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BSI Standards Publication

Road lighting

Part 5: Energy performance indicators

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National foreword

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A list of organizations represented on this committee can be obtained on request to its secretary.

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Contents

Page

European foreword 4
Introduction 5
1 Scope 6
2 Normative references 6
3 Terms, definitions, symbols and abbreviations 6
3.1 Terms and definitions 6
3.2 Symbols and abbreviations 7
4 Power Density Indicator (PDI) 9
4.1 Calculation of the power density indicator 9
4.2 Average horizontal illuminance to be used for calculation of the power density indicator 9
4.3 System power (*P*) to be used for calculation of the power density indicator 10
4.4 Area (*A*) to be used for calculation of the power density indicator 11
5 Annual Energy Consumption Indicator (AECI) 11
Annex A (informative) **Examples of calculation and typical values of energy performance indicators** 13
A.1 Examples of operational profiles 13
A.1.1 General 13
A.1.2 Full power operation 13
A.1.3 Multi-power operation 14
A.1.4 Operation with vehicle and presence detectors 14
A.2 Example of calculation 15
A.3 Typical values of energy performance indicators 16
A.3.1 General 16
A.3.2 Two-lane road for motorized traffic (road profile A) 17
A.3.3 Road with mixed motorized and pedestrian traffic without sidewalks (road profile B) 18
A.3.4 Road and sidewalk on the side of lighting arrangement (road profile C) 19
A.3.5 Road and sidewalk on the opposite side to the lighting arrangement (road profile D) 20
A.3.6 Road and two sidewalks on both sides (road profile E) 21
A.3.7 Road and two sidewalks on both sides separated from carriageway by grass strips (road profile F) 22
A.3.8 Typical values of AECI for different operational profiles 22
Annex B (informative) **Installation luminous efficacy** 24
B.1 General 24

B.2 Calculation of the correction factor 24
B.3 Calculation of the utilance 25
B.4 Calculation of the efficiency of luminaires 25
Annex C (informative) **Lighting factor of an installation** 26
C.1 Installation lighting factor q_{inst} 26
C.2 Role of q_{inst} in road lighting design aimed at energy saving 26
C.3 Typical values of q_{inst} 26
Annex D (informative) **Presentation of energy performance indicators** 27
Bibliography 28

European foreword

This document (EN 13201-5:2015) has been prepared by Technical Committee CEN/TC 169 "Light and lighting", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2016 and conflicting national standards shall be withdrawn at the latest by June 2016.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

EN 13201, *Road lighting* is a series of documents that consists of the following parts:

— *Part 1: Guidelines on selection of lighting classes* [Technical Report]*;*

— *Part 2: Performance requirements;*

— *Part 3: Calculation of performance;*

— *Part 4: Methods of measuring lighting performance;*

— *Part 5: Energy performance indicators* [present document].

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

The purpose of this European Standard is to define energy performance indicators for road lighting installations. The standard introduces two metrics, the power density indicator (PDI) D_P and the annual energy consumption indicator (AECI) D_E that should always be used together.

To quantify the potential savings obtainable from improved energy performance and reduced environmental impact, it is essential to calculate both the power density indicator (D_P) and the annual energy consumption indicator (D_E). In addition, the installation luminous efficacy (η_{inst}) can be used for comparing the energy performances of alternative road lighting installations.

Careful choice of lighting class(es) during the design and specification phase will help to maximize energy savings by ensuring only the necessary levels of illumination provided at the correct times and for the minimum periods necessary. Additional guidance is given in the CEN/TR 13201-1 with regard to the visual needs of road users, e.g. under varying traffic volumes during certain times of night or under varying weather conditions.

During the design phase of a road lighting installation care should be taken to ensure that the design criteria specified in EN 13201-2 are achieved but that excess overlighting is reduced to the minimum technically obtainable. Overlighting can be minimized by the careful selection of the luminaire and light source but the specified lighting class, the designed lighting point spacing and uniformity ratios are all determining factors of the luminous flux emitted by the light source and thus the power of the light source required. However, this precise luminous flux may not, in reality, exist. Where the luminous flux of the light source is greater than that required the designer can by means of continuously variable control gear, compensate for this effect by reducing the luminous flux of the light source to the required level resulting in lower energy consumption. The same principles and control gear can be used to compensate for changes in luminous flux emitted throughout the lifetime of the light sources.

The energy levels calculated using this standard should not be used as a direct input for the calculation of the load on the electrical distribution system. Such calculations are normally based on the energy requirement derived directly from the lighting and electrical design.

Examples of operational profiles and examples of calculation of the energy performance indicators are provided in Annex A. Typical values of energy performance indicators are provided to illustrate the energy performance of recent technological level of luminaires and installations.

Annex B introduces the installation luminous efficacy and its factors as a measure of the influence of various light losses and other parameters.

Lighting factor of an installation, as introduced in Annex C, can be additionally used to characterize the energy performance of road lighting installations independently on the lighting components used. Other factors and parameters having influence to the energy performance, such as the maintenance factor (see CIE 154), can be recognized but are not dealt with in this standard.

Recommendations on presentation of the energy performance indicators are provided in Annex D.

1 Scope

This part of the European Standard defines how to calculate the energy performance indicators for road lighting installations using the calculated power density indicator (PDI) D_P and the calculated annual energy consumption indicator (AECI) D_E. Power density indicator (D_P) demonstrates the energy needed for a road lighting installation, while it is fulfilling the relevant lighting requirements specified in EN 13201-2. The annual energy consumption indicator (D_E) determines the power consumption during the year, even if the relevant lighting requirements change during the night or seasons.

These indicators may be used to compare the energy performance of different road lighting solutions and technologies for the same road lighting project. The energy performance of road lighting systems with different road geometries or different lighting requirements cannot be compared to each other directly, as the energy performance is influenced by, amongst others, the geometry of the area to be lit, as well as the lighting requirements. The power density indicator (D_P) and annual energy consumption indicator (D_E) apply for all traffic areas covered by the series of lighting classes M, C and P as defined in EN 13201-2.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 12665:2011, *Light and lighting — Basic terms and criteria for specifying lighting requirements*

EN 13201-2, *Road lighting — Part 2: Performance requirements*

EN 13201-3:2015, *Road lighting — Part 3: Calculation of performance*

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 12665:2011 and the following apply.

3.1.1
system power (of a lighting installation in a given state of operation)
P
total power of the road lighting installation needed to fulfil the required lighting classes as specified in EN 13201-2 in all the relevant sub-areas, and to operate and control the lighting installation (unit: W)

3.1.2
power density indicator PDI (of a lighting installation in a given state of operation)
D_P
value of the system power divided by the value of the product of the surface area to be lit and the calculated maintained average illuminance value on this area according to EN 13201-3 (unit: $W \cdot lx^{-1} \cdot m^{-2}$)

3.1.3
annual energy consumption indicator AECI (of a lighting installation in a specific year)
$\boldsymbol{D_E}$
total electrical energy consumed by a lighting installation day and night throughout a specific year in proportion to the total area to be illuminated by the lighting installation (unit: $Wh \cdot m^{-2}$)

3.1.4
installation luminous efficacy
$\boldsymbol{\eta_{inst}}$
minimum luminous flux needed to provide the minimum lighting level for the specified area divided by the total average power consumption of the lighting installation (unit: $lm \cdot W^{-1}$)

3.1.5
constant light output CLO (of a road lighting installation)
regulation of the road lighting installation aiming at providing a constant light output from the light sources

Note 1 to entry: This functionality aims to compensate for the light loss caused by ageing of the light sources.

3.1.6
installation lighting factor
$\boldsymbol{q_{inst}}$
dimensionless factor accounting for the relation of the calculated average maintained luminance of road surface over the calculated average maintained horizontal illuminance on this surface and the average luminance coefficient of the r-table adopted in luminance calculation

3.2 Symbols and abbreviations

Table 1 — Symbols and abbreviations

Symbol or abbreviation	Name or description	Unit
A	Area to be lit	m^2
A_{FL}	Area of the left sidewalk	m^2
A_{FR}	Area of the right sidewalk	m^2
A_R	Area of the carriageway	m^2
AECI	Annual Energy Consumption Indicator	
C_L	Correction factor for luminance or hemispherical illuminance based lighting designs	-
c_{op}	Lighting operation coefficient	-
CLO	Constant Light Output	
D_E	Annual energy consumption indicator (AECI)	$Wh \cdot m^{-2}$
D_P	Power density indicator (PDI)	$W \cdot lx^{-1} \cdot m^{-2}$
$\overline{E}$	Average maintained horizontal illuminance	lx
E_{FL}	Calculated maintained illuminance on the left sidewalk	lx
E_{FR}	Calculated maintained illuminance on the right sidewalk	lx

Symbol or abbreviation	**Name or description**	**Unit**
E_{hs}	Hemispherical illuminance	lx
$\overline{E}_{min}$	Minimum required average illuminance	lx
E_R	Calculated maintained illuminance on the carriageway	lx
EIR	Edge Illuminance Ratio	
f_M	Overall maintenance factor (MF) of the lighting installation	-
k_{red}	Reduction coefficient for the reduced level illumination	-
$\overline{L}$	Average maintained luminance	cd·m^{-2}
$\overline{L}_{min}$	Minimum required average luminance	cd·m^{-2}
LOR	Light Output Ratio	
m	Number of operation time periods for different levels of operational power P	-
MF	Maintenance Factor	
n	Number of sub-areas to be lit	-
n_{lp}	Number of light points associated with the lighting installation or the representative section	-
P	System power of all the luminaires designed to lit the relevant area	W
P_{ad}	Total active power of any devices not considered in the operational power P but necessary for operation of the road lighting installation	W
P_F	System power of the luminaire designed for illumination of the sidewalk	W
P_{ls}	Power of lamp(s) inside the luminaire	W
P_R	System power of the luminaire designed for illumination of the carriegeway	W
PDI	Power Density Indicator	
R_{LO}	Optical efficiency of luminaires (LOR) used in the lighting installation	-
q_{inst}	Lighting factor of an installation	-
Q_o	Average luminance coefficient	sr^{-1}
t	Duration of the operation time for a particular system power P over a year	h
t_{full}	Annual operation time of the full level illumination	h
t_{red}	Annual operation time of the reduced level illumination	h
U	Utilance of the lighting installation	-
Φ_A	Luminous flux reaching the area to be illuminated	lm
Φ_{ls}	Luminous flux emitted from the light source(s) in a luminaire	lm
η_{inst}	Installation luminous efficacy	lm·W^{-1}
η_{ls}	Luminous efficacy of the light sources used in the installation	lm·W^{-1}
n_{lu}	Number of luminaires considered in the calculation	-
η_P	Power efficiency of luminaires used in the lighting installation	-

4 Power Density Indicator (PDI)

4.1 Calculation of the power density indicator

Power density indicator for an area divided into sub-areas for a given state of operation shall be calculated with the following formula:

$$D_P = \frac{P}{\sum_{i=1}^{n} (\overline{E}_i \cdot A_i)} \quad (1)$$

where

D_P is the power density indicator, $W \cdot lx^{-1} \cdot m^{-2}$;

P is the system power of the lighting installation used to light the relevant areas (see 4.3), in W;

$\overline{E_i}$ is the maintained average horizontal illuminance of the sub-area “i” determined in accordance with 4.2, in lx;

A_i is the size of the sub-area “i” lit by the lighting installation, in m^2;

n is the number of sub-areas to be lit.

If the required lighting class changes during the night and/or through the seasons (for example reductions in lighting class due to decreased traffic density, changes in the visual environment or other relevant parameters), the power density (D_P) should be calculated separately for each of the lighting classes. Alternatively, where multiple lighting classes are used during the night or year the power density (D_P) may be calculated as an average over this period. The calculation shall clearly indicate the assumptions used for calculation of the power density (D_P) and how this value was evaluated.

Values of the power density indicator (D_P) shall be always presented and used together with the annual energy consumption indicator (D_E) for assessment of the energy performance of a particular lighting system.

4.2 Average horizontal illuminance to be used for calculation of the power density indicator

For illuminance based lighting classes (C and P) the maintained average horizontal illuminance ($\overline{E}$) to be used for the power density (D_P) calculation shall be calculated according to EN 13201-3.

For luminance based lighting classes (M) the maintained average horizontal illuminance ($\overline{E}$) to be used for the power density (D_P) calculation shall be the average of illuminance values calculated on the same grid of points which are used for the calculation of luminance in accordance with EN 13201-3.

For hemispherical illuminance based lighting classes (HS) the maintained average horizontal illuminance ($\overline{E}$) to be used for the power density (D_P) calculation shall be the average of illuminance values calculated on the same grid of points which are used for the calculation of hemispherical illuminance in accordance with EN 13201-3.

Some lighting installations may be over lit in terms of significantly higher lighting levels than those required or specified. When such over lighting occurs, it should be determined if this is as a result of poor design or as an unavoidable consequence of other requirements. From an energy efficiency and environmental perspective corrective action should be taken to minimize any over lighting.

From an energy efficiency and environmental perspective the calculated lighting level for any lighting installation should not exceed the required lighting level of the next higher lighting class (or not exceed the required lighting level by 50 % in case of the highest class) without considering other design solutions.

4.3 System power (*P*) to be used for calculation of the power density indicator

The system power (*P*) shall be calculated from the sum of the operational power of the light sources, control gear(s) and any other electrical device(s) (lighting point control unit(s), switch(es), photoelectric cell(s), etc.) which are directly associated with the lighting of the area to be lit and installed in order to operate or regulate the installation. The system power (*P*) should be calculated for the complete lighting installation or the representative section used during the lighting design according to the following formula:

$$P = \sum_{k=1}^{n_{lp}} P_k + P_{ad} \qquad (2)$$

where

P is the total system power of the lighting installation or its representative section, in W;

P_k is the operational power of the 'k^{th}' lighting point (light source, gear, any other device like lighting point control unit, switch or photoelectric cell and component, which are associated with the lighting point and necessary for its operation), in W;

P_{ad} is the total operational power of any devices not considered in P_k but necessary for the operation of the road installation such as a remote switch or photoelectric cell, centralized luminous flux controller or centralized management system, etc. in W.

Where the system power is calculated for a representative area the total operational power P_{ad} should be proportioned according to the number of luminaires used to illuminate the area over the total number of luminaires supplied from the devices represented by P_{ad}.

n_{lp} is the number of lighting points associated with the lighting installation or the representative section whichever is used in the calculation.

If light sources (and other electrical devices) are operated on constant power, this power shall be used when the system power (*P*) is calculated.

If the lighting class changes during the night and/or seasons (for example reduction in lighting class during the night due to decreased traffic density, changes in the visual environment or other relevant parameters), the system power (*P*) corresponding to the required lighting class in that period should be calculated.

NOTE PDI can be a single number for full-time constant power operation and for 100 % dimming level in regulated systems, or it can represent different numbers for each considered state of operation. Annex A gives examples of calculation and Annex D gives an example of the presentation of results.

Where the luminous flux output of the light source is varied to compensate for changes in luminous flux output throughout lifetime of the light sources (for example the light sources use constant light output (CLO) drivers), the average system power associated with these variations should be used for the calculation of power density (D_P).

If the calculation for the main lighting class is based on a single calculation for a section of the road, i. e. for a typical arrangement and spacing, then the system power (*P*) calculation shall include the sum of the power of all luminaires and the electrical device(s) related to luminaires, lighting points and segments which are inside and on the edges of the calculation area relevant to this typical arrangement, in accordance with EN 13201-3. Annex A shows some typical examples. The number of luminaires and size of the area shall be relevant to each other.

If the calculation is performed for an irregular shaped area, the system power (P) calculation shall include the sum of the power of each luminaire and the electrical device(s) related to luminaires, lighting points and segments, which are needed to light the area.

The system power (P) should not include any power associated with devices which are not used to fulfil the lighting function, even if they are connected to the same network. Typical examples are illuminated advertisement and festive lighting.

4.4 Area (A) to be used for calculation of the power density indicator

The area used for calculation of the power density indicator (D_P) shall be identical to the area used in lighting design for lighting calculation of parameters according to EN 13201-2 and described in EN 13201-3.

If the carriageway of a road is not surrounded by other areas (for example another carriageway, footpath, cycle path or parking areas, etc., which have their own individual specified lighting requirements) and Edge Illuminance Ratio (EIR) is calculated in accordance with EN 13201-2, the surrounding areas used for calculating EIR are not included in the calculation of power density indicator.

5 Annual Energy Consumption Indicator (AECI)

The annual electricity consumption of a road lighting installation depends on:

— the period of time for which lighting is provided,

— the lighting class specified by the relevant lighting standard for each lighting period,

— the efficiency of the lighting installation, when providing the necessary lighting for each period,

— the way the lighting management system follows the change in visual needs of road users,

— the parasitic energy consumption of lighting devices during the period when the lighting is not needed.

For comparison and monitoring of the energy performance of a lighting installation, the energy consumption indicator shall take into account the annual accumulated energy use of road lighting illuminating the street or public area, however actual lighting needs may vary during the year because of the following reasons:

— seasonal variations of daylight / night time hours: this depends on the geographical location of the area,

— changing weather conditions which influence perceived visual performance (i.e. dry or wet road surface),

— changing traffic density on the street or public area during the night (i.e. different temporal pattern of usage such as increased usage at “rush hour”) or following the fluctuation in social activity (i.e. school terms, national holiday periods),

— changing functionality of the street or public area (i.e. roads are closed for a certain period or turned to pedestrian areas in festive seasons).

Annual energy consumption indicator (AECI) shall be calculated with the following formula:

$$D_\mathrm{E} = \frac{\sum_{j=1}^{m} (P_\mathrm{j} \cdot t_\mathrm{j})}{A} \tag{3}$$

where

D_E is the annual energy consumption indicator for a road lighting installation, in Wh·m^{-2};

P_j is the operational power associated with the j^{th} period of operation, in W;

t_j is the duration of j^{th} period of operation profile when the power P_j is consumed, over a year, in h;

A is the size of the area lit by the same lighting arrangement, in m^2;

m is the number of periods with different operational power P_j· m shall also consider the period over which the quiescent power is consumed. This period would generally be the time when the lighting is not operational, i.e. daylight hours and any night time period when the lighting is not lit.

If the light output of a light source is intended to be constant, but the power consumption of this light source (or other electrical devices) varies in time (for example if constant light output (CLO) drivers are used), the average power consumption over the anticipated lifetime shall be included in the calculation. The calculation shall clearly indicate the lifetime assumptions used for calculation of the average consumption and how this value was evaluated.

Annual energy consumption indicator (D_E) shall be always presented and used together with the values of the power density indicator (D_P) for assessment of the energy performance of a particular lighting system.

Annex A
(informative)

Examples of calculation and typical values of energy performance indicators

A.1 Examples of operational profiles

A.1.1 General

Typical examples of daily operational profiles for road lighting are given below. Start time and end time of operation change throughout the year and depend on the geographical latitude and local conditions. It is advisable that the operation of artificial lighting is correlated with illuminance from daylight with respect to the illuminance required for a particular lighting class according to EN 13201-2. In the moment of sunset the illuminance level is considerably high but rapidly decreases. At sunrise the situation is reversed.

Examples of operational profiles in this annex illustrate the daily course of lighting level. Power level needed for the calculation of energy performance is associated with lighting levels depending on lamp type, lamp power and other factors.

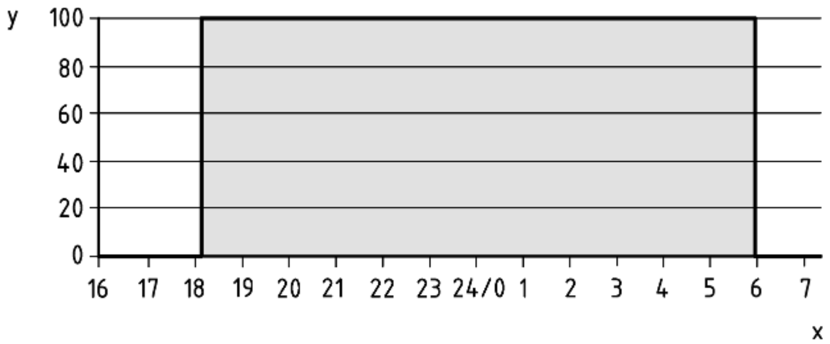
NOTE 1 This annex does not deal with particular relation between lighting level and power level.

For the calculation of AECI it is necessary to sum up daily operation hours for each of the lighting levels throughout a whole year.

NOTE 2 Parasitic power is not included in the operational profiles presented below.

A.1.2 Full power operation

The profile in Figure A.1 is typical for lighting installations with simple switching devices like time switchers or photosensors. Luminaires operate constantly at full power throughout the night time each day.



Key

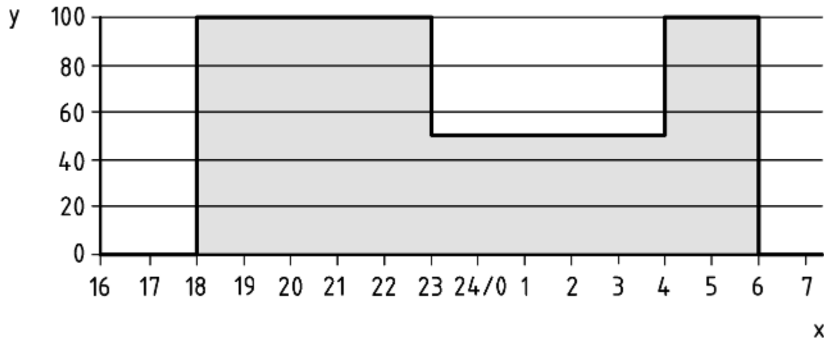
x daily course of operation (h)

y lighting level (%)

Figure A.1 — Full power operational profile

A.1.3 Multi-power operation

The multi-power profile (e.g. bi-power profile shown in Figure A.2) consist of two or more time periods during the daily course when luminaires are operated at different power associated with different lighting levels provided. Each of the lighting levels should be derived from lighting class according to EN 13201-2.



Key

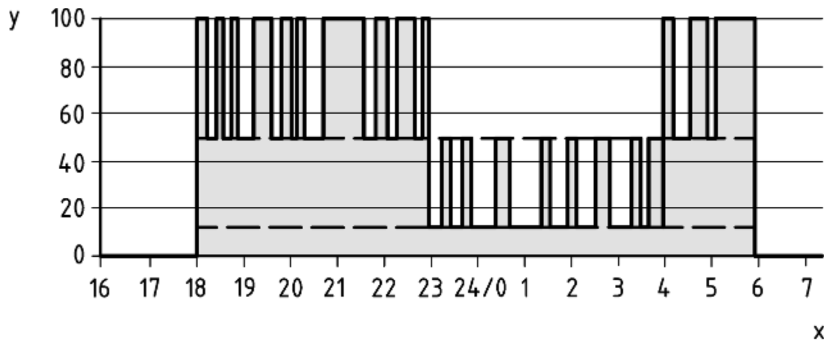
x daily course of operation (h)

y lighting level (%)

Figure A.2 — Bi-power operational profile

A.1.4 Operation with vehicle and presence detectors

If vehicle and/or presence detectors are used to control the lighting system, full power or multi-power operational profiles are truncated by time periods when no traffic is sensed by the associate detectors and luminaires operate at reduced levels. Figure A.3 shows an example of tri-power operational profile for lighting control with detectors where at least a minimum lighting level is kept throughout the night time. Peaks depicted in Figure A.3 depend on sensing and are not periodical. For calculation of AECI it is necessary to assume for annual probability parameter for each of the lighting levels.



Key

x daily course of operation (h)

y lighting level (%)

Figure A.3 — Tri-power detector-driven operational profile

A.2 Example of calculation

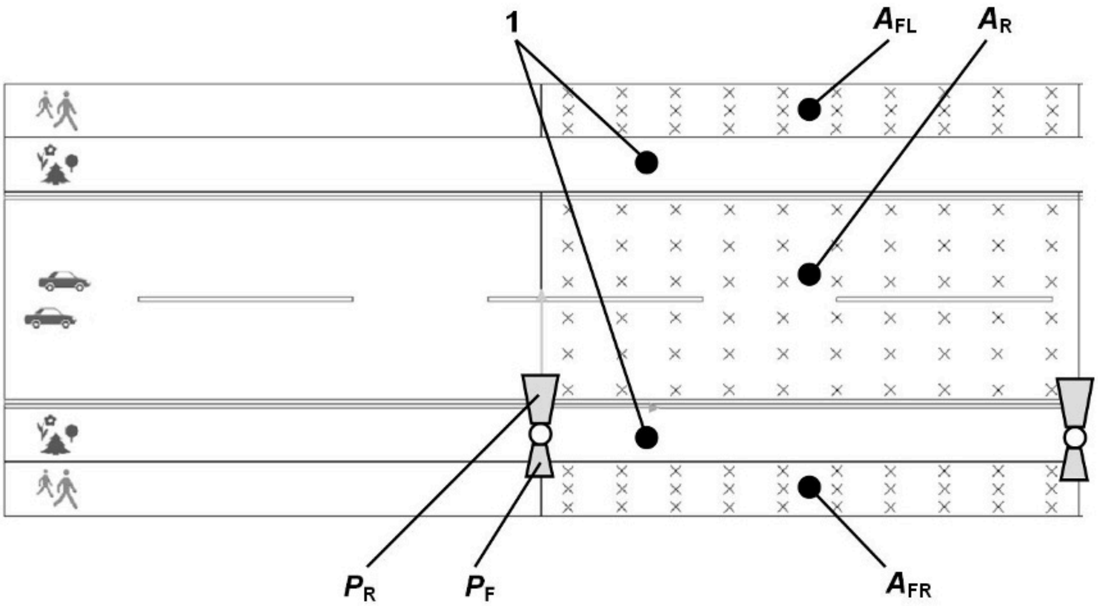
Calculation of the energy performance indicators PDI (Clause 4) and AECI (Clause 5) is additionally explained by means of an example depicted in Figure A.4.

A generic road profile consists of two lane carriageway with sidewalks on both sides and grass strips separating them from carriageway.

Lighting poles are installed in the grass strip between the carriageway and the right sidewalk. Two luminaires are installed per pole: Luminaire P_R for illumination of the carriageway and the distant (left) sidewalk partially also illuminates the right sidewalk. An additional luminaire P_F is installed to support the illumination of the right sidewalk and is, therefore, oriented towards this sidewalk. System power of the luminaires P_R and P_F is the nominal power usually provided by luminaire manufacturer. If calculation of energy performance is performed for a typical field between two consecutive lighting poles according to EN 13201-3, system power P_R and P_F is included in calculation only once. If calculation of energy performance is performed on the entire road length or its section longer than a single field for photometric calculation, all luminaires associated with this road section are included.

Illuminated areas for the carriageway A_R, left sidewalk A_{FL} and right sidewalk A_{FR} can be calculated from the corresponding widths of road profile and the considered length of the installation (length of the road, road section or spacing of luminaires). Illuminance of the carriageway E_R, left sidewalk E_{FL} and right sidewalk E_{FR} should be calculated in accordance with EN 13201-3. Areas of grass strips and strips for calculation of the edge illuminance ratio are excluded from the calculation of energy performance indicators.

For calculation of AECI it is necessary to take into account the lighting control profile applied to lighting system as combination of reduction coefficient and annual operation time for each of the operational regimes and probability of motion detection, if used. For example in case of the widely used bi-power operation (see A.1.3) the total annual operation time is divided to the time of full operation t_{full} and the time of reduced lighting level t_{red} when the system power is lowered by the reduction coefficient k_{red}.



Key

1 excluded from calculation

Figure A.4 — Situation and description of parameters for calculation of PDI and AECI as an example

When applied to the situation in Figure A.4, and respecting the assumptions mentioned above, Formulae (1) and (3) for the calculation of energy performance indicators become as follows:

$$D_{\mathrm{P}} = \frac{P_{\mathrm{R}} + P_{\mathrm{F}}}{E_{\mathrm{FL}} \cdot A_{\mathrm{FL}} + E_{\mathrm{R}} \cdot A_{\mathrm{R}} + E_{\mathrm{FR}} \cdot A_{\mathrm{FR}}} \quad \text{(A.1)}$$

$$D_{\mathrm{E}} = \frac{(P_{\mathrm{R}} + P_{\mathrm{F}}) \cdot (t_{\mathrm{full}} + k_{\mathrm{red}} \cdot t_{\mathrm{red}})}{A_{\mathrm{FL}} + A_{\mathrm{R}} + A_{\mathrm{FR}}} \quad \text{(A.2)}$$

where

P_{R} is the system power of the main luminaire in the lighting installation, in W;

P_{F} is the system power of the auxiliary luminaire for illumination of the right sidewalk, in W;

A_{R} is the area of the carriageway, in m^2;

A_{FL} is the area of the left sidewalk, in m^2;

A_{FR} is the area of the right sidewalk, in m^2;

E_{R} is the calculated maintained illuminance on the road, in lx;

E_{FL} is the calculated maintained illuminance on the left sidewalk, in lx;

E_{FR} is the calculated maintained illuminance on the right sidewalk, in lx;

t_{full} is the annual operation time of the full level illumination, in h;

t_{red} is the annual operation time of the reduced level illumination, in h;

k_{red} is the reduction coefficient for the reduced level illumination.

In Formula (A.2), for both luminaires the same lighting control profile is applied.

A.3 Typical values of energy performance indicators

A.3.1 General

Values of energy performance indicators PDI and AECI depend on many factors like the actual lighting class, road profile arrangement, width of carriageway and sidewalks, type of the light source, quality of optics and position of lamp in luminaires (through photometric data of luminaires), etc. In case of AECI, switching and control profile may strongly affect the value of this indicator. Assuming the lighting system is optimized to target photometric parameters, lighting designs may differ in energy performance. The lower is the value of PDI and AECI, the better energy performance.

Values of energy performance indicators PDI and AECI presented in this annex are based on numerous calculations of optimized lighting systems for different combinations of road profiles, lighting classes, light source types and luminaires that are common in practice. The values should not be used as benchmarks, they are intended to create an imagination on absolute values of the indicators and their variation and to aid how to distinguish between more and less energy efficient solutions.

Assumptions taken into for sample calculations are as follows:

— width of sidewalks and grass strips, where applicable, equals to 2 m;

— maintenance factor is set to 0,80 for all types of lamps and luminaires;

— for road reflection properties the R3 table is considered;

— mounting height is optimized within the range 5 m to 12 m (step: whole numbers);

— spacing of lighting poles is optimized and sought between 20 m to 60 m (step: 1 m);

— arm overhang is ranged from 0 m to 2 m with the (step: 0,5 m);

— luminaires are not tilted;

— annual operation time 4 000 h at full power.

Arrangement of the lighting system is generally single-sided and for some situations with wider carriegeway an opposite arrangement is selected. For each calculation, the lighting system geometry is optimized with preference given to the spacing in order to enlarge the illuminated area as much as possible and to have thus the energy performance indicators as low as possible. Mounting height and arm length affects to the indicators only indirectly.

Luminaires used in calculations cover the possible options. Low-cost or sophisticated luminaires incorporate reflecting diffuser or high-quality smooth or faceted reflectors, respectively. Lamp types comprise ellipsoidal and tubular high-pressure sodium lamps, mercury lamps, metal halide lamps and LEDs of different wattages. Lamp position in the luminaire, where adjustable, is optimized and not taken as an option.

NOTE Calculations are based on lighting products (luminaires) available in Q1/2014.

A.3.2 Two-lane road for motorized traffic (road profile A)

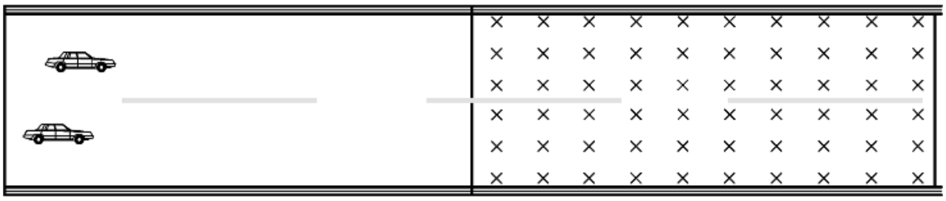


Table A.1 — Typical values of the Power Density Indicator D_P in mW·lx^{-1}·m^{-2} for road profile A

Lighting class	Width of carriageway *m*	Lamp type				
		Mercury	Metal halide	Sodium elliptical	Sodium tubular	LED
M1	7		45		34 - 41	25 - 32
M2	7	100	50		31 - 40	24 - 27
M3	10	85	42	43	31 - 32	25 - 27
	8	83	42	40	30 - 33	27
	7	84	47	40	34 - 38	23 - 25
	6	103	51	43	40 - 44	25 - 28
M4	7	90	60	41 - 47	34 - 42	23
M5	7	86	30	47	38 - 45	24
	6	89	34	53	41 - 51	28
	5	97	41		53	38
	4	116	48		65	46
M6	7	85	37		45 - 49	20 - 27

Table A.2 — Typical values of the Annual Energy Consumption Indicator D_E in kWh·m^{-2} for road profile A

Lighting class	Width of carriageway *m*	Lamp type				
		Mercury	Metal halide	Sodium elliptical	Sodium tubular	LED
M1	7		5,0		4,0 - 5,3	3,0 - 3,8
M2	7	10,8	4,6		3,2 - 4,2	2,4 - 2,5
M3	10	6,0	3,4	3,0	2,3	1,6
	8	6,0	3,4	3,0	2,2 - 2,4	1,6
	7	6,0	3,6	2,8 - 3,1	2,5 - 2,6	1,5
	6	7,0	3,9	3,2	2,7 - 2,8	1,6
M4	7	5,0	3,1	2,3 - 2,5	1,8 - 2,4	1,1
M5	7	3,2	0,9	1,7	1,1 - 1,6	0,8
	6	3,4	1,0	2,0	1,2 - 1,7	0,9
	5	3,6 - 4,0	1,2		1,5 - 1,8	1,0
	4	4,1	1,5		1,7 - 2,3	1,3
M6	7	1,9	0,6		0,2 - 1,2	0,4 - 0,5

A.3.3 Road with mixed motorized and pedestrian traffic without sidewalks (road profile B)

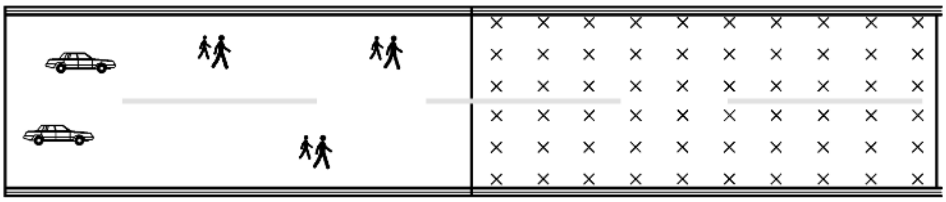


Table A.3 — Typical values of the Power Density Indicator D_P in mW·lx^{-1}·m^{-2} for road profile B

Lighting class	Width of carriageway *m*	Lamp type				
		Mercury	Metal halide	Sodium elliptical	Sodium tubular	LED
C3	10	98	44	43	32	18 - 23
	7	92	51	39 - 45	35 - 41	24
	6	103	57	48	43	25 - 28
C5	7	95	29	60	44 - 53	27
	6	107	36	69	50 - 60	31
	5	110 - 125	43		53 - 59	41

Table A.4 — Typical values of the Annual Energy Consumption Indicator D_E in kWh·m^{-2} for road profile B

Lighting class	Width of carriageway *m*	Lamp type				
		Mercury	Metal halide	Sodium elliptical	Sodium tubular	LED
C3	10	6,0	2,7	3,1	1,9 – 2,0	1,1 - 1,4
	7	5,6	3,2	2,6 - 3,1	2,2 - 2,6	1,5 - 1,6
	6	6,3	3,8	3,0	2,6	1,6 - 1,8
C5	7	3,0	0,9	1,8	1,3 - 1,6	0,8
	6	3,3	1,1	2,1	1,6 - 1,8	1,0
	5	3,8	1,4		1,8 - 1,9	1,3

A.3.4 Road and sidewalk on the side of lighting arrangement (road profile C)

Table A.5 — Typical values of the Power Density Indicator D_P in mW·lx^{-1}·m^{-2} for road profile C

Lighting class	Width of carriageway *m*	Lamp type				
		Mercury	Metal halide	Sodium elliptical	Sodium tubular	LED
M3/P3	7	68	38	33	30 - 43	20 - 21
M4/P4	7	73	50	35 - 38	30 - 34	20
M5/P5	7	71	25	39	33 - 37	21

Table A.6 — Typical values of the Annual Energy Consumption Indicator D_E in kWh·m^{-2} for road profile C

Lighting class	Width of carriageway *m*	Lamp type				
		Mercury	Metal halide	Sodium elliptical	Sodium tubular	LED
M3/P3	7	4,7	2,8	2,2 - 2,4	2,0	1,1
M4/P4	7	4,0	2,4	1,8 - 1,9	1,5 - 1,8	0,9
M5/P5	7	2,5	0,7	1,3	0,9 - 1,2	0,6

A.3.5 Road and sidewalk on the opposite side to the lighting arrangement (road profile D)

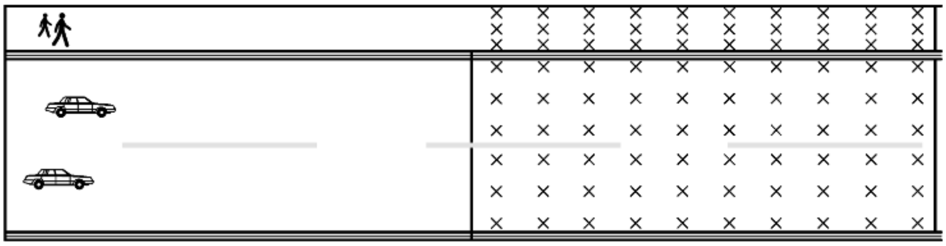


Table A.7 — Typical values of the Power Density Indicator D_P in mW·lx^{-1}·m^{-2} for road profile D

Lighting class	**Width of carriageway** *m*	**Lamp type**				
		Mercury	Metal halide	Sodium elliptical	Sodium tubular	LED
M3/P3	7	73	41	34 - 35	32	20
M4/P4	7	78	48	35 - 40	27 - 35	19
M5/P5	7	74	24	39	32 - 38	20

Table A.8 — Typical values of the Annual Energy Consumption Indicator D_E in kWh·m^{-2} for road profile D

Lighting class	**Width of carriageway** *m*	**Lamp type**				
		Mercury	Metal halide	Sodium elliptical	Sodium tubular	LED
M3/P3	7	4,7	2,8	2,2 - 2,4	2,0	1,2
M4/P4	7	4,0	2,4	1,8 - 1,9	1,4 - 1,8	0,9
M5/P5	7	2,5	0,7	1,3	0,9 - 1,2	0,6

A.3.6 Road and two sidewalks on both sides (road profile E)

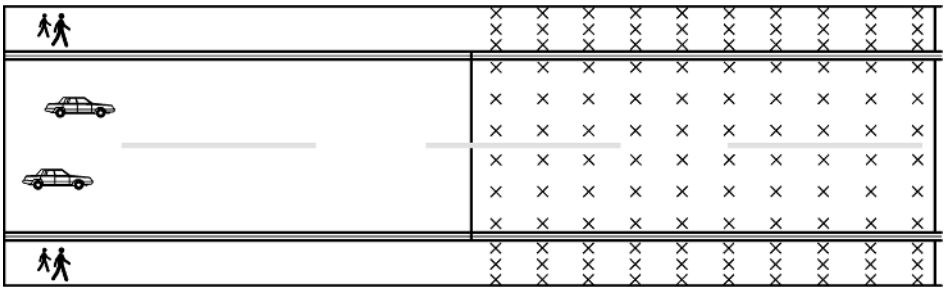


Table A.9 — Typical values of the Power Density Indicator D_P in mW·lx^{-1}·m^{-2} for road profile E

Lighting class	Width of carriageway *m*	Lamp type				
		Mercury	Metal halide	Sodium elliptical	Sodium tubular	LED
M3/P3	7	61	34	29	24 - 33	17 - 18
M4/P4	7	65	41	33 - 34	26 - 28	17
M5/P5	7	63	22	33	28 - 32	17

Table A.10 — Typical values of the Annual Energy Consumption Indicator D_E in kWh·m^{-2} for road profile E

Lighting class	Width of carriageway *m*	Lamp type				
		Mercury	Metal halide	Sodium elliptical	Sodium tubular	LED
M3/P3	7	3,8	2,3	1,8 – 2,0	1,6	1,0
M4/P4	7	3,2	2,0	1,5	1,2 - 1,5	0,7
M5/P5	7	2,0	0,6	1,0	0,7 - 1	0,5

A.3.7 Road and two sidewalks on both sides separated from carriageway by grass strips (road profile F)

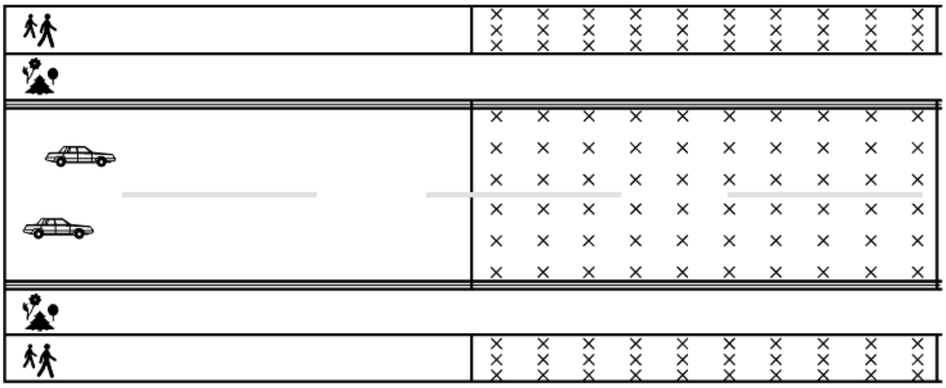


Table A.11 — Typical values of the Power Density Indicator D_P in $mW \cdot lx^{-1} \cdot m^{-2}$ for road profile F

Lighting class	Width of carriageway *m*	Lamp type				
		Mercury	Metal halide	Sodium elliptical	Sodium tubular	LED
M3/P3	7	76	40	34	27 - 33	25
M4/P4	7	71	45	34 - 36	28 - 32	23
M5/P5	7	70	25	37	31 - 35	22

Table A.12 — Typical values of the Annual Energy Consumption Indicator D_E in $kWh \cdot m^{-2}$ for road profile F

Lighting class	Width of carriageway *m*	Lamp type				
		Mercury	Metal halide	Sodium elliptical	Sodium tubular	LED
M3/P3	7	4,5	2,6	2,0	1,6 - 1,9	1,3
M4/P4	7	3,2	2,0	1,5	1,2 - 1,5	1,0
M5/P5	7	2,0	0,6	1,0	0,8 – 1,0	0,6

A.3.8 Typical values of AECI for different operational profiles

Typical values of AECI presented in A.3.2 to A.3.7 apply to full power operational profile (see A.1.2) with annual operation time 4 000 h. To consider different operational profiles it is usually sufficient to combine the annual operation times of individual lighting levels with the associated system power and the detection probability (in systems with detectors) into a single lighting operation coefficient c_{op}. This coefficient can be used to multiply the AECI for full power operation to obtain the value of AECI for actual operational profile.

Table A.13 shows typical values of the lighting operation coefficient c_{op} for different operational profiles under these assumptions:

— Full power: 4 000 h operation at full power *P*;

— Bi-power: 2 175 h at full power P and 1 825 h at reduced power $0{,}7 \cdot P$ with lighting level reduced to 50 %;

— Tri-power: 2 175 h of bi-level lighting control between 100 % and 60 % of the system power with detection probability of 80 % and 1 825 h of reduced bi-level lighting control between 20 % and 60 % of system power with detection probability of 20 %.

Table A.13 — Typical values of the lighting operation coefficient c_{op} in % for different operational profiles

Operational profile	c_{op} %
Flat full power	100,0
Bi-power	86,3
Tri-power with detectors	62,8

Annex B
(informative)

Installation luminous efficacy

B.1 General

Installation luminous efficacy is calculated with the following formula:

$$\eta_{\text{inst}} = C_{\text{L}} \cdot f_{\text{M}} \cdot U \cdot R_{\text{LO}} \cdot \eta_{\text{ls}} \cdot \eta_{\text{P}} \qquad \text{(B.1)}$$

where

η_{inst} is the installation luminous efficacy in lm·W^{-1};

C_{L} is the correction factor for luminance or hemispherical illuminance based lighting designs;

f_{M} is the overall maintenance factor (MF) of the lighting installation;

U is the utilance of the lighting installation;

R_{LO} is the optical efficiency of luminaires used in the lighting installation;

η_{ls} is the luminous efficacy of the light sources used in the installation in lm·W^{-1};

η_{P} is the power efficiency of luminaires used in the lighting installation.

The installation luminous efficacy η_{inst} should be evaluated considering the real operating conditions of the lighting installation.

Maintenance factor should be the same as used for the calculation of photometric parameters according to EN 13201-3.

B.2 Calculation of the correction factor

In case the minimum requirement for one or more areas is expressed in road surface luminance, the ability of the lighting installation to produce luminance may be relatively high or low either because of a value of the average luminance coefficient of the road surface Q_0 deviating from the normally assumed value of 0,07 cd·m^{-2}·lx^{-1} or because of a particular directionality of the illumination. Correction factor accounting for these two aspects is calculated with the following formula:

$$C_{\text{L}} = \sum_{i=1}^{n} (\overline{E}_{\text{i,min}} \cdot A_{\text{i}}) / \Phi_{A} \qquad \text{(B.2)}$$

where

$\overline{E}_{i,min}$ is the minimum required average illuminance;

A_{i} is the sub-area to which the minimum required average illuminance applies;

Φ_{A} is the luminous flux reaching the area to be illuminated.

n is the number of sub-areas to be lit.

For an area A_i where the lighting design criterion is the minimum road surface luminance $\overline{L}_{i,min}$, the value of the minimum required average illuminance is set to:

$$\overline{E}_{i,min} = \overline{L}_{i,min} / 0,07 \tag{B.3}$$

For an area A_i where the lighting design criterion is the hemispherical illuminance E_{hs}, the value of the minimum required average illuminance is set to:

$$\overline{E}_{i,min} = E_{hs} / 0,65 \tag{B.4}$$

NOTE The value 0,65 is empirical and represents an average value for variety of lighting installations.

B.3 Calculation of the utilance

Utilance (U) is defined as the ratio of the luminous flux received by the reference surface to the sum of the individual total fluxes of the luminaires of the installation:

$$U = \frac{\Phi_A}{n_{lu} \cdot \Phi_{ls} \cdot R_{LO}} \tag{B.5}$$

where

Φ_A is the luminous flux reaching the area to be illuminated, in lm;

Φ_{ls} is the luminous flux emitted from the light source(s) in a luminaire, in lm;

R_{LO} is the optical efficiency of luminaires used in the lighting installation;

n_{lu} is the number of luminaires of the installation.

B.4 Calculation of the efficiency of luminaires

Luminous efficacy of a luminaire is lower than luminous efficacy of the lamp(s) inside due to optical losses and consumption of the control gear. Optical efficiency R_{LO}, sometimes abbreviated as LOR (Light Output Ratio) is the ratio of luminous flux going out from a luminaire and the luminous flux of the lamp(s) inside this luminaire. It can be calculated from photometric data of luminaires and it is usually provided by luminaire manufacturers.

Power efficiency of a luminaire is the ratio between power of lamp(s) and the system power of the luminaire:

$$\eta_P = P_{ls} / P \tag{B.6}$$

where

P_{ls} is the power of lamp(s) inside the luminaire, in W;

P is the system power of the luminaire, in W.

NOTE 1 For some LED based luminaires values for P_{ls}, η_{ls} and R_{LO} are not available and need to be replaced by the overall luminaire’s luminous efficacy.

NOTE 2 In general, the system power P can include also other devices which are outside luminaires but directly associated with the area to be illuminated.

Annex C
(informative)

Lighting factor of an installation

C.1 Installation lighting factor q_{inst}

EN 13201-2 prescribes that the lighting installations for the motorized roads be designed and realized according to the average road luminance levels (M lighting classes). However, the power density indicator (D_P), the system power (P) and the annual energy consumption indicator (D_E) depend on the average horizontal illuminance ($\overline{E}$).

Where M lighting classes are used the lighting designer should select the luminaires that realizing the road luminance $\overline{L}$ as defined in EN 13201-2 with the lowest road illuminance $\overline{E}$. With this aim, it is essential to use a simple parameter for an easy and quick comparison of the energy performance obtained with different luminaires and/or in different installations. This can be done through the installation luminance factor q_{inst}, defined as:

$$q_{inst} = \frac{\overline{L}}{Q_0 \cdot \overline{E}} \tag{C.1}$$

where

$\overline{L}$ is the calculated average maintained road luminance in accordance with EN 13201-3:2015, 7.1 and 8.2, in cd·m^{-2};

$\overline{E}$ is the calculated average maintained horizontal illuminance of the road surface when the road surface luminance is $\overline{L}$, in lx;

Q_0 is the average luminance coefficient of the r-table adopted in luminance calculation, in sr^{-1}.

NOTE It is a normalizing parameter, which gives q_{inst} a dimensionless character through reference to a standardized photometric property of the road surface.

C.2 Role of q_{inst} in road lighting design aimed at energy saving

The factor q_{inst} proposed here follows the suggestions of the CIE 144 for a careful consideration of the quotient luminance/illuminance in road lighting. The factor q_{inst}, whose typical range is between 0,8 and 1,3, is in close correlation with energy consumptions and environmental compatibility: for example, increasing values of q_{inst} within the said range correspond to a 40 % decrease of the power density indicator D_P, a result which cannot be neglected.

The factor q_{inst}, characterizes the energy performances of road lighting installations independently of the lighting components used for its actual realization: road luminance and illuminance can be either taken from the lighting design or measured on the road. Thus, the energy performances can be assessed in any case, even if nothing is known about its light source, luminaires, etc. Moreover, at the design stage the performances about energy consumptions can be evaluated immediately, without any further calculations. In all cases, q_{inst} permits an easy comparison of the efficiency of different types of installations, particularly between old and state-of-the-art ones.

C.3 Typical values of q_{inst}

Experience shows that good results for energy consumptions and environmental compatibility can be obtained with q_{inst} >1 with a careful design.

Annex D
(informative)

Presentation of energy performance indicators

The two energy performance indicators – power density indicator (PDI) and annual energy consumption indicator (AECI) are compound parameters, thus they should be always presented together. All values and assumptions taken for the calculation of energy performance indicators should also be displayed clearly with the indicators. Table D.1 gives an example. In some cases graphical interpretation of the operational profile can be a suitable way of presentation.

Table D.1 — Example of information to be presented together with energy performance indicators

System power					
	Luminaire 1	Luminaire 2	Luminaire 3	Luminaire 4	Luminaire 5
Operational power P (W)					
Additional power P_{ad} (W)					
Illuminated area					
	Sub-area 1	Sub-area 2	Sub-area 3	Sub-area 4	Sub-area 5
Area to be lit A (m^2)					
Calculated illuminance E (lx)					
Operational profile					
	Period 1	Period 2	Period 3	Period 4	Period 5
Annual operating hours (h)					
Reduction coefficient (%)					
Detection probability (%)					
Energy performance indicators					
	Period 1	Period 2	Period 3	Period 4	Period 5
Power density indicator D_p ($W \cdot lx^{-1} \cdot m^{-2}$)					
Annual energy consumption indicator D_E ($Wh \cdot m^{-2}$)					

NOTE The table can be extended by additional luminaires, sub-areas or time periods if needed.

Bibliography

[1] CEN/TR 13201-1, *Road lighting — Part 1: Guidelines on selection of lighting classes*

[2] EN 13201-4, *Road lighting — Part 4: Methods of measuring lighting performance*

[3] CIE S 017/E: 2011, ILV, International Lighting Vocabulary

[4] CIE 115:2010, *Lighting of Roads for Motor and Pedestrian Traffic*

[5] CIE 144:2001, *Road Surface and Road Marking Reflection Characteristics*

[6] CIE 154:2003, *The Maintenance of Outdoor Lighting Systems*

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