INNOVATIVE USE OF LED LAMPS IN THE SYSTEM OF STREET LIGHTING WITH REMOTE CONTROL[1]

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***Summary**: The Construction Cluster „DUNDJER“, together with a number of its members, is participating, as a leading partner, in a national project co-financed by the National Agency for Regional Development, which deals with innovative implementation of LED lamps in the system of public enlighting by introducing distance control. The key study is realized in the Municipalities Knjaževac, Bela Palanka, and Preševo. This paper describes the topics of project research, in particular economic background of LED implementation with remote control.*

Keywords: LED lighting, remote control, energy efficiency

1. INTRODUCTION

Under modern life conditions, public lighting is an essential infrastructure component, which directly affects the quality of life, as well as the city image and the village image. This is confirmed by the results of public opinion in Western Europe. In 75% of the surveyed cities it is considered that the high-quality and well-maintained lighting is one of the most important elements of the municipality system, and it is very important for the functioning of the entire infrastructure of the cities. Today, in the structure of public lighting dominate lamps with high pressure mercury (Hg lamps) and lamps with high pressure sodium (Na lamp).

Serbia has installed about 600,000 public lighting luminaires that have an average power of 250W, 25 years old, and spend about 430 GWh annually, what is 1.5% of total electricity consumption in Serbia. In the structure of the existing lamps dominate lamps

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with high pressure mercury (Hg lamps), as well as other types of less energy-efficient lamps, and for the last ten years it is intensive introduction of more efficient high-pressure sodium lamps (Na lamps).

The development of semiconductor technology has enabled appearance lighting lamps with LED light sources (light-emitting diodes) on the world market, as a new, energetic, economically, and environmentally superior technology

2. COMPARATIVE ADVANTAGES OF LED LAMPS REGARDING Na AND Hg LAMPS

LED lamps have the unique features of energy efficiency, management, and service life, thanks to which they have the potential to reduce the electricity consumption of about 25 million to less than 3 million, by replacing all the lamps in Serbia, and that the maintenance costs of public lighting, which is estimated at more than 5 million, reducing at least by half over a longer lifetime of new lamps. Investment costs could be such that would be paid off in less than 4 years, which is three times shorter than the service life of LED lamps.

Taking into account the current electricity price of 0.056 € / kWh and the cost of LED lamps from about 4 €/W, calculation shows that the investment is worth replacing sodium lamps for less than 7.7 years, and halogen lamps for less of 2.2 years. The aforementioned does not include the savings and benefits from reductions in maintenance costs because the operating time of the LED lights is superior compared to the existing lamps.

Na lamps are much more efficient than mercury Hg lamps. Luminous efficiency of the Hg lamps is 60 lumens (lm) per watt (W) power generation, and Na lamp 110-120 lumens per watt (lm / W). This luminous efficiency of Hg lamps and Na lamps is technologically peaked so that cannot be further improved.

However, the real efficiency of Na and Hg lamps is significantly reduced due to the problems of reflection and inability to direct emitted light to the usable surface. Only about 20% of the total light energy is directed to the usable space (road, street, sidewalk), the rest goes into the surrounding space as useless light pollution. Moreover, for technological reasons "dimming" of the Na and Hg lamps is almost impossible and economically unjustified.

LED lamps are more energy-efficient than Na lamps by 65%, and a Hg lamp by 87%. From this it follows that the simple substitution of Na and Hg lamps with LED lamps will achieve savings for those percentages. With the use of programmable control of light intensity (dimming) according to the parameters that one-third of the time the light intensity is 100%, and two thirds of the time the light intensity is 25%, achieved further increase the efficiency of LED lamps compared to the Na lamp to the amount of 83% or 94% in relation to the Hg lamp.

At the today market commercially are available LED light sources with an energy efficiency of 150 lumens (lm) per watt (W) of electricity. It is soon expected LED sources to reach even 180 lm/W.

As punctate light sources LED lamps allow the use of simple optics (lenses) with almost 60% of light energy directed to the desired surface.
In terms of electricity the LED is a linear element. This allows through electronically control and programming, to regulate light intensity and thus the power consumption in the range of 0% through 100% linearly. In this way (dimming) one can achieve significant savings (up to 50%) in the system of public lighting.

Service life of LED light sources is 50,000 hours or more, what compared to Na source (16,000 hours), and Hg source (10,000 hours) makes them superior. Due to this fact, LED light sources in maintaining public lighting system allow considerable savings too.
LED lamp through a range of unique technological solutions, maximize the best qualities that LED light sources offer:

- Technical solution for passive cooling provided by the possibility of realization of electric lamps up to 300 W, which is equivalent to more than 30,000 lumens of light energy;
- Optical light control, which routing through specially designed lenses, enables over 60% of the produced light energy to be directed at the surface that needs to be illuminated;
- Remote control of lights, which allows programmatic control of its intensity during the night;
- The service life of these lamps is about 12 years, that is twice longer than Na lamps.

Based on the above it can be concluded that the reconstruction of the existing lighting system, LED lamps, acquires functional and quality lighting and achieve savings in operation.

Operation of such lamps should be adjusted remotely (dimming) in the range from 0% to 100% of light energy. In this way, power consumption can be further reduced.

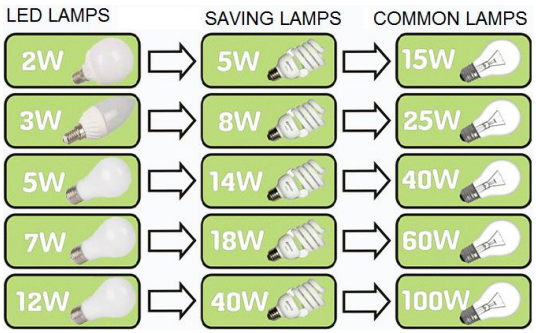


Fig. 1. LED lamps vs. Saving lamps vs. Common lamps

3. THE APPLICATION OF LED LIGHTING

LED lamp is designed initially for ambient lighting of street scene (carriageway and sidewalk area), urban intersections, squares, park areas and other traffic facilities and area (stations for supplying fuel, parking space). Thanks to its functional characteristic, LED light sources are reliable, durable, energy-efficient solution for ensuring the optimal intensity of brightness, colors, customized for requirements of each specific situation.

Different variants of power LED light sources and optics lamps, combined with the height and spacing of the pillars on which it is set, enable respond to different requirements in terms of intensity and uniformity of light traffic area and its immediate surroundings. Initially applied optics ensures uniform brightness (illuminance) rectangular surface of driveway, higher than 0.85 (minimum/ average).

Especially important is the possibility of remote control operation of lamps through a wired or wireless serial communication. The light intensity is automatically (by means of light sensors or based on a timer) or by means of the operator can be varied in the range of 0 to 100%. At the same time the energy consumption in proportion to the total light intensity, which supports the development and implementation of intelligent and energy-efficient lighting control strategy.
LED lighting has a wide range of applications:

- Lighting of outdoor parking space,
- Illumination in parks and promenades,
- Lighting for bike roads and trails for running,
- Lighting on docks and quays,
- Street lighting and marking of major and / or significant signs on the road,
- Lighting courtyards of homes, schools, playgrounds,
- Lighting farm and factory facilities,
- Applications in military bases.

According to the distribution of luminous flux, LED lighting falls under direct or semi-direct luminaire with wide distribution or extremely wide, depending on the need. It can give cold white, neutral white and warm white light that gives an average of 24-30 LED lamps. In terms of environmental standards these lamps fall into the category of "environmentally friendly" i.e. very little negative impact on the environment in which they are placed. They have a small dissipation, reduced CO_2 emissions by 350 kg/year on average. In addition, it does not contain heavy metals and no brightness in the spectrum of ultraviolet radiation, which are far more favorable for the environment than prescribed standard.

The role of lighting is not only limited to lighting road traffic participants, but it can be viewed in a different social context. Good lighting helps to reduce crime and reduce fear of crime (see standard BS 5489-1), promote the tourist offer of a given town, facilitates trade. Thus, the problem of designing these systems must be approached very seriously.

4. PRO'S FOR LED STREET LIGHTING

- LED lamp consumes 5 times less electricity than incandescent lamps.
- LED lamp consumes 3 times less electricity than fluorescent and energy saving light bulbs.
- LED lamp lasts 100 times longer than incandescent lamps.
- LED lamp lasts 10 to 20 times longer than fluorescent and energy saving light bulbs.
- Fluorescent tubes, energy saving light bulbs, light bulbs for street lighting, hall lighting, gas stations and others radiate an invisible spectrum that is extremely dangerous to health. Also affect the psyche of people because of the effect of flicker and extremely poor light spectrum.
- LEDs do not radiate, do not blink, and the light spectrum of them is similar to the sun light, what means that it is a very healthy source of light.
- LED bulbs are available in millions of colors.
- LED lamp does not disperse light in a sphere, but only in a third sphere, which means that for the same light force is 3 times more efficient than fluorescent tubes and energy saving light bulbs.
- LED light bulb shines in the water, the rain does not disturb the functionality.
- LED bulbs have extremely small dimension and weight and are considered as two-dimensional light source.
- The service life of LED lamps is 100,000 hours, which means about 35 years for the daily eight-hour operation.

Prospects for near future are:

- Incandescent lamps, fluorescent tubes and energy saving light bulbs go down in history.
- Power consumption on a global scale will be reduced by 3 to 4 times.
- CO_2 emissions caused by light sources as consumers, will be reduced 3 to 4 times.
- Annual production volume and rotten luminaries will be reduced by 10 times.
- Need to maintain lighting will disappear.

Table 2. Economic indicators of characteristics for fluorescent lights and LED lights in comparison

	fluorescent tube T5 1500mm	LED tube 1500mm
active power	80 W	25 W
reactive power	120 VA	0 VA
CO_2 emissions for the year	120 kg	40 kg
lifetime	10.000 hours	100.000 hours
Equate lifetime	Needed 10 tubes	Needed 1 tube
Consumption of 100,000 hours	8.000 kWh	2.500 kWh

Reactive power for 100,000 hours	12.000 kVAr	0 kVAr
Cost of Energy	1.200 €	375 €
The cost of excessive reactive energy	120 €	0 €
The total cost of energy	1.320 €	375 €
SAVING ENERGY	0 €	945 €
The cost of installation and replacement of 100,000 hours	35 €	55 €
TOTAL SAVINGS	0 €	925 €

Pic. 1. LED street lighting (Niš, ul. Somborska)

5. THE SELECTION OF LED LAMPS

In order to properly define the power LED lamps it is needed to take into consideration the following facts:

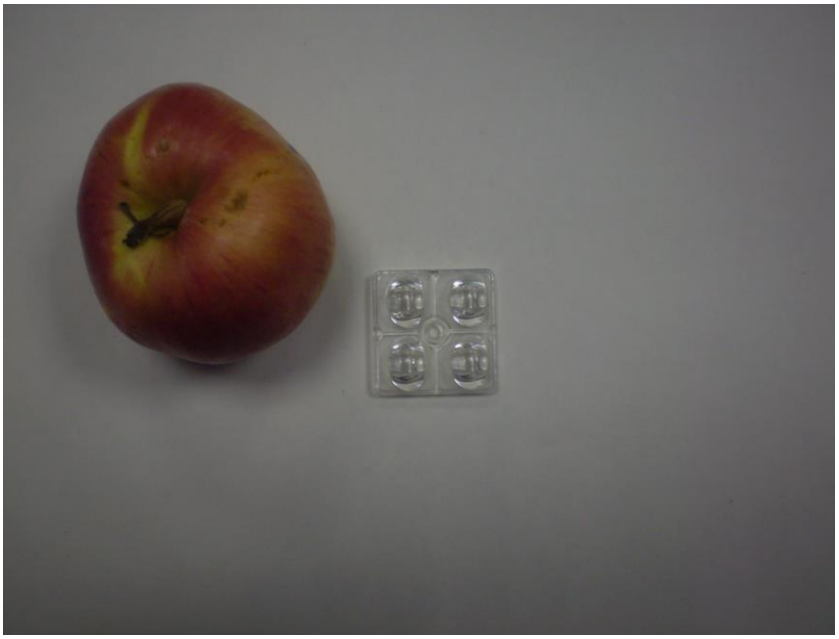
a) The efficiency Na-lamps is 115 lm/W,
The efficiency Hg-lamps is 60 lm/W,
The efficiency of LED lamps is 150 lm/W,
The efficiency coefficient (Ke) between the LED lamps and Na-lamps is:
KeNa = 150/115 = 1.31
The efficiency coefficient (Ke) between the LED lamps and Hg-lamps is:
KeHg = 150/60 = 2.5

b) As previously mentioned, with Hg lamps and Na-lamps only 20% of the emitted light falls on the usable space (road, street and sidewalk).

Of the total emitted light at LED luminaires, without additional optics (lenses) 40% fall on the usable space, while at the LED lamps with additional optics (guiding lens) 60% of the light is falling on the usable space.
Power of LED lamps, which have the additional optics for guidance (lenses) for the same level of brightness can be 7.5 times less than the power of Hg lamps and 4 times less than the Na lamp.

Based on the previous analysis, we can conclude that in the reconstruction of public lighting in order to save electricity it is recommended to use solely LED lamps with optics to focus light on the usable space (road, street, sidewalk). On pic. 2 is presented LED street illumination (right street side) in comparison to classical illumination (left street side).

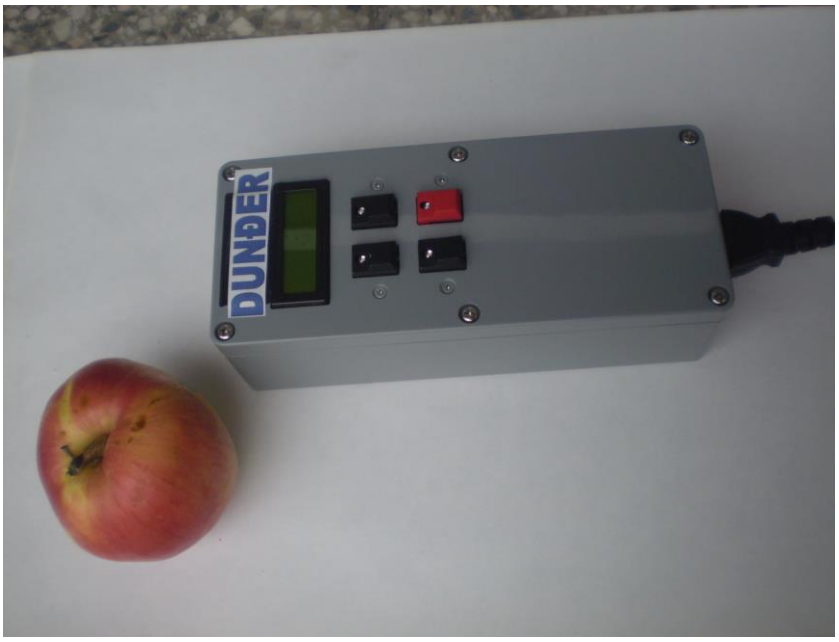
Pic. 2. LED lamps produced for project purposes



Pic. 3. Optical lences for LED light focussing

6. REMOTE CONTROLLED LED LIGHTING SYSTEMS

Light-emitting diodes (LED) are semiconductor devices, which have a linear characteristic when it comes to the relationship between the emitted light and electrical power diode. Power of the emitted light can be adjusted continuosly from 0% to 100%. This fact allows us to install microcontrollers within each lamp and to remote control the level of light that it emits, and thus the consumption of electricity.
Communication with each lamp can be realized through radio (wireless) or wired by cables.



Pic. 3. Remote control unit for testing and demonstration purposes

The wireless communication system can be realized as a dedicated radio system or using a GPRS connection. This solution is quite expensive and critical from the point of interference. Cable transmission is reliable but it requires the installation of additional communication cables. Because of the cost and disruption of city infrastructure (optional digging) this solution is almost unacceptable. The problem can be overcome if the communication uses existing power cables. Data transmission over power cables (PLC - Power Line Communication) is now known and it is very suitable for this application. We have a reliable system for the transfer of data that does not require additional investments in the cables. Hardware realization of remote control lighting, based on PLC, requires the installation of a local control unit (LCU - Local Control Unit) in each transformer station. LCU is directly connected to the same station on which are connected the lamps LCU control unit can be connected to the command center of some by the existing cables or via GPRS connection.

The operating mode of each lamp can be controlled and monitored locally (via LCU) from each transformer station or from the command center.
This concept of a remote control system can reduce power consumption of the LED lamps by another 50%, without significantly impair the quality of lighting.
A set of additional information, which can be provided with a remote control system in real-time and past (functional parameters, alarms in case of failure, the level of consumption etc.), significantly improves maintenance of lighting systems, and cuts down their costs.

7. SAVINGS THAT ALLOW REMOTE CONTROL OF LED LAMPS

If in the reconstructed system of public lighting with remote control (adjust brightness level from 0% to 100% - dimming) one can further save electricity because one does not need the highest level of lighting during the night.
If 30% of the time LED lighting system is operating at 100% of projected power, 30% of the time with 30% of the projected power and 40% of the time with 25% of the projected force, which, given the logarithmic characteristic of the eye, will not significantly affect the quality of light, the coefficient of savings thanks to the remote control will be significantly high.
Overview of annual electricity consumption for the existing system, the reconstructed system without dimming and reconstructed system that has the ability to remote control is given in the table T.6. It is calculated that the average number of working hours per day is 12 hours, a price Electricity 0.05 € / kWh.

Table 3. Annual electricity consumption

No.	System	Power kW	Accrued kWh	Price of annual consumption in RSD
1	Existing (Na, Hg)	100,628	440.851,26	2.556.937,00 RSD
2	LED without dimming	22,786	99.825,47	578.987,00 RSD
3	LED with dimming	11,39	49.908,35	289.469,00 RSD

Guaranteed service life of LED lamps without changing the optical parameters is 50,000 hours - 12 years. After that period, LED lamps continue normal operation with the decreased brightness level of 10%, which, given the logarithmic characteristic of the eye, will not be even noticed. Lifespan of Na lamps (bulb) is 16,000 working hours - about 4 years. Lifespan of Hg lamps is 10,000-12,000 working hours - about 3 years. It means that for 12 years Na bulbs must be changed at least 3 times, and Hg bulbs at least 4 times.

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INOVATIVNO KORIŠĆENJE LED DIODA U SISTEMU JAVNE RASVETE SA DALJINSKIM UPRAVLJANJEM

Rezime: *Građevinski klaster „DUNDJER“ realizuje, kao vodeći partner, nacionalni projekat koji je sufinansiran od strane Nacionalne agencije za regionalni razvoj, u kome razvija inovativnu primenu LED sijalica u sistemu javnog osvetljenja uvodeći, izmedju ostalog, softver za daljinsko upravljanje sistemom osvetljenja. Primena treba da bude realizovana u opštinama Knjaževac, Bela Palanka i Preševo. U ovom radu su date osnove planiranog istraživanja, kao i ekonomsko opravdanje primene LED dioda i daljinskog upravljanja.*

Ključne reči: *LED osvetljenje, daljinsko upravljanje, energetska efikasnost*