201-2 has been made to optimize the required illumination and luminance in roadway lighting, and residential and other cleared areas. When deciding on the required luminance, we observed purpose and function of a given area, which is categorized by zone. All this is done in order not to unnecessarily increased power consumption, and level of illumination. This is, of course, closely related to the problem of light pollution.

In the Republic of Croatia there is preparation of new law called "Law on artificial light". The proposal of law was made on similar legislation, standards and norms in European countries. These are, for example, the Italian standard *UNI 10819:1999* "Light and Lighting - Outdoor Lighting Installations - Requirements For The Limitation Of The Upward Scattered Luminous Flux", and Slovenia's "Decree about limiting values of light pollution of environment".



Figure 2. Italian regulation about light pollution and night light, January 1, 2009 status

Unlike the Italian standards UNI 10819, proposal of "Croatian law on artificial light," provides 5 zone open ambience, according to their illumination. In the zone Z0, a dark zone, provided the 3 zones of respect concerning the distribution of the ambient zone Z0 compared to astronomical observatories.

Croatian draft law also defines the types of light fitting, or luminaire, as well as shaded and unshaded. Shaded is any luminaire that emits a beam of light from the horizontal plane down without dissipation of radiation derived from elements of glass of the luminaire, which is directed above the horizon line. Also shaded is any luminaires which are used for façade lighting of buildings, and is equipped with a visor, louvre or gobo. So, in this article we will talk only about shaded luminaires.

### Using energy efficient light source

Light sources are observed the following characteristics:

- compact (space requirements, size of the luminaires ...)
- use (ease, user comfort: temp. and colour rendering, dimming possibility ...)
- efficiency (luminous efficiency, lifetime, price, replacement cost ...),
- impact on the environment (consumption of electricity, consumption of natural resources, waste...).

In the urban outdoor lighting, one of the most important characteristics is the economy, so we have situation that now in this application still dominate high-pressure sodium lamps. Modern high pressure sodium lamps, although the colour factor of retribution rather low ( $R < 40$ ), have very high energy efficiency (up to 130 lm/W), and a lifetime source of 16 000 hours.

In recent times for the ambient lighting there lighting designers increasingly use a new technology of lamps, e.g. MASTER CosmoWhite CPO-TW. This technology evolved from the need to develop a light source that has an energy efficiency equal to or greater than the high-pressure sodium lamps (light output - input power), but gives much better colour rendering. However, the colour rendering provided by this technology sources (Ra = 65), is not sufficient to complete the application in decorative landscape lighting and a park lighting, or for example illumination of some monument or façade lighting.

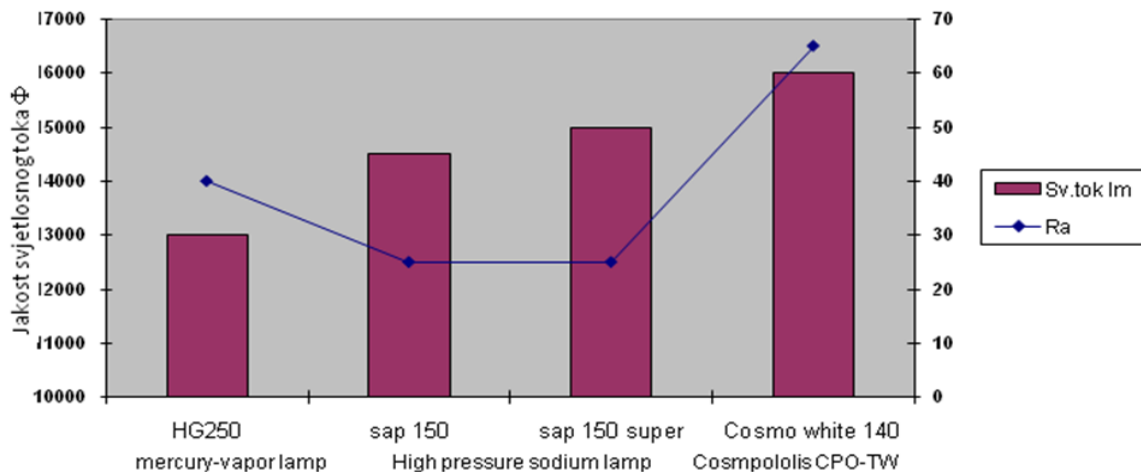


Figure 3. Comparison of Light source

In ambient lighting, other than economy, it is very important a light colour. Therefore, within the European Union in the parks and promenades, squares and shopping malls, are increasingly using ceramic metal halide lamps. Luminous flux of these sources is less than the high-pressure sodium lamps, it is up to 100 lm/W. And their durability is less (up to 12,000 hours). The great advantage of these resources is a factor of colour rendering that is: Ra>80 or even R>90.

The new LED technology of the take the growing momentum in the field of urban, residential environmental, horticultural and landscape lighting. The fact that consumption of these lamps is reduced to only a few watts, and that the lifetime of the source is significantly higher than conventional light sources, greatly contributes to the more frequent use in various applications. Today, it is usually built-in floor lamps (up-lighters), and wall lamps, or lamps in the low columns, up to 1.5m, but the market appears highly sophisticated and high-efficiency lamps with HI-power LED sources, like a classic street lighting, or post-top decorative luminaires, the height of the installation 5-6m.

### Using energy efficient control gears

The European trend is that, as internal, as means for outdoor lighting, leave electromagnetic ballasts and use electronic control gears (ECG) - and thus reduce energy losses. Electronic ballasts (ECGs) have much more smaller losses in the resistance, in compare to electromagnetic ballasts. At a minimum increase of the nominal voltage absolute and relative difference in these losses are significantly increased.

## Using optimal Light Management System (LMS)

Two main factors affect the operating cost of public / outdoor lighting: electricity consumption and maintenance. Given that we are witnessing a continuous growth of energy prices, including electricity, by using efficient electronic control can save up to 50% of electricity, consumed per lamp. Besides the direct impact of energy prices on investment of public lighting, it is necessary to take into account the cost of the maintenance of outdoor lighting. These costs include operating costs of system maintenance, and replacement of worn-out bulbs.

In all practical applications lighting management systems, designed system and his application must be as simple as possible. Given that we have great technology offerings available, our task is to find the simplest "package" to ensure the practicality of the system, and that the system meets the end-user ease of management, and to be easy to handle.



Figure 4. Web link to the MidNight Web application the ON-SiTE, software for programming and street light management

An important recommendation for all cities and municipalities is to establish a database that contains all the techno-economic parameters and the location (position of the pillars) - a register of public lighting. Such a database should contain a list of streets, a list of points, a list of columns, integrating state, a list of events, monthly costs and consumption. Establishing such a database allows you to control spending, reduce maintenance costs and facilitate planning for future needs and expansion of the lighting system.

In each city or county, energy consumption of the public lighting has a share of 1-3% budgetary funds. If we add the costs of current maintenance and, construction costs of new lighting installations, we see that it is not an insignificant amount of budgetary resources. It is also common to see that most parts of the same lighting system not built or maintained in a manner that over time could significantly reduce financial costs for the same installation, but also its impact on overall power consumption. Because of the availability of technical solutions in the construction, maintenance and

use of public lighting, for many cases, clearly visible inefficiencies, the only logical explanation may be lack of information. I guess this will contribute little information about possible energy savings contribute to raising awareness.

## WHY WHITE LIGHTING

### Human eye sensitivity

The sensitivity of human eye to different colours of light at various light levels determines the true, or effective, lumen output of lamp. The eye respond to colour depending upon to amount of light available. Lumens are the standard measure of light output, but light is actually defined as energy evaluated by the eye. Conventional lumen measurement define the light output response of a person only during high light levels (referred to as “photopic” light), typical of daylight and interior lighting. A light meter measures photopic light as seen by the central region of the eye, so published lumen ratings are based on the photopic (“P”) lumen read by light meter.

When light levels are very low, like starlight sky, the viewing conditions are referred to scotopic. Under this conditions, the eye’s response changes dramatically. Sensitivity to yellow and red light is greatly reduced, while response to blue light is significantly increased. If lamp lumens under scotoping viewing conditions have been determined using photopic measuring devices, the lumen accurately measure the true amount of light as perceived by the human eye. Scotopic (“S”) lumens are lumen measurements corrected for night-time conditions.

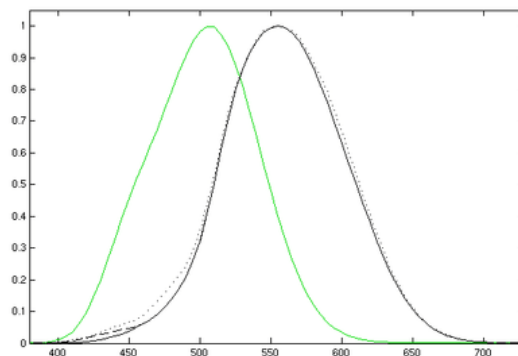


Figure 5. Photopic (black) and scotopic (green) luminosity functions.

The ratio of light measurement by photopic and scotopic methods is called “S/P ratio”. The S/P ratio for white-blue (5000K daylight) light source is 2.1. At 4000K the ratio is 1.65, and for HPS lamps the ratio is 0.64. As a result, 4000K light source are at least twice as effective for viewing at night compared to HPS source at the same photopic luminance. 5000K light source are at least three times as effective.

By understanding how the human eye registers light, an energy auditor can design an energy efficient project using less power and still achieve sufficient light levels. Thus meaning, more money back in your pocket at the end of a lighting retrofit.

Scotopic lumens or Pupil lumens is calculated with a correction factor applied to the initial lumen output. The more “bright white” the light source, the higher the correction factor is. The Metal Halide’s correction factor is 1.49, so the actual Pupil lumens for



the 400W Metal Halide lamp is:  $36000 * 1.49 = 53640$  Pupil lumens. The HPS's correction factor is 0.68, so the actual Pupil lumens for the 400W HPS lamp is:  $50000 * 0.68 = 34000$  Pupil lumens. Even though both parking lots have the same number of lights in them, the Metal Halide parking lot appears brighter than the HPS parking lot.

There are a number of terms engineers use that reference Apparent Brightness; Visually Effective Lumens (VEL), Spectrally Effective Lumens (SEL) or Pupil Lumens as this measurement, but whatever phrase you use, they all refer to the same thing: Apparent Brightness.

Table 1. Apparent Brightness

Type	Wattage	Photopic Value	Scotpic Value	VEL
High Pressure Sodium	150 W	11250	8550	9082
	250 W	22100	16796	17841
	400 W	36000	27360	29063
	1000 W	90000	68400	72630
Metal Halide (Pulse Start)	150 W	8000	11920	10919
	250 W	15000	22350	20473
	400 W	28000	41720	38216
	1000 W	93000	138570	126940

**Main features of yellow and white light lamps**

A comparison between different types of outdoor lamps is detailed below. Each lamp is assessed based on four key parameters: colour temperature, colour rendering, lamp efficiency and life time. The diagrams show the values relating to the above-mentioned factors for each lamp type.

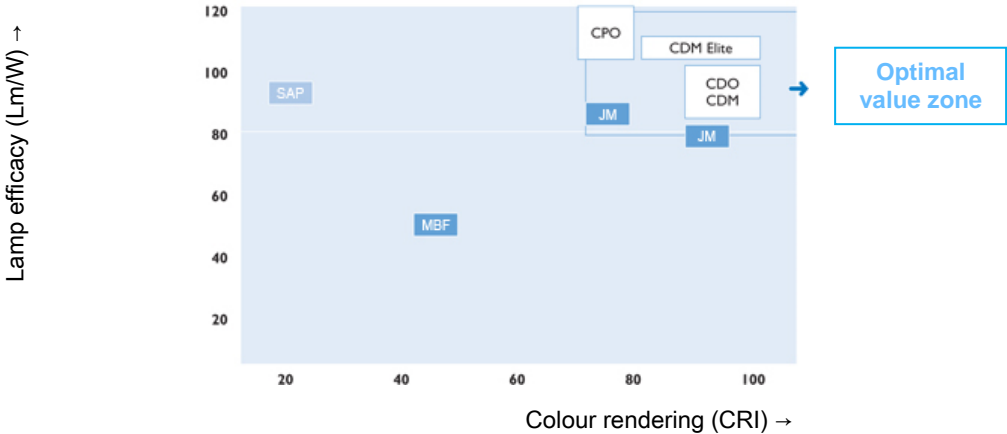


Figure 6. Colour rendering vs. lamp efficacy

Lamp efficiency measures the quantity of light produced per Watt, and it is expressed in lumen per Watt. Energy expenditure and the environmental impact of an installation are proportionate to lamp efficiency. Efficiency should never affect colour rendering, a parameter of the overall importance. The diagram shows data relating to these values for each type of lamp.

The colour rendering index (CRI) shows how accurately colours are reproduced. As regards outdoor lighting, a CRI index over 65 is enough to fulfil user needs. Results show that urban lighting applications require a colour temperature of 2,800 – 3,000 °K. The diagram shows that several different light sources are able to fulfil both criteria.

## HUMAN AND SOCIAL ASPECTS

In the history of lighting design, there are classic shapes that cannot possibly be suppressed, like the typical lighting poles with glass lanterns from the old photographs of every city, and they are present in personal memories and part of the urban décor itself.

It is possible renovation of urban lighting, using new technologies to improve efficiency lighting and energy savings, in order to preserve the infinite charm of the old city centres, and facades of monuments and monumental architecture, using modern optics to reduce light pollution environment and protect the night sky, and Innovative **white light** and **LED** light lamps, thereby taking into account that the design of lighting installations remain inconspicuous, with maximum functionality.



Figure 7. "cluster" version post-top lanterns

Today on a market you have luminaires not only a mere redesigned version of the traditional lamppost, but a new project where great care has been taken over the reshaping of a traditional pattern down to the most minute detail. The lantern comes paired with redesigned poles in matching styles that are decorated with distinctive floral motifs at the base or around the connector joining the pole to the lamp.

The lamp is fitted on the upper part of the lamppost, with light pointing downwards. A floodlight directs light so as to avoid dispersion, in accordance with the latest light pollution regulations. Built from aluminium, lanterns uses state-of-the-art light sources such as metal halide lamps (white light) and LED lights, which enable to obtain aesthetically nicer light effects, and a more efficient and environmentally friendly system.





Figure 8. Modern light technology in classic shape lantern

This lanterns are also a complete urban lighting system suitable for application on single poles, in the double or "cluster" version for squares, as well as for wall or ceiling installation, such as for instance, under porticos, where lampposts cannot be fitted. Therefore, the system lends itself to numerous applications in large and diversified areas, like historic centres, where townscape continuity should be preserved. Renovation is both a complex cultural commitment and an important operation: many public administrations, sensitive to the issue, have made the renovation process of what seemed to be lost possible.

### **WHITE LIGHT IN CONTEMPORARY URBAN LIGHTING**

Over time, man has kept improving the quality of light, attempting to reproduce in the best possible way the only point of reference available, i.e., daylight. The evolution of light has gradually progressed from simple lanterns containing candles, to modern streetlamps, which strive to imitate sunlight as accurately as possible.

This revolution is represented by "White Light", namely, a modern lighting system designed to replace traditional High and Low pressure Sodium lamps, which privilege the quantity of light produced rather than quality. Instead, these new systems produce good quality lighting in the urban contexts desired, retaining optimal colour contrasts and different shades, while also substantially improving safety for pedestrians and drivers alike. The application of these new technologies also mean reduced energy consumption, as the lamps are dimmerable and also use less power, without affecting quality.

The aesthetic value of White Lights should not be ignored, as white lights are able to enhance any work of art or building, without compromising colour. These devices fully enhance cities of art at any time of the day, making them more liveable and easier to visit, and also add even more charm to the nightscape, which outshines, with its fascination, its counterpart "in broad daylight".

## CONCLUSION

Given that technology of using of white lighting source in Croatia is of recent date, and that most city streets and the old city centers in Croatia are handled with high pressure sodium lamps, it leaves considerable room for improvement. Also we must not forget that in most cases, lighting instalations of our city centers are made with luminaires that give a great contribution to light pollution, and use inefficient light source and control gears. According to that, there is a lot of wasted money, spended on undesired energy consumption of light fixtures that light-polluted, and usually they do not fulfill the purpose of functional lighting, and especially emphasize the beauty of ancient architecture and facades of historic buildings.

Unfortunately, we have in Croatia situations, that changing the high pressure vapor lamps into a high pressure sodium some City Administration still considered a big deal, and that do not care about other characteristics of luminaires, such as classes in relation to light pollution, and their overall lumen output. Also, on a market there is a few suspicious suppliers of LED luminaires, suspicious origin, who use ignorance and lack of information among local leaders, and try to sell them a sollutions that are not proved by lighting design experts, and do not meet the purpose of installation. Do not believe anyone when they tell you that the lamp has a lifespan of more than 50000 hours, at least not yet and not in the near future.

Comparison of investment in intelligent systems, which ultimately lead us to preserve the Earth, are negligible, compared with the financial savings, which eventually start to repay investments made complete. It is time to wake up!

## REFERENCES

- (1) Kocet, V., *Lighting and energy efficiency*, Conference "Public Lighting - 2010", Crikvenica,
- (2) Fördergemeinschaft Gutes Licht «Good Lighting for Safety on Roads, Paths and Squares», tehnička brošura
- (3) Fördergemeinschaft Gutes Licht « Urban Image Lighting», tehnička brošura
- (4) licht.de, Fördergemeinschaft Gutes Licht, 2008 <http://www.licht.de/en/lighting-advise>», izvor sa *World Wide Web*
- (5) «Zakon o umjetnom svjetlu» - prijedlog zakona, verzija ožujak 2008. – kontakt CIE Hrvatska (tajnik mr. Sc Ranko Skansi, dipl.ing)
- (6) as.dr. Matej Bernard Kobav, univ.dipl.inž.el. and prof.dr. Grega Bizjak, univ.dipl.inž.el., *Problematika Uredbe o mejnih vrednostih svetlobnega onesnaženja okolja* UL, Fakulteta za elektrotehniko, Laboratorij za razsvetljavo in fotometrijo
- (7) world wide web wikipedija, [http://en.wikipedia.org/wiki/Color\\_temperature](http://en.wikipedia.org/wiki/Color_temperature);  
[http://en.wikipedia.org/wiki/Color\\_vision](http://en.wikipedia.org/wiki/Color_vision)  
[http://en.wikipedia.org/wiki/Luminous\\_efficacy](http://en.wikipedia.org/wiki/Luminous_efficacy)  
[http://en.wikipedia.org/wiki/Light\\_pollution](http://en.wikipedia.org/wiki/Light_pollution), ...