Dorota TYPAŃSKA, Łukasz PUTZ

Poznan University of Technology, Institute of Electrical Engineering and Electronics

Analysis of the light and energy performance inside a lobby with an illumination made in LED technology

***Abstract**. The article presents the results of energy efficiency tests conducted in the lobby of the JET OFFICE building located in Poznań on the basis of the PN-EN 15193 standard. The basic factors on the basis of which the energy efficiency analysis of the lighting was performed were characterized and specific calculations were presented.*

***Streszczenie.** W artykule przedstawiono wyniki badań efektywności energetycznej lobby budynku biurowego JET OFFICE znajdującego się w Poznaniu, w oparciu o normę PN-EN 15193. Scharakteryzowano podstawowe współczynniki, na podstawie, których przeprowadzono analizę wydajności energetycznej oświetlenia oraz przedstawiono konkretne obliczenia. (**Analiza parametrów energetycznych i świetlnych iluminacji lobby wykonanej w technologii LED**).*

Keywords: energy efficiency of lighting, LED technology, LENI factor.
Słowa kluczowe: wydajność energetyczna oświetlenia, technologia LED, współczynnik LENI.

doi:10.12915/pe.2014.03.23

Introduction

The concept of energy efficient lighting appeared as late as in the eighties of the 20th century. It was a response to the first global energy crisis. It was then that the Illuminating Engineering Society of North America recommended minimizing the energy consumed for lighting [1, 8]. The term “energy efficient lighting” means lighting with considerably lower power consumption without compromising the quantitative and qualitative characteristics of the lighting.

The purpose of the present article is to present the basic characteristic values and the evaluation of energy efficiency of the lighting installed in the lobby of the JET OFFICE building. The lighting was based on the LED technology in such a way so as to, first of all, fulfill the esthetic requirements for the representational purposes of the building.

Basic energy requirements for indoor lighting

A number of parameters that should be considered in order to determine the energy efficiency coefficient of lighting are used in the standard. They include, among others, the wattage of the fixtures installed as well as the constant illuminance factor and the daylight dependency factor [5].

The analysis of basic values should start with the energy consumption for lighting factor. This parameter consists of the energy consumed by the fixtures fitted and of the so-called parasitic load consumed when the light source is shut off.

The value of the energy consumed is minimized by means of three techniques, that is:

- controlling the constant illuminance of the lighting,
- controlling and adjusting the fixtures,
- use of daylight.

Another coefficient that is worth describing is the occupancy dependency factor F_o, which expresses the use of the total installed power of the fixtures fitted in relation to the occupancy time in the room and which is dependent on the lighting control and monitoring system. It is used in order to minimize the lighting time of the fixtures and thus, reduce their installed power consumption.

Controlling the constant illuminance level is another factor influencing the energy efficiency of the lighting. It involves the use of overmeasured installed power of the fixtures. This parameter results from the maintenance factor depending on the lighting maintenance period, the construction of the fixtures and the type of the lighting sources assumed in the design of the lighting system. The installed power used increases with time. The time needed to reach full use of the power should correspond with the end of the maintenance period.

(1) $$F_C = \frac{(MF+1)}{2}.$$

The constant illuminance factor F_c is the relation of the average power used in a given period of time to the total power of the fixtures. The value of this factor is averaged depending on the MF factor (the factor determined on the basis of the maintenance period of the fixtures). It is calculated on the basis of two boundary values, the original value and the final value.

A very important issue in the consideration regarding energy efficiency of indoor lighting is the possibility to use daylight with potential additional lighting provided by means of artificial (electric) light. The illuminance of the artificial light on the working surface is adjusted on the basis of the need to maintain the required illuminance level in the room (to which both the natural light and the artificial light contribute). In practice, such a system involves adjusting the luminous flux of the fixtures.

The essence of the consideration regarding the energy efficiency of indoor lighting is the LENI factor. The abbreviation stands for a numeric indicator of the lighting energy which is determined on the basis of the amount of energy consumed by lighting over the period of one year in relation to the total area of the surface lighted [6]:

(2) $$LENI = \{F_C \cdot (\frac{P_N}{1000}) \cdot [(t_d \cdot F_d \cdot F_o) + (t_N \cdot F_o)]\} + \\ +1 + \{\frac{5}{t_y} \cdot [t_y - (t_d + t_N]\} [\frac{\text{kWh}}{(\text{m}^2 \times \text{year})}]$$

where:
F_c – constant illuminance factor,
P_N – installed power density of the lighting in the building [W/m^2]
F_d – daylight dependency factor,
F_o – occupancy dependency factor,
t_d – daylight time usage,
t_y – standard year time, 8760 h,
t_N – non-daylight time usage.

The cut score values of the LENI factor and particular times are specified in the standard [5].

Energy efficiency evaluation of the lighting in the lobby

The room examined is of rectangular shape with the dimensions of 6,5 x 5 m and the height of 2,8 m. In order to light the area, LED strips with the illuminance of 4,8 W/m covered with a semi-transparent material were used and four fluorescent light fixtures 1x 54W (Fig. 1) were fitted in order to provide the appropriate vegetation conditions to the plants. Figure 2 presents the photometric body of the Spotline fixture.

Fig. 1 The shape of the 1x54W fixture of the Spotline company [3]

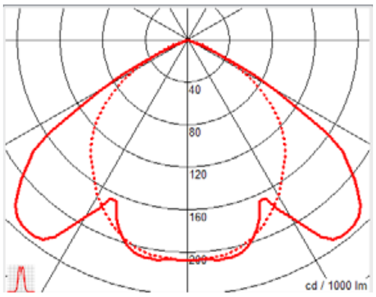

Fig. 2 Light distribution curve of the fixture 1x54W [3]

Additionally, Lovato 3W emergency lighting and escape route lighting was used (the shape of the fixture and the photometric body are presented on figures 3 and 4), also with LED sources in which a single green diode signaling that the fixture is operational is on in the "stand-by" mode. Figure 9 presents activated emergency lighting.

Fig. 3 Lovato emergency lighting [2]

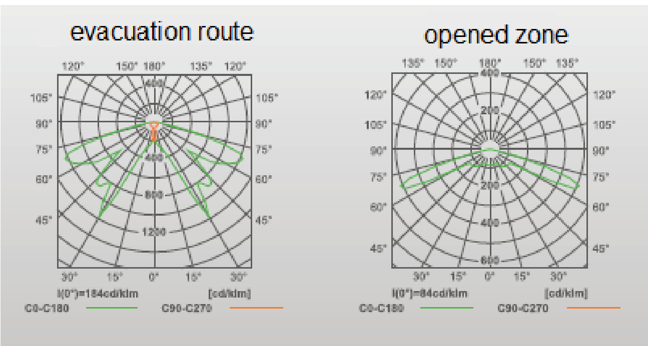

Fig. 4 Photometric curve of the Lovato emergency fixture [2]

The diagram of the lighting installation is presented on figure 5 [4], where:

J – Lovato 3W emergency and escape route lighting,
O – Spotline PD 105 T5 1x54W linear fluorescent fixtures,
M – 4,8 W/m LED strip,
Figures 6,7 and 8 present the installation fitted.
K – 4,8 W/m LED strips covered by light-transmitting material.

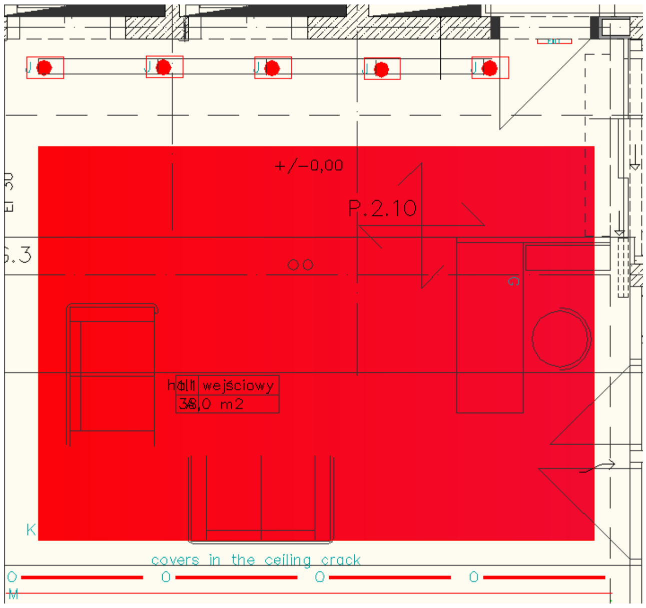

Fig. 5 A plan view of the room with indication of the positioning of the fixtures (highlighted in red) [4]

Fig. 6 A view of the reception desk in the room

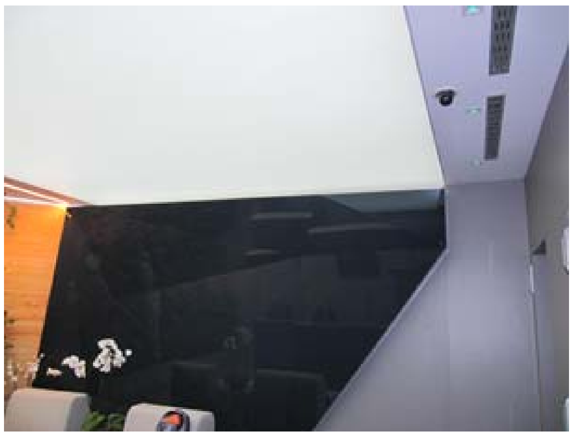

Fig. 7 A view of the room from the entrance door

The measurements were performed on the working surface with the height of 0,75, 1,15 m (two-level receptionist's desk) as well as in the vicinity of the workplace at floor level.

The installed lighting power per unit area is 37,4 W/m^2.

The maximum illuminance value in the room was 686 lx on the working surface and 524 lx in the vicinity of the working area; the average value obtained in all the measurements was 512 lx on the working surface and 367 lx in the vicinity of the working area, at the approximate uniformity of 0,71 and 0,59. The values measured meet the requirements of the standard [6].

Fig. 8 A view of the plant lighting

Fig. 9 A view of the activated emergency lighting

Table 1 presents measurements of the average illuminance (E_m) and of the minimum and maximum illuminance values in the room.

Table 1. Illuminance measurements results

Area	E_m	E_{min}	E_{max}
Working surface	512 lx	361 lx	686 lx
Vicinity of the workplace	367 lx	215 lx	524 lx

The actual adjusted unit power value per 100 lx can be calculated on the basis of the values provided above according to the following formula [5]:

$$P_S = P_{CO} \cdot \frac{100}{E} [\mathrm{W/m^2/100lx}] \quad (3)$$

where: P_s – adjusted unit power [W/m^2/100 lx], P_{op}– unit power of the installed fixtures [W/m^2], E – illuminance [lx].

The following is obtained after particular values are substituted in the formula:

$$P_S = 37{,}4 \cdot \frac{100}{400} [\mathrm{W/m^2/100lx}] \quad (4)$$

It was found that the actual power value per 100 lx is 9,35 [W/m^2/100lx], which is a very low value in comparison to "conventional" light sources and fixtures.

Additionally, it is worth noting the properties of the emergency lighting, or, more precisely, the fact that the illuminance value of escape route lighting is very high for a relatively low power used by the fixtures.

Table 2 summarizes the results of lighting illuminance measurements on the escape route. The average illuminance is over ten times higher than required by the standard [7], as presented on figure 10.

Table 2. Illuminance calculation results

Area	E_m	E_{min}	E_{max}
Lighted area	13 lx	10 lx	15 lx

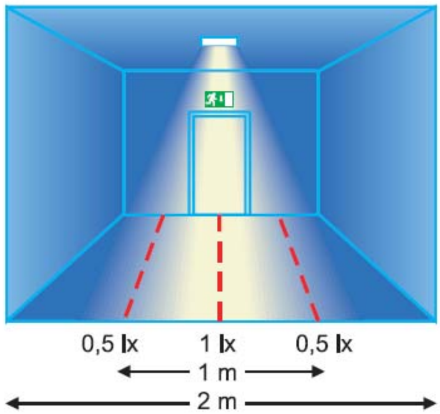

Fig. 10 Illuminance requirements for escape routes [9]

Conclusion

The evaluation of the energy efficiency of lighting involves mainly the calculation of the LENI factor. This is possible through the use of two methods: the quick method and the comprehensive method (fig. 11). The quick method was used for the purposes of the present article.

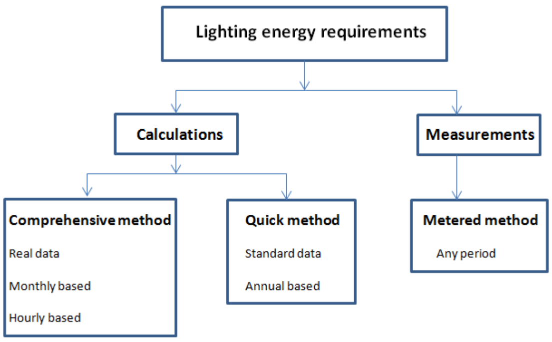

Fig. 11 The routes used to determine energy use [5]

The list of all the parameters needed to calculate the value of the LENI factor is presented in the form of table 3 [5].

Table 3. List of parameters needed to calculate LENI [5]

F_o	F_c	F_d	t_y	t_d	t_N	P_N
-	-	-	[h]	[h]	[h]	[W/m^2]
0,7	0,9	1	8760	3000	2000	37,4

LENI coefficient calculated from the formula (2):

$$LENI = \{0,9 \cdot \frac{37,4}{1000} \cdot [(3000 \cdot 1 \cdot 0,7) + (2000 \cdot 0,7)]\} + 1 + + \{\frac{5}{8760} \cdot [8760 - (3000 + 2000)]\} = 120,96[\frac{kWh}{m^2 \cdot year}]. \quad (5)$$

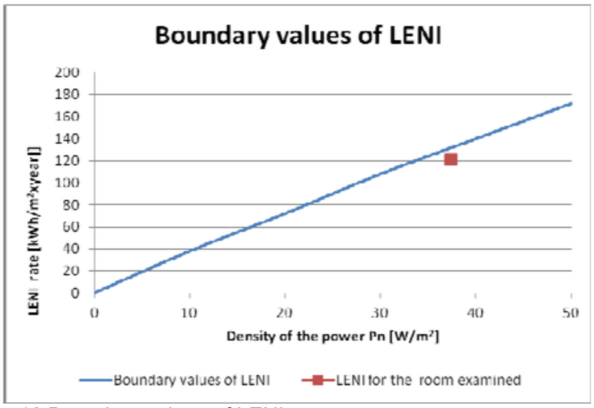

Fig. 12 Boundary values of LENI

The boundary value for the examined room is about 121 [kWh /(m^2 × year)], as presented on figure 12. Then, the energy efficiency factor calculated (5) falls within the limits specified in the standard [5].

The tests performed show that the object was designed and constructed in accordance with the existing lighting standards both with respect to the appropriate illuminance values as well as the energy efficiency. This was possible only thanks to the use of electroluminescent lighting. Mounting the ceiling as a uniform illuminated surface with the use of a different type of luminaires would result in much higher energy consumption.

REFERENCES

[1] Bąk J.:„ Energy-efficient lighting insides”, Warsaw, 2009
[2] Catalog sheet of the Lovato fixture
[3] Fixture catalog of the Spotline company
[4] Lighting installation design in the JET OFFICE building.
[5] PN-EN 15193 standard: Energy performance of buildings – Energy requirements for lighting
[6] PN-EN 12464 standard; 2005: The lighting of workplaces
[7] PN-EN 1838 standard: Lighting applications. Emergency lighting
[8] Typańska D.: „ Evaluation of the energy efficiency of lighting insides based on the norm PN-EN 15193: Energy functional properties of the illumination”, Master thesis, Poznan University of Technology, Poznan 2011.
[9] http://www.am.com.pl/img/42d69e97.pdf

Authors *mgr inż Dorota Typańska, Poznan University of Technology, Institute of Electrotechnology and Industrial Electronics, Piotrowo 3a, 60-965 Poznań, E-mail: Dorota.Typanska@put.poznan.pl; mgr inż Łukasz Putz, Poznan University of Technology, Institute of Electrotechnology and Industrial Electronics, Piotrowo 3a, 60-965 Poznań, E-mail: Lukasz.Putz@put.poznan.pl;*