ng

A New concept

June 2009

Part 1
Energetic Sustainability

Introduction

The technological revolution recorded, in the second half of the last century, led to an unprecedented increase in energy consumption, with a tendency to increase. How long and how it will continue, depends on our behavior as a whole from now on, because of the notorious lack of resources and imbalance of all of our ecosystems.

Our great dependence on fossil fuels for power generation (especially electricity) is contributing to the unevenness of these ecosystems. This imbalance is mainly a result of its combustion and the consequent emissions of harmful gases into the atmosphere (especially CO_2) in excessive amounts, contributing to the increase of greenhouse effect gases. The consequences of this effect are well known and visible every day and tend to get worse if nothing is done to reverse the current situation.

Mission: To increase the efficiency of our systems and reduce our dependence on fossil fuels. Only this way we can achieve the necessary energetic sustainability.

Efficient use of energy

An efficient use of energy is to use a smaller amount of energy to achieve the same objective. The level of reduction in the amount of energy required defines the level of efficiency. So, a bigger reduction means a bigger efficiency in the system.

Efficient lighting systems

In lighting, energetic efficiency is when we use a small amount of electricity without compromising the quality and quantity levels of the lighting desired. In a simple way, itÕs based on the use of efficient lighting systems.

A lighting system involves several distinct components. To be effective, all these components must be efficiently balanced. This applies both to the lamp, and to the power supply system.

The latest LED technology allows achieving the desired overall efficiency levels, typically around 60 lm/W.

Rational use of energy in lighting

Energetic efficiency is also based on the rational use of energy. It is not enough to have an efficient system of energy, it is necessary that it is used efficiently! This principle applies to all areas in general and, of course, lighting in particular.

The rational use of energy in lighting is the proper management of energy used for this purpose, according to needs. The use of more efficient lighting systems is necessary but not enough to achieve higher energy efficiency.

The proper management of available resources thus leads to increase energy efficiency. Therefore, some of the key aspects to consider in a lighting project are:

ÅQuantity and quality of light meet the needs of the space to be lit.

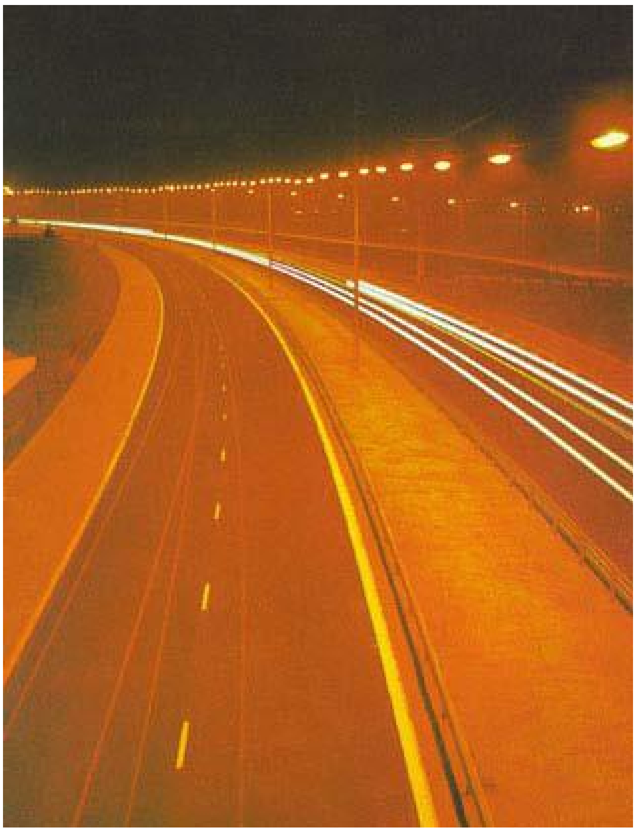
ÅLight color and color temperature adapted to the type of objects to light.

ÅProper light distribution, always seeking to maximize comfort in the spaces to light while reducing light pollution.

Studies about lighting design, in order to design and develop lamps and lighting systems adapted to each need (Light Design) are a key factor in this context.

Additionally, the use of intelligent management systems allows rationalizing energy use in lighting, for example by flux adjustment, according to light ambiance and the presence of people or vehicles on the places to be lit.

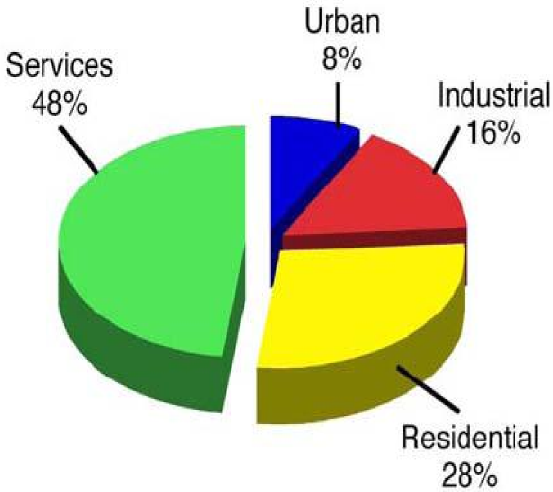
Part 2
Current scenario in street lighting



Energy Dependence

Lighting plays a central role in our lives, being a major contributor to the sharp increase in energy consumption in recent decades.

Each year, about 14,000 TWH are produced worldwide and between 12 and 15% are consumed in lighting. Street lighting is about 8% of this value, as we can see in the graph.



In Portugal, the scenario is not different, just on a smaller scale. The energy consumption in 2005 was around 1.3 TWH (= 1,300,000,000 KWH). Between 1995 and 2005 the average annual growth rate was 5.7%.

Available technology

Solutions on the market

Solutions on the market commonly used for street lighting are:

- Mercury (e.g. HME)
- Low pressure sodium (e.g. SOX)
- High-pressure sodium (e.g. SON)
- Metal halide (e.g. MHD / CDM)

Although still quite widespread in the current infrastructure of street lighting, the mercury solutions will be totally banned from the EU market in the short term, starting in 2010. These have to be fully removed from existing installations and cannot be used in new installations. This is mainly due to its low efficiency and high toxicity.

The most popular technology today is that of high-pressure sodium (HPS).

Main limitations
The main limitations in current street lighting focus on the following points:

Lighting design
Available technology
Infrastructure management

Many lighting projects are old and totally dysfunctional in the current situation. The most recent projects often find themselves poorly scaled.

As for the technology used, some are energy inefficient, have toxic components in their composition (e.g. mercury and HPS) and have very small CRI (e.g. HPS).

In terms of infrastructure management, in most cases, the average levels of lifetime are low and mortality levels are high.

Main consequences
The main consequences of the previously referred limitations are:

Environmental
Economic
Social

The waste of critical natural resources and the emission of large quantities of harmful gases into the atmosphere (especially CO_2) have dramatic consequences for the ng, the greenhouse effect and the overall

Excessive use of energy, considering what is desired and necessary also has economic consequences, since it requires spending of additional resources. Moreover, taking into consideration the relatively low lifetime of the different technologies used, operational costs linked to lamp replacement and general maintenance of equipment go up.

Finally, the high light pollution and low CRI commonly recorded contribute to deterioration in people's quality of life, poor road safety and sense of safety in general. The following pictures illustrate the levels of light pollution in Europe and in the world.

Part 3
LED Technology in street lighting

Main objectives

...ling roads and public spaces in general, ...ecurity. It also plays a social role, ensuring a reduction in crime in general and encouraging the use of public spaces by night in cities and both commercial and social tourist areas.

There are so many aspects to consider in a street lighting project. The safety and security awareness are key factors for pedestrians. For drivers, lighting has a huge range of benefits, especially by reducing the number of road accidents at night, adding further visual comfort and traffic capacity to roads. Compared with most conventional technologies currently on the market, the latest development in LED technology ensures better lighting quality, which is a huge contribution.

Additionally, by ensuring greater efficiency and performance in terms of energy, LED technology directly and indirectly reduces consumption and hence CO_2 emissions into the atmosphere, a key factor to achieve the required energetic sustainability. This will also allow greater financial savings in accordance with the EU program 20-20-20 by 2020 (following the proposals by the European Commission in January 2007, all Government leaders pledged to reduce CO_2 emissions to the atmosphere, increasing the share of renewable energy and increase the EU's energetic efficiency by at least 20% by 2020).
LED technology is in the front line fighting environmental pollution (in addition to the points already addressed, it is important to note that LEDs do not use toxic components in their composition, like some traditional technologies commonly used such as mercury and high pressure sodium) and energy wasting, contributing to the accomplishment of the agreed targets. They are ambitious but absolutely necessary so that in the future we can live in a better, greener and more sustainable world.

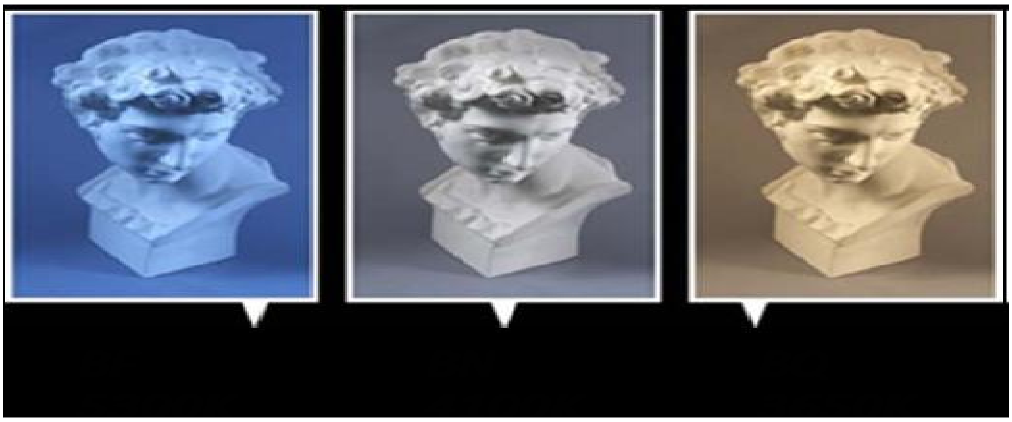
Improved lighting quality

uality using LED technology is mainly due to two

High Color rendering index (CRI)
Wide range of color temperatures available

Color rendering index
A high level of CRI means better color perception of real objects, which results in better lighting quality and hence a greater safety and sense of security. The following pictures clearly illustrate the differences between a street lighting scene based on LED technology (CRI> 75) and a more traditional HPS (CRI <25) technology-based scene.

Color Temperature
Different color temperatures allow a greater visual comfort, according to the surrounding environment. This naturally translates into better lighting quality.



Cooler colors (higher color temperatures) are more suitable for road lighting. The warmer colors (lower color temperatures) are more appropriate for lighting historic centers. However, in practical terms, any of the options are valid in any scenario, without compromising the lighting quality and energetic efficiency.

…cy based on LED technology, there are some assumptions:

- Adequate optical geometry
- Optimized light spectrum
- High performance throughout its lifetime

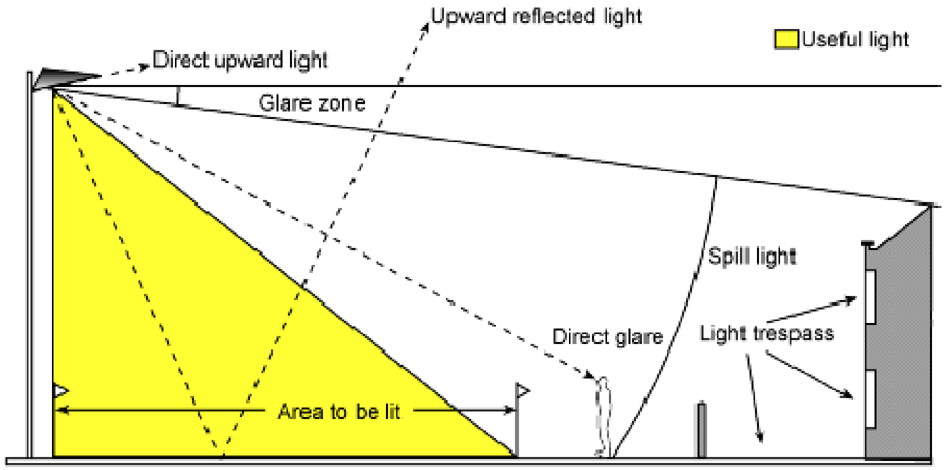
Adequate Optical Geometry

Better results with less lumens

The Leds reduced dimension and the fact that they only radiate from one of the hemispheres allows optimizing the optical geometry in a relatively simple and efficient way, maximizing the utilisation, meaning, the capacity of converting light flux in useful lighting on the plan wished to light (quantified in lux/lm). This factor can equally be evaluated in terms of luminance ((cd/m2)/lm), all depending on the employment.

This fact decisively contributes to the reduction of the energetic consumption, once that, comparing to the traditional technologies generally used, less lumens are necessary to achieve the same lighting levels. In reality, LED technology presents an utilisation factor of around 85/90% superior to what is achieved with the HPS technology (high pressure sodium).

The following figure shows the different incidence areas (in yellow is the area that is wished to be lit, i.e. useful lighting).



Light pollution is often caused by the way light is emitted from lighting equipment. Choosing proper equipment and carefully mounting and aiming it can make a significant difference.

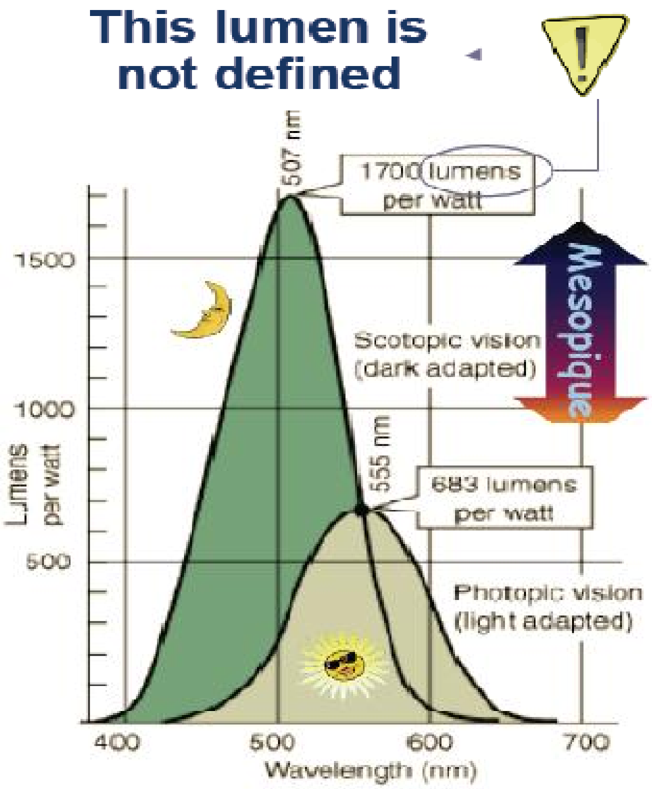
As a consequence of a high usage level, the glare level is normally extremely low; this is a essential point in terms of road safety. The same happens with the light pollution levels, which transforms directly into better life quality.

Optimized Light Spectrum

ıce levels generally used, street lighting puts us in

The properties of all light sources are currently quantified, based on the photopic answer of the human eye. In mesopic conditions this quantification is totally unadjusted from the real performance values.

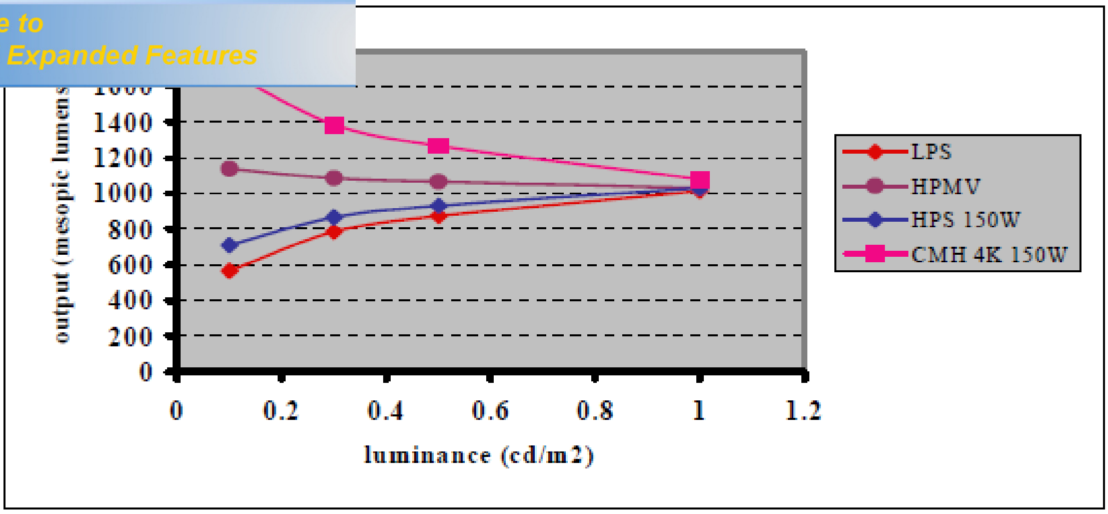
One of the big advantages of using LED technology is the fact that its spectral answer is tuned with the sensitivity of the human eye in the mesopic region, which greatly improves its performance.



The previous figure shows, in a simple way, the curves of human eye sensibility in the limit regions: scotopic and photopic. The mesopic region is between both of these. The sensibility in this region depends on the existent luminance levels. For lower luminance levels the range comes closer to the scotopic region and for higher luminance levels the range comes closer to the photopic region.

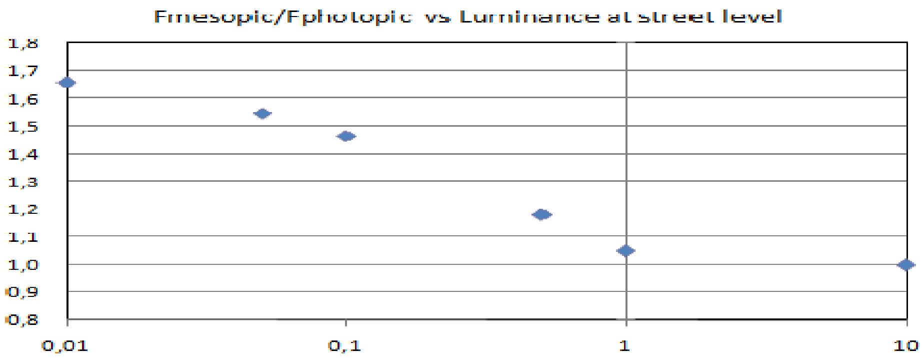
The luminance levels in question are approximately as follows:

- Photopic vision ï L>=3,4cd/m2
- Mesopic vision ï 0,01<L<3,4 cd/m2
- Scotopic vision ï L<=0,01 cd/m2



The previous figure shows the different levels of luminous flux in the mesopic region (mesopic lumens) based on the luminance (photopic measurement). As can be seen, for technologies with strong spectral components in the lower wavelengths (blue regions), the luminous flux level rises considerably. The opposite happens in technologies with stronger spectral components in the higher wavelengths (yellow/red regions), such as widely used high pressure sodium lamps. In reality, for lower levels of luminance, the sensitivity of the human eye favours lights that emit a colder (bluish) colour. A 150W metal iodide lamp with a colour temperature of 4000ºK, in a scenario of only 0,5 cd/m2 it has about 25% more flux than the original value of 1 cd/m2 (closer to the photopic region). On the other hand, in the same conditions, a high pressure sodium lamp shows about 8% less luminous flux. This shows a difference of about 36% between both technologies, considering an HPS lamp.

Due to the fact that it presents an optimized spectrum in the mesopic region, LED technology presents the same behavior as metal iodide lamps, which in reality is a big improvement of performance in this region. The following figure proves this fact.



In this specific case, considering the same luminance reference value (0,5 cd/m2), the LED solution taken into consideration in this study presents a luminous flux increase of about 20%. Once again, considering the 8% reduction for HPS lamps, the difference is at 30%.

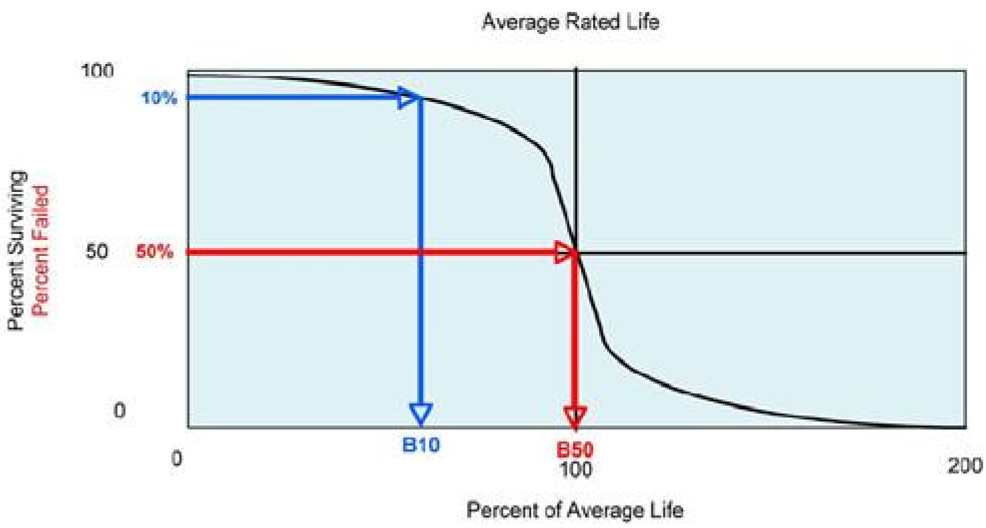
High performance throughout its lifetime

ms throughout their lifetime is one of the most any project and has a huge impact on the energetic consumption. The maintenance factor (MF) qualifies and quantifies that deterioration, especially at the plan lighting level, typically illuminance.

This factor analyses the following aspects:

- The deterioration of luminous flux in the lamps used (LLMF - lamp lumen maintenance factor). This deterioration is strongly conditioned by the working temperature of lamp inside the luminaire and the working conditions in electrical terms. The higher the working temperature is and the voltage fluctuations that power the lamp, caused by disturbances in the electrical system, the bigger the deterioration is and, consequently the smaller the factor.

- The lamp survival factor (LSF). Traditional lamps always present a high mortality rate (when a catastrophic malfunction occurs, making the lamp turn off), considering that the lamps lifetime is measured based on that mortality rate (specified at around 50%). Parallel to this, the average deterioration rate of the entire installationôs luminous flux is also considered, reflecting this mortality rate. In concrete terms, the higher the mortality rate is, the bigger the deterioration of that average rate is and, consequently the lower the LSF is. In street lighting, considering the regular positioning of the lamp poles, the failure of one of the lamps causes the appearance of a dark zone, what directly corresponds to a reduction of the average flux level and, consequently, of the lighting level on the plan. Worse than that, itôs detrimental and can put at risk the compliance with the uniformity levels imposed by the standards, especially the European standard that regulates the lighting levels to be used (EN13201-2). The following figure illustrates the normalized expression used by industry to quantify the mortality rates of the lighting equipments.



naires (LMF - luminaire maintenance factor). This the luminaire's maintenance conditions, specially the optical system. In this system we include the reflectors and optical protections through which the light is emitted. Every traditional lamp emits very high amounts of UV and IR radiation, which (especially UV) highly contribute to the deterioration of these components (beyond the direct responsibility of the deterioration caused by the radiation in sunlight). The bigger this deterioration is the lower the LMF is. Also, the radiation emitted usually attracts insects what equally contributes to the deterioration of the LMF. To this we can still add the dirt that naturally accumulates in the protections, which leads to the same.

In normal working conditions LED technology usually presents very small flux deterioration levels, about 1 to 2% in the high performance systems. HPS technology usually has a deterioration level of 20 to 30%.

In relation to the lamp survival factor, it's not applicable no LED technology. Since this technology does not present a catastrophic end of life (i.e. in normal operation the LEDs do not go out altogether), a new way to quantify their lifetime needed to be found. ASSIST (Alliance for Solid-State Illumination Systems Technologies) determined that 70% is the threshold at which it is possible for the human eye to detect a luminous flux reduction (related to the logarithmic integration of our eye, less sensitive to changes in higher flux levels). Thus, it was specified that an effective reduction of 30% of the luminous flux, in relation to the initial value, determines the end of an LED's lifespan. In other words, when we say that an LED has reached the end of life at 60.000H we are in reality saying that it still has at least 70% of the initial flux. Currently we work with B10/L70 levels, which correspond to a maximum effective reduction of the luminous flux of 30% but only on 10% of the LEDs. It is noteworthy that this level of deterioration only occurs in extreme situations, typically characterized in terms of current and temperature at the LED junction. In the case of high-performance systems, the limit conditions will never be reached (assuming normal operating conditions, for which the system was specified), which is why the levels of deterioration will be considerably lower.

In terms of the deterioration of the luminaires, once it doesn't use a reflector, the deterioration levels in LED technology are much lower. In addition, considering they don't emit UV or IR radiation, the protections don't get damaged (only sunlight can contribute to that but even here the effects will be minimized once anti-UV treated materials are used) nor do they attract insects. To avoid dirt accumulation we resort to antistatic treatment, minimizing its effect. Weather conditions (rain) and maintenances, that may be carried out occasionally, to clean the luminaires, will also completely eliminate this problem.

The MF is higher in LED systems, around 70 to 85%. In HPS technology the MF is around 45% (or less, reaching 33% in extreme situations). So, we can conclude that the LED technology is much more stable during its lifetime, when compared to HPS technology. In other words, the use of HPS technology demands a supersized view over the whole project as a way of compensating for the significant deterioration recorded and to allow the accomplishment of levels specified by the standards.

mount of needed energy since the beginning, to double, meaning that it continuously depends on over the double of the energy to comply with the specified levels in the standards. In another perspective it means that initially much higher levels of lighting than the ones needed are considered. Beyond the waste of energy, it only contributes to increase the discomfort in the utilisation of public spaces, once they will register significant variations on the lighting levels (what equals to an inefficient lighting quality).

Comentários finais

...ogy finally cemented its use in lighting of public spaces (from which road lighting is highlighted), in response to the limitations imposed by most traditional technologies (especially HPS). LED technology provides a significant reduction in energy consumption and unprecedented high levels of efficiency and lighting quality. The reduction of CO2 emissions into the atmosphere and the financial savings are a reflection of this.

Reducing energy consumption

Direct reduction of energy consumption is possible due to the fact that many lighting projects are old and totally dysfunctional, using more energy than needed. The latest projects are often poorly scaled.

Efficiency

Achieving high efficiency also contributes to the reduction of energy consumption, since a smaller amount of energy is necessary to achieve the same objectives. This is achieved by an efficient lighting system, focused on an innovative and high performing optical module. In actual terms, this translates into an optical geometry and the optimized delivery of the luminous spectrum adapted to each need, and a high overall performance throughout its lifetime.

On the basis of this optical geometry, the achievement of a higher usage factor is assured (the ability to convert light that is emitted into light on the ground, quantified as lux / lm), typically between 85 and 90% of what is achievable with the high pressure sodium (HPS) technology. In other words, for the same level of lighting on the ground, only about half of the luminous flux is required. The maintenance factor (factor that qualifies and quantifies the deterioration of the lighting system throughout its lifetime), which is higher in LED systems, significantly contributes to this efficiency level.

Emission of a light spectrum adapted to the sensitivity of the curve of the human eye in conditions typically encountered in street lighting (mesopic conditions), optimizes the use of that spectrum and maximizes the performance of the lighting system. In practical terms, given the same lighting conditions on the ground and to a certain level of luminance, a LED system always displays a higher luminous flux level than originally planned, since the measurements are performed in photopic conditions, therefore totally inadequate to reality. For example, for an average luminance of 0.5 cd/m2, the luminous flux is about 20% higher than the photopic reference. The HPS case is exactly the opposite, i.e., the luminous flux is always less, in this case about 8%. In other words, a LED system always has a bigger luminous flux than measured (this fact is clearly distinguishable on the ground in real terms) and the opposite happens with the HPS system. This is another important contribution to increasing energetic efficiency associated with LED technology and in part helps to explain the fact that in practice we do not need to work with the high light levels on the ground that were initially expected when using the traditional technologies, especially the HPS.

LED technology contributes significantly so that luminaires have a high overall performance throughout their lifetime, which equates to greater efficiency and thus reduces energy consumption. This performance is characterized by the maintenance

the higher the maintenance factor and less
erioration of the system can be analyzed in two
ways: the level of luminous flux and the radiation pattern. The reduction of the luminous flux contributes directly to an effective reduction of lighting levels on the ground (e.g. illuminance). Indeed, if there is a smaller amount of light being emitted by the lamp, either by a reduction of the light bulbôs luminous flux and / or increased losses in its structure (deterioration of materials, in particular the optical system), there will have to be a smaller amount of light on the ground, so a lower illuminance. The deterioration of radiation pattern (photometric curve) has a direct effect on the levels of lighting on the ground. This deterioration is caused by a change in the geometry of the optical system (not necessarily the deterioration of luminous flux). In practice this means that the light is being badly directed to the ground. The greater the deterioration, the greater the losses, therefore lighting will be more inefficient. This will have dramatic effects on the lighting quality, since it will be more difficult to comply with the specifications of prevailing standards (e.g. the global uniformity and longitudinal level).

LED technology has high maintenance factors, of around 75 to 80%. As for traditional technologies, in particular HPS, maintenance factors are generally below 45%. The difference in terms of overall performance is, therefore, quite sharp and this is reflected directly in efficiency and energy consumption. In practice, all lighting projects necessarily take into account the maintenance factor, which involves over sizing the specifications as a way to offset the deterioration that will certainly be registered over the lifetime of lamps. In the case of the HPS technology, given the low maintenance factor that over sizing will be very high (assuming a 45% MF, the power level necessary to meet the standardôs specifications will more than double). This has dramatic consequences not only on energetic efficiency, given the increase in energy use, but also on lighting quality, since the flux change will be quite notorious throughout this period (in the beginning it will have more light than necessary and only at the end it will finally be close to the necessary levels).

This is another reason that helps to explain the fact that a lighting project based on LED technology always presents initial lower levels than the levels given by traditional technologies, considering exactly the same conditions. It would be perfectly possible and viable (even in economic terms) to achieve the same levels of lighting as these technologies. Indeed, since LED technology always presents a much higher usage factor, the amount of energy needed to make that confirmation is always much lower, and the reduction of energy consumption would continue to be high. The point is that it makes no sense, since the deterioration throughout the lampôs lifetime is always lower, the required light levels are always lower and, of course, itôs justifiable to spend only the strictly necessary amount of energy. In practice, if started from a higher initial level of lighting, then we would always be positioned above specifications, so erroneous to the real needs of the project.

Better lighting quality

Better lighting quality contributes significantly to the improvement of road safety (and sense of security) and to greater comfort of public road users. LED technology ensures a superior lighting quality level, basically settled on a high color rendition index (CRI) high (Ra> 75). A high level of IRC allows a better understanding of the actual colors of

. This usually results in an effective reduction of the ed space, which also leads to a reduction of energy consumption. This is one of the reasons why the lighting projects based on traditional technologies, in particular HPS, resort to an effective increase in light output. Indeed, given the low value of CRI that this technology presents (CRI <25), this increase is absolutely necessary to make up for the poor lighting quality, which results in greater discomfort and difficulty in distinguishing objects that are around us , thereby increasing the feeling of insecurity.

In conclusion, the LED technology has excellent qualities and arguments for use in lighting of public spaces, particularly roads, and can contribute decisively to a certainly safer, comfortable and sustainable world.

Part 5 ï Bibliographical References

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