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Road lighting - Part 5: Energy performance indicators

Straßenbeleuchtung - Teil 5: Energieeffizienzindikatoren

Éclairage public - Partie 5: Indicateurs de performance énergétique

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Road lighting - Part 5: Energy performance indicators

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Straßenbeleuchtung - Teil 5: Energieeffizienzindikatoren

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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of an identical text or by endorsement, at the latest by June 2016 and conflicting national standards shall be withdrawn at the latest by June 2016.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)
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
η_{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
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:

$$D_{\mathrm{P}} = \frac{P}{\sum_{i=1}^{n} (\overline{E}_{\mathrm{i}} \cdot A_{\mathrm{i}})} \tag{1}$$

where

D_{P} is the power density indicator, W·lx^{-1}·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:

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

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,