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Revision of the EU Green Public Procurement Criteria for Street Lighting and Traffic Signals

Technical report and criteria proposal (1st draft)

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1 Introduction

Public authorities' expenditures in the purchase of goods, services and works (excluding utilities and defence) constitute approximately 14% of the overall Gross Domestic Product (GDP) in Europe, accounting for roughly EUR 1.8 trillion annually (Buying Green, 2016).

Thus, public procurement has the potential to provide significant leverage in seeking to influence the market and to achieve environmental improvements in the public sector. This effect can be particularly significant for goods, services and works (referred to collectively as products) that account for a high share of public purchasing combined with the substantial improvement potential for environmental performance. The European Commission has identified street lighting and traffic signals as one such product group.

Green Public Procurement (GPP) is defined in the Commission's Communication "COM (2008) 400 - Public procurement for a better environment" as "…a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured."

Therefore, by choosing to purchase products with lower environmental impacts, public authorities can make an important contribution to reducing the direct environmental impact resulting from their activities. Moreover, by promoting and using GPP, public authorities can provide industry with real incentives for developing green technologies and products. In some sectors, public purchasers command a large share of the market (e.g. public transport and construction, health services and education) and so their decisions have considerable impact. In fact, in the above mentioned Commission's communication the capability that public procurement has to shape production and consumption trends, increase demand for "greener" products and services and provide incentives for companies to develop environmental friendly technologies is clearly emphasised.

GPP is a voluntary instrument, meaning that Member States and public authorities can determine the extent to which they implement it.

The development of EU GPP criteria aims to help public authorities ensure that the goods, services and works they require are procured and executed in a way that reduces their associated environmental impacts. The criteria are thus formulated in such a way that they can be, if deemed appropriate by the individual authority, integrated into its tender documents with minimal editing.

GPP criteria are to be understood as being part of the procurement process and must conform to its standard format and rules as laid out by Public Procurement Directive 2014/24/EU (public works, supply and service contracts). Hence, EU GPP criteria must comply with the guiding principles of: Free movement of goods and services and freedom of establishment; Non-discrimination and equal treatment; Transparency; Proportionality and Mutual recognition. GPP criteria must be verifiable and it should

be formulated either as Selection criteria, Technical specifications, Award criteria or Contract performance clauses, which can be understood as follows:

Selection Criteria (SC): Selection criteria refer to the tenderer, i.e., the company tendering for the contract, and not to the product being procured. It may relate to suitability to pursue the professional activity, economic and financial standing and technical and professional ability and may- for services and works contracts - ask specifically about their ability to apply environmental management measures when carrying out the contract.

Technical Specifications (TS): Technical specifications constitute minimum compliance requirements that must be met by all tenders. It must be linked to the contract's subject matter (the 'subject matter' of a contract is about what good, service or work is intended to be procured. It can consist in a description of the product, but can also take the form of a functional or performance based definition.) and must not concern general corporate practices but only characteristics specific to the product being procured. Link to the subject matter can concern any stage of the product's life-cycle, including its supply-chain, even if not obvious in the final product, i.e., not part of the material substance of the product. Offers not complying with the technical specifications must be rejected. Technical specifications are not scored for award purposes; they are strictly pass/fail requirements.

Award Criteria (AC): At the award stage, the contracting authority evaluates the quality of the tenders and compares costs. Contracts are awarded on the basis of most economically advantageous tender (MEAT). MEAT includes a cost element and a wide range of other factors that may influence the value of a tender from the point of view of the contracting authority including environmental aspects (refer to the Buying Green guide for further details1). Everything that is evaluated and scored for award purposes is an award criterion. These may refer to characteristics of goods or to the way in which services or works will be performed (in this case they cannot be verified at the award stage since they refer to future events. Therefore, in this case, the criteria are to be understood as commitments to carry out services or works in a specific way and should be monitored/verified during the execution of the contract via a contract performance clause). As technical specifications, also award criteria must be linked to the contract's subject matter and must not concern general corporate practices but only characteristics specific to the product being procured. Link to the subject matter can concern any stage of the product's life-cycle, including its supply-chain, even if not obvious in the final product, i.e., not part of the material substance of the product. Award criteria can be used to stimulate additional environmental performance without being mandatory and, therefore, without foreclosing the market for products not reaching the proposed level of performance.

Contract Performance Clauses (CPC): Contract performance clauses are used to specify how a contract must be carried out. As technical specifications and award criteria, also contract performance clauses must be linked to the contract's subject matter and must not concern general corporate practices but only those specific to the product being procured. Link to the subject matter

can concern any stage of the product's life-cycle, including its supply-chain, even if not obvious in the final product, i.e., not part of the material substance of the product. The economic operator may not be requested to prove compliance with the contract performance clauses during the procurement procedure. Contract performance clauses are not scored for award purposes. Compliance with contract performance clauses should be monitored during the execution of the contract, therefore after it has been awarded. It may be linked to penalties or bonuses under the contract in order to ensure compliance.

For each criterion there is a choice between two levels of environmental ambition, which the contracting authority can choose from according to its particular goals and/or constraints:

The **Core criteria** are designed to allow easy application of GPP, focussing on the key areas of environmental performance of a product and aimed at keeping administrative costs for companies to a minimum.

The **Comprehensive criteria** take into account more aspects or higher levels of environmental performance, for use by authorities that want to go further in supporting environmental and innovation goals.

As said before, the development of EU GPP criteria aims to help public authorities ensure that the goods, services and works they require are procured and executed in a way that reduces their associated environmental impacts and is focused on the products' most significant improvement areas, resulting from the cross-check between the key environmental hot-spots and market analysis. This development also requires an understanding of commonly used procurement practices and processes and the taking on board of learnings from the actors involved in successfully fulfilling contracts.

For this reason, the European Commission has developed a process aimed at bringing together both technical and procurement experts to collate a broad body of evidence and to develop, in a consensus oriented manner, a proposal for precise and verifiable criteria that can be used to procure products with a reduced environmental impact.

This report presents the findings resulting from that process up to the 1st ad-hoc working group meeting that will be held in Seville on 22 November 2016. Consultation questions are integrated in the document and will serve for updating the document in a later stage of the project.

A detailed environmental and market analysis, as well as an assessment of potential improvement areas, was conducted within the framework of this project and was presented in the Preliminary Report on EU Green Public Procurement Criteria for street lighting and traffic signals. This report can be publicly accessed at the JRC website for street lighting and traffic signals (http://susproc.jrc.ec.europa.eu/Street_lighting_and_Traffic_signs/documents.html).
The main findings presented in the Preliminary Report are summarised in the next section.

2 Summary of the Preliminary report

The goal of this project is to update the GPP criteria for street lighting and traffic signals, with a high degree of leverage in procurement decision-making combined with a significant improvement potential for environmental performance.
The development of criteria for a greener public procurement requires in-depth information about the technical and environmental performance of street lighting and traffic signals, as well as the procurement processes. This report is considered the Preliminary report which is the basis for producing the Technical Report including draft criteria proposals. Both reports comprise the working documents for the 1st Ad Hoc Working group meeting which will be held on 22 November in Seville, Spain. The Technical Report will be revised in light of the output of this meeting.
Street lighting and traffic signals are well defined by their corresponding standards EN 13201 and EN 12368. Street lighting however is called road lighting in that standard. EN 13201 clearly describes the selection of the road lighting classes and the corresponding performance requirements. It should be noted however that the selection of the road lighting classes can be different per country according to specific circumstances regarding road layout and use, and the national approaches which can be based on tradition, climate or other conditions.
In the Preliminary report, the market data on stock and sales of road lighting are given. Different lamp technologies are used in the EU28, i.e. 53% high pressure sodium (HPS) lamps, 23% high pressure mercury (HPM) lamps, 6% low pressure sodium (LPS) lamps, 8% metal halide (HM) lamps, 6% fluorescent (FL) lamps and 4% LEDs. Note that HPM lamps were phased out in 2015 by ecodesign requirements.
The total annual volume of luminaire sales is forecasted from the installed stock and the average lifetime. As presented in the Preliminary report, this results in a projected annual sales of 2.38 million road lighting luminaires for which the majority in replacement sales (2.16 million). With a typical luminaire price data of 220 euro, this represents an annual EU28 sales volume of 520 million euro. It should be noted that luminaire prices can vary strongly and especially new LED luminaires are substantially more expensive than 220 euro but their price is expected to decrease in the future.
A screening of LCA studies identified the main environmental hotspots in terms of environmental impacts and life cycle stages of the product. It shows that the energy consumption of the operational phase should be the focus of the environmental criteria for reducing the impact of the entire product. The second most significant life cycle stage regarding the environmental impacts is manufacturing. Moreover, it is clear that the importance of the manufacturing stage is going to increase if road lighting becomes more energy efficient and/or a low emission electricity mix is used. The lifetime of LEDs becomes relevant because of the higher influence of the manufacturing phase compared to more traditional light sources. Therefore, the most important parameters that have to be considered in the GPP criteria are the energy efficiency, durability and lifetime for both road lighting and traffic signals.
The life cycle assessment studies consider the impact generated at global level. However, there are a range of other environmental impacts that are not so easily defined or quantified by LCA. The main known non covered impact from road lighting is related to light pollution. Light pollution is defined in guideline CIE 126:1997 as a generic term indicating the sum-total of all adverse effects of artificial

light. The light pollution discussed in the report are sky glow, obtrusive light, and ecological impact from outdoor lighting. These kinds of light pollution can be reduces through for example a combination of a correct luminaire with a correct installation and a correct light (lumen) output

For traffic signals LED technology is rather mainstream nowadays while for road lighting applications LED technology is being introduced at the expense of other technologies such as high intensity discharge (HID) and metal halide (MH) lamps. In projects where new luminaires are installed LED is becoming mainstream technology as well.

The reason for a switch to LED technology is that LEDs outperform the other technologies in energy efficiency and lifetime. No frequent relamping is needed so additional saving potential on operational expenditures for LED luminaires can be expected

Converting to LED technologies in existing HID or CFL luminaires, and thereby saving energy, is not straightforward, because the HID and CFL luminaires (i.e. lamp, control gear or ballast, optics and housing) are rather specific per lamp technology. In most cases it would not be beneficial to only change the existing lamp with a LED module, but the whole luminaire, or at least the control gear, has to be replaced as well. Also due to the Regulation on CE marking (765/2008) such a luminaire conversion could require additional paperwork, e.g. related to the Low Voltage Directive (2014/35/EU) including safety certification, new documentation, new serial numbers, etc. Therefore, other costs than the energy cost should be taken into account on a case by case basis. It might even be possible that in case of switching to new technologies new lighting design parameters have to be calculated. The most important output parameters for such a calculation are the power density indicator (PDI) and the annual energy consumption indicator (AECI). The big advantages of these parameters are that they are technology independent and take dimming into account. The implementation of these design parameters should then be fulfilled by a correct installation of the components of the road lighting installation. Minimum energy and lifetime requirements of these components, i.e. lamps and luminaires, are in most cases regulated by ecodesign regulations which are currently under revision. Therefore, these components already perform on a high level. Moreover, little progress has been made in recent years with regard to HID lamp efficacy as the focus is on improving LED technology further.

Finally, road lighting is a complex system made of different components such as light sources, ballasts or control gear, luminaires, and sensors and controls. Next to the components, also the installation has to be considered together with the characteristics of the road. To guarantee that the road lighting system achieves a good environmental performance, criteria for the entire system must be defined with complementary criteria for single components.

3 Criteria development

3.1 Concept

In this task the GPP criteria for road lighting and traffic signals are developed and a rationale for each criterion is included. For road lighting the scope is defined as: “Fixed lighting installation intended to provide good visibility to users of outdoor public traffic areas during the hours of darkness to support traffic safety, traffic flow and public security according to standard EN 13201 on road lighting including similar

applications as used for car parks of commercial or industrial outdoor sites and traffic routes in recreational sports or leisure facilities". Note that the current GPP criteria are titled "*Street* lighting" while a name change to "*Road* lighting" is proposed according to the EN 13201 standard. For traffic signals the scope is defined, in accordance with EN 12368, as: "Red, yellow and green signal lights for road traffic with 200mm and 300mm roundels. Portable signal lights are specifically excluded."

Almost all municipalities require road lighting and traffic signals, and public procurement activities may cover one or more of the following areas:

a. Lighting for a new outdoor public traffic area (road or pathway).
b. Lighting for an outdoor public traffic area that is being completely refurbished.
c. Replacement of luminaires within an outdoor public traffic area, while keeping wiring and lighting controls.
d. Retrofit lighting controls, while keeping luminaires.
e. Replacement lamps.

The structure of the criteria follow the same order as the areas mentioned above, i.e. from criteria for design to installation to equipment. Design of a new system may be carried out by the contracting authority's in-house staff, or by a street lighting contractor or an independent lighting designer. The installation work is usually carried out by a contractor.

For understanding the proposed road lighting criteria it is important to understand the road lighting requirements according to standard series EN 13201 which are explained in Task 1 of the Preliminary report, and the technical solutions installed and provided as explained in Tasks 2 and 3 of that report. It is important to understand that, as opposed to residential lighting, relamping with more efficient retrofit lamps is difficult or sometimes impossible. This is mainly due to the ballast/starter or control gear incorporated in luminaires and the optics that are fitted to the HID lamps often used in road lighting. This creates a so-called luminaire lock-in effect which means that when the control gear remains in the luminaire the power consumption remains the same when changing to a more efficient lamp and only more light output is obtained. Also (LED) retrofit lamps can have different radiant patterns that do not de facto match the optics for very compact light sources such as HID lamps. Nevertheless, GPP criteria are included that could serve for more efficient retrofit solutions for the rare cases where they are available or for the case they might enter the market in the future. These criteria can be found under 4.4 on road lighting equipment. In cases where no retrofit measures are possible it is recommended to consider a complete redesign of the installation with new luminaries. Criteria regarding road lighting design can be found in section 4.2. In cases where a redesign and/or LED retrofitting is not desirable, e.g. because of economic reasons, compatible lamps with the existing luminaire could be procured. However, criteria for these lamps are not included in this proposal because it would have little or no positive impact due to the luminaire lock-in effect. In the past, a positive impact could be expected from slightly increasing HID lamp efficacy requirements in the case the new luminaires were specifically designed for those more efficient lamps. However, as indicated in the Preliminary report, this is irrelevant today because LED luminaires are the main technology sold today. Additionally, as explained in Task 1 of the Preliminary report, the Ecodesign Regulation 245/2009 puts already rather strict

requirements on HID lamps. Therefore, no additional efficiency requirements are set for the traditional, non-LED, lamp types. On the other hand, the criteria are designed to be technology neutral.

The purchase of a complete new lighting system happens less frequently, but has a big influence on energy consumption. Therefore, a guidance is provided to do a quick check if a complete redesign would be appropriate. This guidance, together with the criteria, could provide a stimulus for considering a complete redesign and installation of the system.

The newly proposed design criteria are mainly based on the annual energy consumption indicator (AECI) and the power density indicator (PDI) and provide a more holistic approach rather than criteria on a component level. These indicators are in principle technology neutral, but the requirements in the criteria can only be met by LED lighting or in some cases by the very best designs and HID components. Possible new technologies that are at least as efficient as LED technology could also be integrated. Another benefit from the proposed design criteria is that they not only cover improvements from luminaire efficacy, but also from the lighting design and installation itself. Nevertheless, stand-alone luminaire criteria are proposed as well. Also for control gear and ballasts reference is made to separate requirements.

LED road lighting is becoming the mainstream solution in new or renovation projects and is often sold as luminaires with integrated LED modules. Therefore, the proposed criteria are focused on LED solutions rather than on traditional (HID, MH) lamp criteria. The traditional technologies are only expected for replacements and as explained before not much impact on energy consumption is foreseen from such a replacement.

3.2 Guidance for considering renovation beyond relamping

In case the procurer has to install a complete new system, a new design will have to be put forward by a lighting designer according to the relevant standards, mainly the EN 13201 series. In most cases, however, the task of the procurer will be to maintain part of the installation such as the existing luminaires, poles and cables. It is currently not straightforward to replace existing HID lamps for road lighting with retrofit LED lamps. This is mainly due to the ballast or control gear incorporated in the existing luminaires and the optics that are fitted to HID lamps. This creates the so-called luminaire lock-in effect and does not provide any energy savings. Moreover, it might be difficult to simply retrofit LED lighting given the space constraints that could be found in existing luminaires and the heat dissipation that should be taken into account when working with LED modules. Therefore, it might be recommended to consider a redesign of the installation with new luminaries, especially for installations with HID lamps that do not satisfy the proposed GPP requirements. .

The guidance provided could help building a reference on what commonly could be achieved with redesign and/or LED luminaire retrofitting in comparison with the existing installation. Obviously, this guidance step has to be taken by the procurer before procuring any goods.

The guidance is based on a check of the installed power per km [kW/km] which can be compared with the outcome of a given formula that provides a reference to the state-of-art power consumption for a LED road lighting solution (first quarter 2016). The following steps have to be carried out:

1. The current installed power per km P [kW/km] shall be measured or calculated from the rated lamp wattage multiplied with the ballast loss (or with a factor 1.1 in case the ballast lost is unknown) and pole distance that are currently installed.

2. The minimum suitable road class shall be selected from EN 13201-2:2016 taking into account the local standards for road class selection. The minimum average maintained illuminance (E,m) according to the road class shall be sourced from the standard.

3. The installed power P [kW/km] has to be compared with a LED reference Pref [kW/km], i.e.

   Pref = 0.161 x E, m[lx] for road widths (RW) up to 10 m
   Pref = 0.161 x E, m[lx] x RW/10 for road widths (RW) > 10 m

4. A redesign is recommended when P > 1.1 x Pref.
   Based on these values the possible annual savings for electricity consumption can be easily estimated as (P-Pref) x annual burning hours x electricity cost [euro/kWh].

5. Based on the estimate of the annual savings for electricity a first simple LED luminaire renovation pay back verification could be done. Therefore, given a 20 year lifetime of the installation, the yearly estimated saving should be multiplied by 20 and this should be compared with the reference LED luminaire installation cost per km (e.g. 10 000 euro/km). A detailed life cycle cost analysis (LCC) could be useful as other parameters such as frequency of replacement, inflation, etc. can be taken into account.

6. For the verification step, a final report documenting the justification of the selected road class (according to EN 13201-2:2016), the corresponding reference minimum average maintained illuminance (E,m), the installed wattage per km, projected annual savings for electricity consumption and a final recommendation shall be provided. For cases that not satisfy the simple LED luminaire renovation pay back verification in step 5 the recommendation shall be based on a life cycle costing (LCC) analysis (see award criterion for road lighting design).

3.2.1 Consequences

The procurer can easily check if it is worth to plan a complete redesign, i.e. a change in luminaires (or even pole distances and heights) rather than a changing of the lamps. Combined with a life cycle costing calculation, the procurer should be well informed about a possible renovation and redesign of the existing installation. When combining

the guidance with the LCC information it will become clear that LED luminaires provide in most cases the best solution if installed in optimum conditions. The proposed GPP criteria can then be exploited to their fullest benefit.

3.2.2 Consultation questions

1) Do you think that the guidance provided above is appropriate?
2) Can you suggest any specific tool for implementing LCC, e.g.http://ec.europa.eu/environment/gpp/pdf/SF_SSSUP_ELCC.xlsm?
3) Is the reference power per km (Pref) well defined?
4) Should the ballast loss be included when calculating the installed power per km?
5) Should we use PDI [W/(lx.m²)] values for comparison to a reference instead of installed power per km P[kW/km] (note: the previous formula can be converted)?
6) What would be a good estimate or reference value for LED luminaire installation cost per km?

4 Proposed GPP criteria

4.1 Overview and comparison with current criteria

Current criteria			Updated (√) or discarded (x) in the new proposal
Street Lighting Equipment			
	Subject matter		√
	Technical specifications		
		Lamps efficiency	√
		Ballast efficiency	x
		Packaging	x
		Lifetime (FLLM, FLS)	√
		Ingress protection	√
	Award criteria		
		Lifetime (FLLM, FLS)	√
		Mercury content	x
		Ballast efficiency	x
		Luminaires compatible with dimming/controls	√
Street Lighting Design			
	Subject matter		√
	Selection criteria		√
	Technical specifications		
		Power density indicator (PDI) (formerly called SLEEC value)	√
		Upward light (RULO)	√
	Award criteria		
		Aunnual energy consumption indicator (AECI)	√
		Points per % of dimming	x
		Upward light (RULO)	√
Street Lighting Installation			
	Subject matter		√
	Selection criteria		√
	Technical Specifications		
		Provision of instructions	√

	Contract performance clauses		√

Traffic Signals	*Subject matter*		√
	Technical specifications		
		Operating wattage	√

Proposed criteria			New compared to previous criteria
Street Lighting Design	*Subject matter*		
	Selection criteria		
	Technical specifications		
		Annual energy consumption indicator (AECI)	new
		Power density indicator (PDI)	
		Upward light (RULO)	
		LCC	new
		Metering	new
	Award criteria		
Street Lighting Installation	*Subject matter*		
	Selection criteria		
	Technical specifications		
		Provision of instructions	
	Contract performance clauses		
Street Lighting Equipment	*Subject matter*		
	Technical specifications		
		Luminaires	
		Quality (ENEC+)	new
		Photometric file	new
		Efficiency	new
		Compatible with dimming/controls	
		Lifetime extension	new

		Ingress protection Lamps Efficiency Lifetime (LxBy, LxCz) Ballast/control gear Lifetime (failure rate)	new

Traffic Signals	*Subject matter* *Technical specifications*	Operating wattage Lifetime	new

4.2 EU GPP criteria for road lighting design

4.2.1 Subject matter

Resource and energy efficient design of new lighting systems or renovation of the existing lighting system.

4.2.2 Selection criteria

4.2.2.1 Rationale

In order to properly design a road lighting installation excellent knowledge is required from the market status, the EN 13201 standard series, lighting design software and installation practices. Moreover, the planning and approval of outdoor lighting installations should be according national spatial planning and road legislation which is under the responsibility of municipalities or other authorities. Therefore, this criterion searches for evidence to proof that the required skills are available for the service requested.

The selection criterion for road lighting design has been specified to ensure the range of competencies and experience that would be required to successfully design a new or renovated lighting system. It reflects the need for experience in the specific technical area as well as in the successful management of the work. It is important that the level of experience of the tender and their team can be compared and proved against a clear minimum requirement.

4.2.2.2 Proposed criterion

Core criteria	Comprehensive criteria
Selection criteria	
SC - Competences of the design team Where a new lighting system is being designed or an existing system is being renovated, the tenderer shall demonstrate that the design will be undertaken by personnel with at least three years of experience in lighting design and/or having a suitable professional qualification in lighting engineering or membership of a professional body in the field of lighting design. **Verification:** The tenderer shall supply a list of the persons responsible for the project, including managerial staff, indicating educational and professional qualifications and relevant experience. This should include persons employed by subcontractors where the work is to be sub-contracted. The tenderer shall also supply a list of lighting schemes the tenderer has designed over the last three years.	

4.2.2.3 Consequences

The road lighting system will be properly designed by skilled professionals.

4.2.2.4 Consultation questions

1) Would it be useful to ask for more or less than three years of experience?
2) Would it be useful to substitute the years of experience by relevant courses that have been followed? Or should such courses be added in complement to the years of experience?

4.2.3 Technical specifications for the design of installations

4.2.3.1 Annual energy consumption indicator (AECI) and power density indicator (PDI)

4.2.3.1.1 Rationale

The main goal of these criteria is to compare the energy performance of different lighting solutions and technologies for the same target road and identify the most efficient solution.

The main parameters to define the energy performance for a road lighting installation are the Power Density Indicator (PDI) expressed in W/(lx.m²) and the Annual Energy Consumption indicator (AECI) expressed in kWh/(m²y). These indicators are defined in the European standard EN 13201-5:2016 'Road lighting- Energy performance indicators', are independent of the used technology and include the energy consumptions at component level. Therefore, there is in principle no need to set overlapping efficiency requirements for individual components such as lamps and ballasts when designing a new system. Nevertheless, the calculation of these two indicators is based on product data and therefore verification is necessary to proof that the components are compliant with the data used for the calculations of the PDI and AECI indicators.

PDI

The PDI and AECI values depend on the road class for which the installation is designed and minimum illuminance (E,m) is an important parameter. For road classes that do not have illuminance requirements, conversion formulas are provided in EN 13201-5:2016. In these cases the illuminance conversion formulas are:

- For road lighting where luminance ($\bar{L}$,m) is used instead of illuminance (E,m), the following conversion formula should be used, assuming a reference asphalt reflection coefficient: $E,m = \bar{L},m/0.07$
- For road lighting where hemispherical illuminance (E,hs) is used instead of illuminance (E,m), the following conversion formula should be used: $Em,min = E,hs/0.65$

It should be noted that 1 W/(lx.m²), i.e. the unit of PDI, is equivalent to 1 W/lm which is the reciprocal value of the installation efficacy in lm/W. The PDI indicator does not take into account dimming and/or over-lighting. Dimming and over-lighting are taken into account in the AECI indicator. Therefore, it is recommended to use both indicators together when setting requirements. The PDI and AECI indicators are already used in certain countries and documents. Examples are provided in the Annex of this document.

Annex A of EN 13201-5:2015 provides examples of calculations and typical values of energy performance indicators for different lamp types and reflects the state of art of these lamp types in the first quarter of 2014 (Q1/2014). The best performance values are always related to LED and this technology has been developing further since. The best PDI values obtained in the given conditions were 0.017 W/lm or 58 lm/W which is superior to the current GPP criteria. For LED technology, the PDI values in the standard show that they do not or little depend on the road illuminance requirements or road class (see also Table 4-1). This leads to the fact that for LED technology there is no rationale anymore to link PDI requirements to lamp wattage and/or road illuminance. Note that in the current criteria different requirements where set depending on the wattage. This is not necessary anymore given the availability of |LED technology. The main difference between the PDI values in the standard relate to the road width, especially for narrow roads (< 7m). The fact that for narrow roads the PDI values are rather high is attributed to a lack of optics directing the light precisely to the intended road surface.

In the second quarter of 2016 (Q2/2016) seven reference road designs were analysed in detail. The reference designs correspond to a motorway class M2, a national road class M3, a secondary rural roads class M4, a secondary road with mixed traffic class C3, a residential street class P2, a residential street class P4 and a residential street class M5/P5. These designs were developed and calculated using input from stakeholders in the context of the Ecodesign lot 37 study 'Preparatory study on lighting systems' (http://ecodesign-lightingsystems.eu/) and the findings can be used for this project as well. The best values for PDI found in this analysis are indicated as 'Lot 37 BAT' in Table 4-1 and correspond to LED technology. These values can be compared to the best values in the EN 13201-5:2016 standard and are indicated as 'Best EN standard'. The difference between the column 'Lot 37 BAT' and 'Best EN standard' can be interpreted as a development of LED technology and design optimization practices for road lighting from Q1/2014 to Q2/2016.

Given the observed correlation between PDI and road width a fitting was made to use a simple formula instead of using tables with complementary interpolations. The fitting was done according to road class M3 with a road width of 7 meter and is indicated as '161/RW' in Table 4-1. In general, this fitting relationship shows a lower value for the PDI indicator comparing with the (best) standard EN13201:5 values, but higher than the 'lot 37 BAT' which can be seen as the best on the market currently. Therefore an adjustment factor of 1.3 is proposed in the core criteria and 1.1 in the comprehensive criteria.

The proposed formula to define a criterion for the PDI value is thus

$$PDI = FF \times 161/width$$

with a fitting factor (FF) proposed to be 1.3 for the core criteria and 1.1 for the comprehensive criteria.

Comparing different designs and road layouts, it was also found that not only the road width is important, but also the luminaire arrangement and road profile. For example, it has shown evident that a better utilance can be achieved with central luminaire arrangement or long boom angles. Such an arrangement is however not always possible for several reasons such as safety and local conditions (e.g. infrastructure such as centerbeam). These design optimisations are location dependent and should be taken into account when defining criteria using the PDI value based on this fitting approach. Moreover, a deviation could be allowed if particular

(local) constraints hinder the implementation of the most efficient design. This shows that full optimisations need to be analysed case by case and provides a strong argument for life cycle costing or similarly total cost of ownership analysis.

Table 4-1 Selection of typical values of the Power Density Indicator PDI [mW/(lx.m²)] for various road profiles in Annex A of EN 13201-5:2016 compared to similar recent calculated reference designs 'lot 37 BAT'.

PDI [mW/lx.m²] Annex A EN 13201:5						PDI [mW/lx.m²] Calculation reference designs					
	Width of carriageway	Lamp type*									
road class	m	MH	HPS non-clear	HPS clear	LED	Best EN standard	Lot 37 reference design	Lot 37 BAT	161/RW	Proposed core criterion 161/RW x 1.3	Proposed comprehensive criterion 161/RW x 1.1
road profile A											
M2	7	50		31 - 40	24 - 27	24			23.0	29.9	25.3
M3	10	42	43	31 - 32	25 - 27	25	**M2****	13	16.1	20.9	17.7
	8	42	40	30 - 33	27	27			20.1	26.1	22.1
	7	47	40	34 - 38	23 - 25	23	**M3**	23	23.0	29.9	25.3
	6	51	43	40 - 44	25 - 28	25			26.8	34.8	29.5
M4	7	60	41 - 47	34 - 42	23	23			23.0	29.9	25.3
M5	7	30	47	38 - 45	24	24			23.0	29.9	25.3
	6	34	53	41 - 51	28	28			26.8	34.8	29.5
	5	41		53	38	38			32.2	41.9	35.4
	4	48		65	46	46			40.3	52.4	44.3
road profile B											
C3	10	44	43	32	18 - 23	18	**C3**	9	16.1	20.9	17.7
	7	51	39 - 45	35 - 41	24	24	**P2****	22	23.0	29.9	25.3
	6	57	48	43	25 - 28	25			26.8	34.8	29.5
C5	7	29	60	44 - 53	27	27	**P4****	16	23.0	29.9	25.3
	6	36	69	50 - 60	31	31			26.8	34.8	29.5
	5	43		53 - 59	41	41			32.2	41.9	35.4
road profile E											
M3/P3	10	34	29	24 - 33	17 - 18	17			16.1	20.9	17.7
M4/P4	10	41	33 - 34	26 - 28	17	17	**M4/P4**	14	16.1	20.9	17.7
M5/P5	10	22	33	28 - 32	17	17	**M5/P5**	16	16.1	20.9	17.7

* Note that for the lamp types HPM lamps are omitted since they are phased out by ecodesign measures since 2015.
**Note that the EN standard does not contain reference values for all combinations and also not for all Lot 37 reference designs. Therefore the reference designs are compared to what is considered the most identical design in the EN standard. Because for LED there is little relation between light level and luminaire efficacy the comparisons were made based on fitting with the road width

.

AECI

Not only the PDI value is important in lighting system design, but also the AECI indicator which is expressed in kWh/(m².y). Unlike the PDI indicator the AECI indicator does take into account dimming, over-lighting and a constant light output (CLO) regulation system (see EN 13201-5:2016).

In a worst case scenario with full power all night (i.e. around 11h/day ≈ 4 000 h/y) the AECI [Wh/(m².y)] is related to PDI by the following formula:

$$AECI\ [Wh/(y.m^2)] = CL \times PDI[W/lm] \times E,m[lx] \times 4\,000\ h/y$$

with

CL the factor to compensate for over-dimensioning compared to the minimum requirements;

E,m the minimum average maintained illuminance according to the road class defined in EN 13201-2:2016. For road lighting where luminance ($\bar{L}$,m) is used instead of illuminance (E,m), the conversion formulas from EN 13201-5:2016 should be used.

In the standard, a CL factor of 1.1 has been used to set the values for LED technology.

With traditional lamps over-lighting was typically due to the limited range of available lamp wattages (e.g. 50-70-100 W) that could be used to fulfil the minimum requirements. For LED systems, a more continuous spectrum of different wattages is available and smart dimming can be applied to compensate over-lighting. Therefore, over-lighting should only be applied in the design to account for a decrease in lumen output which is usually defined by the LxBy and LxCz values. For explanation of these values see Preliminary report section 3.4.2.3.

Setting the CL factor below 1 requires the installation to dim. Column 'Lot37 BAT' in Table 4-2 shows the AECI values when dimming is assumed to the lowest class or maximum two classes lower of EN 13201-2:2016 (e.g. class M4 to M6 or M5 to M6) during half the night (i.e. 2000 h/y). As a consequence, more ambitious GPP criteria could be developed for the minimum AECI values when dimming is included in the system.

As in the PDI case, a life cycle cost analysis could clearly show the most cost effective solutions indicating e.g. ambitious designs with full dimming schemes.

Filling the previously defined formula for PDI (i.e. PDI = FF x 161/RW) with a fitting factor FF (1.3 for the core criteria and 1.1 for the comprehensive criteria) would lead to a formula for AECI as follows

$$AECI\ [kWh/m^2] = CL \times FF \times 161/RW \times E,m \times 0.004$$

The CL factor is proposed to be 0.85 for the core criteria and 0.75 for the comprehensive criteria and accounts for dimming. For AECI, the FF has to be multiplied by CL which leads to a total factor of:

- 1.1 for the core criterion (i.e. CL x FF = 1.3 x 0.85 = 1.1)
- 0.8 for the comprehensive criterion (i.e. CL x FF = 1.1 x 0.75 = 0.8)

Table 4-2 Typical values of the Annual Energy Consumption Indicator AECI in kWh/m² for various road profiles in Annex A of EN 13201-5:2016 compared to similar recent calculated reference designs 'lot 37 BAT' and values calculated from PDI 'DE-CL'

	AECI [kWh/m²]Annex A EN 13201:5					AECI [kWh/m²] Calculation reference designs				
	Width of carriageway	Lamp type*								
road class	m	MH	HPS non-clear	HPS clear	LED	Best EN standard	Lot37 BAT	E,m min [lx]	Proposed core criterion	Proposed comprehensive criterion
road profile A										
M2	7	4.6		3.2 - 4.2	2.4 - 2.5	2.4		21.4	2.2	1.6
M3	10	3.4	3.0	2.3	1.6	1.6	0.39	14.3	1.0	0.7
	8	3.4	3.0	2.2 - 2.4	1.6	1.6		14.3	1.3	0.9
	7	3.6	2.8 - 3.1	2.5 - 2.6	1.5	1.5	0.51	14.3	1.4	1.1
	6	3.9	3.2	2.7 - 2.8	1.6	1.6		14.3	1.7	1.2
M4	7	3.1	2.3 - 2.5	1.8 - 2.4	1.1	1.1		10.6	1.1	0.8
M5	7	0.9	1.7	1.1 - 1.6	0.8	0.8		7.1	0.7	0.5
	6	1.0	2.0	1.2 - 1.7	0.9	0.9		7.1	0.8	0.6
	5	1.2		1.5 - 1.8	1.0	1.0		7.1	1.0	0.7
	4	1.5		1.7 - 2.3	1.3	1.3		7.1	1.3	0.9
road profile B										
C3	10	2.7	3.1	1.9 – 2.0	1.1 - 1.4	1.1	0.50	15.0	1.1	0.8
	7	3.2	2.6 - 3.1	2.2 - 2.6	1.5 - 1.6	1.5	0.34	15.0	1.5	1.1
	6	3.8	3.0	2.6	1.6 - 1.8	1.6		15.0	1.8	1.3
C5	7	0.9	1.8	1.3 - 1.6	0.8	0.8	0.38	7.5	0.8	0.6
	6	1.1	2.1	1.6 - 1.8	1.0	1.0		7.5	0.9	0.6
	5	1.4		1.8 – 1.9	1.3	1.3		7.5	1.1	0.8
road profile E										
M3/P3	10	2.3	1.8 – 2.0	1.6	1.0	1.0		14.3	1.0	0.7
M4/P4	10	2.0	1.5	1.2 - 1.5	0.7	0.7	0.21	10.6	0.7	0.5
M5/P5	10	0.6	1.0	0.7 - 1	0.5	0.5	0.22	7.1	0.5	0.4

* Note that for the lamp types HPM lamps are omitted since they are phased out by ecodesign measures since 2015.

4.2.3.1.2 Proposed criterion

Core criteria	Comprehensive criteria
Technical Specification	
TS 1 - annual energy consumption indicator (AECI) and power density indicator (PDI) Where a new lighting system is being provided for a traffic route, the maximum annual energy consumption indicator (AECI) and power density indicator (PDI), must not exceed the following values: PDI [mW/(lx.m²)] < 1.3 x 161/RW[m] AECI [kWh/(m².y)] < 1.1 x 161/RW[m] x 0.004 x E,m [lx] With • RW: the total width of the road including emergency lanes, sidewalks and cycle lanes when they are in the target area. A minimum of 5 m and a maximum of 10 m shall be used. • E,m: is the minimum average maintained illuminance according to the road class defined in EN 13201-2:2016. For road lighting where luminance ($\bar{L}$,m) is used instead of illuminance (E,m), the conversion formulas from EN 13201-5:2016 shall be used, i.e. E,m = $\bar{L}$,m/0.07. For road lighting where hemispherical illuminance (E,hs) is used instead of illuminance (E), the conversion formula from EN 13201-5:2016 shall be used, i.e. Em = Ehs/0.65 **Verification** A calculation of PDI and AECI according to EN 13201-5:2016 shall be provided and shall be conform the conditions defined above. The public authority may accept higher values of PDI and/or AECI where there are particular constraints, for example unusual	**TS 1 - annual energy consumption indicator (AECI) and power density indicator (PDI)** Where a new lighting system is being provided for a traffic route, the maximum annual energy consumption indicator (AECI) and power density indicator (PDI), must not exceed the following values: PDI [mW/(lx.m²)] < 1.1 x 161/RW[m] AECI [kWh/(m².y)] < 0.8 x 161/RW[m] x 0.004 x E,m [lx] With • RW: the total width of the road including emergency lanes, sidewalks and cycle lanes when they are in the target area. A a minimum of 5 m and a maximum of 10 m shall be used. • Em: is the minimum average maintained illuminance according to the road class defined in EN 13201-2:2016. For road lighting where luminance ($\bar{L}$m) is used instead of illuminance (Em), the conversion formula from EN 13201-5:2016 shall be use, i.e. E,m = $\bar{L}$,m/0.07. For road lighting where hemispherical illuminance (Ehs) is used instead of illuminance (E), the conversion formula from EN 13201-5:2016 shall be used, i.e. Em = Ehs/0.65 **Verification** A calculation of PDI and AECI according to EN 13201-5:2016 shall be provided and shall be conform the conditions defined above. The public authority may accept higher values of PDI and/or AECI where there are particular constraints, for example unusual

mounting heights or locations of poles or where the street lighting is intended to be ornamental or decorative. In some cases up to double the requested PDI and AECI values could be acceptable. The particular constraints and their influence on the PDI and AECI values shall be clearly justified in the tender. The tender shall supply the photometric file of the luminaires and the component parameters relevant for defining the PDI and AECI values. The tenderer shall provide the above mentioned technical specifications of the light source, measured by using reliable, accurate and reproducible measurement methods, which take into account the recognised state-of-the-art measurement methods including, where available, harmonised standards adopted by the European standardisation bodies, Where dimming is applied the dimming assumptions shall be described in accordance with EN 13201-5:2016.	mounting heights or locations of poles or where the street lighting is intended to be ornamental or decorative. In some cases up to double the requested PDI and AECI values could be acceptable. The particular constraints and their influence on the PDI and AECI values shall be clearly justified in the tender. The tender shall supply the photometric file of the luminaires and the component parameters relevant for defining the PDI and AECI values. The tenderer shall provide the above mentioned technical specifications of the light source, measured by using reliable, accurate and reproducible measurement methods, which take into account the recognised state-of-the-art measurement methods including, where available, harmonised standards adopted by the European standardisation bodies, Where dimming is applied the dimming assumptions shall be described in accordance with EN 13201-5:2016.

4.2.3.1.3 Consequences

Road lighting installation will have at least a minimum efficiency according to current LED performance. As LED performance is expected to develop further, even better installations, i.e. with better AECI and PDI values, are expected in the future.

4.2.3.1.4 Consultation questions

1) The PDI limits are based on a fitting of 161/RW. Do you agree with this fitting approach?
2) Which are the pros and cons of this simplification into one formula for all road classes and road widths?
3) Is the dependence on road width still expected to be relevant for future LED luminaires with improved optics?
4) Do you agree with the setting the fitting factor to 1.3 and 1.1 for the core and comprehensive criteria respectively? Is this too strict or not strict enough?
5) Should tiers be implemented to account for future LED developments?
6) For the AECI values dimming is already taken into account from the start by setting CL at 0.85 for the core criteria and 0.75 for the comprehensive criteria. Do you agree with this or do you think that dimming should be left out from these calculations and leave it as an extra improvement option?

7) Do you agree that 'The public authority may accept higher values of PDI and/or AECI where there are particular constraints specified in the tender'?
8) Is it necessary to ask for a specific format for the photometric file?
9) Is it sufficient to ask for the photometric file and the other parameters based on self-declaration or should verification or certification be asked for?
10) Are there other criteria related to AECI and PDI that should be added, e.g. the luminaire maintenance factor (FLLM) and/or cleaning cycle?

4.2.3.2 Light pollution, upward light output ratio (RULO)

4.2.3.2.1 Rationale

As explained in the Preliminary report the use of artificial light at night can cause light pollution and have a negative impact on species and star observation.

In order to reduce light pollution and improve the energy efficiency, luminaires have to be designed and installed in order to limit the proportion of light being emitted above the horizon. This is taken into account in the Upward Light Output Ratio (RULO). A full spherical photometry file is needed to provide evidence of this property and tolerances of 3% are sometimes considered. The current GPP upward light output limits are similar to the approach of benchmark values found in Annex VII of EC Regulation 245/2009, but are not identical.

Limits on RULO are formulated in the technical guide CIE 126:1997 (see section 1.4.2.6 of the Preliminary report). This guideline couples the requirement to different zones (urban, natural, etc.). As explained in the Preliminary report (Task 1) this approach is implemented by some regional authorities (e.g. in Catalonia). In that case the procurer has to define the zone and the corresponding requirements.

Note that in a recent review of EN 13201-6:2016 luminous intensity classes for the restriction of disability glare and control of obtrusive light G*1, G*2, G*3, G*4, G*5 and G*6 are introduced in an informative Annex. Although intended for obtrusive light these luminous intensity classes could be considered as an alternative requirement for light pollution on sky glow.

LED luminaires typically include glass envelopes, lenses, optical mixing chambers, reflectors and/or diffusers to obtain the desired light distribution. These features reduce the total light output ratio and RULO is the upward fraction of it. US DoE (DOE, 2014) reports an optical efficiency for LED luminaires of 85% in 2013 and projects to have optical efficiencies of 94% for 2020. With traditional HID cobra-heads there was a trade-off when choosing between drop refractor type lenses and flat glass lenses. Drop lens units were typically used for wider pole spacings and more uniform lighting patterns. Flat glass units usually have less upward light output, better control of light trespass into residential windows, and lower high angle glare. However, flat glass also reduces the total light output or efficiency of the luminaire due to increased internal reflections. Internal reflections can be attenuated by using anti-reflective coatings.

One of the benefits of LED luminaires is that they can better deal with luminaire efficacy and RULO due to their refined optical design combined with anti-reflective coatings on the cover glass. This, however, usually results in a higher manufacturing cost.

From the point of view of environmental impact and products available on the market there is no ground to discriminate RULO requirements according to EN 13201-2 road classes. It should be noted that P classes only occur in residential areas and therefore they could be subjected to less strict requirements.

The proposal hereafter is based on the benchmark provided in ecodesign regulation EC/245/2009 which provides a value of 1% independently of the type of road for areas where light pollution is of concern. Additionally, as described in the Preliminary report in Task 1, negative impact on biodiversity could result from compelling and/or attracting specific species by using outdoor lighting with particular spectral bands. This effect can be indirectly limited by requiring a low colour temperature (CCT < 3000 K) as this will limit the violet and blue light emitted. The spectral bandwidth can be limited by requiring a lower colour rendering index, e.g. CRI < 70. These latter two requirements are proposed to be integratd in the comprehensive criterion.

4.2.3.2.2 Proposed criteria

Core criteria	**Comprehensive criteria**
Technical Specification	
TS2 - Light pollution The maximum proportion of light going above the horizon is not more than 1 % for all road classes and lumen outputs. **Verification** The photometry file shall be provided including the calculated upward light output ratio (RULO). In cases where luminaires are not installed horizontally, the photometric file shall prove that there is no significant light emission within the installation angle.	**TS2 - Light pollution** The maximum proportion of light going above the horizon is not more than 1 % for all road classes and lumen outputs. For areas where light pollution is of concern the correlated colour temperature (CCT) shall be lower or equal to 3000 K and the colour rendering index shall be lower than 70. **Verification** The photometry file shall be provided including the calculated upward light output ratio (RULO). In cases where luminaires are not installed horizontally, the photometric file shall prove that there is no significant light emission within the installation angle. A measurement certificate that proofs that CCT ≤ 3000 K shall be provided. A measurement certificate that proofs that CRI < 70 shall be provided.

	The light source spectrum shall be provided for the wavelengths between 200 and 900 nm in 10 nm steps and the influence on species shall be explained.

4.2.3.2.3 Consequences

Light pollution will be minimized and the impact on certain species will be reduced.

4.2.3.2.4 Consultation questions

1) Is a 1% RULO realistic for all road types? Are there any exceptions that should be mentioned in the criteria?
2) Should a measurement tolerance for RULO already be included in the criteria setting?
3) How would this criteria influence the cost and efficacy of the luminaire?
4) In a recent review of EN 13201-6:2016 luminous intensity classes for the restriction of disability glare and control of obtrusive light (G*1, G*2, G*3, G*4, G*5 and G*6) are introduced in an informative annex and requirements for maximum luminous intensity in cd/klm are provided to be checked for the actual tilt once the luminaire is installed. Should the criteria be based on requiring those classes instead of limits for RULO?
5) In the comprehensive criteria it is stated [For areas where light pollution is of concern…]. Should that be left to the procurer to define or should it be more specifically defined according to the guideline CIE 126 (1997) and depend on environmental zones and distance between these zones?
6) In the comprehensive criteria it is stated […and the influence on species shall be explained]. Should this be more specified or could it be left open for the tenderer to provide specific information on this?
7) Are there any standards available to refer to for the measurement of RULO, CCT and CRI? Is it needed to ask for a certificate for these values or would a verification or self-declaration be sufficient?
8) Should criteria on photo biological safety be included?

4.2.4 Award criteria

4.2.4.1 Least Life Cycle Costing (LLCC)

4.2.4.1.1 Rationale

The proposed criteria in section 4.2.3.1 show cut-off limits for the AECI and PDI parameters but do not provide any incentive to go beyond these limits even though the life cycle cost (LCC) is dominated by the operational electricity expenditure. It would be most interesting for the procurer to know the full life cycle cost of the system before installing and operating the system. In that case, a higher initial purchase price could be justified for installations with even lower AECI values compared to the cut-off limits provided in 4.2.3.1. In case of a renovation a comparison with the current installation in terms of LCC can show the economic convenience of the new proposal.

Therefore, the procurer could call upon Least Life Cycle Costing (LLCC) to compare different offers. Examples of LLCC are provided in the Preliminary report and can be found in the report CIE 115 "Lighting of Roads for Motor and Pedestrian Traffic". The proposed criterion is based on a criterion from the Swedish national agency for public procurement of road lighting.

4.2.4.1.2 Proposed criterion

Core criteria	**Comprehensive criteria**
Award Criteria	
AC1 - Life Cycle Costing (LCC) The tenderer shall present life cycle costs for the planned installation. The designed installation shall also be compared to the existing installation (if any) and at least to one more solution. An analysis of the choice shall be presented. The operation and maintenance plan shall be taken into consideration in the calculation. Points will be awarded to those offers that provide a least life cycle calculation. **Verification:** LCC calculations shall be clearly presented in a spreadsheet including input parameters such as the cost of labour, the amount of man-hours, electricity costs, variable costs, purchase price, expected life time of luminaires, PWF (present worth factor), maintenance costs (time to clean a luminaire in group cleaning, time to repair a luminaire in spot replacement, frequency for luminaire cleaning, etc.).	

4.2.4.1.3 Consequences

The procurer has a clear overview of the cost over the lifetime of the installation. This will help making the best choice based on a life cycle cost analysis. It might also be a tool to go beyond the AECI and PDI limits proposed in the technical specifications.

4.2.4.1.4 Consultation questions

1) Could this criterion jeopardize fair competition as it might be difficult to fairly compare different LCC calculations?

4.2.4.2 Metering

4.2.4.2.1 Rationale

As shown in the Preliminary report the operational costs of electricity are the major contribution in the total cost of ownership of road lighting installations. The electricity has to be billed and purchased for road lighting, but in a lot of cases there are no meters to count the electricity consumption. In those cases it usually means that the bill to pay is calculated by the lamp power and the switching system without considering the real consumption and possible dimming. Additionally, maintenance and correct operation of the control systems can have a further impact on the forecasted energy consumption. These aspects would be taken into account if a metering system is implemented.

Metering could provide extensive and up-to-date information about the electricity use of the installation, so the procurer knows exactly the energy consumption and could take measures in case this deviates from the forecasted values.

As mentioned in the Prelimary report (section 3.3.3) more and more cities understand that a metering system with a streetlight network may play a strategic role in overcoming several challenges such as improving maintenance processes (automatic lamp and electrical failure identification), reducing energy consumption and communicate on associated CO_2 savings. A metering system could be added to the existing street lighting system, even if non-LED technologies are in place.

4.2.4.2.2 Proposed criterion

Core criteria	**Comprehensive criteria**
Award criteria	
AC2 – Metering The tenderer shall include a metering and measurement system that, at least, remotely identifies failures and monitors the energy consumption of each luminaire by collecting data of energy use and run hours. Points will be awarded to those offers that provide a metering and measurement system. **Verification:** The tenderer shall provide the technical specifications of the metering and measurement system and provide clear instructions on how to operate and maintain this system. A calibration certificate compliant with the Measuring Instruments Directive 2004/22/EC (MID) shall be provided for each control zone.	

4.2.4.2.3 Consequences

Real AECI values can be checked in line with forecasted AECI values. Repair cost can be kept under control and failures can be easily identified.

4.2.4.2.4 Consultation questions

1) Is this common practice in some regions?
2) What is the cost of such a metering system?
3) Is a metering system easy to be implemented in renovated systems?

4.3 EU GPP for road lighting installation

4.3.1 Subject matter

Resource and energy efficient installation of new lighting systems or renovation of the existing lighting system.

4.3.2 Selection criteria

4.3.2.1 Rationale

The same rationale as for the selection criteria for the design of the installation hold for the selection criteria for the installation of the road lighting system. In order to properly install a road lighting installations excellent knowledge is required from the market status, the EN 13201 standard series and installation practices. Therefore this criterion searches for evidence to proof that the required skills are available for the service requested.

The selection criterion has been specified to ensure the range of competencies and experience that would be required to properly install a road lighting system.

4.3.2.2 Proposed criterion

Core criteria	**Comprehensive criteria**
Selection criteria	
SC - Competences of the installation team Where a new or renovated lighting system is being installed, the tenderer shall demonstrate that the installation will be undertaken by personnel with at least three years experience in installation of lighting systems and/or having a suitable professional qualification in electrical or building services engineering, or membership of a professional body in the field of lighting. **Verification:** The tenderer shall supply a list of persons responsible for the project, including managerial staff, indicating educational and professional qualifications, relevant experience, and related certificates. This should include persons employed by subcontractors where the work is to be sub-contracted. The tenderer shall also supply a list of lighting schemes the tenderer has installed over the last three years.	

4.3.2.3 Consequences

The road lighting system will be properly installed by a skilled workforce.

4.3.2.4 Consultation questions

1) Would it be useful to ask for five years of experience in the comprehensive criteria or would that not really improve the reliability of the installers?

4.3.3 Technical specifications for installations

4.3.3.1 Provision of instructions

4.3.3.1.1 Rationale

As lamps and luminaires will probably have to be replaced or repaired at least once in their lifetime, it is important that the procurer has the knowledge on how this should be done.

When controls are provided with the system, the procurer has to exactly know how to operate and calibrate them. These requirements also facilitate the maintenance and correct operation of the control systems. This will not only have an impact on the lifetime of the system, but also on the real-life energy consumption compared to the forecasted AECI [kWh/(m².y)].

4.3.3.1.2 Proposed criterion

Core criteria	**Comprehensive criteria**
Technical Specification	
TS – Provision of instructions The tenderer shall provide the following information with the installation of new or renovated lighting systems: • Disassembly instructions for luminaires • Instructions on how to replace light sources (where applicable), and which lamps can be used in the luminaires without decreasing the energy efficiency. • Instructions on how to operate and maintain lighting controls. • For daylight linked controls, instructions on how to recalibrate and adjust them. • For time switches, instructions on how to adjust the switch off times, and advice on how best to do this to meet visual needs without excessive increase in energy consumption. **Verification:** Confirmation that written instructions will be provided to the contracting authority.	

4.3.3.1.3 Consequences

With proper instructions on how to replace light sources and operate lighting controls the real life AECI values will be more in line with forecasted AECI values, also after replacing lamps or when a recalibration of the system has been carried out. Repair cost can be more easily foreseen and recycling at the end-of-life is facilitated.

4.3.3.1.4 Consultation questions

The stakeholders are invited to provide comments on this criterion if need be.

4.3.4 Contract performance clauses

4.3.4.1 Putting into service of lighting systems and controls

4.3.4.1.1 Rationale

Most road lighting control systems are not plug and play and require configuration for correct operation. It is important that these aspects are properly covered in the tender specifications to not face additional or unexpected costs for this work. Moreover, these are necessary conditions in order to have a road lighting system that works properly in terms of energy efficiency.

4.3.4.1.2 Proposed criterion

Core criteria	**Comprehensive criteria**
Contact performance clause	
CP1 - Putting into service of lighting systems and controls The contractor shall ensure that new or renovated lighting systems and controls are working properly and using no more energy than is required. • Daylight linked controls shall be calibrated to ensure that they switch off the lighting when daylight is adequate • Traffic sensors shall be verified to detect vehicles, bicycles and pedestrians depending on the application. • Time switches or control scenes in software shall be set to appropriate switch off times to meet visual needs without excessive increase in energy consumption If after the commissioning of the system, the lighting controls do not appear to meet all the above requirements, the contractor shall adjust and/or recalibrate the controls. The contractor shall deliver a report detailing how the relevant adjustments and calibrations have been carried out and how the settings can be used.	

4.3.4.1.3 Consequences

The total cost of the project is covered with the tender. Additional energy costs due to non-correct working of the system will be avoided.

4.3.4.1.4 Consultation questions

1) Are there any criteria to check for false triggers in traffic sensors?

4.3.4.2 Correct installation

4.3.4.2.1 Rationale

In order to obtain the correct illumination levels on the road as specified with EN 13201-2 for different road classes it is important that luminaires are installed in the correct way complying with the design calculations assumed.

Moreover, those criteria aim to eliminate the substitution of inferior lighting products at the installation stage and to ensure that the installation will properly work from the beginning, avoiding time and economic losses.

For the comprehensive criteria, a attest is required for a certain segment of the road selected by the procurer.

4.3.4.2.2 Proposed criterion

Core criteria	**Comprehensive criteria**
Contract performance clause	
CP2 – Correct installation The contractor shall ensure that the lighting equipment (including lamps, luminaires, lighting controls and metering systems) is installed exactly as specified in the original design. The contractor shall deliver a schedule of installed lighting equipment with appended manufacturers' invoices or delivery notes, and confirmation that the equipment is as originally specified. Note: This contract performance clause is intended to eliminate the substitution of inferior lighting products at the installation stage. Where substitution is inevitable because the originally specified products are unavailable, the tenderer shall provide a replacement schedule and calculation showing that the installation with the substituted products still complies with the original lighting design.	**CP2 – Correct installation** The contractor shall ensure that the lighting equipment (including lamps, luminaires, lighting controls and metering systems) is installed exactly as specified in the original design. The contractor shall deliver a schedule of installed lighting equipment with appended manufacturers' invoices or delivery notes, and confirmation that the equipment is as originally specified. For a road segment randomly selected by the procurer, the contractor shall select two poles for which a measurement certificate shall be supplied that certifies that the lighting system for this road segment is in accordance with the requirements specified in EN 13201-2. For this road segment also the peak power [W] and energy consumption [kWh] shall be measured and/or calculated over a period of one week. Based on this data and the previous EN 13201-2 measurements of illuminance the PDI and AECI shall be calculated and verified with the design (+/- 10% tolerance max.). In order to limit light pollution the boom angle of a set of luminaires in the selected road segment shall be measured and compared to the design specifications (+/- 2° tolerance max.). Note: This contract performance clause is intended to eliminate the substitution of inferior

	lighting products at the installation stage and ensure that the installation is correct. Where substitution is inevitable because the originally specified products are unavailable, the tenderer shall provide a replacement schedule and calculation showing that the installation with the substituted products still complies with the original lighting design.

4.3.4.2.3 Consequences

Lighting systems will be correctly installed according to the original design and will provide the minimum road lighting comfort as required by EN 13201-2.

4.3.4.2.4 Consultation questions

1) In the comprehensive criteria it is asked to provide a measurement for a section of the road randomly selected by the procurer to guarantee a good installation. Would that be too costly? Should this requirement even be in the core criteria?
2) How could it be prevented that dimming scenarios are by-passed or that presence detectors are switched off?
3) What would be an alternative to ensure that the system is installed to deliver the promised AECI and PDI from the design?

4.3.4.3 Reduction and recovery of waste

4.3.4.3.1 Rationale

In line with the WEEE Directive (2012/19/EU) Member States have to organize the collection and recycling. Therefore, collection points where the installer of new lamps or luminaires can return the used equipment have been organized in the Member States. Ideally, both mercury and critical raw materials should be recovered in specialized recycling plants with dedicated recycling processes for these products. Securing reliable and unhindered access to certain raw materials is a growing concern within the EU and across the globe. To address this challenge, the European Commission has created a list of Critical Raw Materials (CRMs) (see https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_nl). Even though it is currently not clear if these critical raw materials can be recovered efficiently at the end of life phase, it could be useful to ask for this information so the procurer could use this information to selcect certain components. This is added in the comprehensive criterion.

Core criteria	**Comprehensive criteria**
Contract performance clause	
CP3 – Reduction and recovery of waste The tenderer shall implement appropriate environmental measures to reduce and recover the waste that is produced during the installation of a new or renovated	**CP3 – Reduction and recovery of waste** The tenderer shall implement appropriate environmental measures to reduce and recover the waste that is produced during the installation of a new or renovated lighting

lighting system. All waste lamps and luminaires and lighting controls shall be separated and sent for recovery in accordance with the WEEE directive. **Verification:** The tenderer shall provide detailed information on how the waste will be separated, recovered or recycled.	system. All waste lamps and luminaires and lighting controls shall be separated and sent for recovery in accordance with the WEEE directive. The tenderer shall include a bill of materials including the weight of antimony, beryllium, cobalt, fluorspar, gallium, germanium, graphite, indium, magnesium, niobium, platinum group metals, rare earths, tantalum, and tungsten. **Verification:** The tenderer shall provide detailed information on how the waste will be separated, recovered or recycled, as well as the specified bill of materials.

4.3.4.3.2 Consequences

Waste will be reduced and recovered as much as possible. Having a detailed materials list might be useful to address the issue of recovery of critical raw materials and should support future actions in recycling of these materials.

4.3.4.3.3 Consultation questions

1) Are these criteria really needed or is reduction and recovery of waste already sufficiently covered by WEEE?
2) Would it be useful to specify the critical raw materials or even ask for a bill of materials?
3) Is a bill of materials describing the critical materials readily available from the manufacturers?

4.4 EU GPP criteria for road lighting equipment

4.4.1 Subject matter

Purchase of high efficiency lighting equipment (light sources, ballasts/control gear, luminaires).

4.4.2 Technical specifications

4.4.2.1 Luminaires

4.4.2.1.1 Efficacy and lifetime

4.4.2.1.1.1 Rationale

Luminaire efficacy is an essential part to start with the design of an efficient road lighting installation. Despite that for energy efficiency in new or renovation projects GPP targets can be set to the metrics of the EN 13201-5 standard (as proposed in the design criteria), it is convenient and highly recommended to set also requirements on luminaires itself. Moreover, these requirements are easier to verify than requirements for PDI and AECI values. IEA (2015) proposes three tiers for street lighting, i.e. 90 lm/W, 105 lm/W and 120 lm/W. The last two tiers are transposed in the proposed GPP criteria.

Another important parameter of the luminaire is its lifetime. It is desirable that lifetime of LED lighting is reported in terms of both lumen maintenance and failure rate, expressed in terms of LxBy and LxCz respectively. Note that for the core criteria a relatively short life time is specified (i.e. 16 000 h) which in principle can also be achieved with HID lamps. For LED technology this is actually not ambitious. Therefore, stricter requirements on lumen maintenance and failure are proposed in the comprehensive criteria. An advantage of requiring specifications at relatively short life times (i.e. 16 000 h) is that it is easier to check by the procurer and that it could still fall under a guarantee of four years (16 000 hours correspond to 4 years night time operation at 4 000 hours/year).

A long lifetime of the luminaires and its components reduces the overall environmental impacts caused at the production and end of life stages. It can also be used to justify the higher initial investment costs as less replacement and maintenance will have to be undertaken.

4.4.2.1.1.2 Proposed criterion

Core criteria	**Comprehensive criteria**
Technical Specification	
TS1 – Efficacy and lifetime of luminaires The luminaires provided shall have: a) a luminaire efficacy higher than 105 lm/W b) lumen maintenance and failure parameters (including LED light sources and drivers) at least: L92B50 at 16 000 hours and L92C08 at 16 000 hours . These criteria shall be considered for all luminaires. **Verification** The tenderer shall provide the above	**TS1 – Efficacy and lifetime of luminaires** The luminaire provided shall have: a) a luminaire efficacy higher than 120 lm/W b) lumen maintenance and failure parameters (including LED light sources and drivers) shall be at least: L92B50 at 16 000 hours and L92C08 at 16 000 hours and L80B50 at 50 000 hours and L80C10 at 50 000 hours . These criteria shall be considered for all luminaires. **Verification** The tenderer shall provide the above

mentioned technical specifications of the luminaire, measured by using reliable, accurate and reproducible measurement methods, which take into account the recognised state-of-the-art measurement methods including, where available, harmonised standards adopted by the European standardisation bodies.	mentioned technical specifications of the luminaire, measured by using reliable, accurate and reproducible measurement methods, which take into account the recognised state-of-the-art measurement methods including, where available, harmonised standards adopted by the European standardisation bodies.

4.4.2.1.1.3 Consequences

These criteria set minimum requirements on the luminaires and are complementary to the design criteria in section 4.2. They ensure luminaires with high efficacy and a long lifetime.

4.4.2.1.1.4 Consultation questions

1) Life time of LED luminaires is in most cases much longer than the practical test times. For that reason the acceptance or rejection of a manufacturer's life time claim, past 25 % of rated life (with a maximum of 6 000 hours) is difficult to verify. In order to validate a life time claim, an extrapolation of test data is needed. A general method of projecting measurement data is currently not available. How can the life time claims robustly be verified? Are there any standards available?
2) It seems that industry has not yet reached consensus on what critical components have to be taken into account when calculating time to abrupt failure, i.e. L0Cz values. Therefore, manufacturers sometimes decide to not publish this value. Could that pose a restriction on the implementation of these criteria?
3) Would it be more convenient to ask for a number of years of warranty?
4) Which metrics and standards should be used? LxBy and LxCz according to IEC 62722-1 or according to IESNA LM-80 (LM > 91.8% at 6 000 hours) and TM-21?
5) In case LxBy and/or LxCz criteria would be used, do you agree with the proposed values? Are they too ambitious or too lenient?
6) How can it be assured that the luminaires comply with the lumen maintenance initially specified until they reach their end of life or e.g. 60 000 hours for which they were specified?
7) Sometimes requirements are set as L70B50 at 60 000h and L0C10 at 60 000 h, i.e at longer times? Would that be more appropriate? Or is it better to ask for requirements that can be physically checked at short term, e.g. at 16 000h?
8) Do you agree with the levels of luminaire efficacy added in the core and comprehensive criteria?
9) Is there a need to discriminate between different types of luminaires?
10) Do we need different tiers to catch up with the ongoing LED technology development?
11) Are these requirements specifically needed or would they be intrinsically part of the design criteria?
12) Is it necessary that the requirements are checked by an independent laboratory or accredited labs?
13) Are such labs sufficiently available and affordable to provide test reports? Would it be sufficient to ask for a self-declaration or that the tests are carried out by an independent laboratory complying with the general principles of ISO 17025?

4.4.2.1.2 Compatibility with dimming and other controls

4.4.2.1.2.1 Rationale

Annex VII of Ecodesign Regulation EC/245/2009, which provides benchmarks for luminaires, states that "*Luminaires are compatible with installations equipped with appropriate dimming and control systems that take account of daylight availability, traffic and weather conditions, and also compensate for the variation over time in surface reflection and for the initial dimensioning of the installation due to the lamp lumen maintenance factor*." This is also the wording in the current GPP criteria where it is an award criterion. It is proposed to keep this criterion, but propose it as a technical specification.

Dimming the light output of a road lighting installation saves energy as with dimming the energy consumption is reduced. This is also reflected in EN 13201-5:2016 where the AECI calculation includes dimming. Therefore, separate requirements on dimming are proposed in the GPP criteria.

Nearly all installations can benefit from dimming, e.g. to provide constant light output regulation (CLO) independent of the flux depreciation over time or the over-lighting due to the mismatch between pole position and/or road surface reflection. However, an exception might be given to low wattage luminaires because the extra cost for controls (estimated around 50 euro) does not outweigh the savings. A quick calculation shows that for a 20W luminaire the cost saving is similar to the extra cost of the controls (0.3 x 20W x 4 000 h/y x 20 y x 0.11 €/kWh = 53€. The factor 0.3 corresponds to an average annual dimming to 70% providing 30% energy saving).

Compatibility with dimming and other controls can be easily verified.

4.4.2.1.2.2 Proposed criterion

Core criteria	**Comprehensive criteria**
Technical Specification	
TS2 - Compatibility with dimming and other controls Luminaires with wattages above 20 W shall be compatible with installations equipped with appropriate dimming and control systems that take account of daylight availability, traffic and weather conditions, and also compensate for the variation over time in surface reflection and for the initial dimensioning of the installation due to the lamp lumen maintenance factor. **Verification:** Documentation shall be supplied that provides the dimming method and defines the dimming interface.	

4.4.2.1.2.3 Consequences

The main impact will come from renovated or new installations designed according to the installation requirements discussed in the design section. However, the criteria on compatibility with dimming systems set a complementary requirement that indirectly reduce

the energy consumption by requesting that the luminaires are compatible with dimming and other controls.

4.4.2.1.2.4 Consultation questions

1) Are these requirements really needed or are they part of the design criteria?
2) Is it necessary to discriminate for low wattage lamps (< 20 W)?
3) Should there be a differentiation between digital and analogue dimming?

4.4.2.1.3 Product lifetime extension

4.4.2.1.3.1 Rationale

Extension of the lifetime of luminaires and its components reduces the overall environmental impacts caused by shorter lifespans, raw material extraction and manufacturing processes. It also partly justifies the higher initial investment in more efficient road lighting installations. An extension of the warranty period would be an addition to the requirements on lifetime and would decrease the frequency of early failures.

Additionally, it might be important that luminaires are easy to maintain and repair. To facilitate this, repair should be possible without using proprietary equipment.

A control interface based on an open standard or specification can positively impact the economic life time of an installation and avoid long term problems related to vendor lock-in, especially when the manufacturer fails to exist during the life time of the installation.

4.4.2.1.3.2 Proposed criteria

A. **Warranty, service agreements and spare parts**

Core criteria	**Comprehensive criteria**
Technical Specification	
TS3 – Product lifetime extension Repair or replacement of the product shall be covered by the warranty terms for minimum four years. During the warranty or service agreement period: a) every defect light source, control gear and/or luminaire will be replaced without any cost. If the luminaire provides less output than initially specified it shall be considered as a defect, b) every batch of lamps or luminaires will be completely replaced in case the number of defect units in the	**TS3 – Product lifetime extension** Repair or replacement of the product shall be covered by the warranty terms for minimum eight years. During the warranty or service agreement period: c) every defect light source, control gear and/or luminaire will be replaced without any cost. If the luminaire provides less output than initially specified it shall also be considered as a defect, d) every batch of lamps or luminaires will be completely replaced in case the number of defect units in the

batch is more than 10% of the batch. Outside the warranty are: a) Luminaires defective because of vandalism, accidents, lightning or storm b) Lamps or luminaires that have been working for a significant time under abnormal conditions (e.g. used with the wrong line voltage) in so-far that this can be proofed by the manufacturer. The tenderer shall further ensure that genuine or equivalent spare parts are available (direct or via other nominated agents) for at least ten years from the date of purchase. This clause will not apply to unavoidable temporary situations beyond the manufacturer's control such as natural disasters. **Verification:** A copy of the warranty or service agreement shall be provided in the tender. For the criterion on the availability of spare parts a self-declaration shall be provided from the manufacturer stating this requirement shall be met.	batch is more than 10% of the batch. Outside the warranty are: c) Luminaires defective because of vandalism, accidents, lightning or storm d) Lamps or luminaires that have been working for a significant time under abnormal conditions (e.g. used with the wrong line voltage) in so-far that this can be proofed by the manufacturer. The tenderer shall further ensure that genuine or equivalent spare parts are available (direct or via other nominated agents) for at least ten years from the date of purchase. This clause will not apply to unavoidable temporary situations beyond the manufacturer's control such as natural disasters. Where control systems are applied their interfaces shall be based on an open standard or a full technical specification shall be provided. **Verification:** A copy of the warranty or service agreement shall be provided in the tender. For the criterion on the availability of spare parts a self-declaration shall be provided from the manufacturer stating this requirement shall be met.

B. Reparability

Core criteria	**Comprehensive criteria**
Technical Specification	
TS 4 – Reparability The tenderer shall make sure that the light source (lamp or LED module) and auxiliaries of the luminaire are easily accessible and replaceable and the replacement can be performed on site (i.e. at luminaire mounting height) and with one of the following types of screwdrivers: - Standard	

- Pozidrive
- Philips
- Torx
- Allen keys
- Combination wrenches.

Verification:
The tenderer shall provide a declaration that original or equivalent spare parts will be made available to the contracting authority or through a service provider. A spare part list with references shall be provided.

A manual shall be provided by the tenderer which shall include an exploded diagram of the luminaire illustrating the parts that can be accessed and replaced. It shall also be confirmed which parts are covered by service agreements under the guarantee.

4.4.2.1.3.3 Consequences

These criteria would help protect the procurer against early failures and helps to procure quality road lighting systems and components. Furthermore, it would reduce the waste production that would be linked to low quality products which would end up as waste sooner than foreseen. The criterion on reparability will ensure that in case a luminaire or a component thereof, fails it can be easily repaired or substituted.

4.4.2.1.3.4 Consultation questions

1) Is a 4-8 year warranty period common for best procurement practices? Could this period be extended to e.g. 10 years?
2) Is the availability of spare parts something that can be offered by the manufacturers?
3) Can design for reparability be guaranteed by the manufacturers?

4.4.2.1.4 Ingress protection

4.4.2.1.4.1 Rationale

The lifetime of the luminaire itself, i.e. the housing, cabling and optics, is usually not an issue, but the output of good quality light depends on design and maintenance. Light quality is in particular affected by the amount of dirt and water getting inside the luminaire and should be reduced as much as possible. This is measured by the IP rating. According to CIE 154:2003, the IP rating (dust and moisture protection) has also a direct impact on the luminaire maintenance factors.

IP is a two digit code. The first digit indicates the level of protection that the enclosure provides against access to hazardous parts (e.g. electrical conductors, moving parts) and the ingress of solid foreign objects. The second digit indicates the protection of the equipment inside the enclosure against harmful ingress of water.

For each type of road class it is necessary that no ingress of dust is allowed and protection against water is guaranteed. This will help to maintain the promised lumen maintenance and will avoid failures because of external factors such as dust and water.

Benchmark values are provided in Ecodesign Regulation EC/245/2009:

- IP65 for road classes ME1 to ME6 and MEW1 to MEW6
- IP5x for road classes CE0 to CE5, S1 to S6, ES, EV and A

IP65 rating means "No ingress of dust; complete protection against contact" and "Water projected by a nozzle against enclosure from any direction shall have no harmful effects".

In the proposed GPP criteria an IP rating of 65 is requested for all road classes.

IP rating can be easily measured and verified.

4.4.2.1.4.2 Proposed criterion

Core criteria	Comprehensive criteria
Technical Specification	
TS5 – Ingress protection Luminaires shall have an optical system that has an ingress protection rating of at least IP65 for all road classes. **Verification:** The tenderer shall provide the technical specifications demonstrating this criterion is met.	

4.4.2.1.4.3 Consequences

This criterion guarantees a high resistance of the luminaire against dust and water.

4.4.2.1.4.4 Consultation questions

1) Do you agree with the proposal to have the same value of IP rating for all road classes or would cost be an important factor herein?
2) Would it be preferred to have different requirements in core and comprehensive criteria?
3) Should there be explicit reference in the verification to the standard EN 60529, i.e. that the determination of the IP rating performance shall be in accordance with EN 60529?

4.4.2.2 Light sources

4.4.2.2.1 Efficacy, lumen maintenance and life time of light sources

4.4.2.2.1.1 Rationale

In principle the light source efficacy is included in the road lighting luminaire efficacy and therefore already included in the installation design requirements for AECI and PDI. Therefore, separate requirements are not needed in new installations and are fully redundant requirements.

However, efficacy requirements for light sources could be relevant for retrofit lamps in case they are available today or when they enter the market in the future. It is important to understand that as opposed to residential lighting, relamping with more efficient retrofit lamps is difficult or sometimes impossible. This is mainly due to the ballast/starter or control gear incorporated in luminaires and the optics that are fitted to the HID lamps often used in road lighting; hence this creates a so-called luminaire lock-in effect. This means that when the control gear remains in the luminaire the power consumption remains and more efficient lamps in principle only result in increased light output.

LED luminaires are now on the market which are more efficient than HID lamps (see http://www.lightingfacts.com/ and DOE, 2016). An important property of LEDs in comparison to HID lamps is that the efficacy is not dependent on the lumen output or wattage. Lower wattage HID lamps, especially HPS, have relative low efficacy compared to high wattage lamps. This is also reflected in the current GPP criteria, but with LED technology there is no technical reason to introduce weaker requirements for luminaires with a lower wattage and/or road illuminance.

The US R&D roadmap 2016 (DOE, 2016) gives an overview of the state-of-art in LED efficacy and the expected progress. Figure 4-1 shows the evolution of LED package efficacy and price. Each time period is characterized by a rectangle with an area bound by the highest efficacy and lowest price products. The figure shows that efficacies up to 170 lm/W (cool white) and 130 lm/W (warm white) can be reached in 2015 together with prices as low as $1/klm (cool white and warm white). The figure also shows that further progress for efficacy and price drops are expected. It should be noted that road lighting luminaires need to be compact and therefore often use high power LEDs which might have lower efficacies than other LED technologies due to relative high current densities (> 35 A/mm²).

The proposed criteria for light source efficacy are based on the proposed luminaire efficacy requirements in section 4.4.2.1.1 including correction factors for control gear and luminaire optics. The resulting values are in line with the US R&D roadmap 2016.

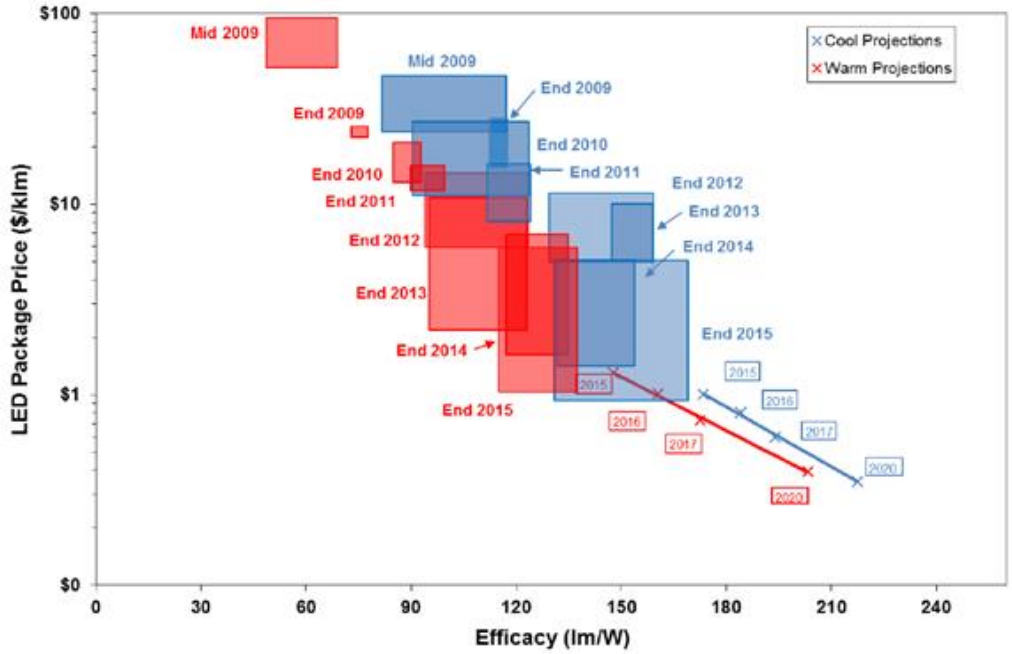

Figure 4-1 Price-Efficacy tradeoff for LED Packages at 1 W/mm² (equiv. 35 A/cm²) and 25°C (DOE, 2016)

For cases where the light sources cannot meet the proposed efficacy criteria it is recommended to consider a complete redesign of the installation with new luminaries as discussed in the Preliminary report (section 3.4.2). For cases where this is not possible, e.g. because of economic reasons, light sources compatible with the existing luminaire can still be procured but no specific criteria for these light sources are included as such criteria would have little or no positive impact on the energy consumption due to the luminaire lock in effect. Note that in the current GPP criteria requirements for non-LED light sources were included. In the past there was a positive impact from slightly increasing HID lamp efficacy because the luminaires were developed together with the high efficiency lamps. However, as indicated in the Preliminary report this is irrelevant today because there is little or no development for these lamp types and luminaires anymore because the main focus is on LED lighting. Moreover, Ecodesign Regulation EC/245/2009 already puts strong requirements on HID lamps and putting even stricter requirements would have little impact.

Note that the purchase of new lighting systems happens less frequently, but has a big influence on energy consumption. The proposed criteria for light sources could stimulate a technology switch to LED lighting.

The reasoning behind proposing criteria for the lifetime of the lamp source is similar to the reasoning provided for the lifetime of the luminaires and the same values are proposed.

4.4.2.2.1.2 Proposed criterion

Core criteria	Comprehensive criteria
Technical Specification	
TS1 – Efficacy and lifetime of light sources a) The light source efficacy shall be higher than 140 lm/W in working conditions. This value shall be multiplied with • 0.90 if an external control gear is used • 0.83 if an external light distribution system is used (luminaire optic) b) Lumen maintenance and failure shall be at least: L92B50 at 16 000 hours and L92C08 at 16 000 hours **Verification** The tenderer shall provide the above mentioned technical specifications of the light source, measured by using reliable,	**TS1 – Efficacy and lifetime of light sources** a) The light source efficacy shall be higher than 160 lm/W in working conditions. This value shall be multiplied by • 0.90 if an external control gear is used • 0.83 if an external light distribution system is used (luminaire optic) b) Lumen maintenance and failure shall be at least: L92B50 at 16 000 hours and L92C08 at 16 000 hours and L80B50 at 50 000 hours and L80C10 at 50 000 h **Verification**

accurate and reproducible measurement methods, which take into account the recognised state-of-the-art measurement methods including, where available, harmonised standards adopted by the European standardisation bodies.	The tenderer shall provide the above mentioned technical specifications of the luminaire, measured by using reliable, accurate and reproducible measurement methods, which take into account the recognised state-of-the-art measurement methods including, where available, harmonised standards adopted by the European standardisation bodies.

4.4.2.2.1.3 Consequences

Efficient light sources with a reasonable lifetime will be procurerd. These criteria can also be used for retrofit (LED) light sources.

4.4.2.2.1.4 Consultation questions

1) The light source efficacy criteria can only be met by LED technology. Would that pose a problem to the procurer if he uses these criteria for a 'relamping tender'? Should these criteria be explicitly specified for LED light sources?
2) Do you agree with the levels of light source efficacy added in the core and comprehensive criteria?
3) Life time of LED light sources is in most cases much longer than the practical test times. For that reason the acceptance or rejection of a manufacturer's life time claim, past 25 % of rated life (with a maximum of 6 000 hours) is difficult verify. In order to validate a life time claim, an extrapolation of test data is needed. A general method of projecting measurement data is currently not available. How can the life time claims robustly be verified? Are there any standards available?
4) Are there any other parameters that could be used for life time and lumen maintenance?
5) Would it be more convenient to ask a product warranty to guarantee the requested values for a number of years?
6) In case LxBy and/or LxCz criteria would be used, do you agree with the proposed values? Are they ambitious enough?
7) Do we need different tiers to catch up with the ongoing LED technology development?
8) Are these requirements specifically needed or would they be intrinsically part of the design criteria?
9) Sometimes requirements are set as L70B50 at 60 000h and L0C10 at 60 000 h, i.e. at longer times? Would that be more appropriate? Or is it better to ask for requirements that can be physically checked at short term, e.g. at 16 000h?
10) Do we need to have both requirements on short life time (e.g. at 16 000 h) and long life time (e.g. at 50 000 h)?
11) Is there sufficient consensus on how to measure LxBy and LxCz to honestly compare different claims?
12) Are there any other parameters that could be used for life time and lumen maintenance?
13) Is it necessary that the requirements are checked by an independent laboratory or accredited labs?

14) Are such labs sufficiently available and affordable to provide test reports? Would it be sufficient to ask for a self-declaration or that the tests are carried out by an independent laboratory complying with the general principles of ISO 17025?

4.4.2.3 Ballast or control gear

4.4.2.3.1 Failure rate of control gear

4.4.2.3.1.1 Rationale

The control gear is often a weak spot in the (LED) luminaire life time. This is typical for the potential weakness of complex electronic controls but it can also be applied to magnetic control gear that has proven its robustness.

As discussed in the Preliminary report (section 3.4.1.2.2) high-quality drivers provide a service life of more than 50 000 hours with a failure rate of 0.2% per 1 000 hours. Low-performance devices come with a service life of 30 000 hours and failure rates of 0.5% per 1 000 hours. Therefore, the core criteria are set at the standard for high quality drivers while the comprehensive criteria go a step further.

4.4.2.3.1.2 Proposed criteria

Core criteria	Comprehensive criteria
Technical Specification	
TS 2 – Failure rate of control gear The control gear failure rate shall be lower than 0.2 per 1 000 h. **Verification:** The tenderer shall provide the above mentioned technical specifications of the control gear, measured by using reliable, accurate and reproducible measurement methods, which take into account the recognised state-of-the-art measurement methods including, where available, harmonised standards adopted by the European standardisation bodies, The tenderer shall provide a test report from an accredited laboratory.	**TS 2 – Failure rate of control gear** The control gear failure rate shall be lower than 0.1 per 1 000 h. **Verification:** The tenderer shall provide the above mentioned technical specifications of the control gear, measured by using reliable, accurate and reproducible measurement methods, which take into account the recognised state-of-the-art measurement methods including, where available, harmonised standards adopted by the European standardisation bodies, The tenderer shall provide a test report from an accredited laboratory.

4.4.2.3.1.3 Consequences

This criterion will ensure a long service life of the control gear and a low risk on early failures. Therefore, the whole product life time will be extended.

4.4.2.3.1.4 Consultation questions

1) Are the limits for the core and comprehensive criteria well chosen?
2) How can these values be consistently verified by the procurer? Are EN test standards available?
3) Would it be of added value to include an additional protection level thanks to increased dielectric strength, e.g. in the comprehensive criterion?

4.5 EU GPP criteria for traffic signals

4.5.1 Subject matter

Purchase of energy efficient traffic signals.

4.5.2 Technical specifications

4.5.2.1 Efficacy and lifetime of signal module

4.5.2.1.1 Rationale

For traffic signals LED technology is rather mainstream nowadays (DOE, 2016). The main progress for LEDs made in the last years is not so relevant for red/green/orange LEDs that are used in traffic signals and are already on the market for a while. Therefore, LEDs for traffic signals are a mature technology and the current state of the art already allows minimizing operating wattage of a LED traffic signal head down to 1W (Siemens, 2016).

The current criteria focus the attention on the power consumed by the traffic signals. For each specific module a different power consumed at 25ºC temperature is introduced.

Apart from the higher efficacy, the LED lifetime is an important parameter. LED traffic signals can also be dimmed at night, which reduces the energy consumption further.

The proposed criteria are the current comprehensive criteria which are now proposed to be core criteria as well. These requirements can be met by LED technology. For the lifetime, the relevant core criteria used for light sources in section 4.4.2.2 are copied here.

4.5.2.1.2 Proposed criterion

Core criteria	**Comprehensive criteria**
Technical Specification	
TS – Efficacy and lifetime of traffic signal modules Where contracting authorities are installing new or upgrading old traffic signals the power consumed by the signal modules shall not exceed the following values: Module Type Operating Wattage (at 25ºC) 300mm Red Ball 8	

200mm Red Ball	7.5
300mm Red Arrow	7
300mm Amber Ball	9
200mm Amber Ball	8
300mm Amber Arrow	7
300mm Green Ball	9.5
200mm Green Ball	8
300mm Green Arrow	7

The wattage requirements in the table above are to be met by the individual module, not the traffic signal heads. These levels include power demand from the lamp power circuit.

Lumen maintenance and failure of the signal modules shall be at least:

L92B50 at 16 000 hours and L92C08 at 16 000 hours

Verification
The tenderer shall provide the technical specification of the individual modules within traffic signal heads showing this criterion is met

4.5.2.1.3 Consequences

Traffic lights with high efficiency and reasonable lifetimes will be procured.

4.5.2.1.4 Consultation questions

1) Do you agree to use the same criteria for the lifetime of traffic signal modules as the criteria used for light sources? Or are other metrics used for this kind of appliances?
2) Is it in this case better to use a criterion based a warranty for LED modules?
3) Is there any standard to which could be referred for the verification of the parameters in the criteria?
4) The core criteria are the same as the current comprehensive criteria? Should there be a split between core and comprehensive, e.g. asking in the comprehensive criteria to go below 5 W (given the possibility of Siemens to go to 1 W)?

5 Criteria from current criteria set proposed to be discarded

5.1 Efficiency of ballast and control gear

5.1.1 Rationale

In principle the road lighting control gear, e.g. an HID ballast or LED power supply, is included in the road lighting luminaire and therefore already in the installation design requirements for the PDI calculation according to EN 13201-5:2016 or in the separate luminaire requirements. Therefore, requirements on the efficiency of the ballast or control gear are not needed in new installations and are redundant. It is however important that repair components are of equal efficiency or better, as stated in the technical specifications for luminaires (section 4.4.2.1.3). Moreover, HID ballast efficiency is already regulated in Ecodesign Regulation EC/245/2009.

Finally, as shown in section 3.4.1 of the Preliminary report, little differences are reported in control gear efficiency and no changes are expected in the future.

As a conclusion no explicit GPP criteria are proposed for control gear efficiency.

5.1.2 Consultation questions

1) Do you agree with removing an explicit requirement for the efficiency of ballasts and control gear?

5.2 Packaging of lighting equipment

5.2.1 Rationale

According to section 3.1 of the Preliminary report the packaging of the lighting equipment is not a hotspot of the environmental impact of the product. That is the main reason why it is proposed to erase this criterion.

5.2.2 Consultation questions

1) Do you agree with removing the requirement on packaging of lighting equipment?

5.3 Mercury content

5.3.1 Rationale

As explained in the Preliminary report (section 3.4.2.4) thanks to recycling and correct waste collection significantly less mercury is released as waste to the environment and the amount will decrease in the future. Indeed the production of HPS lamp with mercury is decreasing due

to the introduction of LEDs in road lighting. Therefore, no significant impact is expected from constraints on the mercury content and it is proposed to erase this award criteria.

5.3.2 Consultation questions

1) Do you agree with erasing a specific criterion for mercury content?

5.4 Points for the percentage of dimming

5.4.1 Rationale

Additional points as an award for percentage of dimming would not useful for LED lighting where dimming can be performed from 0% to 100%. An alternative criteria could be related to standby loss for LED dimming or efficiency of the dimming. However, such criteria are judged not to be important at this stage as it would only contribute little to an overall better performance of the lighting system.

5.4.2 Consultation questions

1) Should a criterion be added for standby loss for LED dimming? Or criteria for the efficiency of the driver and dimmer in the dimming state compared to the full power of the module?

5.5 Packaging for traffic signals

5.5.1 Rationale

According to section 3.1 of the Preliminary report the packaging of the traffic signals is not a hotspot of the environmental impact of the product. That is the main reason why it is proposed to erase this criterion.

5.5.2 Consultation questions

1) Do you agree with removing the requirement on packaging of traffic signals?

6 Annex

This annex provides some exmaples where PDI and AECI values are used.

Current GPP criteria for road lighting
Note that in the current GPP criteria SLEEC corresponds to the PDI value. This is due to a renaming in the standard EN 13201-5.

The current GPP criteria propose for M classes (previously ME or MEW) a PDI value of

- $W \leq 55$: 0.974 W/Cd
- $55 < W \leq 155$: 0.824 W/Cd
- $155 < W$; 0.674 W/Cd

depending on the lamp wattage.

With the luminance conversion formula (E.m=L.m/0.07) from EN 13201-5:2016 these GPP criteria for M classes corresponds to a PDI value of:

- $W \leq 55$: 0.068 W/lm or 14.7 lm/W
- $55 < W \leq 155$: 0.058 W/lm or 17.2 lm/W
- $155 < W$; 0.048 W/lm or 20.8 lm/W

For the lighting classes for conflict areas (C) and the road lighting for pedestrians and low speed areas (P), where viewing distances are short, the illuminance [lx] is recommended as design criterion. That is the reason why the criteria are based on the required horizontal illuminance (E).

For C and P classes, (previously CE or S) the current GPP criteria for the PDI value are:

- $E \leq 15$ lux 0.054 W/lm or 18.5 lm/W
- $E > 15$ lux 0.044 W/lm or 22.7 lm/W

ADEME, France
More ambitious requirements compared to the current GPP criteria have been set in France for the PDI value (ADEME, Cahier des charges Diagnostic de léclairage public 2012):

- Highways and national routes (typically M classes according to EN 13201-5): 0.03W/m².lux = 0.03 W/lm = 33.3 lm/W
- Other routes: 0.045W/m².lux = 0.045 W/Lm = 22.2 lm/W

Spain
In Spain, the Spanish decree technical guide EA-01 version 2013 had minimum corresponding installation efficacies (PDI) for typically M road classes ranging from 9.5 lm/W ($\leq$ 7.5 lx) up to 22 lm/W ($\geq$ 30 lx) and has reference values for typically C and P road classes from 3.5 lm/W($\leq$ 5 lx) up to 9 lm/W ($\geq$ 20 lx).

7 References

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