Evaluation of the energy efficiency of lighting inside sports facilities on the basis of the PN- EN 15193 norm

Dorota Typańska
Poznań University of Technology
60-965 Poznań, ul. Piotrowo 3a, e-mail: Dorota.Typanska@put.poznan.pl

The article presents the findings of energy efficiency examination of the lighting used inside the swimming pool hall of the existing water park facility based on the PN-EN 15193 norm. It describes the basic factors on which the analysis of the lighting energy efficiency is based and provides specific calculation

1. Introduction

The idea of energy efficient lighting appeared relatively recently, around the 80's of the twentieth century. It was then that the Illuminating Engineering Society of North America ordered reduction of the installed power in lighting luminaires in response to the first global energy crisis [3]. Mostly due to the need for environmental protection, a norm that makes it possible to verify whether the parameters of particular lighting systems allow for any energy savings was created [5].

The purpose of the present article is to present the basic characteristic quantities and to evaluate the energy efficiency of lighting as described in the norm. The constant illuminance factor F_c in a room, the occupancy dependency factor F_o or the daylight dependent artificial lighting factor F_d, which comprise the lighting energy numeric indicator (LENI) can serve as examples.

2. The characteristics of lighting parameters described in a normative way

2.1. Energy use evaluation

The determination of energy use by lighting luminaires is possible on the basis of two methods, that is the calculation method and the measurement method, as presented on the diagram on Fig. 1. The illustration above shows that while performing calculations, the quick method is only used when annual based energy use is estimated. In practice, this is the most frequently used method. On the other hand, by using the comprehensive method, one can determine the amount of energy used by lighting in any period of time [2]. An alternative to performing calculations is performing lighting system measurements. Measurements can be performed at any time as the illuminance values in a building must always comply with the requirement specified in the norm [4].

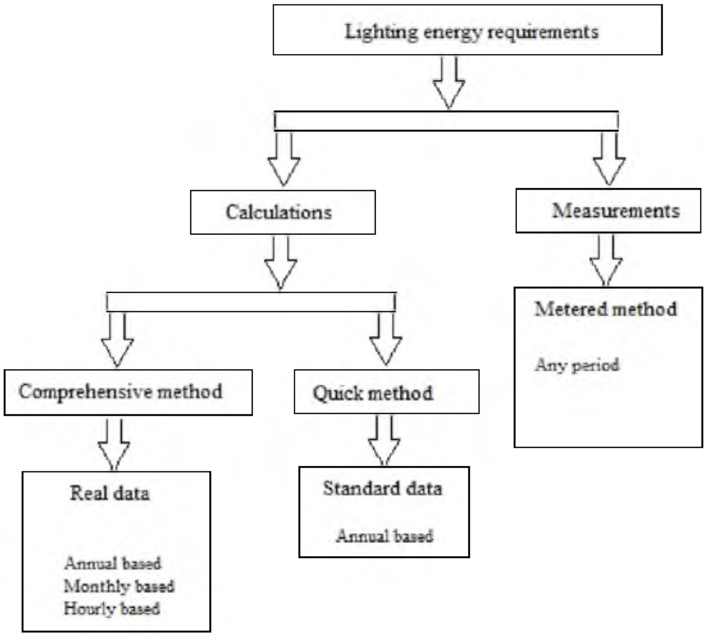

Fig. 1. The routes used to determine energy use [3]

The analysis of the basic factors should start with the total energy used for lighting W_t. This parameter is comprised of the energy consumption used by the luminaires installed for illumination $W_{L,t}$ and of the so-called parasitic energy consumption $W_{P,t}$ which is the energy consumed when the luminaires are not operating (e.g. by the charging circuit of emergency lighting or by the standby lighting control system) [4]:

$$W_t=W_{L,t}+W_{P,t}\ [kWh] \tag{1}$$

The energy use value is minimized through three known techniques, that is:

– constant illuminance control,
– control and adjustment of lighting luminaires,
– using natural light.

Using those three methods is related with the creation of the appropriate factors F_c, F_o, F_D which will be described in more detail later in the article. The values of those factors are always less than or equal to 1.

The occupancy dependency factor F_o reflects the installed power consumption of lighting luminaires with reference to the occupancy period in the room. It depends on the lighting control and supervision system. This parameter is used in order to minimize the operation time of lighting luminaires and thus – to reduce the installed power they consume.

Controlling constant illuminance levels has considerable influence on the energy efficiency of the lighting system. It involves using the oversized installed power of the luminaires. The value is derived from the maintenance factor assumed in the lighting design which is dependent on the lighting maintenance period, the maintenance activities required for particular luminaires and the light source type. The value of the installed power capacity used increases over time. The moment when the total installed power capacity is reached should mean the end of the maintenance period [4]:

$$F_c = \frac{(1+MF)}{2} \tag{2}$$

The constant illuminance factor F_c is thus defined as the ratio of the average input power over a given time to the initial installed input power of the luminaires. The value is averaged depending on the maintenance factor MF and calculated on the basis of two boundary values, the initial value and the final value.

The possibility to use daylight with optional use of artificial (electrical) lighting is very important in the consideration of the energy efficiency of indoor lighting. The illuminance values of artificial lighting on the operation area are standardized [4] and implemented in practice through adjusting the luminous flux of the luminaires.

The essence of any consideration of the energy efficiency of indoor lighting is the LENI factor. The abbreviation - LENI - stands for *Lighting Energy Numeric Indicator*, which is determined on the basis of the annual energy use for lighting in relation to the total area of the surface lighted [4].

$$LENI = \{F_c \frac{P_N}{1000}[(t_d F_d F_0) + (t_N F_0)]\} + 1 + \{\frac{1}{t_y}[t_y - (t_d + t_N]\} \quad [\frac{kWh}{m^2 year}] \tag{3}$$

P_N – installed lighting power density load in the building [W/m^2].

The hourly based values for the times included in the equation above are provided in table G1 in appendix G to the norm [2]. Their summary will be presented in Table 1.

Table 1. Hourly based time values t_d, t_N [2]

Facility type	t_d	t_N
Offices	2250	250
Schools	1800	200
Hospitals	3000	2000
Sports halls	2000	2000

t_d – annual number of operating hours during the daylight time, measured in hours,
t_n – annual number of operating hours during the non-daylight time, measured in hours.

3. The results of energy efficiency analysis for the lighting system in a sports swimming pool hall

The design assumptions for the sports swimming pool were verified by means of the Dialux design software program (Fig. 2).

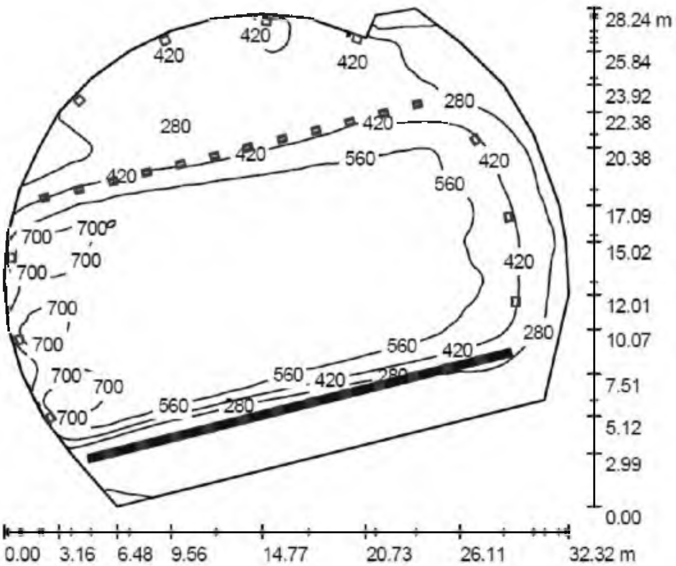

Fig. 2. Illuminance diagram for the swimming pool surface

The total area lighted by the luminaires was 699,62 m^2, and the total calculated luminous flux for the luminaires was 725000 lm, and the total power of the luminaires was 9830W. This means that the lighting power per unit area was 14,05 W/m^2 [1].

Table 2. Illuminance calculation results for the swimming pool hall [6]

Area	Em [lx]	Emin [lx]	Emax [lx]	Emin/Em
Operation area	460	121	784	0,263
Floor	446	134	694	0,300
Ceiling	122	71	2579	0,581
Walls	216	92	15812	-

The basic parameters necessary to calculate the LENI factor were read from the appropriate tables provided in the norm and noted in the form of the Table 2 provided in Table 3.

Table 3. Summary of the parameters necessary to calculate LENI

Swimming pool hall							
F_o	F_c	F_d	t_y	t_o	t_d	t_N	P_N
-	-	-	[h]	[h]	[h]	[h]	W/m²
1	0,855	1	8760	4000	2000	2000	14,05

The value of the LENI factor can be calculated from the data provided in the Table [3]:

$$\begin{aligned} LENI &= \{0{,}855 \frac{14{,}05}{1000}[(2000 \times 1 \times 1) + (2000 \times 1)]\} + \\ &+ 1 + \{\frac{1}{8760}[8760 - (2000 + 2000]\} = 49{,}59 \ [\frac{\text{kWh}}{\text{m}^2 \, year}] \end{aligned} \quad (4)$$

The starting point for the energy efficiency analysis performed is the comparison of the results obtained for particular rooms with table F1 in appendix F to the PN-EN 15193 norm [2].

4. The analysis of illuminance distribution measurements in the swimming pool hall

The analysis of the illuminance measurement report prepared directly after the construction of the object was completed is presented below. It presents a comparison between the measurement results and the existing lighting norms. The PN – EN 12193 norm; Light and lighting. Sports lighting. will be used for that purpose. The measurement grid assumed for the room was 10 x10 which gives 100 measurement points. The Table 4 presents a few measurement point examples.

The values measured presented in the table are service values that include the maintenance factor MF.

The maximum illuminance value in the room was 690 lx, and the average value for the total of one hundred measurements was 549 lx, with the uniformity value of about 0,8. The values measured meet the requirements of the norm according to table A6 of the norm which assume the illuminance value of 500 lx and uniformity value equal to at least 0,7 [4].

On the basis of the values provided above, the real power correction unit per 100 lx can be calculated according to the following equation [2]:

$$P_s = P_{co}\frac{100}{E} \qquad [\frac{W}{m^2}/100lx] \qquad (5)$$

where: P_s – power correction unit $[\frac{W}{m^2}/100lx]$, P_{op}- power per unit area for the luminaires installed $[\frac{W}{m^2}]$, E – illuminance [lx].

$$P_s = 14{,}05\frac{100}{549} = 2{,}56 \qquad [\frac{W}{m^2}/100lx] \qquad (6)$$

Table 4. Sample illuminance measurement results for the swimming pool hall [7]

Place of measurement	Light source type	Illuminance [lx]			Uniformit y
		measured	max	average	
Room W1- Sports swimming pool 1	Metal-halide lamps	556	690	549,1	0,7958
Room W1- Sports swimming pool 2	Metal-halide lamps	534	690	549,1	0,7958
Room W1- Sports swimming pool 3	Metal-halide lamps	521	690	549,1	0,7958
Room W1- Sports swimming pool 4	Metal-halide lamps	567	690	549,1	0,7958
Room W1- Sports swimming pool 5	Metal-halide lamps	546	690	549,1	0,7958
Room W1- Sports swimming pool 6	Metal-halide lamps	529	690	549,1	0,7958
Room W1- Sports swimming pool 7	Metal-halide lamps	532	690	549,1	0,7958
Room W1- Sports swimming pool 8	Metal-halide lamps	567	690	549,1	0,7958
Room W1- Sports swimming pool 9	Metal-halide lamps	546	690	549,1	0,7958
Room W1- Sports swimming pool 10	Metal-halide lamps	555	690	549,1	0,7958

What can be concluded from the calculations performed is that the real value of power per 100 lx is 2,56 , whereas the design value is 3,06, which is a bit higher than the real value resulting from the assumed average illuminance of 460 lx and which is caused by the fact that the luminaires were placed over the tribunes (due to easier access for maintenance purposes) rather than in the places that would be most advantageous in terms of lighting efficiency.

5. Conclusions

The analysis of the factors provided in the norm [2] makes it possible to determine the detailed value of lighting energy use. Every parameter must be included for the calculations to be correct, regardless of the method selected (either quick or comprehensive).

For the facility examined, the boundary values of the LENI factor presented in table F1 of the norm [2] were presented on the diagram on Fig. 3.

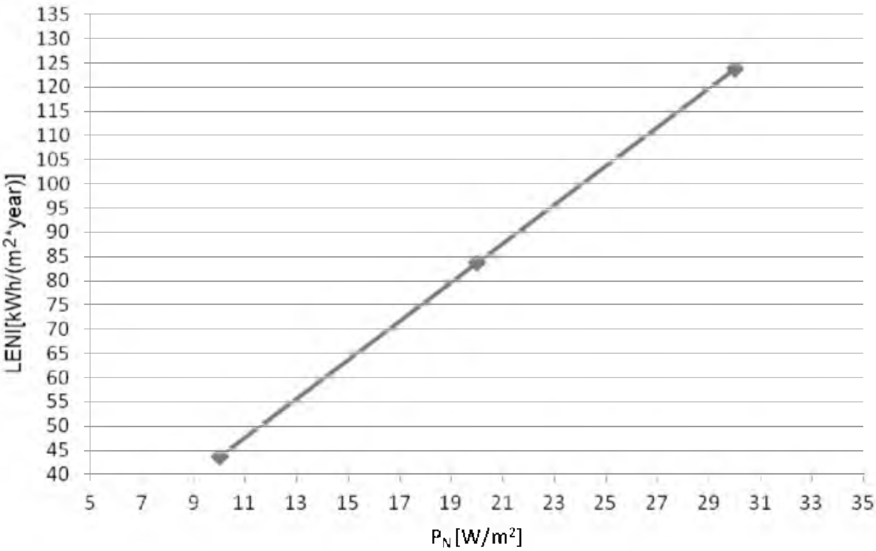

Fig. 3. Diagram of boundary values of the LENI factor for sports facilities [2]

It was discovered that the diagram of boundary values of the LENI factor for sports objects has an approximately linear form. The boundary value in this case is $49{,}6\ [\frac{kWh}{m^2 year}]$. This means that the energy efficiency of the lighting system in the swimming pool hall examined is high as the calculated value of the factor is below the permissible limit provided in the norm.

The research conducted shows that the facility was designed and constructed in accordance with the existing norms regarding lighting both with respect to the appropriate illuminance levels and lighting uniformity as well as with respect to energy efficiency.

References

[1] Typańska D.: „Ocena wydajności energetycznej oświetlenia wnętrz na podstawie normy PN-EN 15193: Energetyczne właściwości użytkowe budynków – Wymagania energetyczne dotyczące oświetlenia", master thesis, Poznań University of Technology, Poznań 2011.
[2] PN-EN 15193 Norm: Energy performance of buildings. Energy requirements for lighting.
[3] Bąk J.: „Wydajne energetycznie oświetlenie wnętrz", Warsaw, 2009.
[4] PN-EN 12193:2007 Norm , Light and lighting. Sports lighting
[5] Stowarzyszenie Elektryków Polskich: "Energooszczędność w oświetleniu", Poznań, 2010.
[6] Water park lighting documentation, Aga Light, Ożarów Mazowiecki, 2010.
[7] Typański P: "Protocol of measurements of the lighting installation of the sports swimming pool", Poznań, 2010.