C.E.L.M.A.
Federation of National Manufacturers Associations for Luminaires and Electrotechnical Components for Luminaires in the European Union

CELMA GUIDE ON OBTRUSIVE LIGHT
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INTRODUCTION / FOREWORD

CELMA is a European Federation representing 18 National Manufacturers Associations for Luminaires and Electrotechnical Components for Luminaires in 12 countries of the European Union.

CELMA Member Associations represent around 1200 companies, which include many small and medium-sized companies, directly employing more than 52.000 people generating around 10 billion Euro annually.

CELMA acts as a Body of contact, co-ordination, representation and assistance for the European and National Associations, Federations and Organizations in the manufacture of luminaires and electrotechnical components for the Luminaire Industry.

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The problem of controlling obtrusive lighting (limitation of sky glow) is well known in Europe being faced in different ways in the various Member States.

In some Member States, legislative instruments have been issued or are under consideration, while in others the problem is considered, for the time being, only in the scientific circles.

At European level, sensitivity on the problem has been expressed at political level and by lobbies such as ecologists and non professional astronomers. At the European Parliament some questions on the matter have been presented and Standardization Bodies, in particular CEN, are also considering this argument.

In these circumstances it appears appropriate for European Manufacturers of Lighting Equipment, having particular involvement in the problem, to issue a CELMA guide supporting their point of views.

CELMA POSITION ON OBTRUSIVE LIGHT
GENERAL

A. What is Obtrusive Light?

Obtrusive Light is that part of the light from a lighting installation that does not serve the purpose for which it was designed.

In other words, if the light does not illuminate the visual task and, where necessary, its immediate surrounding area, then this light goes somewhere else where it is not needed and has to be paid.

Obtrusive light is identified by:

- disturbance caused by light improperly falling outside the area to be lit,
- discomfort generated by diffused light in the neighbourhood,
- sky glow, which is the brightening of the night sky that results from the direct and indirect reflection of radiation (visible and non-visible), scattered from the constituents of the atmosphere (gas molecules, aerosols and particulate matter) in the direction of observation. In this particular report reference shall be made to the sky glow engendered by visible radiation. Two separate components can be distinguished:

  - *natural sky glow* - that part of the sky glow which is attributable to radiation from celestial sources and luminescent processes in the upper atmosphere;
  - *man-made sky glow* - that part of the sky glow which is attributable to artificial outdoor lighting, including both radiation that is emitted directly upwards and radiation that is reflected from the lit surfaces.

The main nuisances of obtrusive light being:

- disturbance to users on ground and buildings levels,
- potential by unwanted influence on the natural cycles of plant and animal environment,
- sky glow disturbing astronomical observations,
- waste of energy and money.

The term « pollution » is inadequate because it points out a phenomenon that affects simultaneously all the living beings of a delimited zone and cannot be suppressed instantly by a single method, whilst the nuisances caused by the light phenomenon, are many, diverse, specific and only affect, in a certain place, a small amount of population.
Rather then use the generic term of “pollution” that designate, as a generic term, the phenomenon, it is therefore better to use the expression “nuisance caused by the lighting” in order to express that there are many different types of obtrusive light and that each one have a specific treatment taking into account the priorities given to lightning.

B. What are the benefits of better lighting

The proper design and selection of luminaires will provide the following benefits:

- improved visual performance for the given task
- reduced rate of accidents
- protection of the dark sky
- improved quality of life
- reduced crime and fear of crime
- increased pedestrian activity
- contribution to a better sustainable development (energy savings, limitation of sky glow)

All living beings adjust their behaviour according to natural light. Invention of artificial light has done much to maintain daytime safety and security levels during the dark hours. Nobody can question the benefits of lighting in terms of improving road safety and reducing crime and the fear of crime. But, if not properly controlled, **obtrusive light** can present serious problems and cause waste of energy and consequently also of money.

1. Improved visual performance of the given task

Control of the distribution of light onto the visual task as well as glare reduction improves the visual performance of that task. Correct illumination of the task, limitation of unwanted glare and surround illuminance each combine to enhance the performance of users.
Outdoor lighting is called "*functional*" if its performance, in terms of level and uniformity, can ensure the security of persons and property in a defined location and allow the visual accuracy requested by the task to be carried out.
In this case, the essential functions for which the lighting has been designed, are fulfilled.

Lighting is "obtrusive" when it provides lighting where it is not wanted, mainly in areas such as residential, roadways, countryside, sports arenas and entertainments, floodlighting, concourse lighting, etc.

2. Reduce the number of accidents

Provision of the right lighting for a given task will enable better anticipation of the task to be performed. Mobility will inherently be safer as obstructions and dangers are more readily visible. Safety is important not only for those who drive but also for those who are liable to interact with the drivers. Proper street lighting, in particular, minimise risk and situations conducive to accidents.

3. Improved quality of dark sky / better quality of life / reduced crime and fear of crime / increased pedestrian activity

Only one century ago very few people went out during night-time. Cinemas did not even exist and very few thought of going out for a walk to enjoy their city during the dark hours: outdoor life usually stood by for that time; things have changed with an acceptable quality of lighting in the XXI century.

Lighting accomplishes it essential function as it serves for security, visual orientation and guidance, beautification of the surroundings, selection of landscape.
To prevent any light escaping into the sky would require the city to be painted black (to minimise reflections) and then impairing to recognise the surroundings. So, the goal today must be to identify where the wasted light is coming from and going to, then find how to minimise it.
Yes, minimise rather than prevent it.
For instance, office windows transmit a proportion of the interior light out into space. If this were completely eliminated, together with all upward light from street lanterns, towns and cities would look deserted and uninteresting. It is, therefore, necessary to allow some spill light to provide this essential “interest” aspect to the urban night-time scene.

This nocturnal beautification involves:

- avoidance of a drastic 'cutting off' and/or 'screening' of the outdoor luminaires,
- provision of lighting (directly and indirectly) for the environment surrounding the functionally lit areas,
- playing with diffusing or specular conditions of clear or dark lit areas.

In urban environments, light is necessary in the surrounding areas in order to improve visual performance and provide a better perception of the area.

Cities must be well lit, welcoming and safe.

The correct choice of lighting will enhance the environment, whether it is indoors in an office or factory, or outdoors. The improved feeling of well-being will encourage people to be there. This means more people to be out and to enjoy the use of their street, village and city at night.

As many recent studies have shown, appropriate lighting design sets the basis for:

- prompting people to walk around and attend entertainment areas by night,
- reducing crime and fear of crime,
- encouraging city inhabitants and visitors to socialise and discover the beauty of the city in the evening,
- beautification of commercial areas.

Improvements in better lighting will result in a:

- reduction in operating costs
- minimalising of the total (emitted directly and reflected) upwards flux (light)

4. Reduce operating costs

Energy saving and reduction of CO_2 emissions are a must and could be provided by:

- reducing the operating costs by the installation of more efficient lighting equipment,
- using more durable luminaires with less maintenance requirements

Designing the lighting installation with this in mind will, therefore, automatically improve the efficiency of the installation; possibly reduce the number of luminaires required, reduce the power consumed, reduce CO_2 emission and improve sustainability (economical, environmental and social needs).

5. Minimise the total (emitted directly and reflected) upwards luminous flux

Ways of minimising the total upwards flux (light) are described in the Technical part - Section A.

CELMA POSITION ON OBTRUSIVE LIGHT
TECHNICAL

A. Aiming for Good Lighting Environments with public lighting and floodlighting

Obtrusive light, whether it impedes the view of the night sky, or shines through a bedroom window, is a form of discomfort and may be substantially reduced, in the majority of cases, without detriment to the performance of the lighting task.

The aim of this paper is to give guidelines concerning direct and indirect sky glows.

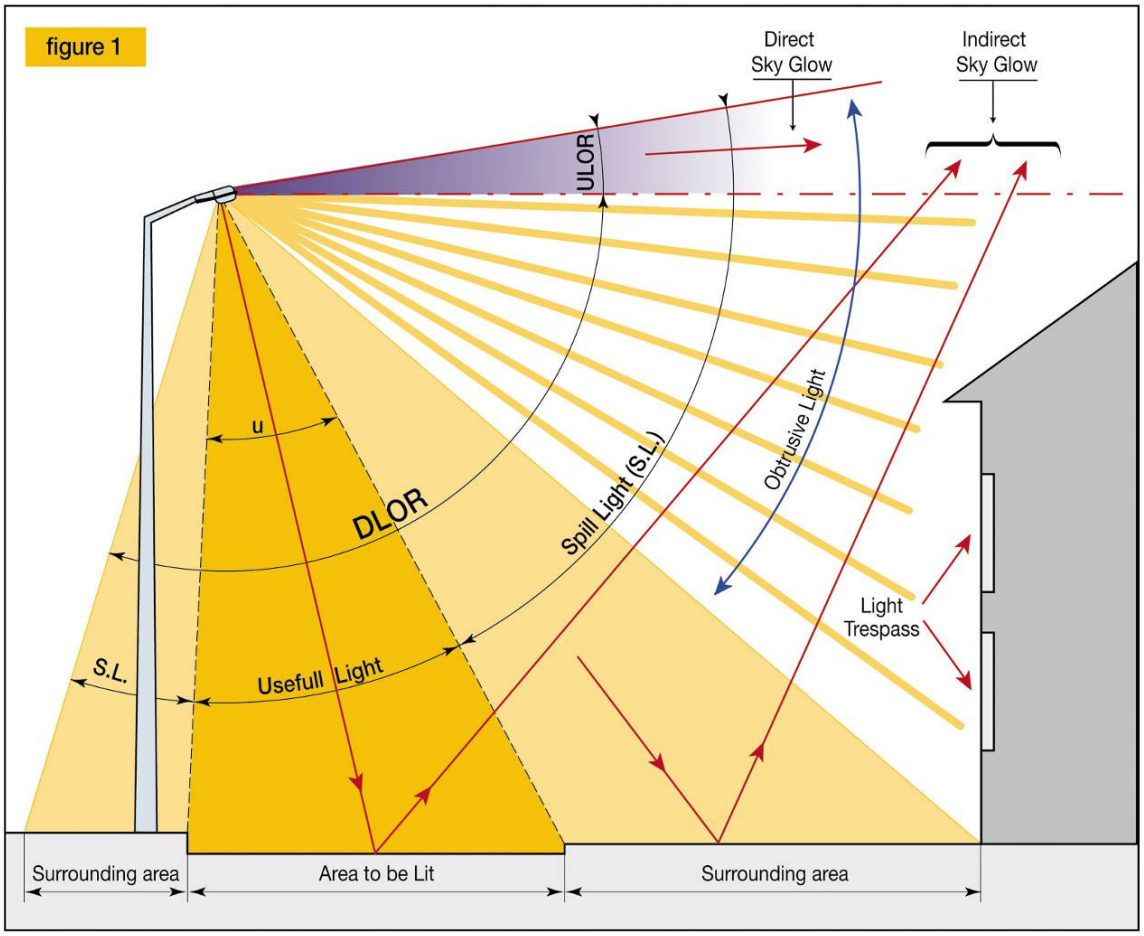

***Figure 1* - Street lighting installation: distribution of the light**

1. Minimising Sky Glow: Installation guidelines for the outdoor lighting installations (excluding advertising)

Sky glow is not a newly arrived concern for European Luminaire Manufacturers. For years, most of them have improved the performance of their luminaires as well as issuing installation recommendations and following standards in order to minimise sky glow.

The following points need to be considered:

- 'Sky Glow' is due to directly emitted light as well as to reflected light. Several studies have been made showing the importance of the reflected contribution. An installation design considering only the direct component can be worse than an “all-components considered” installation, in terms of sky glow.

- a methodology is given in order to compare lighting installations in terms of total upward luminous flux including reflections from illuminated surfaces.
- 'Sky Glow' can be minimised and energy saving maximised by means of a suitable lighting design process using recommendations given in this CELMA guide

A compromise must be found between providing light and controlling 'Sky Glow' while minimising energy use.

- outdoor lighting is only a part of the whole 'Sky Glow' problem. Neither lighting engineers nor manufacturers can do anything to control:
  - atmospheric pollution
  - atmospheric humidity
  - vehicle headlights
  - reflection coming from illuminated surfaces or surroundings
  - advertising, laser shows, searchlights, etc
  - private and commercial indoor lighting

Luminaire manufacturers can only control the design and production of luminaires and provide recommendations on how they should be installed.

- It is impossible to say, on a catalogue basis comparison, that some luminaire sends more light towards the upper hemisphere than any other luminaire. A well designed luminaire, wrongly aiming towards the sky, could send more light upwards than a poorly designed luminaire installed in the intended position. Luminaires must be considered installed and the surrounding reflection properties then taken into account. This is why the manufacturer's recommendations concerning installation shall be closely followed in order to get the best possible mounting in terms of obtrusive light.

1.1 Design and installation

- "**Good lighting design**" means providing the correct amount and quality of light where and when it is needed with minimum use of energy and maintenance. There are published minimum maintained photometric data specified in standards for most visual tasks. CEN (European Committee for Standardisation) standards give values for the majority of outdoor lighting applications and in particular for roadways, outdoor workplaces and sports lighting. Reference to CIE (International Commission on Illumination) documents is also useful where necessary.

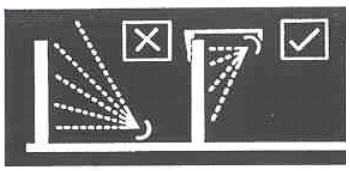

Figure 2 – Floodlighting: use direct light downwards

- **Lighting control** (switch off, dimming and/or lighting scenario, etc) when not required for security or enhancement of the night-time scene. In this respect one can introduce the concept of periods of lighting reduction, i.e. a period in which more restrictive controls are applied to lighting. (N.B. The local Planning Authority, as part of the planning approval process, may set times between which the curfew is applied.)
- **Downward lighting** should be used wherever possible when lighting vertical structures (see Figure 2)
- **Upward lighting with well designed floodlights** should be used if there is no other choice. Use of appropriate devices such as shields, baffles and / or louvers will help minimise spill light (*) around and over the structure.

The location and height of poles and luminaires shall be carefully selected in order to optimize the amount of light on the surface to be illuminated. The aiming of the beam of light from the luminaire is of prime importance in the reduction of spill light. Light should not overflow the targeted area.

***Figure 3:* optimise the emitted light only on the surface to be illuminated**

1.2 Current best practice for luminaires and lighting design

European manufacturers are already putting into practice measures that ensure a maximum control of sky glow by, for example, the following provisions:

- **Use of specifically designed optical systems** that minimise the spread of light near to or above the horizontal.

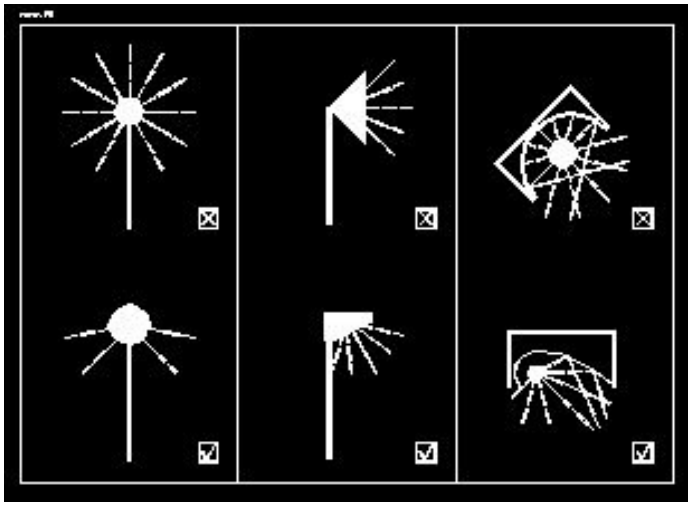

***Figure 4*: use specifically designed luminaires**

- Designers and installers are recommended to request photometry documents from qualified laboratories to be sure that the chosen luminaires have the right ULOR(*); DLOR(*) and u(*) factor when installed as intended.
- **Light near to and above the horizontal plane to be minimised**. The use of full cut-off luminaires installed at 0° uplift reduces visual intrusion and direct upward light to a minimum. As already said, reflected light cannot be avoided; luminaires providing good control of light near to and above the horizontal can provide a satisfactory solution whilst maximising the spacing of the luminaires. In any case, optical systems without reflectors or with a value of ULOR not exceeding a certain value which may depend on national legislation and on designated environmental zones.
- Energy saving is a major concern to all of us and has a direct connection with sky glow. The less power is used to get the same result, the less flux (all the rest of things being equal) will be sent (directly or indirectly) towards the sky.
- Efficient installation with the best possible utilisation factor “u” for the particular application. In street lighting applications the **luminance efficiency**(*) should also be **the best possible (ratio between average illuminance and average luminance).**
- Luminaires fitted with lamps whose **luminous efficacy**(*) (lamp and control gear) is **the best possible** for that particular use, in order to reduce the installed power and/or the number of installed luminaires.
- Use luminaires with a **high IP degree of protection** against ingress of dust and pollution in order to improve the maintenance factor and to minimise the initial illuminance or luminance levels (and therefore to minimise obtrusive light). IP65 for luminaires should be considered a minimal value.

1.3 Methodology to design an outdoor lighting installation in order to minimize sky glow

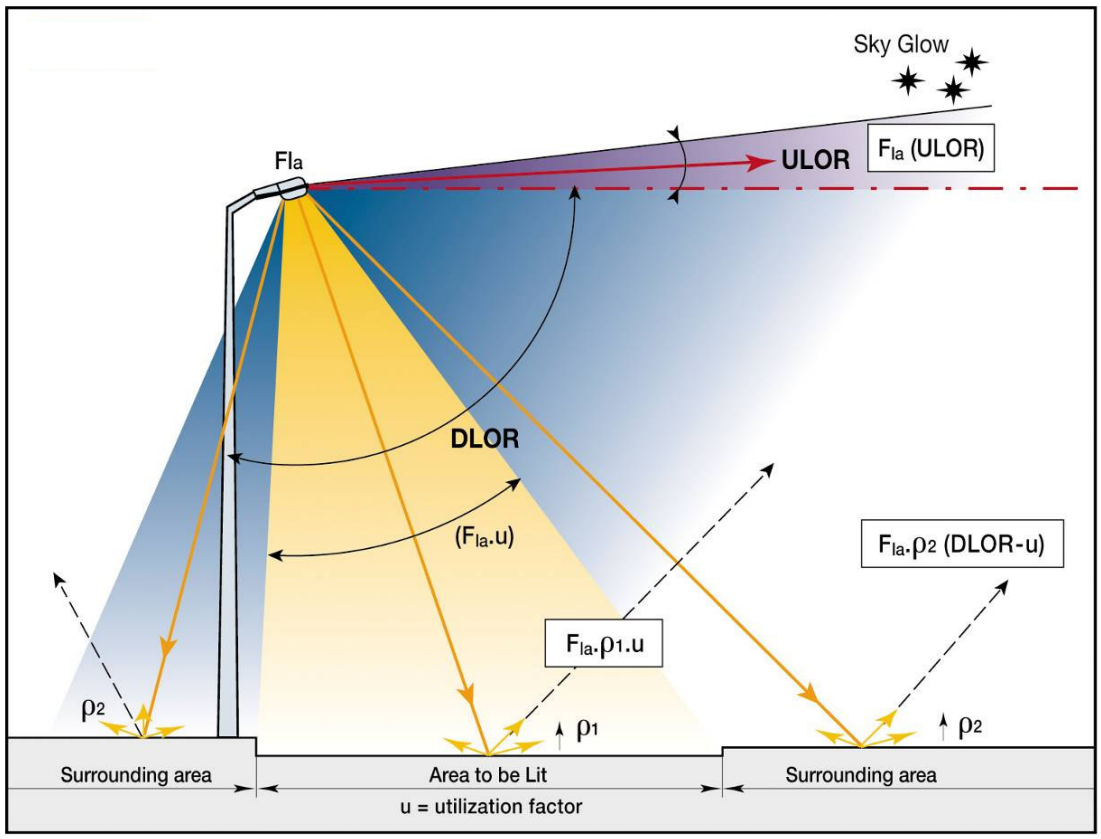

***Figure 5* - Street lighting installation: contributions to sky glow**

Contribution of an outdoor lighting installation to sky glow can be determined from data provided by:

- the luminaire manufacturer:
  - Lamp lumen output: F_{la}
  - Upward Light Output Ratio: ULOR [%]
  - Downward Light Output Ratio: DLOR [%]
  - Utilization factor of the lighting installation: u [%]
- contracting authorities and site conditions:
  - Average maintained level of illumination: E [lx]
  - Area of the surface to be lit: S [m²]
  - Reflection factor of the area to be lit: ρ_1 [%]
  - Reflection factor of the surrounding area: ρ_2 [%]

The upward light of an outdoor lighting installation which feeds the sky glow is given by UPF which is made up of the following elements:

- Direct luminous flux emitted upward by the luminaire: $F_{la} * ULOR$
- Luminous flux reflected by the area to be lit: $F_{la} * \rho_1 . u$
- Light reflected by the surrounding area: $F_{la} * \rho_2 (DLOR - u)$

Consequently:

$$UPF = F_{la}\left[ULOR + \rho_1 * u + \rho_2 (DLOR - u)\right] \text{ [lm]} \qquad (1)$$

F_{la}, ULOR, DLOR in the installed position as recommended by the lighting designer are measured by a competent photometric laboratory and provided by the manufacturer,
Typical Reflection factors ρ_1 - ρ_2 could be measured with a reflectometer or be estimated according to the below data:

- road surfaces: 0,06 (dark) to 0,15 (clear)
- sports areas: 0,04 (cinder track) to 0,24 (clear concrete)
- neighbour areas: from 0,05 to 0,30.

UPF can be calculated in the following alternative way:

- initial level of average illumination of the lit area (the EN 13201-2 value divided by the MF according to CIE 154): E [lx]
- area of the lit surface: S [m^2]

Given that $F_{la} = (E * S) / u$, from equation (1) a new expression of UPF is:

$$UPF = E * S\left[\frac{ULOR}{u} + \rho_1 + \rho_2 (\frac{DLOR}{u} - 1)\right] \quad (2)$$

When DLOR = u and ULOR = 0 the inescapable part of upward luminous flux is described by the factor UPF_{min}, with:

$$UPF_{\min} = E * S * \rho_1 \quad (3)$$

In a lighting design, optimization of the upward lumen output is calculated from formula (2) ; in such a way, the most efficient lighting installation could be selected among different schemes in term of sky glow limitation (see AFE Guide [12] – “Les nuisances dues à la lumière”)

In order to classify between them each possible technical solution of the lightning project, it is advisable to add to the standard photometric characteristics (luminance, illuminance, glare, uniformities), the maximum luminous flux potentially spilled (UPF) that can easily be calculated by computer from the manufacturer’s photometric statements.

Note 1: To be able to compare, between them, the different values of UPF of the project, it is necessary to apply formula (2), in each case, to the same length of road or area under consideration.

Note 2: Different methodologies are under consideration by CIE.

1.4 Maintenance and management of installations

- **Overall lighting design plan** should be prepared wherever possible in order to understand the type of facility and environment as well as to select the function and type of lighting. The purpose of the lighting design plan will be to find an acceptable balance between the provision of required light and prevention of obtrusive light whilst minimising the use of energy.
- **Rigorous maintenance** of the installations is beneficial for the good working conditions, energy savings and efficiency of the installation. Covers should be externally and systematically cleaned, in order to reduce the light losses and any diffusion effect that increases the upward emission of light.
- **Remote management systems** (EN 13201) could help to better control of light and energy as they allow to choose how much of light is needed at a particular time.

B. Relevant quality criteria and rules for the limitation of sky glow

Sky glow may be considered as the sky luminance at night. This luminance is highly variable and dependent upon many parameters such as the turbidity and the humidity of the atmosphere, the altitude and the geographical position.

Two separate grounds for the making of decisions are:

1. Parameters to be monitored by the luminaire manufacturer

- ULOR (upwards light output ratio)
- DLOR (downwards light output ratio)
- u (utilization factor)
- Luminous intensity diagram (table)

2. Parameters and data to be specified by the lighting authority

Maintained lighting performance according to EN 13201-2 (eventual lighting level of the surrounding area - illuminance in lx or luminance in cd/m²):

- Dimensions of the illuminated areas
- Reflection factors of the surface to be lit and surrounding areas: ρ_1 and ρ_2

Optimisation of a solution, therefore, may only be achieved by properly defining the design criteria. The solution will be a compromise between the:

- features of the lighting equipment
- requirements of the contracting authority
- environmental conditions of the site

Research is progressing on the quantification of the sky glow in terms of lighting optimisation. The natural parameters, which influence this glow (hygrometry, fog, clouds, etc) still need to be investigated further.
Considering the parameters linked to artificial lighting, it is very complex to calculate the inter-reflections of the light on various surfaces and absorption when hitting buildings and vegetation. Nevertheless, almost all the time negligible compared with direct upward luminous flux and reflection of the lit surfaces towards the sky.
The following criteria and rules are given in order to reduce the quantity of luminous flux emitted upwards (directly and indirectly); for beautification purposes, other priorities could come before the following:

- **<u>Upward light output ratio (ULOR) should be limited:</u>**

  This criteria should be minimised when the luminaire is in its installed position.

- **<u>Difference between DLOR and utilization factor should be minimised:</u>**

  a) The installation will be more efficient so less flux is needed to light the surface (and obviously, less flux will be emitted towards the sky),
  b) more proportion of flux will be on the right place and less will be reflected by the surroundings. This means that the more efficient an installed luminaire is, the less amount of light will be sent upwards.

Conclusions

It is impossible, in outdoor lightning, to eliminate completely the obtrusive lightning towards the sky.
Nevertheless, it is necessary in a modern outdoor lightning installation to limit as far as possible this *harmful effect*.
It appeared finally that the best results can be obtained in simply following some common sense and “good practice” rules.

It is necessary to:

- know the characteristics of the zone to be lit and its surroundings in order to optimize the lighting solution with the minimum spill light

- define precisely the necessary and sufficient light quantity needed by the zone to be lit according to EN 13201-2 and the type of roads and visual tasks to be performed;

- choose high efficiency luminaires and lamps, well adapted to the nature of the need

    - good utilization factor and luminance efficiency
    - high degree IP of protection
    - lamps with the best luminous efficiency

- design the lighting installation complying with EN 13201-2 specifications and minimizing the upward factor (UPF) that become an indispensable parameter associated with the other standard ones (luminance, illuminance, glare, uniformities)

    - follow precisely the luminaire manufacturer’s recommendations concerning installation.

Finally, on these conditions that a good balance between the need for lighting and the environmental protection will be effective for the well being of all.

DEFINITIONS

Cover: translucent part of the luminaire, which protects the lamp and, eventually, the reflector from the penetration of dust, dirt, water, etc…

DLOR (Downward Light Output Ratio): proportion of the total flux of the lamp of a luminaire that is emitted under the horizontal plane crossing the luminaire in its installed position.

Glare: uncomfortable brightness of a light source when viewed against a dark background. This is the most critical sort of obtrusive light as it influences the performance of the visual task; disability glare and discomfort glare have to be differentiated

IP degree: degree of protection of luminaire against ingress of dust, solid objects and moisture according to IEC 60598-1

Light trespass: unwanted or nuisance light which is spilled beyond the boundary of the property intended to be illuminated.

Luminance efficiency [lx/(cd/m²)]: this ratio is only applicable to functional street lighting for practical reasons. It is the ratio between the light power (illuminance in lx) reaching the road and the amount of light effectively perceived by the driver (luminance in cd/m2).

Luminous efficiency of lamp and control gear: ratio between the light power emitted by a lamp and the electrical power needed for it from the mains. This is measured in **lumen/Watt** and it includes the control gear consumption.

Luminous intensity diagram (table): in the form of polar curve or table; in cd/1000lm of lamp flux, gives the light distribution of the luminaire.

MF (Maintenance Factor): ratio of the maintained value of lighting specified by the standard (CIE) to the initial value.

Obtrusive light: spill light outside the area to be lit, which is not correlated with specified lighting data for a given installation. It can give rise to annoyance, discomfort, distraction and reduction in the ability to give essential information.

Spill Light: Light emitted by a lighting installation which falls outside the design limits

Sky glow: brightening of the night sky that results from the reflection of radiation scattered from the constituents of the atmosphere: natural sky glow & artificial sky glow.

ULOR (Upward Light Output Ratio): proportion of the total flux of the lamps of a luminaire that is emitted above the horizontal plane crossing the luminaire in its installed position

UPF (UPward Flux): maximum luminous flux potentially spilled towards the superior hemisphere, coming from direct and indirect luminous flux.

UPF_{min} (minimum UPward Flux): irreducible value of the luminous flux potentially spilled (UPF).

Utilization factor (u): ratio of the luminous flux received on the surface to be lit to the sum of the individual fluxes of the lamps of the installation. (CIE abbreviation is UF but not used in this document because of potential mistakes with U, UPF, F,…)

GLOSSARY - Reference standards or national guidance notes

1. CIE 31: “Glare and uniformity in road lighting installations” (1976)
2. CIE 126: “Guidelines for minimizing sky glow” (1997)
3. CIE 150: “Guide on the limitation of the effects of obtrusive light from outdoor lighting installations” (2003)
4. CIE 154: “The maintenance of outdoor lighting systems” (2003)
5. EN 60598: Luminaires - Part 1: General requirements and tests and relevant parts 2
6. TR EN 13201-1 Road lighting - Part 1: Selection of lighting classes (2003)
7. EN 13201-2 Road lighting - Part 2: Performance requirements (2003)
8. EN 13201-4 Road lighting - Part 4: Methods of measuring lighting performance (2003)
9. Italian standard UNI 10819: “Outdoor lighting installations - Requirements for limiting the upward flux scattering” (1999)
10. The Institution of Lighting Engineers Guidance Notes for the Reduction of Light Pollution (2000)
11. Environment Agency of Japan Guideline for light pollution: Aiming for good lighting (March 1998)
12. AFE Guide [12] – « Les nuisances dues à la lumière » (2006)

CONTACT CELMA

Stéphanie Mittelham
CELMA Managing Director

Diamant Building
Bd. A. Reyers, 80
B-1030 Brussels

Tel: +32 2 706 87 12
Fax: +32 2 706 87 13
stephanie.mittelham@celma.org

CELMA – The Federation of National Manufacturers Associations for Luminaires and Electrotechnical Components for Luminaires in the European Union
http://www.celma.org