Energy Efficient Street Lighting with LED Lighting Fixtures

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Abstract
With the increasing requirements for street lighting (such as better quality lighting, complication of the transport task, energy efficiency, etc.) there is a demand for the usage of modern lighting fixtures with energy efficient lighting sources. The use of LED lighting fixtures reveals new aspects in the construction of street lighting.
The report represents the results from calculations made for typical street lighting in various tasks and the use of LED lighting. Data obtained from the calculations can be used in the implementation of street lighting for typical situations encountered in practice.
A comparative analysis of different solutions was made.

Keywords: energy efficient; street light; LED.

Introduction

An impetuous development of lighting products has been observed during the last few years. Light-emitting diode sources (LED) are now known in practice. Up until now, there has been a tendency for the light-emitting diodes to be used predominantly for street lighting. With the application of these types of lighting sources, factors such as the quality of light and the energy efficiency are improved, thus the increasing demands for street lighting are met.

The current work examines the application of LED sources in the building of typical lighting installations for the territory of the Republic of Bulgaria. A comparison was made between different lighting options with both LED and classical sources, regarding the technical and economical parameters of each [3].

Exposition

The territory of the Republic of Bulgaria is subdivided into 264 municipalities, which are part of 28 regions. Considering the almost identical conditions of street lighting in the majority of municipalities, identical lighting situations are being created on the territory of the country. This work intends to shed light on the conditions created in the smaller settlements of Bulgaria.

For the purposes of this project, three typical lighting situations are being examined for the different types of streets, considering the following factors:

a) The illuminating engineering situation (based on the typical speed of the main users and the other kinds of users);
b) The lighting class;
c) Rate indicators for the street lighting on a given street.

The types of lighting situations are:

I. Service Streets (intended for pedestrians and bikers on sidewalks, byciclist alleys, emergency lanes, and other road sections situated separately or along roadways, neighborhood streets, walkways, parking lots, areas around sites of interest, parks, etc.):

I.1. Lighting situation E2: typical speed – pedestrian; main participants in traffic – pedestrians and possibly vehicles and byciclists moving slowly [1].
I.2. Lighting class S5 (normal criminal risk; necessary face identification; low pedestrian traffic) [1].
I.3. Illumination: average maintained – 3 lx (lux); minimal maintained – 0.6 lx. [1].
I.4. Typical parameters – roadway width 4 to 5 m; distance between lighting poles 20 m; illuminator suspension height 5 m; distance from the side of the roadway 0.5 m; console 0 m.

II. Collective Streets (for collective and service streets in villages and small towns):
II.1. Lighting situation B1: typical speed (>30 and ≤ 60) km/h; main participant in traffic – motorized traffic with slowly moving vehicles; other possible participants – byciclists and pedestrians [1].
II.2. Lighting class ME6 (no criteria for geometrical limiting of traffic; number of crossroads less than 3 per 1 km; normal complication of the transport task; motorized traffic flow – under 7,000 vehicles [1]).
II.3. Recommended measures: average brigthness of 0.3 cd/m^2; $U_O > 0.35$; $U_l > 0.4$; TI = 15 %.
II.4. Typical parameters – roadway width 6 to 7 m; distance between lighting poles 30 m; illuminator suspension height 7 to 8 m; distance from the side of the roadway 0.8 m; console 1 m.

III. Main streets (for main and collective streets and incoming-outgoing streets in villages and small towns):
III.1. Lighting situation B1: typical speed (> 30 and ≤ 60) km/h; main participant in traffic – motorized traffic of slowly moving vehicles; other possible participants – byciclists and pedestrians [1].
III.2. Lighting class ME5 (no criteria for geometrical limiting of traffic; number of crossroads more than 3 per 1 km; normal complication of the transport task; motorized traffic flow – under 7,000 vehicles [1].
III.3. Recommended measures: average brigthness 0.5 cd/m^2; $U_O > 0.35$; $U_l > 0.4$; TI = 15 %.
III.4. Typical parameters – roadway width 9 m; distance between lighting poles 30 m; illuminator suspension height 7 to 8 m; distance from the side of the roadway 0.8 m; console 1.5 m.

The lighting calculations were executed with the Dialux 4.9 program. Data about the mentioned lighting fixtures was obtained from leading producers in the field. Calculations were made for the typical lighting situations, shown above, with the application of different types of LED lighting fixtures from different producers and with different electric powers (18, 36, 52W and others). Figure 1 shows screens of the work of the aforesaid program for lighting calculations, made for the different street types.

The results of the calculations helped guide the choice of light-emitting diode sources for the different types of streets, in order to meet the standard requirements for each lighting class. Over 82 calculations were made, experimenting with different suspension heights, distances between the lighting poles, and different models of street lighting fixtures.

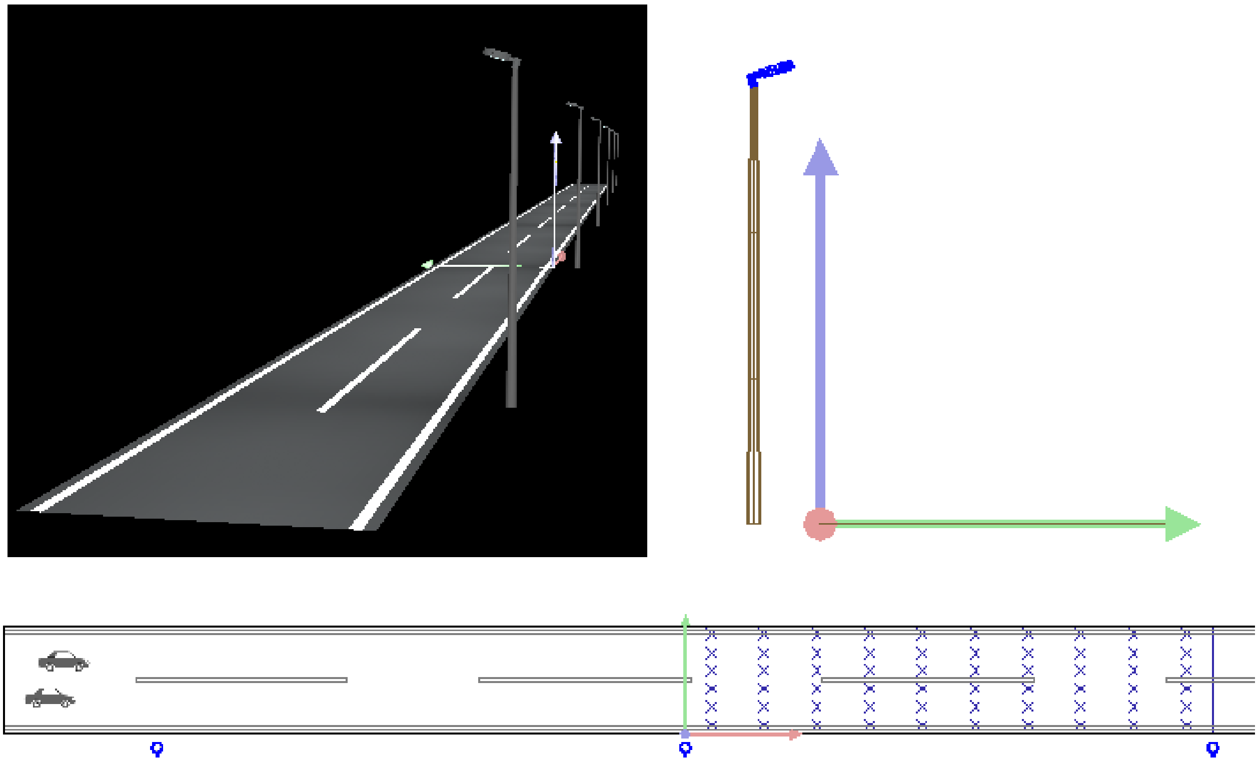

Fig.1. Instants of simulation of street lighting installations

The chosen LED street illuminators are as follows:

- for **Service Streets** – LED street illuminator with an electrical power of 18 W and implemented parameters of street pavement – E_{av} = 5 lx; TI = 7 %; U_0 = 0.25; U_l = 0.1. Experiments show that alterations in the width of the roadway and the suspension height of illuminators for the respective street type do not result in considerable changes in the implemented parameters.

- for **Collective Streets** – LED street illuminator with an electrical power of 36 W and implemented parameters of street pavement – L_{av} = 0.3 cd/m^2; TI = 8 %; U_0 = 0.69; U_l = 0.7. Experiments show that alterations in the width of the roadway and the suspension height of illuminators for the respective street type results in changes in the implemented parameters, but within permissible limits. In cases of increased street width it may be necessary to use illuminators with larger unit power (for example, 40 or 50 W);

- for **Main Streets** – LED street illuminator with electrical power of 52 W and implemented parameters of street pavement – L_{av} = 0.52 cd/m^2; TI = 13 %; U_0 = 0.58; U_l = 0.7. Experiments show that alterations in the width of the roadway and the suspension height illuminators for the respective street type results in changes in the implemented parameters, but within permissible limits. In cases of increased street width it may be necessary to use illuminators with larger unit power (for example, 70 W);

In analogical lighting situations and types of streets, up until now street lighting has been conducted by the following types of lighting sources:

- for **Service Streets** – street lighting fixture with compact luminescent lamps and an electrical power of 36 W. The implemented parameters of the street pavement are E_{av} = 5 lx; TI = 6 %; U_0 = 0.64; U_l = 0.62;

- for **Collective Streets** – street lighting fixture with compact luminescent lamps and an electrical power of 55 W. The implemented parameters of the street pavement are L_{av} = 0.39 cd/m^2; TI = 5 %; U_0 = 0.60; U_l = 0.59;

- for **Main Streets** – street lighting fixture with sodium lamps, high pressure, and an electrical power of 70 W. The implemented parameters of the street pavement are L_{av} = 0.6 cd/m^2; TI = 6 %; U_0 = 0.58; U_l = 0.61.

After specifying the types of street lighting fixtures, we can proceed to executing their energy and economical comparison. An assessment of the street lighting in its economical and energy aspects was made when experimenting with replacing the classical lighting sources with LED ones. Generalized data is shown in the table below (Table 1).

Table 1

Energy and Economical Indicators of Street Lighting In the Settlements of a Given Municipality

Order №	**Indicators**	**Indicator Values**	
		Current (Existing) Situation	Project Situation
1	2	3	4
1	Number of lighting fixtures for street lighting	545 163 x 36 W (PL-S) 284 x 55 W (PL-S) 98 x 70 W (SON-T)	545 163 x 18 W (LED) 284 x 36 W (LED) 98 x 52 W (LED)
2	Installed electrical power of street lighting (includes the loss in ballasts or drivers), *kW*	29.765	18.619
3	Annual electrical energy consumption in street lighting, *kWh/ year*	128,019.27	80,080.32
4	Annual emission of hothouse gases, *t/ year*	64.009	40.040
5	Decrease in expenses of electrical energy used for street lighting, *%*	-	37.45
6	Decrease in the annual emission of hothouse gases used in street lighting, *%*	-	37.45

From the table above it becomes clear that the decrease of electrical energy for street lighting is approximately 40%. As a whole, the decrease is not enormous, but some other factors, regarding the use of LED lighting fixtures, also must be taken into consideration:

- the longer operation life of LED street light fixtures (approx. 80 000 hours, or with normal exploitation of the street lighting, that is approx. 18 years);
- a much better color of light in comparison to the classical lighting sources;
- a decrease in the emission of hothouse gases;
- a possibility for easier and more fluent regulation of the light flux;
  and more.

The price of the LED lighting fixtures is still relatively high (about 1,000 Euro), which makes their use inefficient for the illumination of big streets from a higher light class; whereas the lighting fixtures with sodium lamps in these cases are more economically advantageous. However, at certain places, where impressive appearance, lighting comfort, and good energy efficiency are sought, LED lighting fixtures are a nice, contemporary alternative.

Conclusion

1. Three typical lighting situations for the different types of streets in the territory of the Republic of Bulgaria have been specified, considering the following: the lighting situation (based on the typical speed of the main users and the other kinds of users); the lighting class; and the standard indicators of street lighting for a given street.

2. Lighting calculations were executed using the Dialux 4.9 program for the typical lighting situations where different kinds of LED fixtures were applied, made by different producers and with different electrical powers (18 W, 36 W, 52 W, etc.). The results of the calculations helped guide the choice of light-emitting diode sources for the various types of streets, aiming at meeting the standard requirements for the respective lighting class. Over 82 calculations were made, experimenting with different suspension heights, distances between the lighting poles, and different models of street lighting fixtures.

3. As a consequence of the lighting calculation conducted, three types of LED lighting fixtures were chosen for the three typical lighting situations, in accordance with point #1.

4. An estimation of the energy and economical aspects was made when a replacement of the classical lighting fixture with LED lighting fixture was conducted. In the instance of having 545 street illuminators, a decrease of 37.45% may be observed in the expense for electrical energy.

5. With the replacement of the classical street fixtures with LED fixtures the following may be achieved: improved lighting conditions; better color quality of light; longer operation life; a decrease in the emission of hothouse gases.

References

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