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JUSTIFICATION OF LIGHTING REDESIGN IN ENERGY SAVING ON THE EXAMPLE OF THE RIGHT BANK OF THE VRBAS RIVER BETWEEN TWO BRIDGES

ABSTRACT

Modern technologies are evolving in the direction of energy efficiency and artificial light sources that today meet such targeted requirements have many other advantages that are not always recognized in planning. Utilizing the total capacity of energy efficient light sources requires a redesign and a different approach to public lighting planning. Using a small coverage along the river as a representative example, the possibilities of fulfilling the set strategic goal of the city development were presented through a proposal for redesign of urban lighting, and then the energy and economic justification of such a proposal was examined using the APEE method, which is also implemented in public lighting reconstruction in Banja Luka.

Key words: *public lighting reconstruction, urban lighting, coastline, APEE*

ЕНЕРГЕТСКА ОПРАВДАНОСТ РЕДИЗАЈНА ОСВЈЕТЉЕЊА НА ПРИМЈЕРУ ДЕСНЕ ОБАЛЕ РИЈЕКЕ ВРБАС ИЗМЕЂУ ДВА МОСТА

Апстракт: Савремене технологије развијају се у смијеру енергетске ефикасности и вјештачки извори свјетлости који данас одговарају на овако усмјерене захтјеве имају многе друге предности које нису увијек препознате у планирању. Користити укупни капацитет енергетски ефикасних извора свјетлости, захтијева редизајн и другачији приступ у планирању јавне расвијете. На репрезентативном примјеру, малом обухвату дуж ријеке, представљене су могућности испуњења постављеног стратешког циља развоја града кроз приједлог редизајна урбаног осветљења, а потом испитана енергетска и економска оправданост таквог приједлога примјеном методе АПЕЕ по којој се и врши реконструкција јавне расвјете у Бањој Луци.

Кључне ријечи: *реконструкција јавне расвјете, урбано осветљење, приобаље, APEE*

1. INTRODUCTION

The aim of global energy policy is to slow down climate change, and the issue of energy consumption in residential buildings, industry and transport is at the centre of the European Union energy efficiency policy. Many studies are focused on the possibilities of saving energy from lighting in different fields of planning, and it has been established that public lighting is one of the major energy consumers. Therefore, there is a need for a detailed analysis of the existing public lighting systems and better planning of the new ones. Some Balkan countries have managed to harmonize their legislation with the EU standards and introduce mandatory energy audits for public lighting in settlements with more than 20,000 inhabitants [1]. Public lighting systems are city-owned and the costs for investments, reconstructions, system maintenance and finally for the consumed electricity in the best case amounts to about 3% of the total city budget costs [2].

In the Republic of Srpska, the public lighting alone participates in energy consumption with more than 20% [3] and it is necessary to carry out the reconstruction of the public lighting system in cities. The Law on Energy Efficiency was adopted in 2013 in order to legally regulate the area of energy efficiency and meet the requirements referred to in the Treaty establishing the Energy Community of Southeast Europe, and promote and implement measures to improve energy efficiency in final consumption [4]. The purpose of the law is to achieve sustainable energy development by applying energy efficiency policies and measures in final consumption. Among other things, this includes reducing the negative impact on the environment and rationalizing energy consumption, both at national and local level. In these laws and regulations, public lighting is viewed from the energy aspect through the management system, the system of light flux regulation and the use of energy efficient light sources. Over the past few years, the City Administration of Banja Luka has recognized the issue of public lighting and city lighting and the modernization of public lighting is in process, in accordance with the recommendations defined through the Energy Efficiency Action Plan of the Republic of Srpska (APEE) [4]. The practice of developing a lighting master plan has not yet taken root in the city of Banja Luka and there is no publicly available plan and unique document on lighting in the city.

The awareness on the importance and benefits of properly designed public lighting plans has been growing since the beginning of the 21st century. There were many factors that influenced this significant change, and in addition to the development of lighting technology and energy conservation, there are others such as branding, night image of the city, impact on the environment and human health, as well as people-oriented sociological aspects. The first major lighting projects emerged due to functional requirements in France (for the cities of Lyon, Caen and Niort) and in the United Kingdom (for Edinburgh) in the late 1980s [5]. Slowly, in the early 1990s, access to public lighting progressed from functional to cultural needs. To this day, the needs have grown and the public lighting quality can be evaluated from many aspects, so apart from the energy and economic aspect in planning process of city lightning it is also necessary to include other aspects important for quality urban life.

Based on a representative example, this paper presents energy and economic justification of urban lighting planning using the method of reconstruction of public lighting in local communities (APEE). The paper objective is to present the importance of lighting planning in specific urban areas on a small coverage along Vrbas River coastline, which includes different and specific needs for quality urban lighting, and to prove equal or better energy and economic effects.

2. PUBLIC LIGHTING RECONSTRUCTION IN BANJA LUKA ACCORDING TO RS APEE

According to the data obtained from the Department for Municipal and Communal Affairs, of the Banja Luka City Administration, the coverage of the city with public lighting is 96%, and the total number of lighting fittings in the city urban area is 17,500. The age of the lighting fittings dates from 2002-2004 when the last reconstruction of the lighting was carried out. Some of the problems the public lighting maintenance services are facing with include cable deterioration, malfunctions and energy supply, and public lighting maintenance works refer to regular maintenance and small-scale remediation and reconstruction works. Regular maintenance of public lighting includes replacement of light bulbs, ballasts, lighters, sockets, fuses, defects and resolving malfunctions, painting poles, replacement of destroyed poles and lamps in traffic accidents, replacement of damaged cables and foundations [6]. Small-scale rehabilitation and reconstruction and upgrading of lighting include the replacement of dilapidated poles and lamps, measuring cabinets, upgrading a smaller number of lighting places to the existing lighting system. The City budget regularly plans funds for public lighting for current and investment maintenance, reconstruction and construction. Table 1 presents the official data of funds planned for public lighting in the period from 2015 to 2020.

Table 1. Funds planned for public lighting in the City budget per year in the period from 2015 to 2020 [7] [8] [9] [10] [11] [12]

	2015	**2016**	**2017**	**2018**	**2019**	**2020**
Costs for current maintenance of public lighting (and traffic lights 2015,2016)	360.000,00	360.000,00	220.000,00	270.000,00	230.000,00	240.000,00
Costs for investment maintenance of public lighting		50.000,00	50.000,00	50.000,00	50.000,00	50.000,00
Costs for the construction of public lighting and cable canalization	50.000,00	50.000,00	40.000,00	50.000,00	45.000,00	54.000,00
Costs for the construction of public lighting - designated funds			50.000,00	40.000,00	90.000,00	96.000,00
Costs for the reconstruction of public lighting - designated funds	50.000,00	40.000,00	40.000,00	40.000,00	40.000,00	150.000,00
Total regularly planned	**460.000,00**	**500.000,00**	**400.000,00**	**350.000,00**	455.000,00	**590.000,00**
	- Costs for the construction of public lighting - according to the Decision on the distribution of the determined surplus and unspent designated funds for 2018 (surplus distribution)				123.000,00	
	- Costs for the construction of public lighting - according to the Decision on the distribution of the determined surplus and unspent designated funds for 2018 (assigned income)				167.00,00	
	- Costs for current maintenance of public lighting - according to the Decision on the distribution of the determined surplus and unspent designated for 2018 (surplus distribution)				50.000,00	
Total for public lighting	460.000,00	500.000,00	400.000,00	350.000,00	**795.000,00**	590.000,00

In 2019 was planned a significantly higher total investment in the construction of public lighting, almost twice as much as in the previous years, whereas in 2020, along with ongoing maintenance, more significant funds were intended for reconstruction. This sum was the result of a public lighting reconstruction project in Banja Luka. Namely, during 2016 was adopted the Energy Efficiency Action Plan (APEE) of the City of Banja Luka for the period from 2016 to 2019 [4].

The Energy Efficiency Action Plan (APEE) defines measures to improve energy efficiency in the services sector, thus reducing energy consumption for the operation of public lighting systems by installing energy efficient public lighting systems and introducing management systems. Effective public lighting management implies adequate use of available resources and implementation of measures and activities of local self-government units and other institutions, resulting in increased functionality and quality of public lighting and reduced costs necessary for public lighting systems. In this regard, the Republic of Srpska Association of Municipalities and Cities and the Federation of BiH Association of Municipalities and Cities, in cooperation with GIZ, developed a guide Public Lighting and Local Self-Governance. [13] The Guide provides a detailed economic analysis based on the replacement of one existing luminaire with an appropriate energy efficient replacement luminaire. The initial investment of the replacement was performed on the basis of replacing the complete lamp, and not only the light bulbs, since new sets of light bulbs with accompanying equipment cannot be installed in the existing fittings (housings). It was also taken into consideration that there are a large number of fixtures (fittings) in municipalities that are inadequately constructed and do not meet contemporary environmental criteria (spherical light scattering). For the economic analysis of lamp replacement, the technical parameters of the lamp are defined, namely the lamp power [W], energy consumption [kWh/year] and service life [hours] for the existing and replacement luminaire; economic parameters of the luminaire, namely for consumed energy [EUR/year] and maintenance costs [EUR] for the existing and replacement luminaire, as well as the initial investment [EUR] for the replacement luminaire; profitability analysis for initial investment [EUR], difference in exploitation before and after replacement [EUR] and unique payback period [year]. Since HID luminaires are present in Bosnia and Herzegovina, as well as in the entire Balkan region, the Guide suggests appropriate replacement luminaires (Table 2), and it also provides a calculator and an example of economic analysis of replacement (Figure 1), with the result in annual electricity and maintenance savings, as well as the payback period.

Local self-governance units that modernized the entire or majority of the public lighting network in accordance with this guide have significantly reduced the energy costs of public lighting and practically no longer have maintenance costs or have reduced them to a minimum [14]. There are data on the situation regarding the city public lighting after the first part of the reconstruction according to this guide, indicating that there are about 18,000 lamps in the city [15], which is 500 more than in 2018, and the number of lamps older than 30 years has been reduced, from 1000 to slightly less than 200 [15] in two years. During this period, a total of 1,834 lamps in 64 streets were replaced in the framework of the first part of the "LED 1" project [15]. During 2020, new lighting was installed in several streets in the city area in the length of 4.7 kilometres, thus initiating the second part of "LED2" project, and the plan is to replace approximately 1,400 existing lamps with LED lamps in 80 streets [15]. The Department for Communal Affairs believes that this type of reconstruction would reduce energy consumption for more than 60 percent.

Table 2. The most common situations in practice during the reconstruction or modernization of public lighting [6]

Postojeće stanje	Zamjena	Postojeće stanje	Zamjena	Postojeće stanje	Zamjena	Postojeće stanje	Zamjena	Postojeće stanje	Zamjena
Živa 80W	NVP FMB 70W	Živa 125W	NVP FMB 70W	Živa 250W	NVP FMB 150W	Živa 400W	NVP FMB 250W	NVP FMB70W	LED 73W*
Živa 80W	NVP ELB 70W	Živa 125W	NVP ELB 70W	Živa 250W	NVP ELB 150W	Živa 400W	NVP ELN 250W	NVP FMB150W	LED 73W*
Živa 80W	LED 73W*	Živa 125W	LED 73W*	Živa 250W	LED 73W*	Živa 400W	LED 150W*	NVP FMB250W	LED 110W*
Živa 80W	MH 70W	Živa 125W	MH 70W	Živa 250W	MH150W	Živa 400W	MH 150W	NVP FMB400W	LED 150W*

**Snaga zavisi od geometrije saobraćajnice i optike koja se nalazi u svetiljci.*

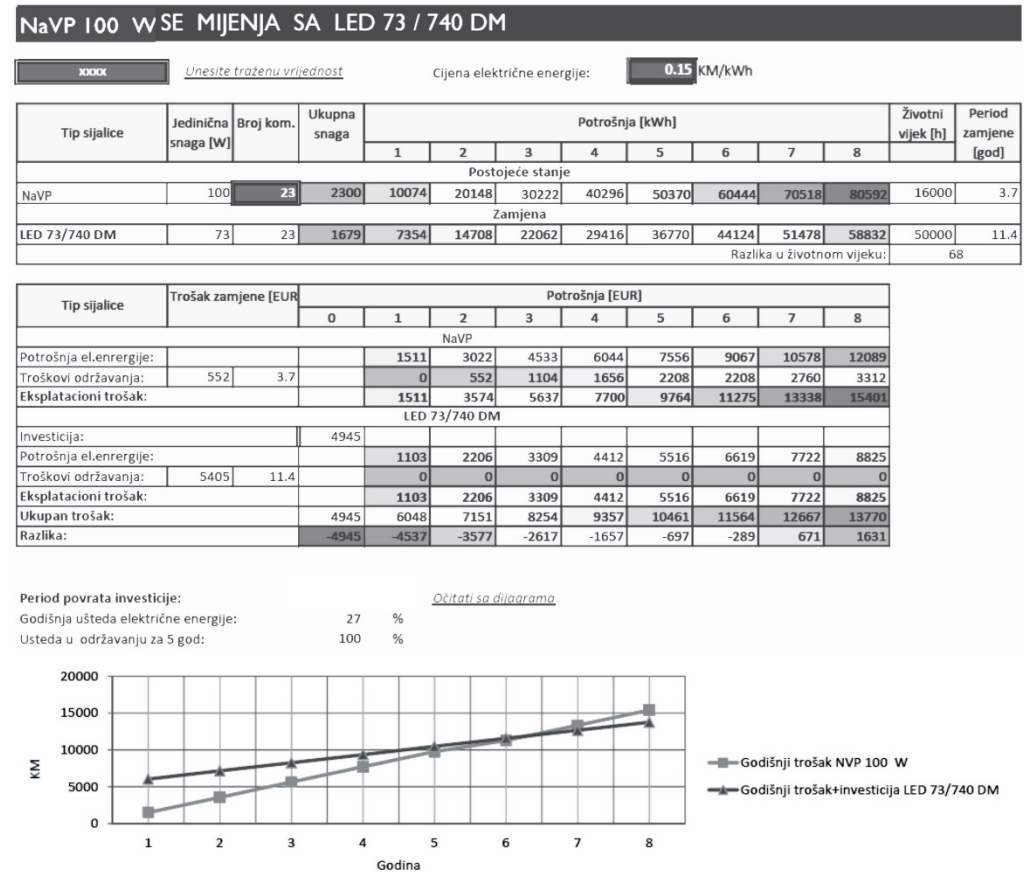


Figure 1. Economic analysis of lamp replacement with the recommended replacement lamp referred to in Table 2 according to the APEE reconstruction method. Calculator for local governments 2013-2014 [13]

In the document Joint Communal Spending of the Department for Communal Affairs for 2021, the budget for public lighting is significantly lower, with different relations in terms of maintenance and investment works. The document states that *the construction and reconstruction of public lighting in a number of streets in recent years resulted in a significant increase in the number of lamps, but that energy consumption costs for public lighting are lower, indicating the expected positive effects in cost savings on these grounds* [16]. Table 2 shows funds planned in the city budget as the current costs for electric energy used for public lighting per year in the period from 2015 to 2020.

These documents indicate that the reconstruction of public lighting in Banja Luka is in progress, and according to the economic analysis method, the reconstruction means the replacement of lamps as an investment, motivated by energy savings. The quality of the existing lighting system and its adequacy for the planned new sources are assumed, so the possible effects of a different

approach and planning of urban lighting according to the character and purpose of individual urban areas are missing.

Table 3. Funds planned in the City budget for joint communal spending (current costs) - public lighting energy consumption per year for the period from 2015 to 2020 [7] [8] [9] [10] [11] [12]

	2015	2016	2017	2018	2019	2020
Consumption of energy for public lighting	1.540.000,00					
Expenses based on energy consumption for lighting in public areas		1.600.000,00	1.605.000,00	1.900.000,00	1.885.000,00	
Expenses based on energy consumption in public areas						2.200.000,00

3. THE IMPORTANCE OF URBAN LIGHTING OF THE CITY ON VRBAS RIVER

One of the strategic development goals of the city on Vrbas River is "Ecologically sustainable, infrastructurally developed and energy efficient environment - Green City". In the document City of Banja Luka Development Strategy for the period 2018-2027 [17], the "green" city concept includes the arrangement of green urban areas, parks, recreational areas, Vrbas River banks and its headwaters and the management of natural resources in a responsible and creative way. Both aesthetic and functional aspects are considered, with particular emphasis on the urban environment protection, in the context of social and economic development. The city is strategically returning to the river and the coastline is recognized as an important location for the development of the "green" city, and over the last twenty years there have been individual attempts to build on the coastline with a changed attitude towards the water [18]. There is a unique approach to the coastline arrangement, since the City of Banja Luka Assembly adopted the "Regulatory plan for the development of Vrbas River coast" based on the results of the open public international urban and architectural competition in 2006 [19]. Unfortunately, the majority of the plan neglects the city's contact areas with water and treats only the narrow strip of coastline, as shown in the *Regulatory plan for the development of Vrbas River coast in Banja Luka* in the central part of the city between the two city bridges (Figure 2).

The landscaped coastline in Banja Luka represents an important meeting, recreation and resting point, as well as a place for various sports and artistic events, numerous activities during the day and in the evening. One of the few designed locations that allows the urban population to enjoy physical and mental benefits is the coastline stretch between the Venecija and the Rebrovac Bridge in Banja Luka. The presence of different user profiles and age groups only highlights the importance of this part of the coast. The stretch between Venecija and the Rebrovac Bridge is the longest pedestrian path along Vrbas River with landscaped green areas, sports fields and similar facilities. The dominant tree species in this area are autochthonous species such as white willow, white and black poplar, white elm, black alder, field maple, whereas other tree species such as plane tree, cottonwood, Norway maple and sophora were planted, so it could be observed as a linear park [20]. The natural coast is rich in vegetation in this part, and even though it is simply arranged, it is popular and intensively visited by the users for recreation. Considering the fact that one part of the park is connected to one large free

area, there is a potential for the development of additional park facilities. However, there is no plan or any logical continuity in the further development of this option, nor any architectural framework of space with the necessary contents that would support the active use of the urban coastline.

Figure 2: Part of Regulatory plan for development of the Vrbas coast in Banja Luka, including a narrow strip of coast

Cities located on riverbanks, also have bridges connecting two separate territories naturally separated by the river and they carry power in relation to the river flow strength. If observed generally and throughout the history, people have high respect of bridges and appreciate their role in unifying the divided territories, thus the bridges have a double role - physical unification and symbolic unity. The eastern and western banks of Vrbas River in Banja Luka are connected with bridges in the length of 27 km, including eleven road bridges, four bridges for pedestrians and bicycles and one railway bridge [18]. In this region, the bridges that enable communication between the opposite banks of the city are most often engineered rationally, without great design solutions and ambient features, and none of them have the feature of a public space of the city in the river [20]. The well-known everyday image of the city could be significantly changed if we carried out a quality plan of decorative architectural lighting of numerous bridges, especially those in the central city zone.

In the framework of the "Small Interventions" project, which is implemented on the territory of Banja Luka, was recognized the potential of the space underneath the bridge, and it was cleaned and adapted to pedestrians [21]. Since there is no lighting in that part, this space remains an unpleasant and dangerous place in the evening and its use has never come to life. Such important central city areas along the coastline, whether it is a pedestrian path along Vrbas with landscaped green areas, or an important meeting, recreation and resting point, or a place for sports and art events, are available to the citizens during the day, but due to inappropriate lighting, they are not safe and secure for an evening by the river.

3.1. ANALYSIS OF THE EXISTING PUBLIC LIGHTING SITUATION

There are 23 light poles along the coast stretch between the Venecija and the Rebrovac Bridge, at a distance of thirty meters from one another. Light poles represent the only source of direct lighting. The name of the luminaire installed on the site is K-lux, manufactured by the company Minel-Schreder, which finds its application in the lighting of parks, squares, walks, promenades and other pedestrian areas. The design meets the conditions necessary to avoid light pollution. The built-in light bulb is 100 W high pressure sodium. (Figure 3)

Figure 3. Characteristics of the existing luminaire with the source applied [22]

In this stretch, the luminous comfort was analyzed using the light inspection method or the "walk-through survey" method, which consists of a tour of the site, visual inspection and analyzing the site characteristics with minimal or no measurement. It was determined that there is a lack of available light at the location, both due to improper operation of lighting poles (Figure 4) and due to defective or insufficiently maintained luminaires, resulting in occurrence of dark islands (Figure 5). The 30 m distance between the luminaires is too large to provide a satisfactory level of illumination from existing luminaires, and the distance between the luminaires is not even and depends on physical structures that interrupt the continuity (sports

equipment zone and one hospitality facility near the Venecija Bridge). The lighting consistency is also smaller due to dirty lamps (especially those near the hospitality facility) and unmaintained vegetation that is too close to the lamps. Plant species that have grown over the years and formed some kind of shrubs and woody plants obscure the lamps with their branches and leaves, thus reducing the level of available light and affect the surface illumination evenness. Trees and leaves absorb light wavelengths, reduce light pollution, but also reduce the level of available light. A small part of the reflected lighting is obtained from the adjacent sports field, but it is insufficient because of the height of plants and trees.

The analysis of the coverage intended exclusively for pedestrians, through the analysis of technical lighting characteristics, physical structure, history of criminal activities in this part of the coastline, social and cultural aspects, traffic flows, flora and fauna, provided an insight into the effect of lighting quality on the environment and ambient values. The current condition of public lighting in the part of the coastline between the Venecija and the Rebrovac Bridge in Banja Luka does not meet the required level of luminous comfort from the functional aspect (the surfaces are insufficiently and unevenly lit). At the same time, the lighting solution is not in accordance with the character of the space. Urban city areas such as pedestrian zones, natural structures, river banks and parks require ambient lighting. Recreation zones and sports fields should be lit in accordance with high functional requirements, and yet harmonize it with the environment and the evaluation of the environment.

Figure 4. Fluctuations in the operation of the lamp at the transition between the two recreation zones (left) and the illumination level (right), measured using the Fusion Optix Android App [21]

Figure 5. Appearance of a dark island along the path (left) and the illumination level (right), measured using the Fusion Optix Android App [21]

3.2. URBAN LIGHTING PROPOSAL

City image changes at night and lighting plays an important role in city attractiveness and one's impression of it. With this regard, lighting is crucial in the night presentation of urban space, and it can significantly differ from the daytime image. Quality lighting is achieved using a plan that takes into account the city identity or one of its parts, as well as the hierarchy of its urban units [23]. First of all, urban lighting should be functional, but it should also create a certain atmosphere and new night spaces with ambient and decorative lighting. It is most often expected that certain functional lighting goals are achieved using street illumination and public lighting, and to emphasize aesthetic values through architectural lighting. In fact, it is possible to achieve that both architectural and ambient lighting respond to functional requirements and vice versa [23]. The impression of the urban environment is the result of the joint contribution of functional and architectural lighting, and well-designed urban lighting can bring visibility to things that are not visible during the day, thus creating completely new urban spaces. This is very important, especially in parts of the city with abundant activities, whereas in the dark they hide a structure that would highlight the city identity with architectural lighting and offer new urban places.

Following the analysis of the current situation, it was determined not only that there is a lack of adequate ambient park lighting of the promenade, architectural and decorative lighting of bridges, but also that functional lighting in the form of public lighting does not fulfil its primary assignment. The lighting in the part of the coast between the Venecija and Rebrovac Bridge needs to be redesigned in order to create atmosphere during the night, emphasize the attractiveness of the space and prolong its night use. Lighting design affects the feeling and the experience, and its improvement would result in increased number of visitors, activation of the space, extended usage time and a complete change in users' perceptions of safety. Considering all these matters, and respecting the recommendations for lighting of different areas and establishing a hierarchy in lighting specific parts, we suggested the pedestrian zone lighting redesign on the coastline.

The urban lighting (re)design proposal includes the reconstruction of the existing public lighting system, but also the introduction of new forms of lighting, responding primarily to the natural context of the coverage and its importance in the representation of the city at night (Figure 7). By recognizing different atmospheres, the character of the parts within the coverage, as well as the different requirements of all user profiles, the lamps were carefully selected for a unique presentation of the "green" city on Vrbas River. In addition to previously defined environment

and activities of different lighting needs, restrictions and requirements, as a replacement for the existing public lighting luminaire, we selected a LED luminaire for ambient urban lighting, with modern, simple and modest design. The lamp was selected in accordance with the technical lighting characteristics, the purpose of the space and the design solution, and all the proposed lamps have a colour temperature of up to 3000 K [24]. It was suggested to make a smaller distance between the lamps, and in the case of the selected lamp, the optimal distance would be 18m.

ARCLUCE 0864001A+730 SOUL 180 - Urban
3000mm - 27W
Article No.: 0864001A+730
Luminous flux (Luminaire): 1900 lm
Luminous flux (Lamps): 1900 lm
Luminaire Wattage: 27.0 W
Luminaire classification according to CIE: 100
CIE flux code: 20 58 95 100 99
Fitting: 1 x 0864001A+730 (Correction Factor 1.000).

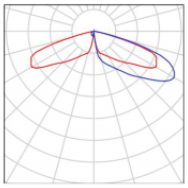


Figure 6. Characteristics of the applied replacement luminaire with source applied [25]

Urban lighting in such specific spaces, in addition to the suggested functional lighting of pedestrian paths, as replacement lamps for existing lighting, also includes architectural lighting, primarily bridges in this case. Bridges are most often constructed in exposed locations and are unintentionally marked as facilities desirable for lighting. Illuminated bridges attract attention, and with good lighting they can become one of the city symbols. As a rule, lighting is limited to the outlines or bridge contours, since there are no other surfaces in question other than the road itself. Lighting of the load-bearing structure, apart from public lighting on the road, is the most common and usually the best solution. Narrow beam reflectors attached directly to the structure offer the best solutions, provided that the atmospheric reflection on dark water should not be destructed by the overemphasized bridge structure [26]. Illumination of bridges helps to achieve the quality of decorative lighting without endangering the safety of traffic participants, and environment protection is achieved by directing light only to the lower surface of the bridge (Figure 8). In this way, the light connects the city divided by the river, and expands the public urban space, and illumination of the bridge construction contributes to the attractiveness of the location and emphasizes the identity of the city on the river. Illumination of the space under the Venecija Bridge would result in the continuity of the pedestrian path, since it is interrupted by a bridge and a heavy traffic road, but also emphasize the transition from one zone to another, that is the entrance to the observed location. In this way, introduction of lighting would increase the level of use and the attractiveness of the space, and the location underneath the bridge would get its own identity.

Figure 7. Proposal of the redesign lighting solution of the right bank of Vrbas River between the bridges Venecija and Rebrovac [21]

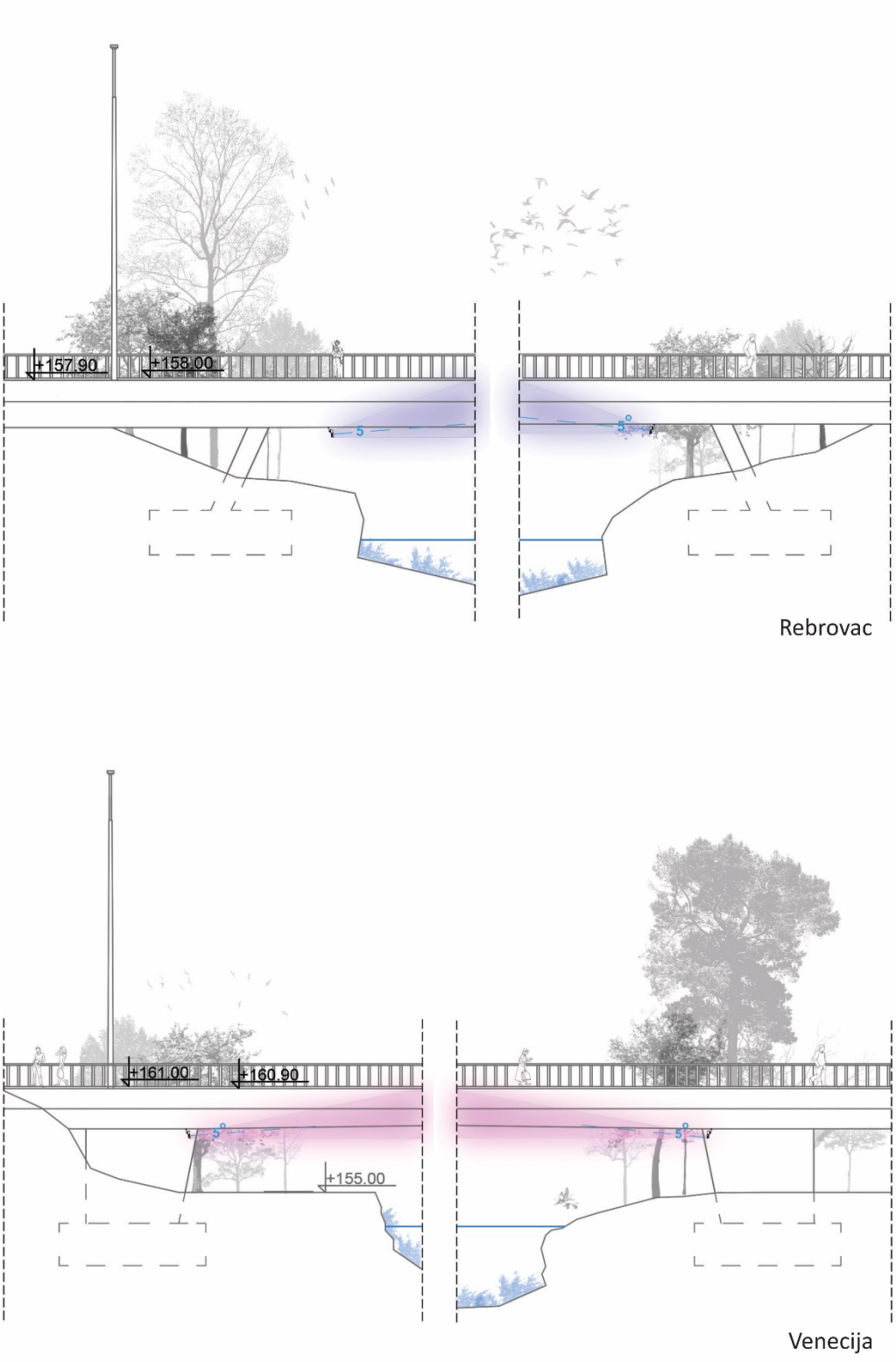


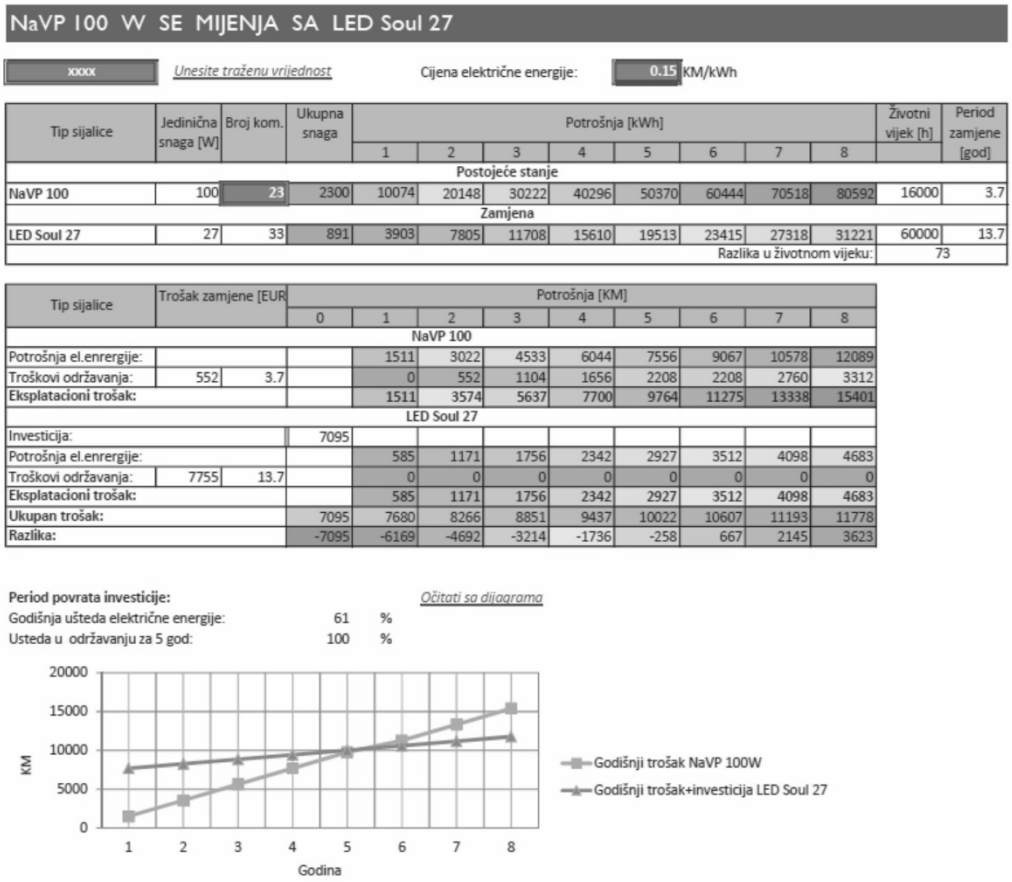
Figure 8. Proposal of the lighting redesign solution of Venecija Bridge (above) and Rebrovac Bridge (below) [21]

This small coverage along the river was used as a representative example to examine the possibilities of fulfilling the set strategic goal of the city development, with particular emphasis on urban lighting planning. In addition to the urban lighting design of this stretch, minimal urban and architectural landscaping interventions have also been suggested, offering adequate lighting. Apart from suggesting new lighting fixtures that meet the elementary needs of users and activities within the area, it also provides new opportunities to night users, in the form of direct and safe access to Vrbas River. Therefore, in addition to new public lighting lamps and architectural lighting of the bridge, there is also ambient lighting of the pathway down to the river, using ecological lamps. Views from the bridges or from the neighbouring coast to the observed location reveal the existence of activities along the coastline. The idea is to use interventions in space and increase the level of visual comfort through the regulation of lighting, thus affecting the man, and the city itself, to connect with the nature, river and the coast. On the other hand, by establishing a hierarchy in lighting, bridges stand out and their light recognition has a wider significance than it does for the observed coverage. In the end, the goal of good lighting is not only to provide a system with exactly calculated level of brightness without glare and good contrast, but also to integrate urban design, architecture and landscape.

3.3. POSSIBLE ENERGY SAVINGS ACCORDING TO APPE

In order to examine the energy and economic justification urban lighting re-design, we used the *Calculator for local self-governments - Public Lighting* (APEE). We compared the characteristics of the existing public lighting luminaires (power, number, annual energy consumption and lifetime) with the suggested replacement luminaires for the paths, and then with the total, replacement and additional luminaires of the coastal urban redesign proposal between the bridges Venecija and Rebrovac in Banja Luka. We also analyzed the energy consumption in kWh for 23 existing 100W high pressure sodium lamps and for 33 replacement lamps, or a total of 79 LED lamps of different power, suggested in accordance with the redesign, for a period of eight years. We calculated the energy consumption, maintenance costs and operating costs for all lamps and then the obtained results were compared and graphically displayed in the Pay-back period chart.

In the first case of replacement according to the Guide, 23 NVP100W lamps were compared with the corresponding 23 73W LED lamps according to Table 1. The obtained results show annual energy savings of 27%, and the payback period is shown in the chart in Figure 1. In the second case, it was proposed to replace 23 NVP100W lamps with 33 LED Soul 27W lamps, selected as appropriate for lighting walking paths in the framework of urban lighting redesign. The obtained results show annual energy savings of 61%, and the payback period is shown in the chart in Figure 9. In the end, we examined the energy saving options for full redesign lighting, and in this third case, 23 NVP100W luminaires were compared with 79 LED luminaires of different power. The obtained results show annual energy savings of 39%, and the payback period is shown in the chart in Figure 10. In all three cases, the five-year maintenance savings are 100%, and the initial investment for a greater number of luminaires is relatively higher. The existing NaVP 100 W lamps consume more energy than the suggested lighting from new LED lamps of different powers. Additionally, the suggested lighting is more energy efficient in terms of longer lifetime and the number of working hours, not only in relation to existing but also in connection with the replacement lamps suggested in the Guide. Another advantage of these lamps includes a longer replacement period.



NaVP 100 W SE MIJENJA SA LED Soul 27

xxxx *Unesite traženu vrijednost* Cijena električne energije: 0.15 KM/kWh

Tip sijalice	Jedinična snaga [W]	Broj kom.	Ukupna snaga	Potrošnja [kWh]								Životni vijek [h]	Period zamjene [god]
				1	2	3	4	5	6	7	8		
Postojeće stanje													
NaVP 100	100	23	2300	10074	20148	30222	40296	50370	60444	70518	80592	16000	3.7
Zamjena													
LED Soul 27	27	33	891	3903	7805	11708	15610	19513	23415	27318	31221	60000	13.7
											Razlika u životnom vijeku:		73

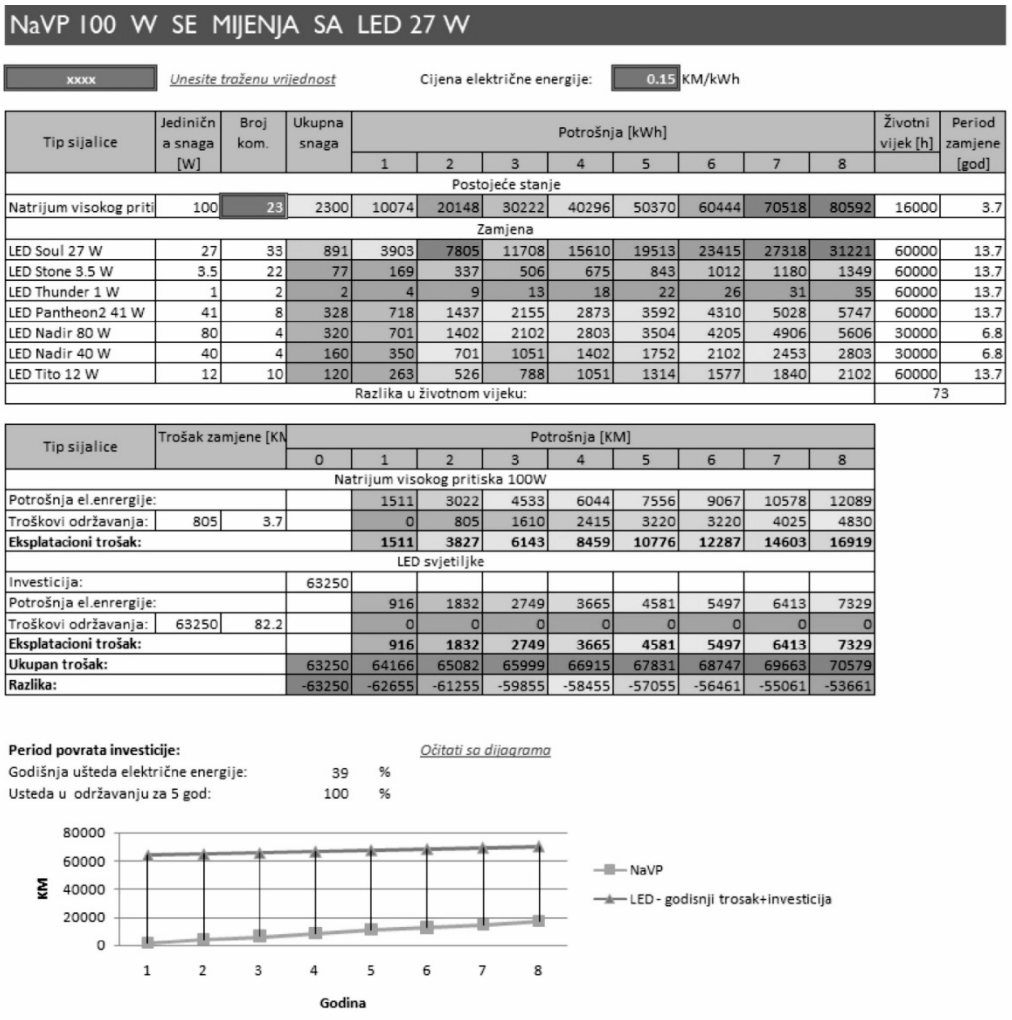
Tip sijalice	Trošak zamjene [EUR		Potrošnja [KM]								
			0	1	2	3	4	5	6	7	8
NaVP 100											
Potrošnja el.enrergije:				1511	3022	4533	6044	7556	9067	10578	12089
Troškovi održavanja:	552	3.7		0	552	1104	1656	2208	2208	2760	3312
Eksplatacioni trošak:				1511	3574	5637	7700	9764	11275	13338	15401
LED Soul 27											
Investicija:			7095								
Potrošnja el.enrergije:				585	1171	1756	2342	2927	3512	4098	4683
Troškovi održavanja:	7755	13.7		0	0	0	0	0	0	0	0
Eksplatacioni trošak:				585	1171	1756	2342	2927	3512	4098	4683
Ukupan trošak:			7095	7680	8266	8851	9437	10022	10607	11193	11778
Razlika:			-7095	-6169	-4692	-3214	-1736	-258	667	2145	3623

Period povrata investicije: *Očitati sa dijagrama*

Godišnja ušteda električne energije: 61 %

Usteda u održavanju za 5 god: 100 %

Figure 9. Energy and economic analysis of urban lighting redesign of the coverage in the part of the pedestrian path according to the APEE reconstruction method. Calculator for local governments 2013-2014 [13]



NaVP 100 W SE MIJENJA SA LED 27 W

xxxx *Unesite traženu vrijednost* Cijena električne energije: 0.15 KM/kWh

Tip sijalice	Jedinična snaga [W]	Broj kom.	Ukupna snaga	Potrošnja [kWh] 1	2	3	4	5	6	7	8	Životni vijek [h]	Period zamjene [god]
Postojeće stanje													
Natrijum visokog priti	100	23	2300	10074	20148	30222	40296	50370	60444	70518	80592	16000	3.7
Zamjena													
LED Soul 27 W	27	33	891	3903	7805	11708	15610	19513	23415	27318	31221	60000	13.7
LED Stone 3.5 W	3.5	22	77	169	337	506	675	843	1012	1180	1349	60000	13.7
LED Thunder 1 W	1	2	2	4	9	13	18	22	26	31	35	60000	13.7
LED Pantheon2 41 W	41	8	328	718	1437	2155	2873	3592	4310	5028	5747	60000	13.7
LED Nadir 80 W	80	4	320	701	1402	2102	2803	3504	4205	4906	5606	30000	6.8
LED Nadir 40 W	40	4	160	350	701	1051	1402	1752	2102	2453	2803	30000	6.8
LED Tito 12 W	12	10	120	263	526	788	1051	1314	1577	1840	2102	60000	13.7
Razlika u životnom vijeku:												73	

Tip sijalice	Trošak zamjene [KM		Potrošnja [KM] 0	1	2	3	4	5	6	7	8
Natrijum visokog pritiska 100W											
Potrošnja el.enrergije:				1511	3022	4533	6044	7556	9067	10578	12089
Troškovi održavanja:	805	3.7		0	805	1610	2415	3220	3220	4025	4830
Eksplatacioni trošak:				**1511**	**3827**	**6143**	**8459**	**10776**	**12287**	**14603**	**16919**
LED svjetiljke											
Investicija:			63250								
Potrošnja el.enrergije:				916	1832	2749	3665	4581	5497	6413	7329
Troškovi održavanja:	63250	82.2		0	0	0	0	0	0	0	0
Eksplatacioni trošak:				**916**	**1832**	**2749**	**3665**	**4581**	**5497**	**6413**	**7329**
Ukupan trošak:			63250	64166	65082	65999	66915	67831	68747	69663	70579
Razlika:			-63250	-62655	-61255	-59855	-58455	-57055	-56461	-55061	-53661

Period povrata investicije: *Očitati sa dijagrama*

Godišnja ušteda električne energije: 39 %

Usteda u održavanju za 5 god: 100 %

Figure 10. Energy and economic analysis of urban lighting redesign of the coverage according to APEE reconstruction method. Calculator for local governments 2013-2014 [13]

4. CONCLUSION

Banja Luka is a city on the river and the left and right bank are connected with numerous bridges. The development strategy of the city has changed during its history and the coastline itself has been on the city margins for many years, and one of the contemporary strategic goals is ecologically sustainable, infrastructurally developed and energy efficient environment - green city on Vrbas River. In the framework of the Action Plan for Energy Efficiency of the City of Banja Luka, the reconstruction of public lighting was carried out in two stages, but it is not possible to determine the success of these operations on the basis of available documentation. The annual costs of the City for consumed public lighting energy are either the highest when least expected or the results of successful reconstruction are not pointed out enough, or they are simply insignificant and invisible in such short period of exploitation. Additionally, the Vrbas coastline was not in the scope of the reconstruction, and there were no unique documents of the city lighting or a project that would integrate different aspects of urban lighting.

A small coverage along the river was used as a representative example to present the possibilities of fulfilling the set strategic goal of the city development through urban lighting re-design proposal Further on, we examined the energy and economic justification of such proposal by implementing the APEE method, which is also used in public lighting reconstruction in Banja Luka. Following the analysis of the current situation, it was determined not only that there is a lack of adequate ambient park lighting of the promenade, architectural and decorative lighting of bridges, but also that functional lighting in the form of public lighting does not fulfil its primary assignment. Respecting the recommendations for lighting of different areas and establishing a hierarchy in lighting specific parts, we suggested the pedestrian zone lighting redesign on the coastline. Redesign includes the reconstruction of the existing public lighting system and introducing new lighting types, primarily responding to the natural context of the coverage. After recognizing different environmental atmospheres, character of specific parts of the coverage and diverse demands of all user profiles, we carefully selected the lamps and luminaires for a unique presentation of the 'green city' on Vrbas river.

The paper presents three cases of replacing the existing luminaires. The first case refers to replacement luminaires suggested in the Guide, the second one to replacements from the redesign and the third one to total lighting of the coverage, all with the purpose of justification required by the APEE. Considering the fact that the solution of urban lighting reduced the distance between the lamps and thus increased their number, it was necessary to correct the formula for the investment calculation. The calculator assumed that the number of lamps did not change during the reconstruction, so the unit price of a replacement lamp was multiplied by the number of existing ones, not the replacement ones. Economic analysis according to APEE does not identify other changes than simple replacement of lamps and only for the most economically justified energy efficient replacement lamps. This confirms the fact that the reconstruction of public lighting assumes the quality of the existing system and does not question its adequacy for new sources and forms of lighting or considers any other aspects.

Justification of urban lighting redesign in terms of energy savings has been confirmed on example of the right bank of Vrbas River between two bridges, whether in minimal (in stages) or in full scope. The results indicate that the investment costs of complete redesign are relatively high. However, these expenses should not be considered only form economic perspective. They should be also considered in the context of total effects, first of all environmental and architectural, bringing significant contribution to the total development and branding of the city and long-time improvement of the life quality in the urban environment.

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