MINISTRY OF FINANCE OF THE SLOVAK REPUBLIC

SlovakAid
GOOD IDEA SLOVAKIA

UNDP

FEASIBILITY STUDY FOR INSTALMENT OF NEW EE STREET LIGHT SYSTEM FOR MUNICIPALITY OF KALESIJA

Disclaimer

This publication has been issued within the Project “Development of a private-public investment model for EE street light systems in Bosnia and Herzegovina” funded by the Ministry of Finance of the Slovak Republic, implemented by the United Nations Development Programme (UNDP).

Document informations

Title	FEASIBILITY STUDIES FOR INSTALLATION OF NEW EE PUBLIC LIGHTING SYSTEMS FOR 12 MUNICIPALITIES IN BIH, LOT1 AND LOT2 – MUNICIPALITY OF KALESIJA
Client	UNDP
Client contact information	Arnesa Borčak UN House, Zmaja od Bosne bb 71000 Sarajevo Tel: +387 33 293 448 Fax: +387 33 552 330 Mail: arnesa.borcak@undp.org Web: http://www.ba.undp.org/
ENOVA reference	022/20 — Version 2
Status	Final

Contact

ENOVA d.o.o. Podgaj 14 71000 Sarajevo Bosna i Hercegovina Tel:+387 33 279 100 Fax: +387 33 279 108	ZGI d.o.o. Rudarska 247 88000 Mostar Bosna i Hercegovina Tel:+387 36 334 280 Fax:+387 36 334 281	Lightech d.o.o. Stará Vajnorská 90 83104 Bratislava Slovačka Tel:+421 2 63 811 070 Fax:+421 69 200 1961

ENOVA and ZGI are accordant with ISO 9001:2008 standards.

Completed by	MIRSAD MADEŠKO ENOVA d.o.o. ZGI d.o.o. Lightech d.o.o.
Approved by	FETHI SILAJDŽIĆ SANDRO ZOVKO
Date	September 18th, 2020

1 TABLE OF CONTENT

2 LIST OF TABLES

3 LIST OF PICTURES

4 INTRODUCTION

The fact is that energy, i.e. the availability of energy at affordable prices, is a key prerequisite for achieving economic and social development of any society. However, it is also a fact that energy production and its use significantly affect the environment, causing pollution of local and regional character, but also problems such as global warming and climate change.

Therefore, it is clear that the energy sector in Bosnia and Herzegovina, the European Union, and around the world is facing the challenge of sustainable development - development that enables secure energy supply, while reducing negative environmental impacts.

High energy consumption, but also great potential for savings, have made energy efficiency a priority, and for it to have increasingly important place in the public sector in Bosnia and Herzegovina, which has significant potential for energy conservation in the region. Bosnia and Herzegovina can base its long-term economic development and creation of new jobs on measures to improve energy efficiency. There is high potential to conserve energy in the public lighting system.

Special importance to the application of energy efficiency principles is given by the fact that public lighting in use today was mainly designed at the time when high-effective lighting technology was not available and when electricity was significantly cheaper. Currently, the public lighting systems are one of the main sources of electricity consumption with 3,19% of global electricity production being allocated for the public lighting.

This amount is higher than the production of all hydro or nuclear power plants and it is equal to the production from natural gas. It is known the public lighting is the sector characterized by excessive and disproportionate energy consumption compared to the quality and functionality of the service offered to citizens. Investing in optimal measures to improve energy efficiency of the public lighting system has become strategic for economic, technological and social development of cities.

Therefore, it is necessary to design and construct the public lighting in accordance with the energy efficiency principles, and existing ones, if possible, should be adapted and adjusted. Improving efficiency of energy consumption is one of the most important pillars of modern energy policy, and it is the key and economically the most effective mechanism to achieve goals of sustainable development of the energy sector.

Improving efficiency of energy consumption reduces costs and contributes to the competitiveness of national economy. Energy efficiency means consuming less energy for same product or service. Energy efficiency offers many benefits, depending on type of intervention. It can:

- reduce the burden of rising energy prices,
- increase energy security,
- increase the necessary energy supply investment,
- reduce air pollution and slow down climate change,
- improve the employment of skilled and unskilled work force,
- reduce burden on budgets,
- Increase economic competiveness.

Existing situation has to be defined in order to assess saving potential of public lighting. In other words, following basic activities have to be established:

- preparation,
- inspection/review,
- description of the current situation and identified measures,
- energy estimate and,
- Economic estimate.

It is important to point out that the energy efficiency cannot seen as energy saving. Namely, *saving*always implies certain sacrifices, while *efficiency*means maintaining, in this case, the default level of lighting by using smaller amounts of electricity.

Costs of public lighting are becoming an increasing burden on budgets of different levels of government from year to year. Newer technologies and more economical light fixtures offer the possibility of saving while keeping the existing or even improving the quality of lighting. Municipalities can reduce allocations for exploitation of public lighting system by using newer technologies and with acceptable investments, thus creating possibility to redirect funds saved in such manner to further expand the system, development or some other priority purposes.

Therefore, there is a need to increase energy efficiency in the field of lighting. This has also been recognized by the international community, and through various analyses, general directives and guidelines have been created that are used to influence the increase of this efficiency.

These directives and guidelines are defined within EU under the title EU Directive 2002/91/EC, and in Bosnia and Herzegovina they are translated and adopted under the title **BAS EN 12464-1:2012** for indoor lighting and **BAS EN 1838** for panic lighting, while for the outdoor lighting they are adopted under titles:

- **BAS CEN/TR 13201-1:2016** - Road lighting - Part 1: Selection of lighting classes,
- **BAS EN 13201-2:2017** – Road lighting - Part 2: Performance requirements,
- **BAS EN 13201-3:2017** - Road lighting - Part 3: Performance estimates,
- **BAS EN 13201-4:2017** – Road lighting – Part 4: Methods for measuring road lighting characteristics,
- **BAS EN 13201-5:2017** – Road lighting - Part 5: Energy performance indicators.

As a technology to reduce emissions and costs, LED public lighting should be the first instance of every municipality's investment. The latest energy efficient LED light bulbs can achieve energy savings between 50- 70%. LED public lighting offers instant savings in terms of energy, maintenance and running costs.

5 GENERAL PART

5.1 Geographical location

Municipality of Kalesija is located in the north-east part of Bosnia and Herzegovina (BiH) in Tuzla Canton (TK) which consists of cities Tuzla, Živinice, Srebrenik, Gradačac and Gračanica, and eight municipalities (Banovići, Čelić, Doboj Istok, Kalesija, Kladanj, Lukavac, Sapna and Teočak). The surface of Tuzla Canton is 2.649 km^2 which makes up 10,15% of the surface of the Federation of Bosnia and Herzegovina (FBiH),the surface of which is 26.110,5 km^2, that is 5,17% of BiH teritorry (51.209,2 km^2). The Municipality of Kalesija takes up the surface of 201 km^2 which is 7,6% of TK's territory, 0,77% of FBiH's territory and 0,39% of the territory of Bosnia and Herzegovina. The main road Tuzla – Zvornik goes through its territory. Also, the railway Tuzla – Živinice – Kalesija – Zvornik goes through Kalesija's territory. Thanks to the mentioned communications, the area of Kalesija has quality connection with the region and other parts of BiH. Average height above sea level is 270 m with moderate continental climate. Average annual air temperature is 10,4 °C, with average value of summer air temperature of 19,4 °C. There is 6.300 hectares of the arable land, which takes up 35% of the total surface of the Municipality of Kalesija. Forests take up 7.505 hectares or 41,7%[1]. Official language majorly in use is Bosnian language. Image 1 is showing the position of the Municipality of Kalesija in TK, FBiH and BiH.

Image 1: Position of the Municipality of Kalesija in TK, FBiH and BiH[1]

[1] Federal Institute for Statistics, TK in numbers, 2020

5.2 Overview of socio-economic situation

According to the 2013 census the Municipality of Kalesija has 33.053 residents[2], while according to the Federal Institute for Statistics from newsletter USK in numbers from 2020 the estimated number is 32.697 residents, territorially organized in 22 local communities. Relative population density is approximately 164 residents per 1 km^2. Estimate of the total number of residents according to the age structure is made up of 5.814 young people up to 14 years of age, 24.483 residents aged 15-64 years and 2.756 residents older than 65 years. Rate of the population growth in 2019 was 16, and the rates of natality and mortality in 2019 were 8,1 and 7,6 respectively, while the population growth rate for 2019 amounted 0,5%. The current percentage of the population living in urban areas is approximately 2.039 or 6,17%, while in 1991 the same indicator amounted 2.206 or 5,27%, which shows there is the migration of the population from urban to rural areas. In 2011-2015 period, the Municipality of Kalesija recorded negative migration saldo, which was-85 on average, and the lowest value in the past period was recorded in 2012 (-156). Difficult economic situation is the most often reason for the population leaving (primarily to other countries). According to the 2013 census the majority of the population are Bosniaks 97,4%, Croats 0,07%, Serbs 0,88% and Others 1,65%.

The economy of the Municipality of Kalesija is made up of 1.386 registered business entities according to the statistic data on a number of registered business entities in 2016; of this 414 are legal entities, 337 subsidies of legal entities and 635 physical entities craftsmen. The number of business entities on the territory of the Municipality of Kalesija in 2019 was 1.496, and it was 1.459 in 2018. The Municipality of Kalesija is recording an increase in the number of physical entities (craftsmen), with number of physical entities amounting 542 in 2015 and 668 in 2019. A number of companies per 1000 residents is also recorded, and the mentioned value was 35,4 for 2015 and 45,8 for 2019. The number of crafts in 2016 (635 crafts) is higher by 17% compared to 2015 (542 crafts). It can be concluded that lately the number of newly registered crafts continuously grew, according to the mentioned data. Out of total number of registered legal entities in 2015-2016 period, the most important increases were registered in the area of the agriculture, the forestry and fishing (increase by approximately 250%), but the increase is also recorded in business such as manufacturing industry (6,94%), business of providing accommodation and preparing food (1,4%). Gross domestic product per capita in the Municipality of Kalesija in 2014 amounted 1.904 KM which is more compared to the GDP in 2010 (1.721 KM), thus recording the growth of 10,63%. The indicator of import/export for 2015 is showing that the export value for the whole year (40.668,7 KM) is lower by 37% compared to 218 data (55.717 KM). The export increase is followed by import increase, thus the data for 2015 is 41.964,34 KM and for 2018 56.209, which is 25,34% increase.

The net salary in the area of the Municipality Kalesija was 622 KM in 2016, which is 73,9% compared to the average in FBiH. The average salary in 2015 was 614 KM meaning that the average salary was increased by 1,3% compared to a previous year. The average net salary in 2018 was 680 KM which is 10,75% higher compared to 2015. However, the value from 2018 is by 29,85% less compared to the net salary in FBiH.

In the period 2015-2019 the Municipality of Kalesija recorded the increase in a number of employed people from 3.507 to 4.371 in 2019 by 24,63%. Image 2 gives overview of employed people in the Municipality of Kalesija from 2011 to 2019.

[2] Federal Institute for Statistics, final census of the population 2013

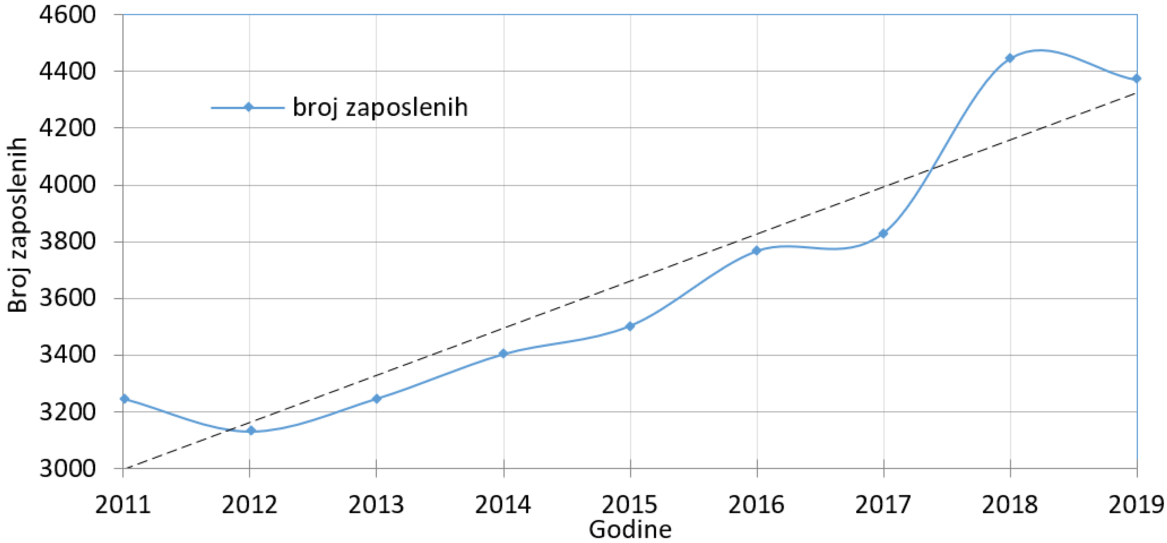


Image 2: Overview of employed people in the Municipality of Kalesija

The reason of the increased number of employed can be connected to the increased number of companies in the private sector. However, the number of unemployed people reduced from 9.482 in 2011 to8.741 in 2015 (approximately 52% of unemployed are women) which represent reduction of 7,82%. The trend continued in 2019 and it amounted 6.701 unemployed, which is 29,33% less unemployed people compared to 2011. In addition to structural unemployment, serious problem is big number of unemployed youth 18-35 years of age who make up 31,12% of the total population. Precisely this employment insecurity and bad economic situation of people within this age range are the reason they are leaving these areas in search for better work and more stable income. According to the data of the Pension and Disability Insurance Fund (PIO Fund), a number of pensioners in the period 2011-2015 in the area of the Municipality of Kalesija was in constant increase and thus, 3.521 pension users (age, disability and family) was registered in 2015 which is 10,45% more compared to 2011. Ratio of pensioners and number of employed is 1:1,24 which is extremely unfavorable from the perspective of providing financial sources out of which pensions are paid out (salary contribution). The number of pensioners increased, but the amount of pension did not increase sufficiently, and in 2019, on average it was 448 KM for age pension, 343 KM for family pension and 350 KM for disability pension.

According to the data of the Institute for Healthcare Insurance of TK, there were 30.567 people with healthcare insurance in 2016 in the area of the Municipality of Kalesija[3]. The problem that needs to be solved in the coming period is related to the fact that approximately 7,52% of the population does not have the healthcare protection on any basis (if one compares the number of residents of the Municipality and the number on insured people in the Institute for Healthcare Insurance).

5.3 State of public infrastructure electric network

At the moment, the basis of functioning and development of the electric-energy sector in Tuzla Canton is made of thermal power plant ''Tuzla'' (power 715 MW) and ''Elektrodistribucija'' Tuzla, as the subsidiaries of the public company (JP) Elektroprivreda BiH d.o.o. Sarajevo, small hydro power plants ''Modrac'' (power 1.898 MW) and ''Snježnica'' (power 0,422 MW), and JP ''Elektroprenos BiH'' is taking care of a part of transmission network.

[3] Strategy of local development of the municipality of Kalesija 2018-2027

The area of the Municipality of Kalesija is powered from three distributive junction transformer stations (JTS) 35/10 kV and they are: Kalesija, Tojšići and Požarnica. Total installed power of the transformer station (TS) is 10(20)/0,4 kV is 31,18 MVA. The total number of TS 10(20)/0,4kV is 124, of that 112 TS is owned by ''Elektrodistribucija'' Tuzla, and remaining 12 are private property. Between TS 35/10 kV Tojšići and TS 35/10 kv Kalesija there is connection by 35kV power-transmission line Al/Fe of 120 mm^2 cut, thus the Municipality of Kalesija has the possibility of two-way power supply. The construction of new electricity-energy objects is necessary due to increase of connections to the already existing power grid. In order to provide all end buyers with continuous supply of electricity, 17 investment projects are planned in the coming period (the period 2017-2025).

Analyzing spending of the electricity in the area of the Municipality of Kalesija in the past 10 years, we reach the data that the spending of electricity increased year by year and with annual average of 5,5%. The total amount of spent electricity was 38.945.712 kWh in 2007, and in 2016 it was 60.189.578 kWh.

In the area of the Municipality of Kalesija 18 local communities out of 22 have public lighting. On poles of the street lighting is placed 2.917 light bulbs out of which 318 are LED. The cost of the electricity for the street lighting on the annual level amounts to 81.524,00 KM. The Municipality of Kalesija should implement energy efficiency measures in the future in order to achieve the goal that the EU underlined (20-20-20), that is, 20% savings of the primary energy, 20% of the energy from renewable energy sources (RES) and 20% decrease of CO_2 until 2020[3].

5.4 Analysis of socio-economic survey of the population

5.4.1 Introduction

As part of the Feasibility Study for the installation of new energy efficient public lighting systems for the municipality of Kalesija, a survey of the population was conducted with the aim of assessing citizens' satisfaction with the quality of key dimensions of public lighting performance.

The survey questionnaire was chosen as the method for gathering primary data. The survey was carried out from 14 July until 1 September 2020. The survey questionnaire was distributed in electronic (web) form with the aim to attract as many people as possible. The Municipality of Kalesija has 36.748 residents, and 108 respondents participated in the survey. The level of reliability for this number of respondents is 95%, and the reliability interval is 9,4. The survey was carried out anonymously and respondents were previously informed about the aim of the survey.

5.4.2 General information on respondents

Out of the total number of respondents (108), 55,56% of surveyed people were males, while 44,44% were females, thus respecting the gender equality (Image 3).

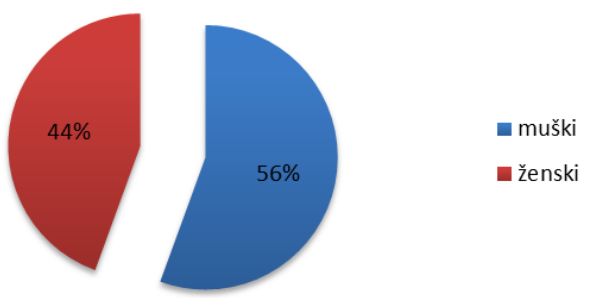


Image 3: Gender structure of respondents

Respondents' age is categorized in four age groups: 18 – 29; 30 – 39; 40 – 49; 50 – 64; 65+. The age group 30-39 years (34,26%) is the most represented in the sample, followed by respondents in the group 40-49 (31,48%), and then by respondents in the group 50-64 years (18,52%). The least represented were the group of respondents 50-64 years of age (14,81%) and respondents in the group 65+ (0,92%). The mentioned structure of respondents according to the age showed that almost equal percentage of respondents belonging to the younger and older population took part in the survey, thus fulfilling age group equality.
Percentage wise, there are more of the respondents who are employed 90,74%, while the percentage of unemployed is 9,26%. In addition, out of total number of respondents the biggest number had university level education (VSS)/baccalaureate level of the education 53,7%, while the percentage of the respondents with high school is 22,22%. Percentage of the respondents who have college level education (VSŠ) is 8,33%, while those with master degree is 13,89%. Respondents with PhD did not take part in the survey, and the percentage participation of the respondents who completed 6-year studies and have M.D. is 0,92%, the same like the respondents who have student status (0,92%) (Image 4).

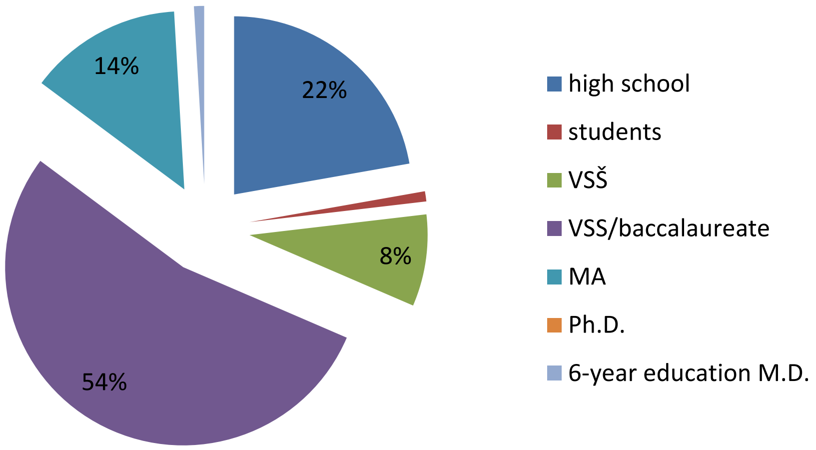
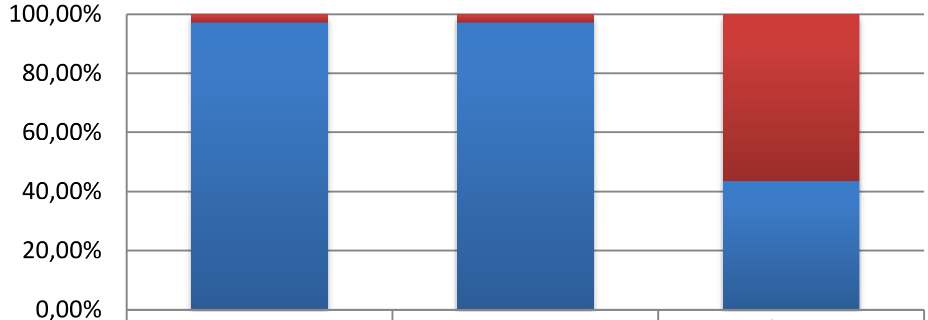


Image 4: Structure of respondents according to the education level

5.4.3 Energy efficiency and population's satisfaction with key dimensions of public lighting performance

Knowledge on the energy efficiency is the key to understand needs of the implementation of the energy efficiency measures. Therefore a set of three questions was formed with the aim to identify existing knowledge of the respondents on the energy efficiency. 97,22% respondents answered they are familiar with the term energy efficiency, while 2,78% answered they are not familiar with it. 97,22% respondents who participated in the survey answered that the energy efficiency is connected with preserving the environment, while 2,78 % answered it is not connected with preserving the environment. However, when it comes to the knowledge on costs of public lighting, majority of the respondents 56,48% is not familiar with the costs of public lighting, while 43,52% of the respondents is familiar with data of costs of the public lighting in the Municipality of Kalesija (Image 5).



	Do you know what is the term energy efficiency?	Is energy efficiency related to preserving the environment?	Do you know costs (KM) for the public lighting of the Municipality of Kalesija?
NO	2,78%	2,78%	56,48%
YES	97,22%	97,22%	43,52%

Image 5: Respondents knowledge on energy efficiency

According to respondents' opinion on whether the Municipality of Kalesija is taking some of the energy efficiency measures, majority of the respondents answered that the measures are being taken in the form of replacing existing ligt bulbs with LED 50%, while 23,15% respondents answered there are no taken measures. In addition, 20,37% of the respondents noted turning off the lights as the measure implemented by the Municipality of Kalesija, 3,7% respondents noted that the Municipality of Kalesija is implementing dimming of lighting as the energy efficiency measure, and 2,78% noted that dimming of lighting, turning light bulbs on and off with movement sensor are being implemented (image 6).

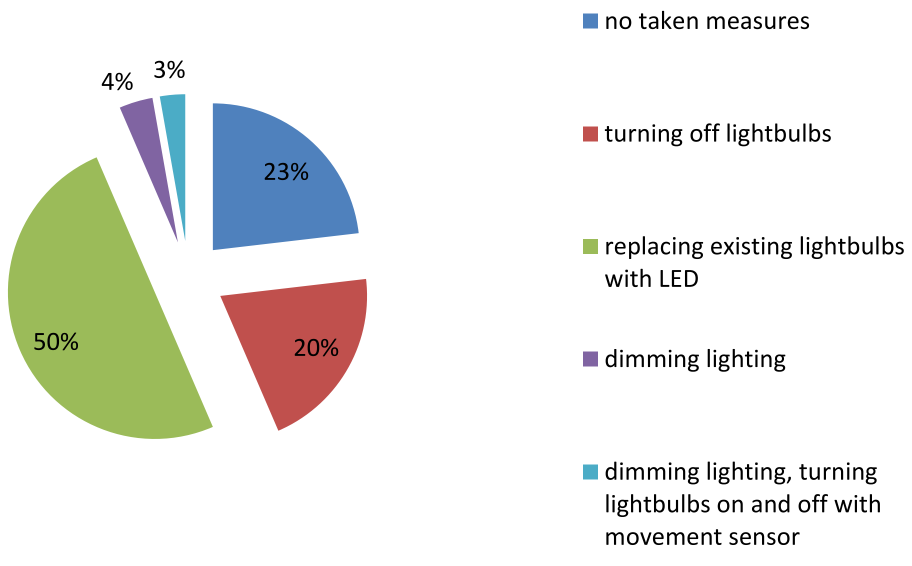


Image 6: Percentage of respondents' answers to the question: In your opinion, is the Municipality of Kalesija taking some energy efficiency measures

Taking into account the guideline on Likert scale, from one = (the lowest) up to five (the highest), the respondents expressed their satisfaction with current public lighting. Of the total number of respondents, 35,78% of them expressed their satisfaction with the current public lighting with the grade four, while 25,69% respondents gave the highest grade five. 5,5% gave the lowest grade to the state of the public lighting in the Municipality of Kalesija (Image 7). The respondents are mostly satisfied when all answers are taken into account.

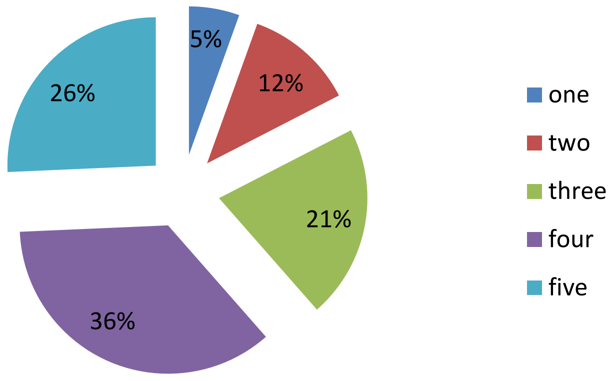


Image 7: Percentage of respondents' answers to the question: Your degree of satisfaction with the current public lighting?

Majority of the respondents, 31,48%, rated the maintenance of the public lighting in the Municipality of Kalesija with the grade five, while 23,15% gave the grade three, and 20,37% gave the grade four. According to the data showed on the Image 8, over 75% of the respondents gave the grades three, four or five to the maintenance of the public lighting, while 11,11% gave the grade two, and 13,89% gave the lowest grade, one. According to the results of the survey, it can be concluded that the majority of questioned residents of the Municipality of Kalesija are satisfied with the current way of the maintenance of the public lighting.

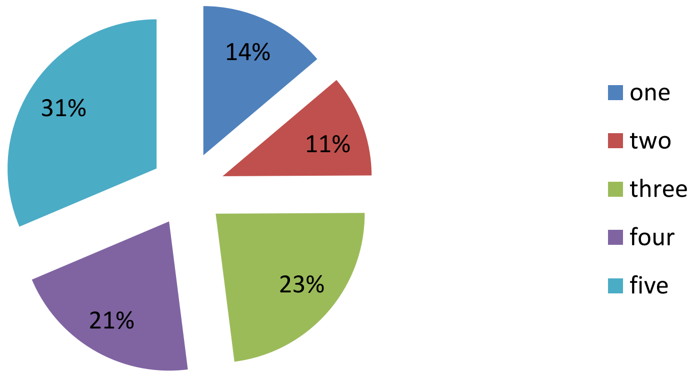


Image 8: Percentage of respondents' answers to the question: Does the Municipality of Kalesija regularly maintain the public lighting?

For the investments in innovative technologies when it comes to the public lighting in the Municipality of Kalesija, majority of the respondents answered that it is the grade three, 28,7%, while 24,07% stated it is the grade one. The smallest number of the respondents, 10,19%, stated that the level of the investment in innovative technologies is at the highest grade, five.

More than 58,33% of the respondents stated that in the Municipality of Kalesija there are lightbulbs that are covered by trees, objects, billboards, while 41,67% of the respondents stated it is not the case (Image 9).

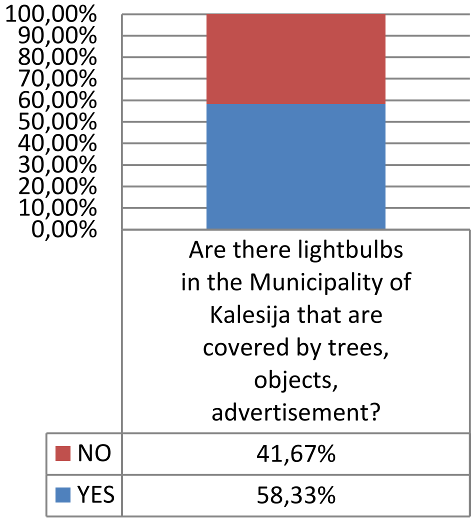


Image 9: Percentage of respondents' answers to the question: Does the Municipality of Kalesija invest enough in the innovative technologies (in this case e.g. in LED lighting or automatic management of the public lighting system)?

Through the survey the respondents were also asked about the characteristics of the current lighting, and they answered the questions related to the lighting pollution (?) and flashing effect. Respondents in the highest percentage (35,19%) rated with the grade three the case of the existence of light bulbs that cause the lighting pollution, as well as with the lowest grade, one (35,19%). When it comes to the existence of light bulbs causing the flashing effect, 87,96% of the respondents, who represent the majority, rated it with the grades one, two or three, while 12,04% rated it with the grades four or five (Image 10).

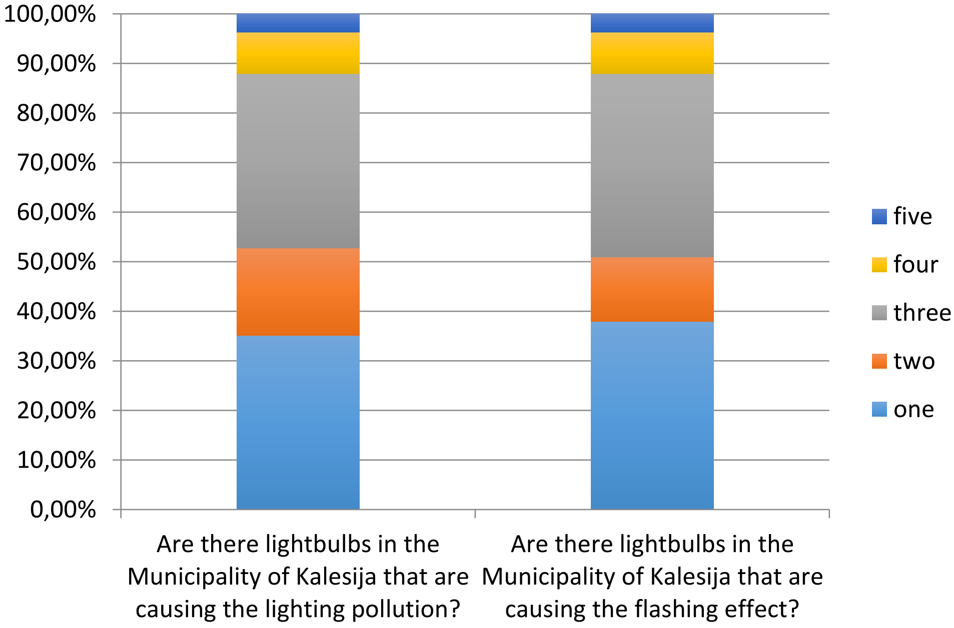


Image 10: Percentage of respondents' answers to the question on characteristics of the current public lighting in the Municipality of Kalesija

5.5 Overview of trends of energy efficient public lighting

The trend of using public lighting starts from the discovery of fire, which man used as a source of heat and light. Lighting in public areas was primarily used for safety when the ancient Romans and Greeks illuminated their streets to prevent looting and maintain the safety of citizens. The era of electric lighting began only with the invention of the incandescent light bulb, Thomas Alva Edison's first commercial lamp in 1879. Until then, oil lamps, candles and torches were used to produce light from oil or gas.

The first electric lighting in Bosnia and Herzegovina began to be used in 1890 in Semizovac near Sarajevo. The first electric lighting in Sarajevo began to be used on May 1, 1895 (the first test ignition was performed on April 3, 1895). Thanks to technological advances, and the evolution of ideas, humanity has been able to create an artificial light source that is used daily in the lighting of public spaces. Electricity is generated to light in light sources, on the principle of luminescence or temperature radiation.Over the years, the lamps have experienced rapid development. All today's light sources are divided into two basic groups: sources with bursts in precious gases or metal vapors and sources with incandescent filament. In the public lighting system, electric sources based on electroluminescence are mainly used, i.e. they convert energy directly into light, without gas discharge and these are:

- High pressure sodium lamp -NAV,
- High pressure mercury lamp - HQL,
- High pressure metal halide lamp – HQI,
- Low pressure sodium tube –SOX-E,
- Low pressure fluorescent tube –L.

Image 11 shows the trend of using individual lighting sources, and the following will describe the trends in the use of individual lamps and the use of additional technologies to increase the energy efficiency of public lighting.

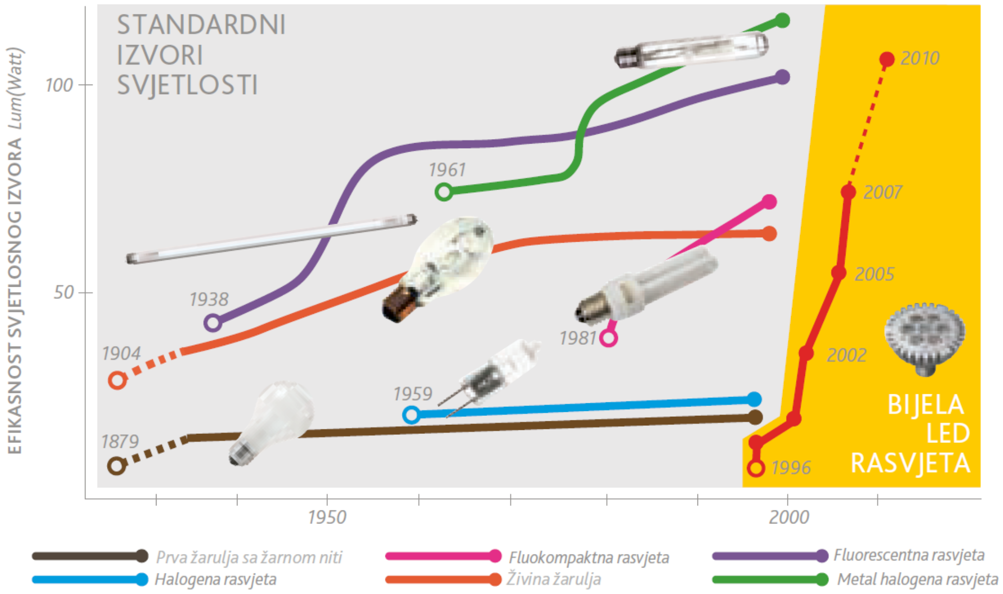


Image 11: Development trend of some light sources[4]

High pressure sodium lightbulb (NAV)

High-pressure sodium lamps (NAV) are light sources that operate on the basis of high-pressure sodium vapor eruptions up to 10 millibars, emitting a yellow light color, with good color rendering, which allows their wide application, especially in public lighting systems.Light efficiency is between 95 and 150 lm / W. The lamp can reach a lifespan of up to 24,000 hours, electricity 1,000 W, and a color temperature of up to about 2,000 K. The lamp consists of a glass balloon inside which is a ceramic weevil. The outer glass balloon is usually transparent, tubular or ellipsoidal in shape, having a thin white layer on the inside that lowers the luminance to only 4 to 30 cd / cm², which is advantageous for use in road lighting.

Image 12: High-pressure sodium lightbulb[7]

High pressure mercurylightbulb (HQL)

[4] www.osram.hr

High-pressure mercury lamps (HQL) are one of the first light sources to be used in public lighting systems. They work on the basis of the eruption,through mercury vapors, of high pressure into the lamp coil, creating visible and invisible ultraviolet radiation, blue or green. In its most common variant, this lamp gives a neutral white color of light and has a very weak color rendering index reaching from 23 to 50. Electrical power ranges from 50 W to 1,000 W. This type of lamp has good luminous efficiency (from 40 to 60 lm / W) and a lifespan of about 8,000 to 10,000 hours. The color of mercury lamps is monochromatic and therefore their application is limited to places where color recognition is not required but it is important to achieve good illumination over a large area. They are produced in a large selection of strengths, different designs and dimensions. They are used to illuminate highways, squares, streets, parks, etc. According to the EU Eco design Directive no. 2005/32 / EC, which requires the phasing out of inefficient forms of lighting, the year of cessation of use of high-pressure mercury lamps is 2015.

Image 13: High pressuer mercury lightbulb

High pressure metal halide lightbulb (HQI)

High-pressure metal halide lamps (HQI) are a special version of high-pressure mercury lamps. They were created to obtain a light source with an improved spectrum. As with high-pressure mercury lamps, mercury is added to the weevil, but also a number of other compounds such as iodine with sodium and indium with thallium. The high-pressure metal halide lamp is a modern light source with high light efficiency, good color rendering and high durability. The HQI light color is warm white, neutral white, or daylight color. The life of the lamp is about 15,000 hours, the color temperature depends on the exact composition of the inert gas and can reach from about 3,000 K to 20,000 K, and the efficiency ranges from 67 to 95 lm / W. Because it has a wide power range, it is compact in shape and has a good color rendering index. It is used in public lighting mainly in urban areas, where good color reproduction is required. According to the EU Eco design Directive no. 2005/32 / EC, which requires the phasing out of inefficient forms of lighting, the year of cessation of use of high-pressure metal halide lamps is 2015.

Image 14: High pressure metal halide lightbulb

Low Pressure Sodium Tubes (SOX)

Low pressure sodium tubes (SOX) produce light based on the eruption of low pressure sodium vapor. They are similar in mode of operation to mercury lamps, except that they contain sodium instead of mercury. This produces a monochromatic distinct yellow-orange color of light. The color rendering of the low-pressure sodium tube is extremely weak because the white color is reproduced as yellow and all the others as shades of black.The wavelength of the maximum radiation of this light source is very close to the wavelength at which the human eye is most sensitive and thus makes them suitable for conditions and spaces where increased visual acuity is required, namely roads with frequent fog. They emit a yellow-orange color of light that numbs the ambience and puts people to sleep. The color temperature of the low-pressure sodium lamp is 1,750 K, the lifespan is about 16,000 hours, and the electricity takes values up to 180 W. The main advantage of low-pressure sodium lamps is their high light efficiency of up to about 180 lm / W. The dimensions of low-pressure sodium bulbs are relatively large, and this in combination with the low color rendering index is one of the reasons why they are almost never used. According to the EU Eco design Directive no. 2005/32 / EC, which requires the phasing out of inefficient forms of lighting, the year of cessation of use of the low-pressure sodium lamp is 2012.

Image 15: Low pressure sodium tube –SOX-E

Fluorescent tube (CFL)

Fluorescent tubes (CFLs) are light sources based on the evaporation of low-pressure vapor through mercury, which produces ultraviolet radiation that is converted into visible light by a phosphor applied to the inside of the glass tube wall. Fluorescent tubes are filled with krypton and argon gases with little presence and mercury. They are energy efficient and have good color rendering, but poor optical monitoring capabilities. Rare products do not drastically reduce the luminous flux by dropping the ambient temperature. A special group of fluorescent tubes with improved color rendering properties, better light efficiency and greater durability are fluorescent with the commercial name LUMILUX. Important light sources that are increasingly found in road lighting systems are DULUX compact fluorescent luminaries. They are small in strength, small in size, but of great economy. DULUX is a small bent fluorescent tube with a special ballast integrated in the luminaire instead of a ballast and starter. Fluorescent tubes and fluorescent lamps are also produced in different designs, powers, light colors and dimensions. They are connected directly to a voltage of 230 V. According to the EU Ecological Design Directive no. 2005/32 / EC, which requires the phasing out of inefficient forms of lighting, the year of cessation of use of a fluorescent lamp is 2012.

Image 16: CFL lightbulb

LED based lightbulb

LED (Light Emitting Diode) is a semiconductor element that in a conductive state, when connecting electrons and cavities, emits light of a certain wavelength. As with diodes, an LED consists of a chip made of a semiconductor material to create a PN junction. By the action of voltage, electrons pass from the N to the P side, merge with cavities, pass into lower energy levels, and by releasing energy create Imagens. There are two ways to produce white LED light. The first is that the LED itself emits white light, and the second way is to get white light by mixing the three primary colors. Another advantage of LED lighting is that it has an almost instantaneous response to voltage changes, and the flicker is almost imperceptible. When using an LED lighting system that uses a color temperature of up to 3500 K, very good contrast sensitivity, color recognition and minimal light pollution are achieved. A color temperature that exceeds 4000 K and reaches 5000 K is extremely unfavorable because it contains a large proportion of blue light. The law stipulates that roads with motor traffic do not exceed the temperature of LED lights at 4000 K, because the share of blue light is much lower. The advantage of LED lighting is its high energy efficiency.The lifespan of LEDs is more than 50,000 hours (lamps used in the study for 100,000 hours) and this largely depends on the cooling quality of the LEDs. Color rendering and light efficiency characteristics improve significantly from year to year. The current efficiencies of this type of diodes in use in public lighting range from 50 - 70 lm / W, while the color rendering index is 60 - 80.Their use in public lighting has led to major changes in lamp design. The compact shape and relatively low intensity of the LEDs require the use of a larger number of diodes in the lamp and the direction of the light flux of each diode separately.

Image 17: LED lightbulb

Organic light emitting diode lamp (OLED)

The latest trends in electric lighting speak of OLED lighting, which is the next step in LED lighting, the letter "O" in the abbreviation OLED stands for "organic", but it is still LED lighting. The difference is that organic materials are used to make OLED lighting, which is claimed to be mechanically more flexible, which can lead to OLED lamps being made or printed using a 3D printer one day, while the principle of operation of the LED remains the same. As light emitting diodes will reach the maximum possible theoretical efficiency, OLED technology, even if it replaces them, will not be due to efficiency but due to some other trends, i.e. if it manages to be cheaper than LED lighting. Also, if some new artificial light sources appear, it is questionable whether it will be profitable to develop them and replace LED lighting with them because they cannot be more efficient than LED technology, and LED technology will become very cheap and accessible to everyone. Therefore, the only ways to increase the energy efficiency of public lighting today is to replace existing luminaires with LED technology and to manage public lighting and use additional technologies such as solar panels, rather than creating new light sources.

Trends in the use of additional technologies to increase the energy efficiency of public lighting

Currently, the world believes that LED lighting sources have reached the pinnacle of technology, and the possibility of increasing energy efficiency is reflected in technological additions to LED sources such as solar panels and lighting control.

The basic principle of solar lighting is that the Image-voltaic PV module located at the top of the pole converts solar radiation into electricity that accumulates in batteries. The accumulation itself is electronically monitored via a regulator that keeps the battery charging voltage within the allowable limits. Solar public lighting has proven to be a very cost-effective, economical and durable solution in many situations where bringing electricity networks is too expensive or the terrain is ungrateful for laying cables or electrification poles. The advantages of solar public lighting are:

– no digging, laying cables or mounting electrification transmission poles,
– simple project implementation requires minimal human resources,
– no need for transformer installation, calculation of KS currents and voltage drops,
– environmental friendliness,
– economic profitability - no electricity bills.

Image 18: Example of solar LED public lighting (island of Murter – croatia)

The current trend of public lighting management has mostly relied on the following ways:

1. Manual control,
2. By means of a time relay
3. By means of a Imagecell,
4. A combination of different commands.

Previous systems have made it possible to manage public lighting in terms of turning on the lights at the end of the day and turning them off at the beginning of the day. The new systems enable the management of public lighting during the night as well. Technological advances have made it possible to replace the traditional public lighting management system with a more modern system that is energy efficient, simplifies maintenance and reduces their costs, is more environmentally friendly and improves pedestrian and road traffic.

Such system includes the use of equipment and services such as:

- on / off switch depending on the light intensity or depending on a fixed (desired) on / off schedule,
- fault signaling part,
- remote control of the on / off switch lighting (WSN wireless sensors) enabling remote communication and control
- calculation of lighting costs from a remote central point (central technical monitoring of the system),
- dimming of lighting,
- turning on public lighting on a motion sensor, etc.

Nowadays, more and more cities are accepting the urban way of city development and acquiring the name "Smart City". The goal is to increase comfort and living standards through advanced information and communication technology solutions and Internet interfaces. Precisely these types of technology bring many advantages and improvements in the management and optimization of public services, and among them are transportation and parking, public lighting, surveillance and maintenance of public areas, collection of waste,preservation of cultural heritage, etc.Data collected in this way can be used to increase transparency and promote local government action.Furthermore, a very important component of a smart city concept is precisely the public lighting system. By using information and communication technologies and the Internet, smart cities strive to improve the quality of urban services and their energy efficiency. As the percentage of urbanization increases and the economy develops, the public lighting system becomes one of the key items of every modern city.

Thus, smart public lighting is used through advanced surveillance; it reduces electricity consumption, optimizes energy efficiency, increases safety and reduces maintenance costs. The latest public lighting systems consist of an LED lamp, a solar panel and a smart pole.Such systems can be used for various purposes such as: wireless remote control system, electric advertisements, digitalized traffic signs, power station for electric vehicles (cars and bicycles), traffic monitoring sensors, traffic counter, speakers, air quality sensors, decorative lighting, water level display, Push- to- talk service, Wi- Fi and mobile network, cameras, etc. (Image 19).

Image 19: Example of smart solar lighting

One or more different control network protocols are used for continuous communication between individual components in the smart public lighting system as well as the public lighting system and the central computer system. Thus, such a network protocol is a set of rules and standards that allow the display and verification of collected data and the detection and verification of possible errors in the public lighting system. If the geographical area is wider, then there are several public lighting networks, and each has its own control network protocol. Most often, these control protocols are not connected and each network system requires a separate central control system. The most commonly used control network protocols in public lighting are: DALI (Digital Addressable Lighting Interface), TCP / IP (Transmission Control Protocol / Internet Protocol), 6LoWPAN (Low power Wireless Personal Area Networks), ZIGBEE, KNX (Konnex), 0 - 10V analog type control protocol and PLC (Power Line Communication).

6 PUBLIC LIGHTING ENERGY CHARACTERISTICS ANALYSIS AND ENERGY CONSUMPTION AND EXPENSES MANAGMENT CHARACTERICTICS

6.1 General

According to development strategy of municipality of Kalesija, internal strengths analysis, electronetwork and lighting is well developed. Main streets are illuminated , as most rural streets. However, existing public lighting has low energyefficiency. The Municipality of Kalesija worked on increasing energy efficiency, and in 2018 and 2019 the existing HQL lighting was replaced with LED. Table 1 gives general dana on public lighting system, and table 2 gives a list of overviewed streets.

Amenable administration	Općina Kalesija	Street	Patriotske lige	No.	15
Contact person	Fahrudin Haličević	Phone	035 367 717		
Cell phone	+387 61 727 939	Mail:	fahro.halicevic@gmail.com		
Public lighting (type) goal			Street lighting, walking zone lighting, suburb residental zone lighting		
First year of building			Before 1990		
Lamp operating system			√ Imagecell □ Time reley □ Timer switch		
Daily operating time (h)			Summer: 8 pm - 5 am Winter: 4:30 pm - 7:00 am Average: approx 11 hours		
Operating system			Not regulated		
Subject obligated/under contract for public lighting maintenance			-		
Contact person			-		
Phone			-		
Electricity supplier			PC Elektroprivreda BiH		

Table 1: General informations on public lighting system

Ordinal No.	Street name
1	Patriotske lige
2	Senada Požegića
3	Trg šehida
4	Naselje Tibići - Hubići
5	Kalesijskog odreda
6	Kalesijskih brigada
7	Ulica Senada Mehdina Hodžića
8	Patriotske lige
9	Ulica žrtava genocida Srebrenice

10	Ulica 23.maja
11	Ulica braće Bukvarević
12	Ulica žena boraca armije BiH
13	25. novembar ZAVNO-BiH
14	Ulica 12. marta
15	Novo naselje
16	Sarajevska ulica
17	Muhamed age Hadžiefendića
18	Begana Ferhatovića
19	Kapetana Hajre Mešića
20	Ulica Podrinjska
21	Naselje Palavre
22	Naselje Katanovići
23	Halisijska ulica

Table 1: Streets listed for an overview [5]

6.2 Energy characteristics analysis

The Municipality of Kalesija does construction, managment and public lighting and device maintenance. Outside lighting in the City shares into: street, urban and spotlight lighting. Street lighting or traffic lighting provides:

- safe, quick and comfortable movement for motor vehicle drivers, bikers and cyclists,
- safe walking, in terms of providing possibilities to notice a threat, to orient themselves and recognize other walkers,
- repair a night look for traffic proximate surrounding.

Urban lighting meets a need for creating ambient atmosphere on public places, squares and streets. Spotlight lighting emphasizes architectual work and significant historic monuments. Image 20 shows public lighting system elements.

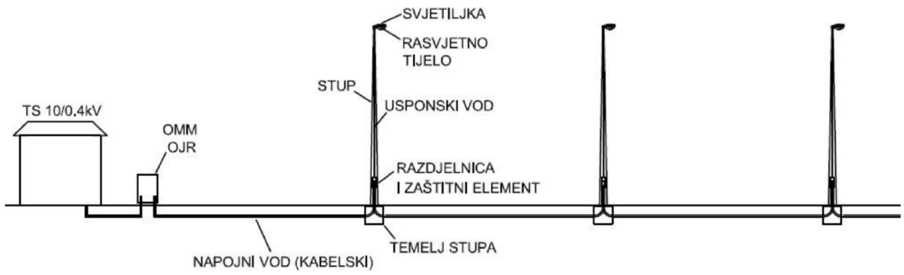


Image 20: Public lighting system elements

Energy characteristics analysis consists of light source optical and technical characteristics analysis, measuring points and substation, poles, conductiors/lines and geolocation coordinates of poles and lighting bodies. Detailed information on all anaysis and collected dana are shown on the following pages.

[5] Informations given by Amenable Administrating Service

6.2.1 Lighting source optical and technical characteristics

The subject part of the Study of Public Lighting in the Municipality of Kalesija performed 85.75% LED, and 12.10% Fluo lamps. Mercury and sodium lamps account for 2.16%. The total amount of energy efficient lamps is 97.84 %%, which ranks the Municipality among the most efficient municipalities in BiH in the subject area of public lighting. and sodium lamps. The lamp housings are mostly made in the mechanical protection IP65 degree.

Public lighting in st. Izet Nanić was made partly with LED technology, while only one compact fluorescent lamp was made in Street Kalesijskih Brigada. High-pressure sodium lamps were installed in other streets. Table 3 shows the types of light sources by the considered streets, and the participation of individual types of light sources is shown in Image 21.

Ordinal No.	Street name	Lighting source type	Rated power per source (W)	Lighting sources (pcs)
1	Patriotske lige	LED s	18	4
2	Senada Požegića	LED	99	10
3	Senada Požegića	LED s	15	5
4	Trg šehida	LED s	18	4
5	Naselje Tibići - Hubići	LED s	18	24
6	Kalesijskog odreda	LED	134	21
7	Kalesijskih brigada	LED	163	19
8	Ulica Senada Mehdina Hodžića	LED	134	20
9	Ulica Senada Mehdina Hodžića	Fluo	35	21
10	Patriotske lige	LED s	18	15
11	Ulica žrtava genocida Srebrenice	LED s	15	35
12	Ulica 23.maja	LED s	18	21
13	Ulica braće Bukvarević	LED s	18	6
14	Ulica žena boraca armije BiH	LED s	18	3
15	25. novembar ZAVNO-BiH	Živa	125	6
16	Ulica 12. marta	LED s	18	19
17	Novo naselje	LED s	18	7
18	Sarajevska ulica	LED s	18	14
19	Sarajevska ulica	Fluo	35	6
20	Sarajevska ulica	Natrij	150	2
21	Muhamed age Hadžiefendića	LED s	15	19
22	Muhamed age Hadžiefendića	Natrij	150	2
23	Begana Ferhatovića	LED s	15	13

Ordinal No.	Street name	Lighting source type	Rated power per source (W)	Lighting sources (pcs)
24	Kapetana Hajre Mešića	LED	50	3
25	Kapetana Hajre Mešića	LED s	15	17
26	Kapetana Hajre Mešića	Fluo	35	23
27	Kapetana Hajre Mešića	LED s	18	27
28	Ulica Podrinjska	LED s	18	23
29	Naselje Palavre	LED	50	8
30	Naselje Palavre	Fluo	35	6
31	Naselje Katanovići	LED s	18	20
32	Halisijska ulica	LED s	18	40
UKUPNO				463

Table 2: Lighting types by subject streets

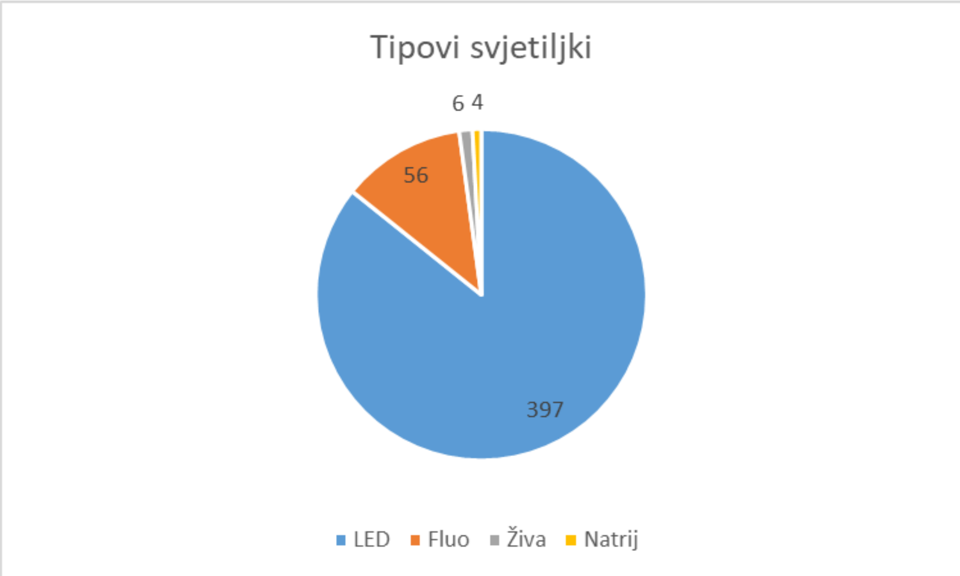


Image 21: Partaking lighting source types

Image 22 i **Pogreška! Izvor r**e shows an existing public lighting lamps overview in . Municipality of Kalesija. Due to lighting source obsolescence, lamps are filthy and that characteristic is a poor one for illumination. Lighting engagement regime especially has a seasonal character due to different day lengths in a year. Table 3 shows a conclusion on outdated inadequate lighting system which has a certain unwanted consequences, and they are:

- frequent malfunctions in public lighting system,
- extra damaging as a consequence due to poor gear quality,
- maintenance expenses,
- great electricity consumption,
- lamps without (quality) reflector lead to dispersing luminocity on unintended surfaces, flare and extra unnecessary energy loss,
- outdated lamp design,
- luminous environment pollution in terms of unintended sky illuminations and obstructing light.

Image 22: Sodium lamps

Image 23: Sodium lamps

6.2.2 Gelocation coordinates of poles and lighting bodies

Public lighting mapping is done by using GARMIN GPS73 instrument and a mobile application SW Maps. Mapped lamps are lamps located on parts of traffic roads with different lamp order, done in a way of moving –from lamp to lamp and marking a lamp/pole and found on vertical axis of a lamp, picturing significant lamps. After done lamp mapping, data was delivered into computer program QGIS. In QGIS there was installed an addition for OpenStreetMap map and addition for import/export of Images. Processing dana, we get a mapped lamp overview (Image 24)

Mapping comes to expression when it is necessary to write down several distribution cabinet, substations and extra lamp types, etc. Detailed report on geolocation coordinates is shown in annex. Besides mapping distances between poles are measured and tested, lamp console length, pole height, road to pole distance with an instrument – Leica DISTO D210 and in a QGIS program. Image 25 shows a measuring example. Data on all measurings is shown in the following chapters.

Image 24: Pole and lamp mapping example

Image 24: Laser measuring parameter example

6.2.3 Measuring points and substation

Total number of measuring points (OMM) in the system reffering to this study, there are 4 measuring points for measuring public lighting system energy consumption. One measuring point is located inside substation, remaining two are located on the outside of substation. Releys are installed in central building for controlling power of installed lamps. It is a partial convinient managment system, due to it is not necessary to set a new time interval in every central building for turning public lighting on/off.

Circuits are secured with automatic and fuses that show signs of fuse damage. There is an increased risk of electric shock when handling. The supply cables for all public lighting distributors are not mechanically protected. Control and safety parts are not predominantly protected by covers to prevent electric shock and can be life-threatening to maintain. Table 4 gives data on billing metering points (OMM), and Image 26 gives the layout of OMM.

Image 25: OMM

Measuring point unique ID (based on electricity supplier numeration)	Label OMM (officially based on EE overview numeration)	Substation name/label	OMM is located inside substation (yes / no)	Average lighting daily working hours (h)	Managment type	Switching device functional (yes / no)	Luminous flux regulation (yes / no)	Regulation type	Regulation device functional (yes / no)	Public lighting power lines in OMM	Labels for the right circuits	Power line type for PL (overground/ underground/ mix)
01/A	7970293	PL ZTS	no	11	Photo cell	yes	no	no regulation	-	4	01/A/1	MIX
											01/A/2	MIX
											01/A/3	MIX
											01/A/4	MIX
02/A	7969783	PL ROBNA KUĆA	yes	11	Photo cell	yes	no	no regulation	-	5	02/A/1	MIX
											02/A/2	MIX
											02/A/3	MIX
											02/A/4	MIX
											02/A/5	MIX
03/A	7969872	PL NOVO NASELJE	yes	11	Photo cell	yes	no	no regulation	-	5	03/A/1	MIX
											03/A/2	MIX
											03/A/3	MIX
											03/A/4	MIX
											03/A/5	MIX
04/A	1797174	PL CARSKA	no	11	Photo cell	yes	no	no regulation	-	5	04/A/1	MIX
											04/A/2	MIX
											04/A/3	MIX

Measuring point unique ID (based on electricity supplier numeration)	Label OMM (officially based on EE overview numeration)	Substation name/label	OMM is located inside substation (yes / no)	Average lighting daily working hours (h)	Managment type	Switching device functional (yes / no)	Luminous flux regulation (yes / no)	Regulation type	Regulation device functional (yes / no)	Public lighting power lines in OMM	Labels for the right circuits	Power line type for PL (overground/ underground/ mix)
											04/A/4	MIX
											04/A/5	MIX

Table 3: Data on measuring points (OMM)

6.2.4 Poles and support bracket

Lighting construction support is made out of lighting poles and support brackets (also called ''Lire'') mounted on poles. Lighting places in a circle of overviewed part of the network are made out of reinforced concrete poles and metal poles, there are no wooden poles.

Most poles are installed as one-sided and zig-zag. Existing steal poles are corroded on some places and it is necessary to protect adequately with protective coating and paint it. Supporting brackets on some places are out of lesser length , which leads to uneven lighting.

Metal poles are made as an anchor, concrete poles are secured with concreate foundations. Depending on zone and part of network, poles are set on green surfaces, as on walking and traffic surfaces. Lamps are mounted under 15 degrees with a console set on poles. Console length is from 0,5 to 1 m. Pole height varies from 8 and 9 m. Table 5 shows dana on pole construction.

Ordinal No.	Municipality	Metal (kom)	Reinforced concrete (AB) (pcs)	Total
1	Kalesija	119	344	463
		25,70%	74,30%	100%

Table 5: Pole construction

l	Street name	Average distance between poles (m)	Pole schedule (two-sided in a line, two-sided apart or one-sided)	Pole height (m)	Lamp mounted on a console (yes/ne)	Console length (m)	Console incline (%)	Po dis fro roa
	Patriotske lige	30	one-sided	4	ne	-	-	2
	Senada Požegića	40	one-sided	10	da	0.5	10	1,5
	Senada Požegića	40	one-sided	10	da	0,5	5	1,5
	Trg šehida	40	one-sided	8	da	0,5	5	1,5
	Naselje Tibići - Hubići	30	one-sided	8	da	0,2	5	1
	Kalesijskog odreda	30	one-sided	10	da	1	5	1,5
	Kalesijskih brigada	30	one-sided	10	da	1	5	1,5
	Ulica Senada Mehdina Hodžića	30	one-sided	10	da	0,3	5	1,5
	Ulica Senada Mehdina Hodžića	30	one-sided	8	da	0,3	5	1,5
	Patriotske lige	30	one-sided	8	da	0,3	5	1,5
	Ulica žrtava genocida Srebrenice	30	one-sided	4	ne	-	-	0,5

Street name	Average distance between poles (m)	Pole schedule (two-sided in a line, two-sided apart or one-sided)	Pole height (m)	Lamp mounted on a console (yes/ne)	Console length (m)	Console incline (%)	Pole dista from roac
Ulica 23.maja	40	one-sided	8	da	0,3	5	1,5
Ulica braće Bukvarević	35	one-sided	6	da	0,5	5	0,5
Ulica žena boraca armije BiH	40	one-sided	8	da	0,3	15	1
25. novembar ZAVNO-BiH	40	one-sided	8	yes	0,3	5	1
Ulica 12. marta	35	one-sided	6	yes	0,5	10	1,5
Novo naselje	40	one-sided	8	yes	0,3	15	1
Sarajevska ulica	40	one-sided	8	yes	0,3	10	1
Sarajevska ulica	40	one-sided	8	yes	0,3	15	15
Muhamed age Hadžiefendića	40	one-sided	8	yes	0,3	10	1
Muhamed age Hadžiefendića	40	one-sided	8	yes	0,3	15	1,5
Begana Ferhatovića	40	one-sided	8	yes	0,3	10	1,5
Kapetana Hajre Mešića	40	one-sided	8	yes	0,3	10	1,5
Ulica Podrinjska	40	one-sided	8	yes	0,3	10	1,5
Naselje Palavre	40	one-sided	8	yes	0,3	10	1,5
Naselje Katanovići	40	one-sided	8	yes	0,3	10	1,5
Halisijska ulica	40	one-sided	8	yes	0,3	10	1,5

, image 26 i image 27 show technical characteristics for pole geometry and consoles.

Image 26: Poles (Reinforced concrete - left, metal – desno)

Image 27: Console overview

Ordinal No.	Street name	Average distance between poles (m)	Pole schedule (two-sided in a line, two-sided apart or one-sided)	Pole height (m)	Lamp mounted on a console (yes/ne)	Console length (m)	Console incline (%)	Pole distanced from the road
1	Patriotske lige	30	one-sided	4	ne	-	-	2
2	Senada Požegića	40	one-sided	10	da	0.5	10	1,5
3	Senada Požegića	40	one-sided	10	da	0,5	5	1,5
4	Trg šehida	40	one-sided	8	da	0,5	5	1,5
5	Naselje Tibići - Hubići	30	one-sided	8	da	0,2	5	1
6	Kalesijskog odreda	30	one-sided	10	da	1	5	1,5
7	Kalesijskih brigada	30	one-sided	10	da	1	5	1,5
8	Ulica Senada Mehdina Hodžića	30	one-sided	10	da	0,3	5	1,5
9	Ulica Senada Mehdina Hodžića	30	one-sided	8	da	0,3	5	1,5
10	Patriotske lige	30	one-sided	8	da	0,3	5	1,5
11	Ulica žrtava genocida Srebrenice	30	one-sided	4	ne	-	-	0,5
12	Ulica 23.maja	40	one-sided	8	da	0,3	5	1,5
13	Ulica braće Bukvarević	35	one-sided	6	da	0,5	5	0,5
14	Ulica žena boraca armije BiH	40	one-sided	8	da	0,3	15	1
15	25. novembar ZAVNO-BiH	40	one-sided	8	yes	0,3	5	1

Ordinal No.	Street name	Average distance between poles (m)	Pole schedule (two-sided in a line, two-sided apart or one-sided)	Pole height (m)	Lamp mounted on a console (yes/ne)	Console length (m)	Console incline (%)	Pole distanced from the road
16	Ulica 12. marta	35	one-sided	6	yes	0,5	10	1,5
17	Novo naselje	40	one-sided	8	yes	0,3	15	1
18	Sarajevska ulica	40	one-sided	8	yes	0,3	10	1
19	Sarajevska ulica	40	one-sided	8	yes	0,3	15	15
20	Muhamed age Hadžiefendića	40	one-sided	8	yes	0,3	10	1
21	Muhamed age Hadžiefendića	40	one-sided	8	yes	0,3	15	1,5
22	Begana Ferhatovića	40	one-sided	8	yes	0,3	10	1,5
23	Kapetana Hajre Mešića	40	one-sided	8	yes	0,3	10	1,5
24	Ulica Podrinjska	40	one-sided	8	yes	0,3	10	1,5
25	Naselje Palavre	40	one-sided	8	yes	0,3	10	1,5
26	Naselje Katanovići	40	one-sided	8	yes	0,3	10	1,5
27	Halisijska ulica	40	one-sided	8	yes	0,3	10	1,5

Table 4: Technical characteristics of geometry poles and consoles

6.2.5 Lines/Cables

Public lighting powering is done accordant to instructions received from amenable power company, which is defined in previous electricity approval. Powering poles is done over ground 8concrete poles) and under ground (metal poles). Over ground conductors are isolated.

The supply line type for JR ZTS, JR DEPARTMENT STORE, JR NOVO NASELJE and JR CARSKA is 4X25mm2 Cu. All cables are dimensioned according to the installed power in the circuit and voltage requirements (in accordance with the subject standards), and are from about 50 to about 1,200 meters long. The underground supply lines are connected to the distribution board in metal light poles, and the riser connects and provides power to the lamp or lighting fixture. The luminaires powered by the overhead line are connected directly to the mains. Lighting circuits (supply lines) have up to 100 lighting points or poles.

On some parts, poles are used for overground distribution for other purposes (exp. cable operators) even though poles are powered under ground. (Image 29).

Image 28: Poles (unauthorized cabling - left, under ground cabling – centre, over ground cabling – right)

6.3 Measurings

6.3.1 Measuring electric parameters and electricity quality analysis

Analysis is done based on measuring electric values (voltage, power, cosϕ, strength). Measurings of electric parameters are published accordant to Law of electricity in Federation Bosnia and Herzegovina (''Official gazzete FBiH2'', no. 66/13) and a Rulebook on determining fulfillment of terms for doing periodical examinations, measurings on electric energy facilities, electric devices, electric installations and issuing documentation ('' Official Gazzete Federation of Bosnia and Herzegovina'', No. 18/15).Measuring we have a referencal energy parameters of public lighting system. Manpower is set for every measuring point (OMM) based on implemented measures and based on completed budgets.

Measurements are taken using Metrel Mi 2892 and AC CLAMP METER MT 486 A devices, and budgets are calculated accordant to methodology and defined standard En 13 201. Metrel MI 2892 is a device with three phase energy control quality. It has a LCD screen that works in real time. Owns an option for simultaneous writing down parameters, tracking events providing users with a possibility for detailed energy quality analysis and corelation of occasional events. Data on types and strengths of existing lighting sources is collected on a field visit, while losses in dimmers, accordant with EN 13201-2 standard are taken as 15% of rated lighting source power on discharge. Image 30 shows an example of measuring electric parameters.

Image 29: Electric parameters measuring analyzer

Measurements are taken in three phase system and an instrument during measuring is connected as Image 31 shows. Electric coils are individually taken phases L_1, L_2, L_3 i N guide, while voltage clamps were attached on metal conductable parts of the phases L1, L2, L3 under voltage and zero N guide which was on the ground potential. Before measuring, it was necessary to ground a device and check a connection if the same power and voltage connectors are connected on a same phase, because otherwise, measurements would not be correct.

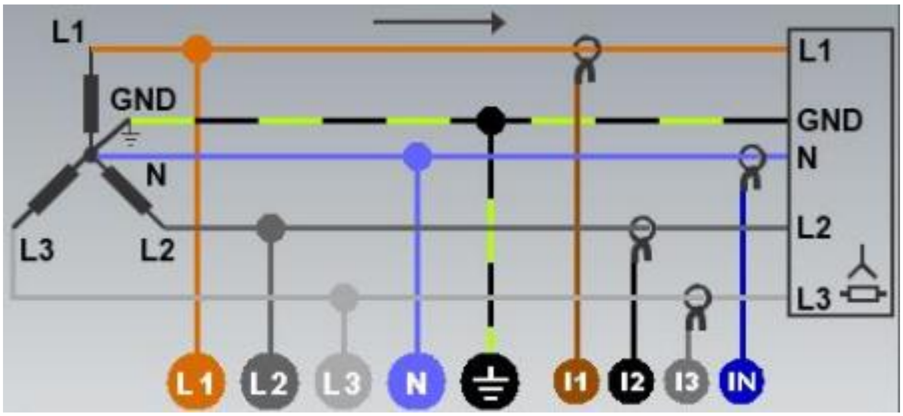


Image 30: Measuring instrument connection overview

Measuring voltage are generated sinus wave forms as Image 32 shows. It is visible on a Image that voltages inside phases are mutually moved closely to 120° per phase and their maximum and minimum values are around ±230 V.

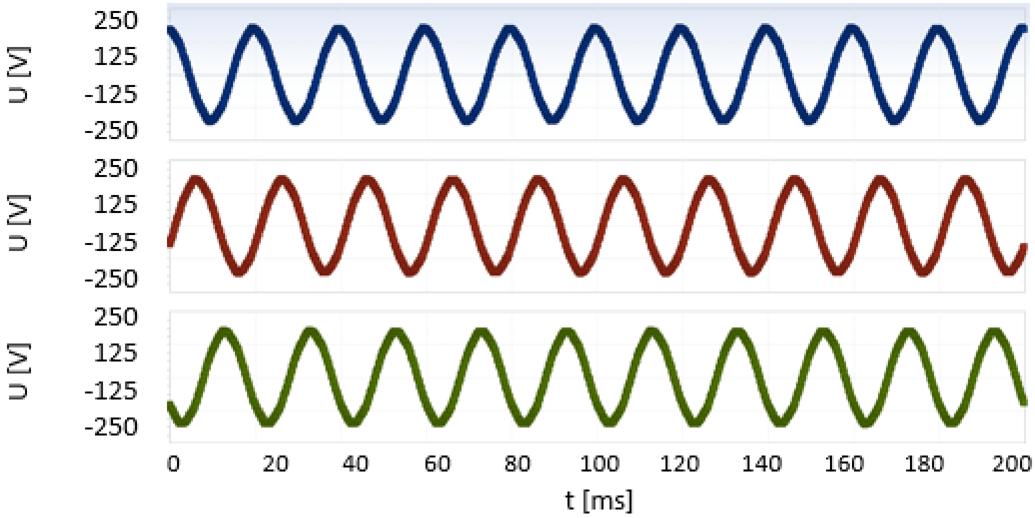


Image 31: Sinus wave form of measured voltage during 10 periods

Besides sinus wave form, a linear voltage overview is generated (Image 33). During turning public lighting on, voltage on effective value was the lowest, while reactive power component was vannishing, that is how voltage was growing inside overviewed time period of 20 minutes and in that moment it had a maximum effective value.

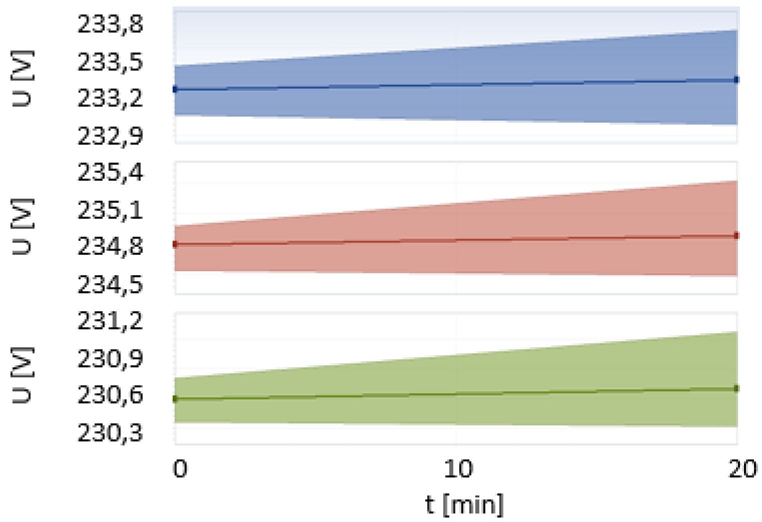


Image 32: Voltage effective values overview

Measuring power, similar review was given same as voltage. Image 33 shows a sinus wave power form which is deformed due to reactive power activity that is energy which is necessary for this lighting type. From sinus wave power form, it is closer to more pointed wave form due to which is necessary to enhance cross-sections surfaces for the purpose of stopping destruction of isolation during heating up guides.

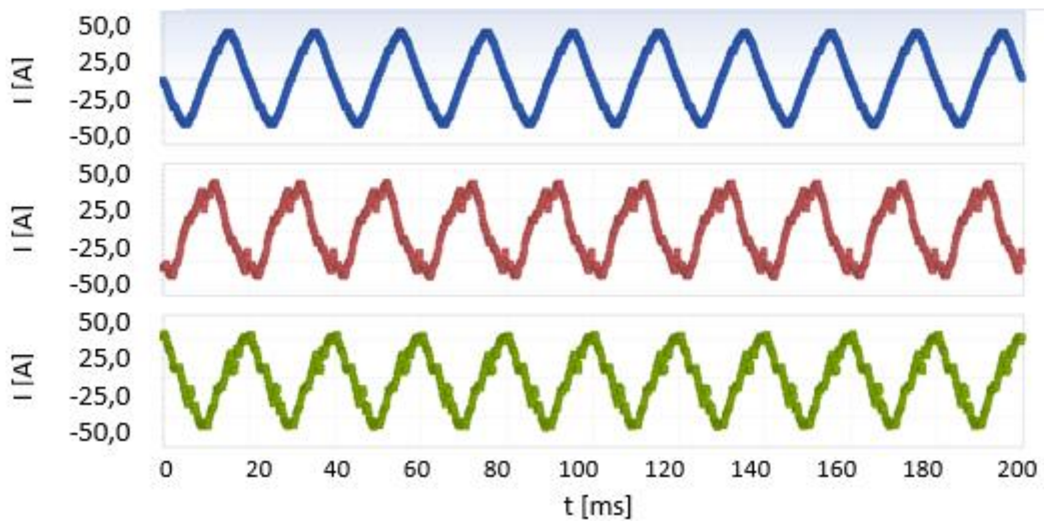


Image 33: Sinus wave form of measured voltage during 10 periods

Unlike voltage effective characteristics where there was a rise while need for reactive power was lowering, that is energy at power effective characteristics while there is no significant change in value (Image 35).

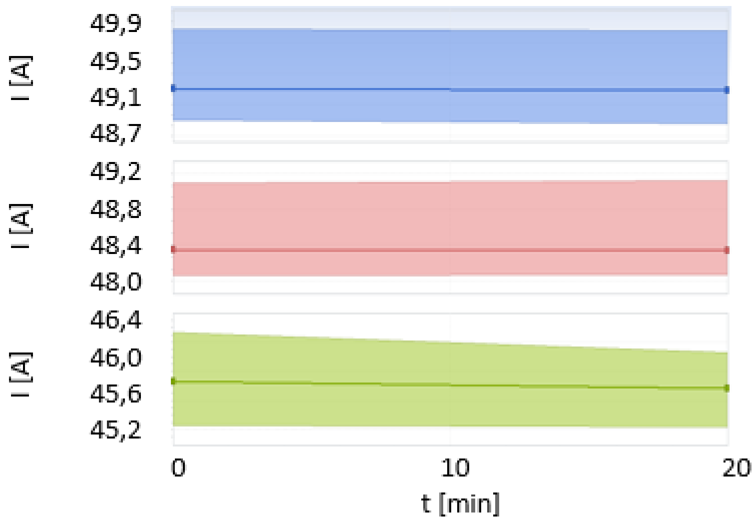


Image 34: Power effective value overview

During measuring voltage and power, effective display for working, reactive and apparent power triangle is generated. Great partaking in apparent power has a reactive power shown in Image 36 which needs to be compensated due to measured cosφ is lower than 0,95.

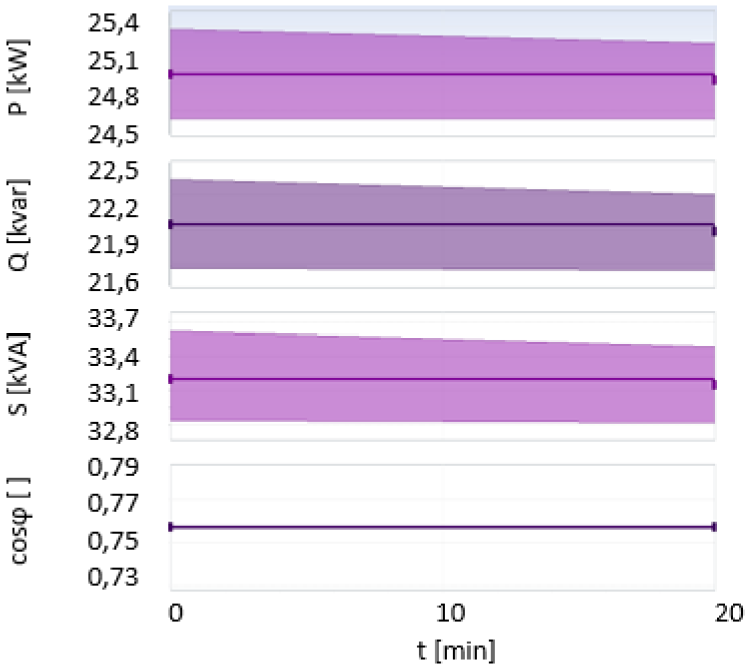


Image 35: Active, reactive, apparent powers and cosφ overview

Measured active and reactive energy follows power values in measuring period shown in Image 37.

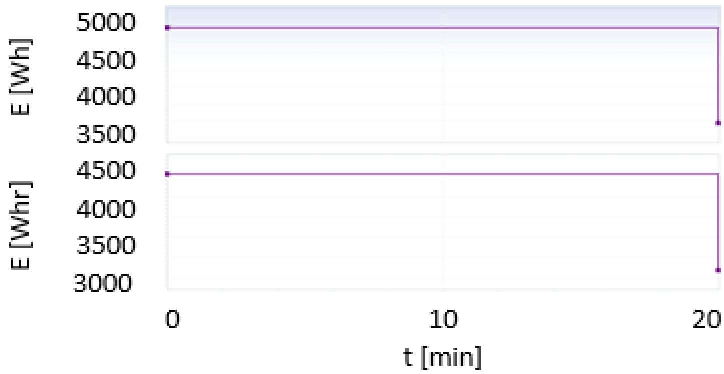


Image 36: Active and reactive energy

During measuring THD voltages are noted as general harmonics while from higher harmonics 5, 7 and 11 were noted and in total harmonic deformation approx 1% of total rated voltage value. Image 38 shows first 49 harmonics and total THD.

Image 37: Column overview THDU

Image 38 shows maximum (top line) and average (bottom line) values of THDU during overlooked period

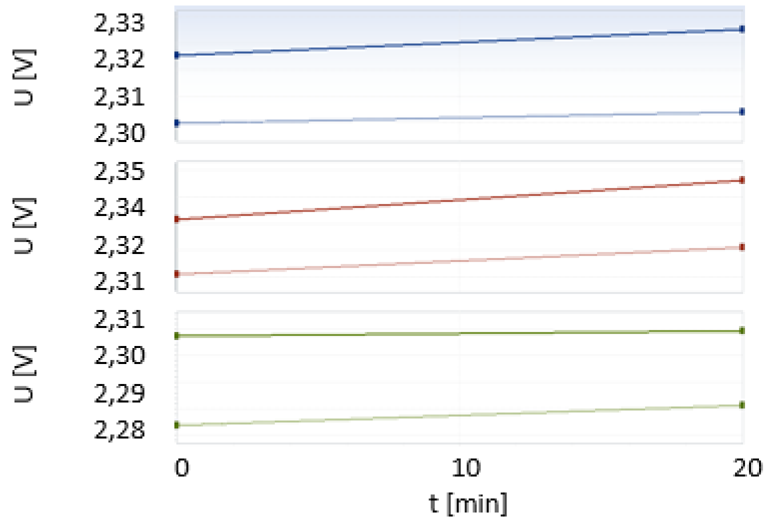


Image 38: Maximum and average value of THDU

Unlike voltages, power has greater harmonic deformation. Apperance of higher harmonics causes unlinearity consumption, that is pre-connected consumption device that makes them. During analysis of THDI, odd harmonics are noted up to 47th. Total harmonic deformation of power is approx 24%. Image 40 shows an overview of higher power harmonics up to 49th harmonic.

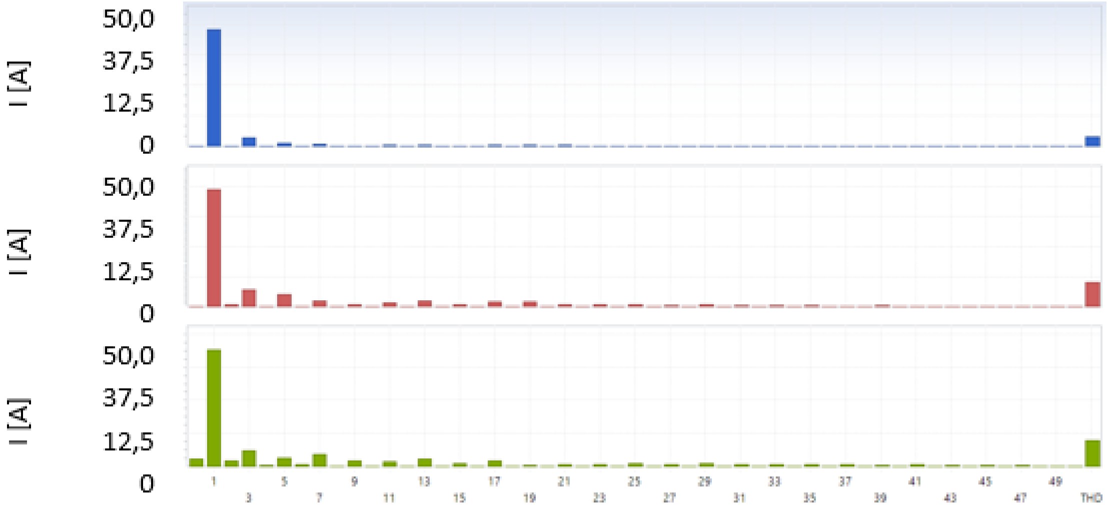


Image 39: Column overview THDI

Image 40 shows maximum (top line) and average (bottom line) values of THDi during overlooked period. Table 7 shows measuring results.

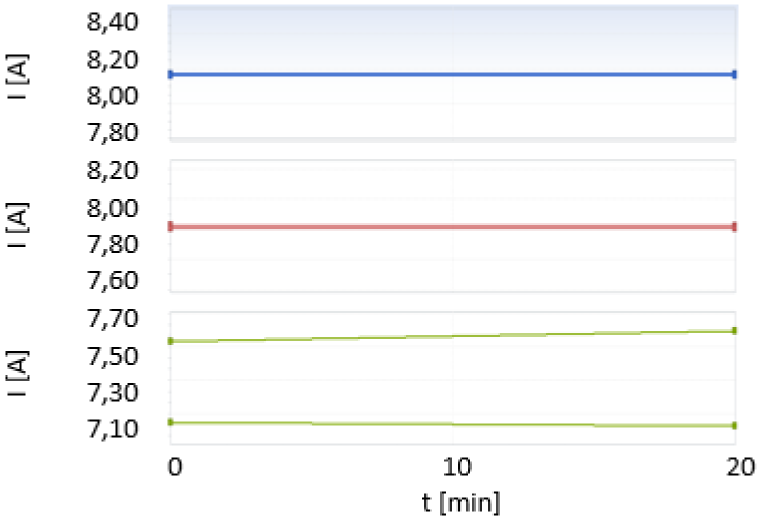


Image 40: Maximum and average value of THD

OMM name	Cable	Voltage (V)			Electricity (A)			Power (kW)			Cosϕ		
		L1	L2	L3	L1	L2	L3	L1	L2	L3	L1	L2	L3
PL ZTS	4X25mm2 Cu	233,3	234,8	230,6	49,09007	48,4358	45,66479	7,787845	8,529544	8,529544	0,68	0,75	0,81
PL ROBNA KUĆA	4X25mm2 Cu	236,3	235,1	226,7	41,98317	50,21061	54,0175	7,837292	8,381204	7,837292	0,79	0,71	0,64
PL NOVO NASELJE	4X25mm2 Cu	226,7	236,3	233,3	45,39515	52,61668	46,71144	8,232865	8,578991	8,282311	0,8	0,69	0,76
PL CARSKA	4X25mm2 Cu	236,9	238,1	226,4	41,36752	40,88537	49,14087	8,133971	7,787845	8,232865	0,83	0,8	0,74

Table 5: Electric parameters measuring results

6.3.2 Measuring luminosity intensity

Luminosity intensity analysis is done based on luminosity intensity measurements. For mentioned analysis the following standards are used:

- **BAS CEN/TR 13201-1:2016** – Traffic lighting - Part 1: Lighting class selection,
- **BAS EN 13201-2:2017** – Traffic lighting - Part 2: Performance requests,
- **BAS EN 13201-3:2017** – Traffic lighting - Part 3: Performance budget,
- **BAS EN 13201-4:2017** – Traffic lighting - Part 4: Traffic lighting characteristics of measuring methods,
- **BAS EN 13201-5:2017** – Traffic lighting - Part 5: Energy working characteristics indicators.

Bosnia and Herzegovina does not have accepted luminous pollution protection Law. For measuring luminosity intensity, we used measuring instrument LUX meter UNI-T UT383 and METREL. Image 42 shows luminosity intensity measuring example.

Image 41: Horizontal luminosity intensity measurement (left) and vertical luminosity intensity measurement (right)

Measuring is done in artificial lighting conditions. According to measured values, mostly it satisfies required values defined by standard. However, in parts where horticultural design where luminosity intensity unsatisfies required values defined by standard due to tree positioning which block a lamp (Image 43)).

Image 42: Lamp covered by trees example

By removing branches or other solutions it can concluded that current lighting as it's intensity satisfies issued values defined by standard.

6.4 Energy characteristics analysis in electricity consumption system

6.4.1 Public lighting electricity consumption budget

Standardized annual electricity consumption calculates in a way:

$$E_{ref}=(P_{is} + P_{gub}) * T_{ref} \quad (1.)$$

$$E_{ref}=P_{ref} * T_{ref} \quad (2.)$$

where the following is:
Eref – standardized annual electricity consumption (kWh/annually);
Pis –lamp source power;
Pgub – ballast losses;
Pref – total reference power - Pis+Pgub;
Tref – reference value of working hours for public lighting system (4.100 hours) – accordant to BAS EN 15900:2011 standard.

Lamp source installed power overview, working periods are taken from BAS EN 15900:2011 standard and total standrdized annual consumption is shown in table 8..

Street name	Lamp source type	(Pis) - Lamp source power	Quantity	(Tref) - Working period	(Eref) - Total standardized annual consumption
		(W)	(pcs)	(h/annually)	(kWh/annually)
Patriotske lige	LED s	18	4	4100	339,48
Senada Požegića	LED	99	10	4100	4667,85
Senada Požegića	LED s	15	5	4100	353,63
Trg šehida	LED s	18	4	4100	339,48
Naselje Tibići - Hubići	LED s	18	24	4100	2036,88
Kalesijskog odreda	LED	134	21	4100	13268,01
Kalesijskih brigada	LED	163	19	4100	14602,36
Ulica Senada Mehdina Hodžića	LED	134	20	4100	12636,20
Ulica Senada Mehdina Hodžića	Fluorescent	35	21	4100	3465,53
Patriotske lige	LED s	18	15	4100	1273,05
Ulica žrtava genocida Srebrenice	LED s	15	35	4100	2475,38
Ulica 23.maja	LED s	18	21	4100	1782,27
Ulica braće Bukvarević	LED s	18	6	4100	509,22
Ulica žena boraca armije BiH	LED s	18	3	4100	254,61
25. novembar ZAVNO-BiH	Mercury	125	6	4100	3536,25
Ulica 12. marta	LED s	18	19	4100	1612,53
Novo naselje	LED s	18	7	4100	594,09
Sarajevska ulica	LED s	18	14	4100	1188,18
Sarajevska ulica	Fluorescent	35	6	4100	990,15
Sarajevska ulica	Sodium	150	2	4100	1414,50
Muhamed age Hadžiefendića	LED s	15	19	4100	1343,78
Muhamed age Hadžiefendića	Sodium	150	2	4100	1414,50
Begana Ferhatovića	LED s	15	13	4100	919,43
Kapetana Hajre Mešića	LED	50	3	4100	707,25
Kapetana Hajre Mešića	LED s	15	17	4100	1202,33
Kapetana Hajre Mešića	Fluorescent	35	23	4100	3795,58
Kapetana Hajre Mešića	LED s	18	27	4100	2291,49

Street name	Lamp source type	(Pis) - Lamp source power	Quantity	(Tref) - Working period	(Eref) - Total standardized annual consumption
		(W)	(pcs)	(h/annually)	(kWh/annually)
Ulica Podrinjska	LED s	18	23	4100	1952,01
Naselje Palavre	LED	50	8	4100	1886,00
Naselje Palavre	Fluorescent	35	6	4100	990,15
Naselje Katanovići	LED s	18	20	4100	1697,40
Halisijska ulica	LED s	18	40	4100	3394,80
Total (kWh/annually)					88934,33
Lamp sources (pcs)					463
Specific annual consumption (kWh/per lamp source annually)					192,08

Table 6: Calculated public lighting electricity consumption overview

From table 8 we can notice that there are LED lamps which are energy efficient, therefore it is necessary to make a calculation and overlook electricity consumption of existing system that is not energy efficient, that is lamps that are not LED. Standardized annual electricity consumption of unefficient public lighting is calculated in the following:

$$E_m = E_{ref} - E_{LED} \quad (3.)$$

where the following is:
Em – standardized annual electricity consumption that is unefficient public lighting (kWh/annually);
Eref – standardized annual electricity consumption (kWh/annually);
E_{LED} – standardized annual consumption of LED lamps (kWh/annually).

Total standardized annual electricity consumption overview of unefficient public lighting by lamp types is shown in table 9, while Image 47 shows percentaged partking of total standardized consumption Em) by unefficient public lighting types. Ballast losses are 15%.

Lamp source type	(Em) – Total standardized annual electricity consumption of unefficient public	Lamp sources (pcs)	Specific annual consumption (kWh/per lighting source annually)	Expenses (KM/annually)	Expenses (EUR/annually)
Fluorescent	9241,40	56	165,03	1965,65	1005,02
Mercury	3536,25	6	589,38	752,16	384,57
Sodium	2829,00	4	707,25	601,73	307,66
Total	15606,65	66	236,46	3319,53	1697,25

Table 7: Calculated consumption and unefficient public lighting electricity expenses overview

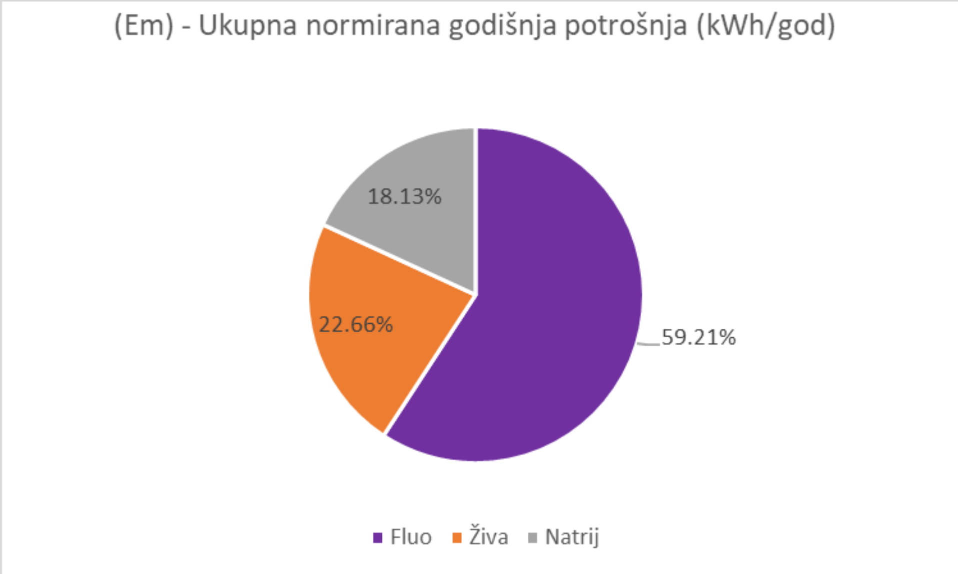


Image 43: Total standardized (Em) electricity consumption by unefficient public lighting types overview (kWh/annualy)

Total standardized annual electricity consumption overview of unefficient public lighting per street classification from chapter ''Lighting technical requests and street classifications'' shown in table 10 while Image 45 shows percentaged partaking of total standardized consumption (Em) per types of unefficient public lighting.

Street classification	(Em) – Total standardized annual electricity consumption of unefficient public	Lighting sources (pcs)	Specific annual consumption (kWh/per lighting source annually)	Expenses (KM/annually)	Expenses (EUR/annually)
M4	7355,40	16	459,71	1564,49	799,91
M6	8251,25	50	165,03	1755,04	897,34
Ukupno	15606,65	66	236,46	3072,95	1571,17

Table 8: Calculated consumption overview and electricity expenses of unefficient public lighting by street classifications

Image 44: Total standardized (Em) electricity consumption overview by street classifications of unefficient public lighting (kWh/annualy)

6.5 System regulation and managment analysis

In the Municipality of Kalesija, OMM does not have any equipment installed for central supervision and management of public lighting systems.

A way and type of managment per OMM is shown in table from previous chapter ''Measuring points and substations''. Percentaged partaking of managment devices per OMM (Image cells, time releys, manual, etc.) is shown in Image 46.

Image 45: Percentaged partaking overview of managment device per OMM

6.6 Public lighting maintenance analysis

The user replaces the light source on his own initiative and in accordance with the possibilities. According to the information received from the Municipal Service, the costs of annual maintenance according to the invoices of the subject part of the study amount to 1500 KM.

.

7 ANALYSIS OF ENERGY COSTS AND FORECASTING FUTURE CONSUPTION

The analysis of electric energy consumption energije was done on the basis of data from the bills received from the costomers (UNDP) and municipality Kalesija for 2017, 2018 i 2019. Based on the bills received from the municipality Kalesija, the control of bills received from the costomers was performed. The tables and graphs in the following chapters show the electric energy consumption for public lighting. Electricity is supplied from the public electricity distribution network, PC "Elektroprivreda BiH" Elektrodistribucija Tuzla, through 4 measuring points.

The cost balance presents the total costs for electrical energy, whereby the energy and cost balances were prepared on the basis of the received bills on consumed electricity for 2017., 2018., and 2019. Total annual electric energy consumption is shown in the energy balance. The energy balance is shown in the chapter above.

Electricity Metering Point measure energy consumption, and it is measure consumption of active power. Total costs for electricity are presented in the cost balance, which is divided into two types (electricity and network charges) and tariff elements. The following tables provide an overview of electric energy consumption and costs by electricity metering points.

The average price of electricity for the analyzed period is **0,1915 KM/kWh ili 0,097912 EUR/kWh.**

Month	01/A JPL ZTS 7970293					
	2017.		2018.		2019.	
	kWh	KM	kWh	KM	kWh	KM
January	4.081,00	721,60	4.645,00	937,71	4.316,00	900,34
February	3.404,00	602,78	3.538,00	714,71	3.503,00	731,11
March	3.054,00	541,36	3.326,00	672,00	3.128,00	656,38
April	2.604,00	468,41	2.738,00	547,22	2.800,00	593,15
May	2.631,00	473,21	2.802,00	559,96	3.012,00	637,93
June	2.372,00	427,16	2.141,00	432,96	2.259,00	478,94
July	1.488,00	269,97	2.814,00	569,36	2.457,00	520,74
August	2.571,00	395,33	2.821,00	570,76	2.655,00	562,54
September	2.920,00	524,59	2.859,00	578,42	2.840,00	601,60
October	3.563,00	638,93	3.286,00	664,52	3.460,00	732,51
November	3.915,00	701,52	3.768,00	761,72	3.891,00	823,49
December	4.046,00	724,80	3.866,00	781,47	3.663,00	775,37
Total	**36.649,00**	**6.489,66**	**38.604,00**	**7.790,81**	**37.984,00**	**8.014,10**

Table 11: Electricity consumption and costs for the analyzed periodic metering PL ZTS

Month	02/A PL DEPARTMENT STORE 7969783					
	2017.		2018.		2019.	
	kWh	KM	kWh	KM	kWh	KM
January	4.911,00	867,26	5.022,00	1.013,64	7.206,00	1.501,86
February	3.423,00	606,12	5.176,00	1.044,67	5.859,00	1.221,50
March	3.113,00	551,71	4.742,00	957,25	5.860,00	1.227,93

April	2.577,00	463,60	3.970,00	792,55	3.605,00	763,12
May	2.632,00	473,38	4.517,00	901,47	4.755,00	1.005,92
June	2.547,10	458,28	3.639,00	734,48	4.250,00	899,31
July	1.726,90	312,45	4.323,00	873,62	3.250,00	688,17
August	2.775,00	498,81	4.403,00	889,74	4.245,00	898,26
September	3.255,00	584,16	4.742,00	958,09	4.504,00	952,93
October	3.836,00	687,47	5.350,00	1.080,68	5.628,00	1.190,24
November	4.076,00	730,14	5.820,00	1.175,44	6.225,00	1.316,29
December	4.104,00	735,12	6.005,00	1.212,74	2.967,00	628,42
Total	**38.976,00**	**6.968,50**	**57.709,00**	**11.634,37**	**58.354,00**	**12.293,95**

Table 12: : Electricity consumption and costs for the analyzed periodic metering PL ROBNA KUĆA

Month	03/A PL NOVO NASELJE 7969872					
	2017.		2018.		2019.	
	kWh	KM	kWh	KM	kWh	KM
January	2.824,00	500,99	2.481,00	501,77	2.199,00	459,69
February	2.269,00	403,59	1.790,00	362,58	1.821,00	381,01
March	2.258,00	401,66	2.088,00	422,62	1.612,00	339,23
April	1.792,00	324,02	1.485,00	297,71	1.492,00	270,94
May	1.840,00	332,56	1.536,00	307,85	1.538,00	326,71
June	1.858,00	335,75	1.227,00	248,98	1.122,00	238,88
July	1.167,00	212,89	1.203,00	244,54	1.312,00	279,00
August	1.719,00	311,04	1.656,00	335,87	1.278,00	271,83
September	1.928,00	348,20	1.549,00	314,31	1.156,00	246,05
October	2.307,00	415,60	1.989,00	403,02	2.438,00	516,73
November	2.292,00	412,93	2.187,00	442,94	2.058,00	436,49
December	2.307,00	415,60	2.001,00	405,44	2.134,00	452,54
Total	**24.561,00**	**4.414,83**	**21.192,00**	**4.287,63**	**20.160,00**	**4.219,10**

Table 13: : Electricity consumption and costs for the analyzed periodic metering PL NOVO NASELJE

Month	04/A PL CARSKA BAŠČA 1797174					
	2017.		2018.		2019.	
	kWh	KM	kWh	KM	kWh	KM
January	2.942,00	521,70	2.754,00	475,87	3.356,00	700,51
February	2.262,00	402,36	2.084,00	421,80	2.812,00	587,29
March	2.208,00	392,89	2.119,00	428,86	2.425,00	509,31
April	1.749,00	316,38	1.697,00	339,92	2.138,00	453,39
May	1.828,00	330,42	1.922,00	384,72	2.202,00	466,90
June	1.479,00	268,36	1.639,00	331,89	1.607,00	341,28
July	1.421,00	258,06	1.968,00	398,79	1.750,00	371,48
August	1.691,00	306,06	2.073,00	419,95	1.856,00	393,85
Septembar	2.020,00	364,56	2.225,00	450,59	1.801,00	382,24
October	0,00	0,00	2.813,00	569,16	2.548,00	539,96
Novembar	2.598,00	467,33	3.259,00	659,08	2.848,00	603,30
Decembar	2.530,00	455,25	2.863,00	579,23	2.967,00	628,42
Total	**22.728,00**	**4.083,37**	**27.416,00**	**5.459,86**	**28.310,00**	**5.977,93**

Table 9: : Electricity consumption and costs for the analyzed periodic metering PL CARSKA BAŠTA

Month	Općina Kalesija					
	2017. godina		2018. godina		2019. godina	
	kWh	KM	kWh	KM	kWh	KM
January	14.758,00	2.611,55	14.902,00	2.928,99	17.077,00	3.562,40
February	11.358,00	2.014,85	12.588,00	2.543,76	13.995,00	2.920,91
March	10.633,00	1.887,62	12.275,00	2.480,73	13.025,00	2.732,85
April	8.722,00	1.572,41	9.890,00	1.977,40	10.035,00	2.080,60
May	8.931,00	1.609,57	10.777,00	2.154,00	11.507,00	2.437,46
June	8.256,10	1.489,55	8.646,00	1.748,31	9.238,00	1.958,41
July	5.802,90	1.053,37	10.308,00	2.086,31	8.769,00	1.859,39
August	8.756,00	1.511,24	10.953,00	2.216,32	10.034,00	2.126,48
Septembar	10.123,00	1.821,51	11.375,00	2.301,41	10.301,00	2.182,82
October	9.706,00	1.742,00	13.438,00	2.717,38	14.074,00	2.979,44
Novembar	12.881,00	2.311,92	15.034,00	3.039,18	15.022,00	3.179,57
Decembar	12.987,00	2.330,77	14.735,00	2.978,88	11.731,00	2.484,75
Total	**122.914,00**	**21.956,36**	**144.921,00**	**29.172,67**	**144.808,00**	**30.505,08**
Month	2017. godina		2018. godina		2019. godina	
	kWh	EUR	kWh	EUR	kWh	EUR
January	14.758,00	1.335,26	14.902,00	1.497,57	17.077,00	1.821,43
February	11.358,00	1.030,18	12.588,00	1.300,60	13.995,00	1.493,44
March	10.633,00	965,12	12.275,00	1.268,38	13.025,00	1.397,28
April	8.722,00	803,96	9.890,00	1.011,03	10.035,00	1.063,79
May	8.931,00	822,96	10.777,00	1.101,32	11.507,00	1.246,25
June	8.256,10	761,59	8.646,00	893,90	9.238,00	1.001,32
July	5.802,90	538,58	10.308,00	1.066,71	8.769,00	950,69
August	8.756,00	772,68	10.953,00	1.133,19	10.034,00	1.087,25
Septembar	10.123,00	931,32	11.375,00	1.176,69	10.301,00	1.116,06
Octoear	9.706,00	890,67	13.438,00	1.389,37	14.074,00	1.523,36
Novembar	12.881,00	1.182,07	15.034,00	1.553,91	15.022,00	1.625,69
Decembar	12.987,00	1.191,70	14.735,00	1.523,08	11.731,00	1.270,43
Total	**122.914,00**	**11.226,11**	**144.921,00**	**14.915,75**	**144.808,00**	**15.597,00**

Table 10: Total electric energy consumption and costs in the period from 2017. to 2019.

A more detailed analysis of electricity consumption by months and years, shown in the following Images and pages, can be very useful for proposing energy efficiency measures. This is especially evident when the nature of public lighting is taken into account, which directly affects the way electricity is consumed. After a more detailed analysis of consumption and costs, measures can be suggested to reduce or increase energy efficiency.

Image 46 shows a diagram of electric energy consumption and its costs by months in 2017. It can be concluded that monthly consumption varies significantly throughout the year. Variations are noticeable by months within the season (winter or summer), and trend lines (added to the diagram) show a marked decline in consumption during the summer. The reason for the drop in consumption is the reduced use of artificial light. Consumption in June is the lowest due to the shortest nights of the year.

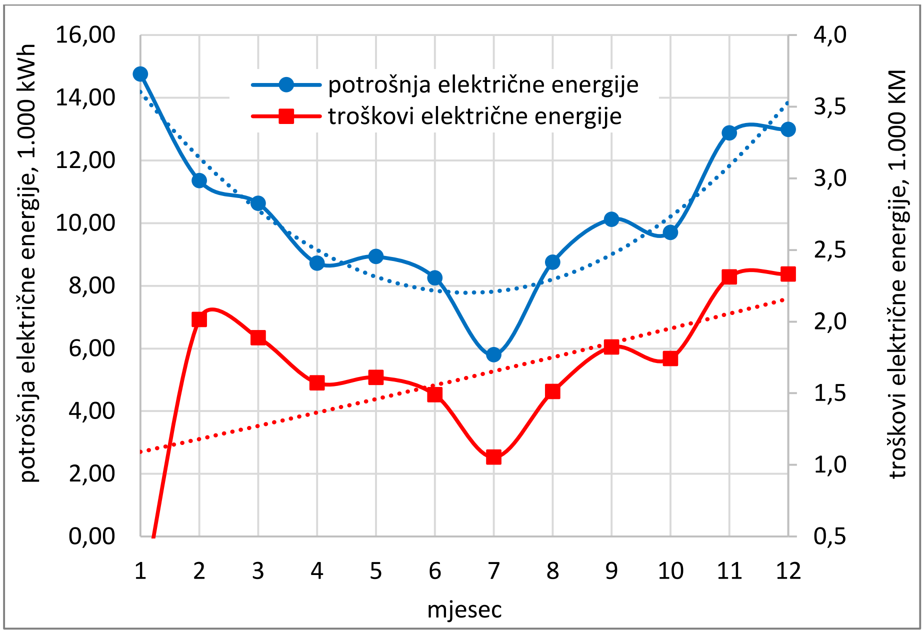


Image 46: Overview of total electric energy consumption and costs during 2017.

Image 47 shows diagrams describing electric energy consumption and its costs by months in 2018.

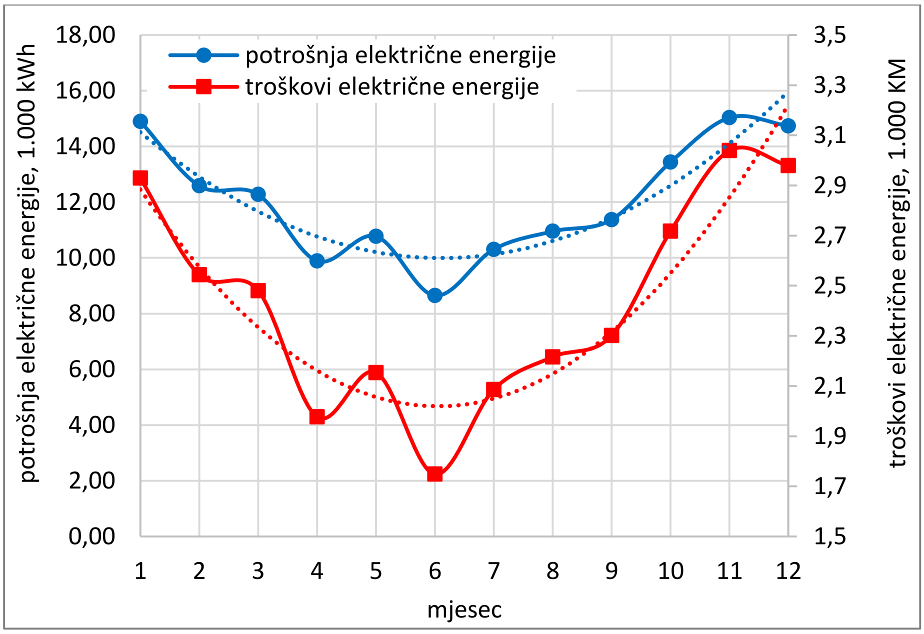


Image 47: Overview of total electric energy consumption and costs during 2018.

It can be concluded that the consumption and costs have similar trends compared to those of the previous year (as shown by the trend line). In some months, consumption is slightly increased or decreased, which is the difference caused by the dynamics of use, or weather conditions. Electric energy consumption has been reduced, but costs of electricity have increased due to changes in the electricity tariff. The electricity transmission tariff has not changed..

Image 48 shows electric energy consumption and its costs by months in 2019. It can be concluded that consumption and costs are similar trends compared to those of the previous two years, generally similar (as shown by trend lines). Electric energy consumption increased compared to 2018, and is lower compared to 2017. Costs electricity also increased due to the change in the electricity tariff compared to the previous two years. The electricity transmission tariff has not changed.

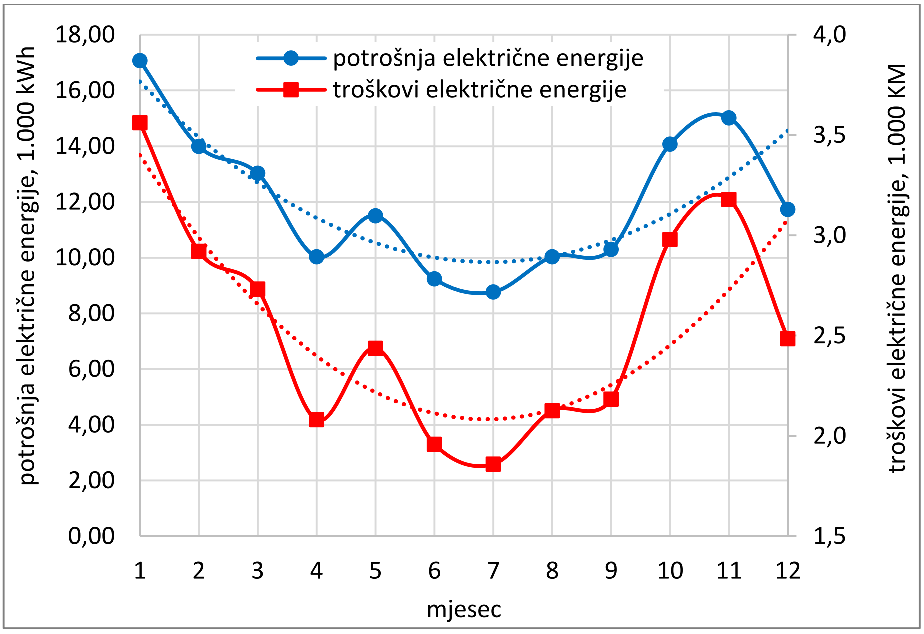


Image 48: Overview of total electric energy consumption and costs during 2019.

Consumption data are available for all three years, and it is noticeable that the consumption profile is relatively similar. Occasionally there are deviations that can be explained by changes in weather conditions. As can be seen, consumption is almost constant. Image 49 shows a diagram of total convertible marks (KM) and specific (Kf / kWh) electricity costs in the period from 2017 to 2019. As can be seen, the lowest price was 2017. godine, due to the lower electricity pricing. The electricity transmission tariff has remained constant in all three years.

.

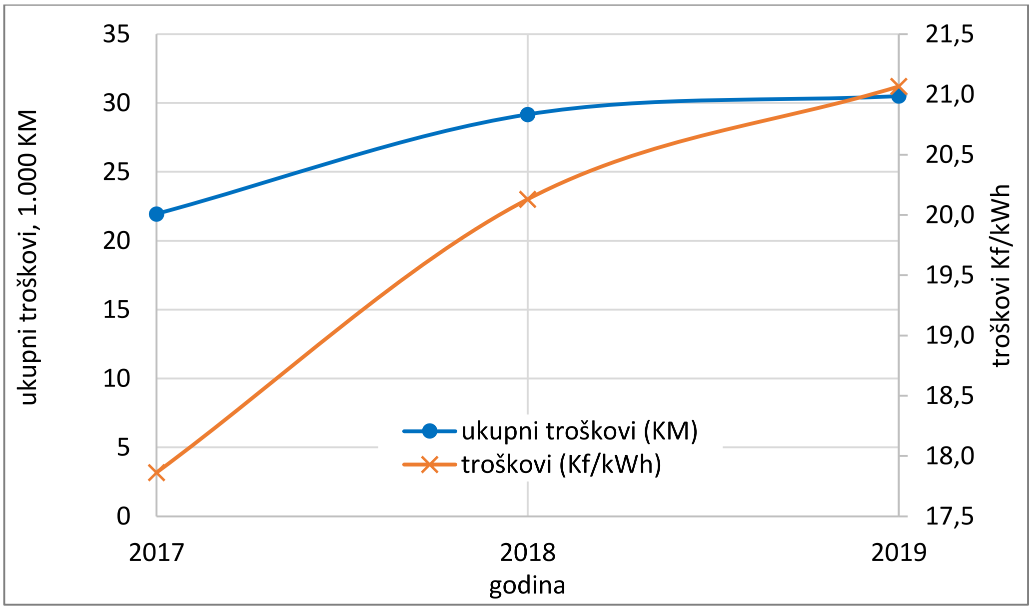


Image 49:Total and specific costs of electricity in the period from 2017 to 2019.

If some energy efficiency measures are implemented, both consumption and costs could fall. In the future we can expect a further price increase, which has happened in the last three years by electricity suppliers and distributors, it is to be expected that the price of kWh will continue to rise.

8 PHOTOMETRIC ANALYSIS

Photometric analysis was performed according to the defined requirements for the design of outdoor lighting, apropos the following norms: BAS CEN/TR 13201-1:2016 - Roadway lighting - Part 1: Selection of lighting classes, BAS EN 13201-2:2017 - Roadway lighting - Part 2: Performance requirements, BAS EN 13201-3:2017 - Roadway lighting - Part 3: Performance calculation, BAS EN 13201-4:2017 - Roadway lighting - Part 4: Methods of measuring roadway lighting characteristics, BAS EN 13201-5:2017 - Roadway lighting - Part 5: Indicators of energy performance in outdoor areas.

With medium brightness E_m , determined in lux (lx), it is necessary to calculate the uniform illuminance U_0, which is determined by the ratio of the minimum and average value of illuminance (E_{min}/E_m) and must be greater than or equal, specified in the norm. The budget also needs to determine glare control. The calculation of the level of illumination in a mathematical way is obtained by the lighting calculation. The designer is obliged to determine by calculation how many lamps are needed for a certain purpose and with which light sources to determine the level of illumination. The maintenance factor has a major role in the design of lighting, and the designer when calculating must take into account the reduction of the luminous flux of the lamp through the time calculated according to this relationi:

$$MF = LLMF \times LSF \times LMF \ (\times SMF) \quad \text{(vanjski prostori)} \qquad (4.)$$

MF maintenance factor, indicates how quickly the light intensity in a system decreases

LLMF lamp lumen maintenance factor, indicates the minimum luminous flux the luminaire has at the end of its useful life

LSF Lamp survival factor, indicates how the total failure of individual bulbs should be assessed

LMF Luminaire maintenance factor, indicates how the luminous flux of the luminaire decreases due to contamination

RMF room maintenance factor, indicates how the luminous flux decreases due to contamination of the room

SMF surface maintenance factor, takes into account the reduced reflection due to impurities on the illuminated surface (outdoor lighting)

During the creation a proposal and the optimal lighting solution, it is necessary to take into account the following basic principles:
- that the solution relies on the existing electrical installation,
- to propose a rational solution that satisfies the necessary lighting standards relating to a given category of roadway, to satisfiest he required levels of brightness with a minimum number of quality lamps,

- to reduce the maintenance of the lighting installation to a minimum by choosing the appropriate types of luminaires, without the need to clean the luminaires and replace the protectors, and
- to significantly reduce electricity consumption and CO2 emissions.

8.1 Light – based technology requirements and street classification

Light – based technology requirements and calculation must be corensponded with the required conditions of the roadway lighting class in accordance with the Standards BAS CEN/TR 13201-1:2016 - Roadway lighting - Part 1: Selection of lighting classes, BAS EN 13201-2:2017 - Roadway lighting - Part 2: Performance requirements, BAS EN 13201-3:2017 - Roadway lighting - Part 3: Performance calculation, , BAS EN 13201-4:2017 - Roadway lighting - Part 4: Methods of measuring roadway lighting characteristics, BAS EN 13201-5:2017 - Roadway lighting - Part 5: Energy performance indicators. The suggested lighting solution must satisfy all parameters prescribed by the competent legislation as well as the relevant standards, in accordance with the rules of public lighting design. The requirements for the calculation of lighting as well as the geometry of the road they cover and the method of calculation must be identical to those applied in the calculation of the reference condition. During selection of luminaires and light sources to optimize public lighting should only be used existing lighting poles and connection points, and the newly constructed condition must be based on the existing infrastructure (installation) so that the minimum power of the lamps satisfies the required levels of illumination. The lighting must be such as to significantly reduce the consumption of electric energy and maintenance, which should be accordance with the laws, guidelines and recommendations of BiH (Smjernice za projektovanje, građenje, održavanje i nadzor na putevima / FBiH i RS), and in accordance with the recommendations of International Commission on Illumination CIE1 - No. 88/90, No. 115/95, No.15/2-10, European Standard EN 13201-2 do 4 / EN 12464, and Summaries of EU Legislation CEN/TC 169/WC 6/9. The suggested light – based technology solution should be suitable and appropriate quality and performed in such a way that during operation it satisfies the projected lighting technical and electrical parameters (according to the attached Photometric calculation and technical specification).

In order to perform a Photometric calculation, it is primarily necessary to classify the roadway according to Table 1-Table 3 of the above standards. To determine the class of the street and for the Photometric calculation, input dana are required on: vehicle speed, number of street lines, average distance between light poles, light pole height, the ratio of the lamp mounted on the console, the inclination... The input data was collected by the consultant ZGI d.o.o. Mostar. The Photometric calculation and determination of the street class is define by the appropriate equations from the established norms. Nowadays, computer softwares are used for Photometric calculation and determination of street class. Photometric analysis and Photometric calculation for the subject study was done in Dialux software, and "Road Wizard" software was used to determine the street class. Ecological characteristics must also be taken into account during calculating and selecting luminaires. It is important to mention that mercury gas discharge lamps (VTF) as well as sodium lamps (NaVT) need to be dispatch and properly disposed of as well as existing lamps. Newly installed luminaires must satisfy all environmental requirements and standards. According to the BiH adjustment program to EU standards, and according to the EU directive on ecological design no. 2005/32 / ECU which require decommissioning inefficient forms of lighting, lighting that is not coordinate with the requirements of sustainable development and environmental protection, stop using certain types of light sources in 2012. for: fluorescent lamps 38 mm / 26mm, high-pressure lamps, low-pressure lamps, high-pressure lamps and metal-halide lamps. As a large number of such light sources are present within the existing public lighting system, this is another of the additional motives to approach the optimization of the public lighting system, replacement of existing light sources with LED sources.

In the course of proposing and analyzing measures for the reconstruction of the public lighting system, it is necessary to respect the following minimum parameters and project guidelines for the public lighting system:
- light efficiency of the light source: minimal 100 lm/W;
- correlated temperature of the shade of white light - maximum 4000 K;
- shade design - full cut off (straight) ili semi cut off (slightly rounded shading);
- bulb protection
- light sources lifetime - minimum 50.000 h;
- lamp ingress protection code IP66;
- impact protection - minimum IK08;
- input voltage 220-240V
- frequency of current 50 Hz;
- uninterrupted operation of the lamp in the temperature range of -20°C to +35°C;
- surge protection

Maximum permissible ULOR factor in accordance with the light pollution protection zone:
- E0, Areas of natural light, Nearby observatories, Dark sky parks, ULOR ≤ 0
- E1, Areas of dark landscape, Mostly unlit long-distance local roads, ULOR ≤ 0
- E2, Areas of low ambient light, habitat zones, ULOR ≤ 2,5
- E3, Areas of medium ambient light, Communication, industrial and trade zones, ULOR ≤ 5
- E4, Areas of high ambient light, Urban areas of commercial character with a high degree of night activity, ULOR ≤ 15

The process simulation is performed for characteristic sections of the public lighting system. The characteristic section is defined by the following parameters:
- classification of the illuminated surface in accordance with the norm BAS EN 13201;
- illumination zone (E0-E4);
- road width and number of lanes (W);
- width of the sidewalk (on the side of light pole, on the opposite sideof light pole);
- lightpole height – lamp height (H);
- average distance between light poles (S);
- console tine length (K)
- tine console inclination (N)
- light pole position (one-sided, two-sided, opposite);
- estimate the distance of the optical axis from the road edge (lamp suspension height) (O);
- road surface classification (R1, R2, R3 i R4).
- the type and power of the lamp illuminating the section

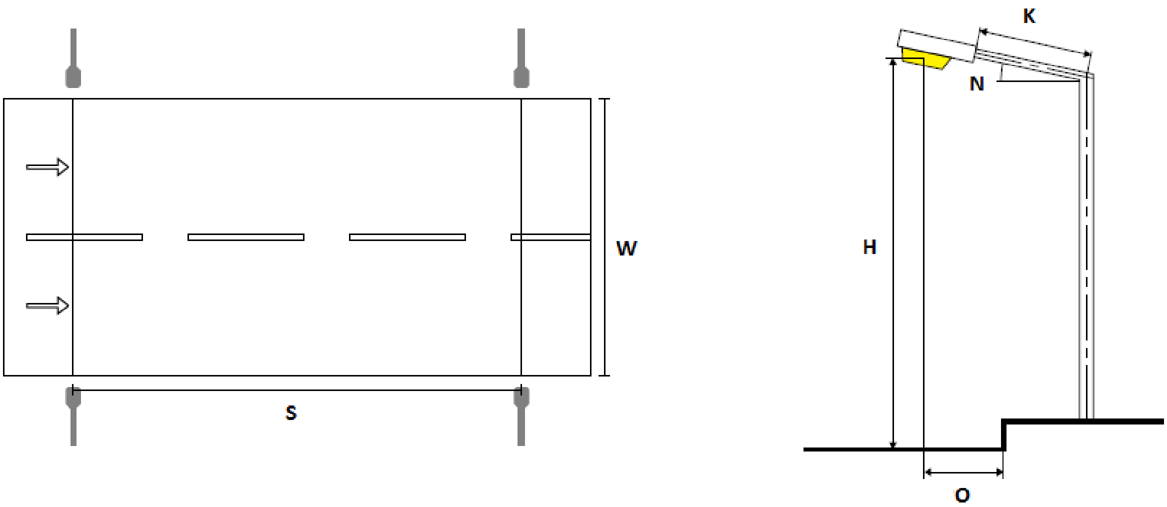


Image 50: Geometric display of characteristics parameters

Image 51 gives an example of Photometric calculation and determination of street class in software.

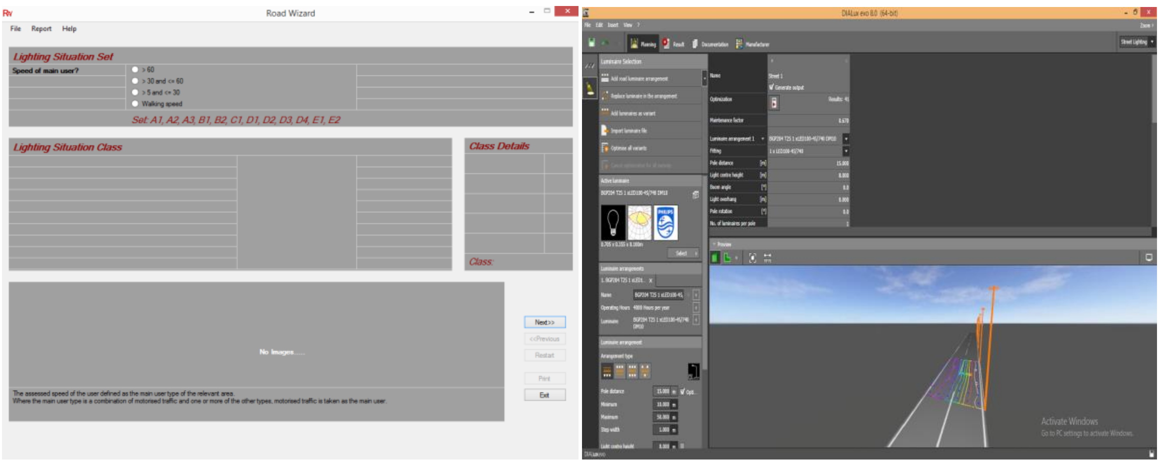


Image 51: Left - example of determining the class of the street in the software "Road Wizard", right - example of Photometric calculation of the road in the software "Dialux "

For the purposes of the study, a calculation of completely new lighting was made on all the above streets from the previous chapter, and it is attached: "Photometric calculation".

It was determined that the replacement of existing lamps will achieve significant savings, all in accordance with the required values of the norms. Therefore, it can be concluded that this way of lighting will be satisfied by the law and the standard of the prescribed value. Table 16 gives certain classes of streets with all the input data necessary for Photometric calculations. Image 53, Image 54, Image 55 and Image 56 show examples of a new lighting solution.

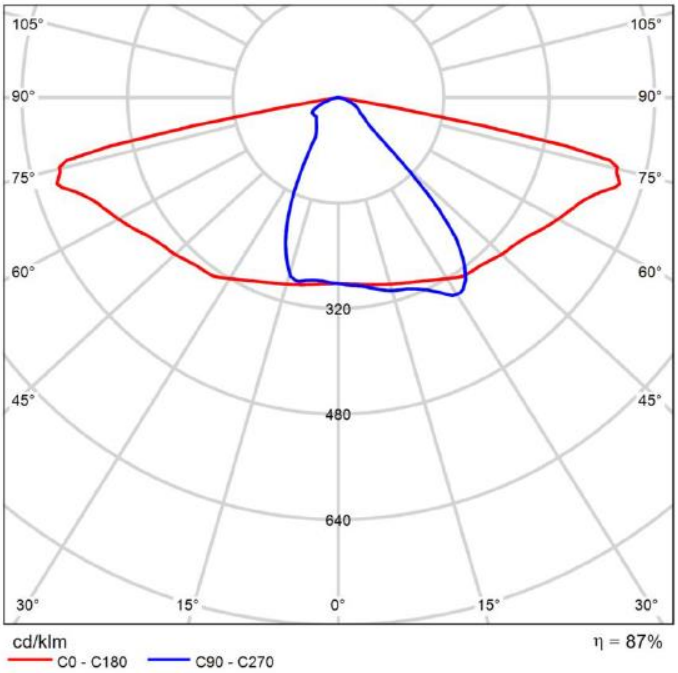


Image 52: Example of light emission calculation

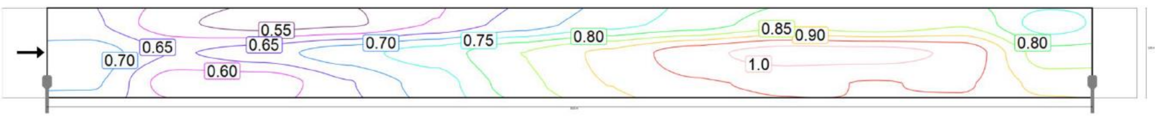


Image 53: Example of light intensity calculation and analysis results

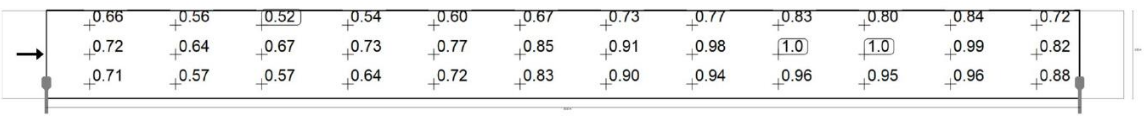


Image 54: Example of horizontal brightness calculation and analysis results

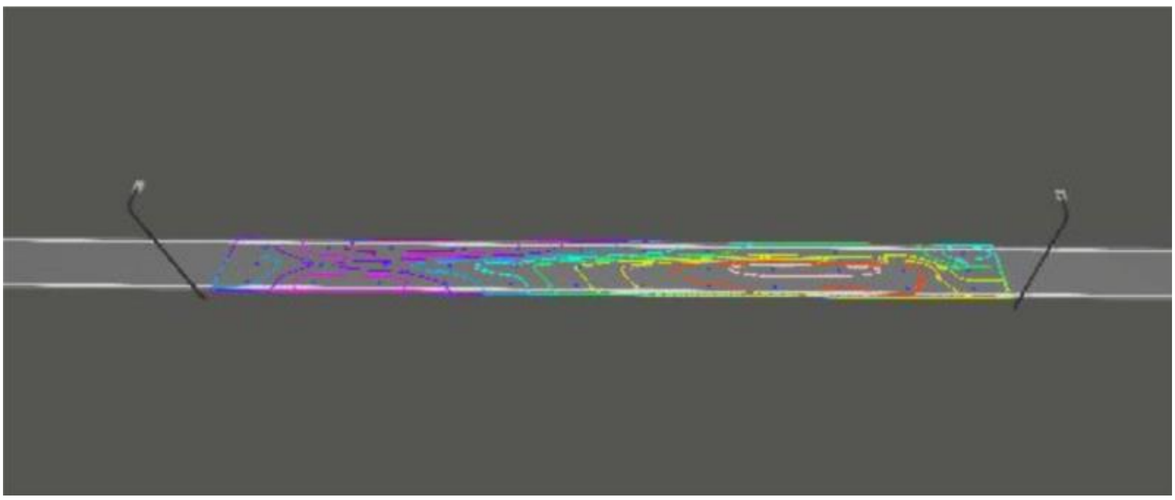


Image 55: Replacing the existing lighting with LED lighting

Ordinal No.	Street name	Movement speed (km/h)	Number of lane	Total road width (m)	Sidewalk width 1 and 2 (m)	Average distance between light poles (m)	Arrangement of light poles	Light pole height (m)	Lamp mounted on tine / console (yes/no)	Tine / console length (m)	Inclination of the tine / console (%)	The distance of the light pole from the road (m)	Type of traffic participants	Road class
1	Ulica Senada Mehdina Hodžića	50	2	6	1,2/1,2	30	one-sided	8	yes	0,3	5	1,5	mixed	M6
2	25. novembar ZAVNO-BiH	50	1	3	0/0	30	one-sided	8	yes	0,3	5	1	mixed	M4
3	Sarajevska ulica	50	1	3	0/0	30	one-sided	8	yes	0,3	10	1	mixed	M4
4	Sarajevska ulica	50	1	3	0/0	30	one-sided	8	yes	0,3	15	1	mixed	M4
5	Muhamed age Hadžiefendića	50	1	3	0/0	30	one-sided	8	yes	0,3	15	1	mixed	M4
6	Kapetana Hajre Mešića	50	1	3	0/0	30	one-sided	8	yes	0,3	10	1,5	mixed	M6
7	Naselje Palavre	50	1	3	0/0	30	one-sided	8	yes	0,3	10	1,5	mixed	M6

Table 11: An overview of specific classes

9 ANALYSIS AND SUGGESTION ON POSSIBLE MEASURES FOR ENHANCEMENT OF PUBLIC LIGHTING

Replacement of existing lamps with LED lamps is considered based on existing condition and Imagemetry budget. Lighting measures are meant for lowering consumption of lighting electric energy while leaving quality of lighting intact. Besides direct profits (energy consumption savings, or electric energy expenses), implementation of this measure, like better lighting conditions, after implementation of previously mentioned measure, lowering negative effects on environment could be expected.

In the following, possible measures of improving energy efficiency of the facility are described and analyzed in detail. The following scenarios are analyzed:

1. Replacement of existing lighting with LED technology,
2. Lighting management analysis.

9.1 Replacement of existing lighting with LED technology

Replacement of existing lighting with LED technology is considered by 1 on 1 principle using existing electrical installations and existing lampposts for installing LED lamps. Replacement of existing system refers only to energy, not efficient public lighting, therefore existing LED lamps are not a subject of replacement and budget, because it refers to already energy efficient public lighting.

Based on Imagemetry budget, replacement of existing energy, not efficient lamps with LED lamps is suggested. Lighting bodies overview is found in table 17.

Ordinal number	Street name	Lighting source type		Rad class
1	Ulica Senada Mehdina Hodžića	Type as Philips BGP307 LED40-4S/730 II DN10 D9 48/60S	Type 6	M6
2	25. novembar ZAVNO-BiH	Type as Philips BGP307 LED54-4S/730 II DN10 D9 48/60S	Type 5	M4
3	Sarajevska ulica	Type as Philips BGP307 LED40-4S/730 II DN10 D9 48/60S	Type 6	M4
4	Sarajevska ulica	Type as Philips BGP307 LED69-4S/730 II DN10 D9 48/60S	Type 4	M4
5	Muhamed age Hadžiefendića	Type as Philips BGP307 LED69-4S/730 II DN10 D9 48/60S	Type 4	M4
6	Kapetana Hajre Mešića	Type as kao Philips BGP307 LED40-4S/730 II DN10 D9 48/60S	Type 6	M6
7	Naselje Palavre	Type as Philips BGP307 LED40-4S/730 II DN10 D9 48/60S	Type 6	M6

Table 12: Lighting bodies overview for which energetic efficiency measures are suggested

Installed power overview (W) and total annual consumption (kWh) per particular lighting body types for which enhancement of lighting energetic efficiency as suggested measure is given in the following chapters by streets.

9.1.1 Electric energy consuption budget by applying replacement measures of existing lighting with LED technology

Electric energy consumption budget by applying replacement measures of existing lighting with LED technology was made by equation:

$$E_{m11}=(P_{isLED}+P_{gubLED})*T_{ref} \quad (5.)$$

$$E_{m11}=P_{refLED}*T_{ref} \quad (6.)$$

where the following is:
Em1 – standardized annual electric energy consumption for considered measures 1 – M1 (kWh/annually);
PisLED –LED lamp source power;
Pgub – ballast losses;
PrefLED – total reference power – Pis + Pgub;
Tref – reference value number of public lighting system working hours (4.100 hours) – according to BAS EN 15900:2011 standard.

Ballast losses of LED lighting is calculated into total lamp power and standardized annual budget for account consumption as $E_{m1}=P_{refLED}$*Tref, where into P_{refLED} , a lamp manufacturer included losses and lamp power sources shows as total power with ballast losses.

Installed power overview (W) and total annual consumption (kWh) by particular lighting bodies types for which is suggested energetic efficiency enhancement measure found in table 1.

Street name	Lighting source type	PrefLED – Total reference power	Quantity	(Tref) - Working period	(Em1) - Total standardized annual consumption
		(W)	(pcs)	(h/annually)	(kWh/annually)
Ulica Senada Mehdina Hodžića	Type as Philips BGP307 LED40-4S/730 II DN10 D9 48/60S	27	21	4100	2324,70
25. novembar ZAVNO-BiH	Type as Philips BGP307 LED54-4S/730 II DN10 D9 48/60S	37	6	4100	910,20
Sarajevska ulica	Type as Philips BGP307 LED40-4S/730 II DN10 D9 48/60S	27	6	4100	664,20
Sarajevska ulica	Type as Philips BGP307 LED69-4S/730 II DN10 D9 48/60S	43,5	2	4100	356,70
Muhamed age Hadžiefendića	Type as Philips BGP307 LED69-4S/730 II DN10 D9 48/60S	43,5	2	4100	356,70

Street name	Lighting source type	PrefLED – Total reference power	Quantity	(Tref) - Working period	(Em1) - Total standardized annual consumption
		(W)	(pcs)	(h/annually)	(kWh/annually)
Kapetana Hajre Mešića	Type as Philips BGP307 LED40-4S/730 II DN10 D9 48/60S	27	23	4100	2546,10
Naselje Palavre	Type as Philips BGP307 LED40-4S/730 II DN10 D9 48/60S	27	6	4100	664,20
Total (kWh/annualy)					7822,80
Broj izvora svjetla (pcs)					66
Specific annual consumption (kWh/per lighting source annually)					118,53

Table 13: Total electric energy consumption for public lighting after implementing measures

Imagemetry analysis confirmed that replacing existing lamps will achieve significant savings, but also that brightness will demand values accordant to BAS CEN/TR 13201-1:2016 standard – Traffic roads lighting – Part 1: Lighting class selection. Therefore, it can be concluded that with this way of lighting, as it's intensity, it will fulfill issued values as issued values by standards for degree of mechanical protection accordant to BAS EN 60598 – 1:2016 standard (or BAS EN 60529:2007) and for degree of impact resistance of the safeguard accordant to BAS EN 62262:2010 standard.

9.2 Public lighting managment analysis

Lighting managment plays an important role in electric lighting system providing turning lights on and off function with switches and/or setting light intensity with light intensity regulator. Managing lighting system can be managed manually or automatically. Manual managment cannot complete all requested lighting system functions. Considering a decision on turning on/off lights depends on a man, from a perspective of energetic efficiency, this way of managing is especially inconvenien.

In the last decades these functions are automatized and integrated into greater, more flexible systems. Accomplished results significantly expand possibilities of energy savings, flexibility, reliability, interoperability among devices of different manufacturers. In the Study there will be presented a possibility of electric energy savings through lighting system automatization. In the following, measures of automatic lighting managment will be analyzed and in two ways:

- Replacement of existing lamps with LED lamps with a possibility of dimming – where dimming is possible and will not have any effect on functionality and safety.
- Replacement of existing lamps with LED lamps with a possibility of dimming – where dimming is possible and will not have any effect on functionality and safety with built in central technical survilance.

9.2.1 Replacement of existing lamps with LED lamps with possibility of dimming – where dimming is possible and will not have any effect on functionality and safety

Replacement of existing lamps with LED lamps with a possibility of dimming – where dimming is possible and will not have any effect on functionality and safety is considered with built in autonomous dimmer (Dynadimmer). Dynadimmer (image 56) is a managing device which provides dimming luminous flux to 5 levels, in intervals set by an investor. It is designed for internal and external use. Optimized for built in box for public lighting which provides great energy savings with minor installation efforts. It can be mounted in any postion if the box has IP43 protection or higher. Wiring has to be accordant to BAS EN 60598 – 1:2016 standard.

Image 56: Autonomous dimmer overview (Dynadimmer)

Main advantages of using Dynadimmer are:

- Energy savings by dimming,
- Lighting lowered interferences,
- Very small sizes,
- Fits almost into any lamp,
- Software provides energy savings prognosis,
- Software easy to use,
- Possession of programmed regimes.

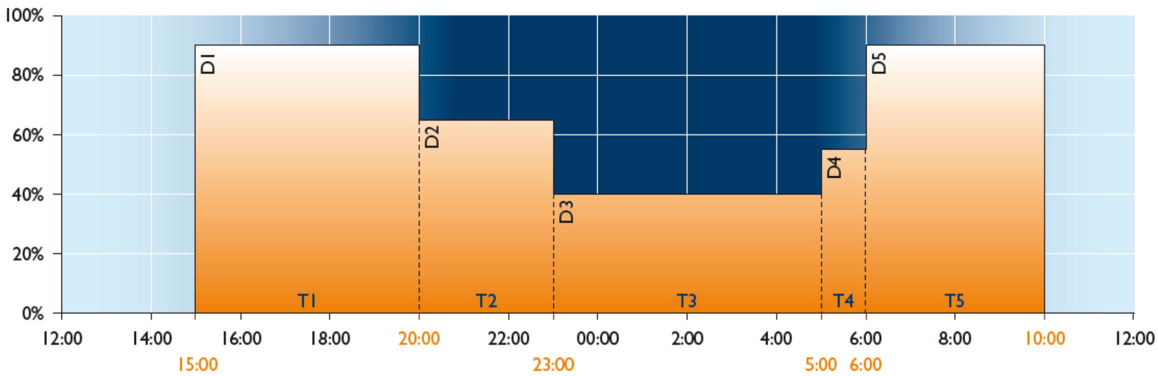


Image 57: Example of dimming luminous flux into 5 levels

For electric energy consumption budget by applying replacement measures of existing lamps with LED lamps with a possibility of dimming – where dimming is possible and will not have any effect on funcionality and safety, practice during winter and summer period system is implemented. Standardized annual electric energy consumption was done by equation:

$$E_{m2}=E_{m1} * k_{m2} \quad (7.)$$

Where the following is:

E_{m2} – standardized annual electric energy consumption for considered M2 – measure 2 (kWh/annually);

E_{m1} – standardized annual electric energy consumption from M1 – measure 1 (kWh/annually);

k_{m2} – coefficient applied from practice during winter and summer period – 0,223929

Used model can be ordered programmed and built in a lamp. Due to low price, architects usually order lamp with dynadimmer. These systems are most commonly used in an outside part of the city due to possibility of bad influence on functionality and safety. However, if taken into consideration if dimming luminous flux is always possible to reprogramme, these systems are also use din urban parts of the city.

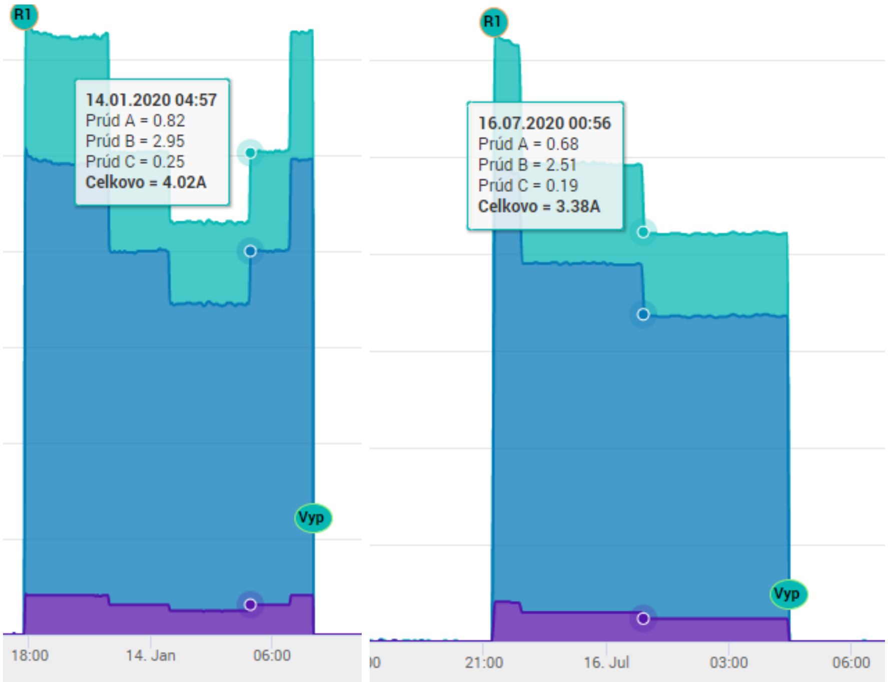


Image 58: Used model for dimming luminous flux for considered measure (left – diagram example for winter period, right – diagram example for summer period)

Table 14 shows a total electric energy consumption applying measures based on a considered model.

Street name	Lighting source type with built in dimming device	(Em2) - Total standardized annual consumption (kWh/annually)
Ulica Senada Mehdina Hodžića	Type as Philips BGP307 LED40-4S/730 II DN10 D9 48/60S – Dynadimmer DDR2 ugrađen u svjetiljci	1804,13
25. novembar ZAVNO-BiH	Type as Philips BGP307 LED54-4S/730 II DN10 D9 48/60S – Dynadimmer DDR2 ugrađen u svjetiljci	706,38
Sarajevska ulica	Type as Philips BGP307 LED40-4S/730 II DN10 D9 48/60S – Dynadimmer DDR2 ugrađen u svjetiljci	515,47
Sarajevska ulica	Type as Philips BGP307 LED69-4S/730 II DN10 D9 48/60S – Dynadimmer DDR2 ugrađen u svjetiljci	276,82
Muhamed age Hadžiefendića	Type as Philips BGP307 LED69-4S/730 II DN10 D9 48/60S – Dynadimmer DDR2 ugrađen u svjetiljci	276,82

Street name	Lighting source type with built in dimming device	(Em2) - Total standardized annual consumption (kWh/annually)
Kapetana Hajre Mešića	Type as Philips BGP307 LED40-4S/730 II DN10 D9 48/60S – Dynadimmer DDR2 ugrađen u svjetiljci	1975,95
Naselje Palavre	Type as Philips BGP307 LED40-4S/730 II DN10 D9 48/60S – Dynadimmer DDR2 ugrađen u svjetiljci	515,47
Total (kWh/annually)		6071,05
Lighting sources (pcs)		66,00
Specific annual consumption (kWh/per lighting source annually)		91,99

Table 14: Total electric energy consumption for public lighting after applying measures with LED lighting and autonomous dimmer

9.2.2 Replacement of existing lamps with LED lamps with a possibility of dimming – where dimming is possible and not will not have any effect on functionality and safety with built in central technical survilance

Ugradnja tehničkog nadzora poznat kao "telemenadžment" je automatizovani digitalni sistem upravljanja koji se sastoji od nekoliko podsistema. Telemenadžment je sistem koji omogućava daljinsku dijagnostiku, prikupljanje i obradu podataka svake pojedinačne svjetiljke ili na jedan krug svjetiljki (npr. do 200 svjetiljki), kao i upotrebu istih sa ciljem daljnje regulacije (uključenje/isključenje svjetiljki, dimmanje i dr.). Telemenadžemntom se omogućava detekcija kvara na svjetiljci, problemi u napajanju i sl., dvosmjerna komunikacija između svjetiljke i upravljačkog modula i postoji povratna informacija o statusu pojedinačne svjetiljke. Sistem se sastoji od 3 glavna elementa:
- Gateway-a,
- kontroler-a,
- upravljački softver u novije vrijeme „Cloud“.

Building techincal survilance known as ''telemanagment'' is an automatized digital managment system consisting of few subsystems. Telemanagment is a system which provides remote diagnostics, collecting and processing data for each lamp or a full circle of lamps (exp. to 200 lamps), as use of the same ones with purpose of further regulation (turning lamps on/off, dimming and other). Telemanagment provides malfunction detection on a lamp, powering problems and etc., two-way communication between a lamp and managment module where exists a feedback on a particular lamp status. A system consists of 3 main elements:
- gateway,
- controller,
- managment software, recently ''Cloud''.

Remote managment and control system of public lighting (telemanagment) is concieved as a network system with a few command levels. User interface is accessable using mobile phone with

GPRS connection and correct IP address, also using Internet accessing on a correct Web address and registration (WAN or LAN address). Server ha san applicating software in charge of whole managment system, collecting, analyzing and processing data. From this managment centre is possible to simultaneously manage more public lighting systems using segment controllers which is most commonly found on poles. Communication is two-way operative and it is done through TCP/IP protocol (GPS, GPRS, Edge, 3G, DSČ, ADSL, technologies, as existing LAN). This system presents general system ''Smart city'' in which is possible not to only control every lamp and consumption but to also collect remaining informations as number of traffic participants based on regulating traffic lights and other traffic electronic signs and other. Image 60, Image 61, Image 54 and Image 62 show an interface overview, using software with possibilities and settings.

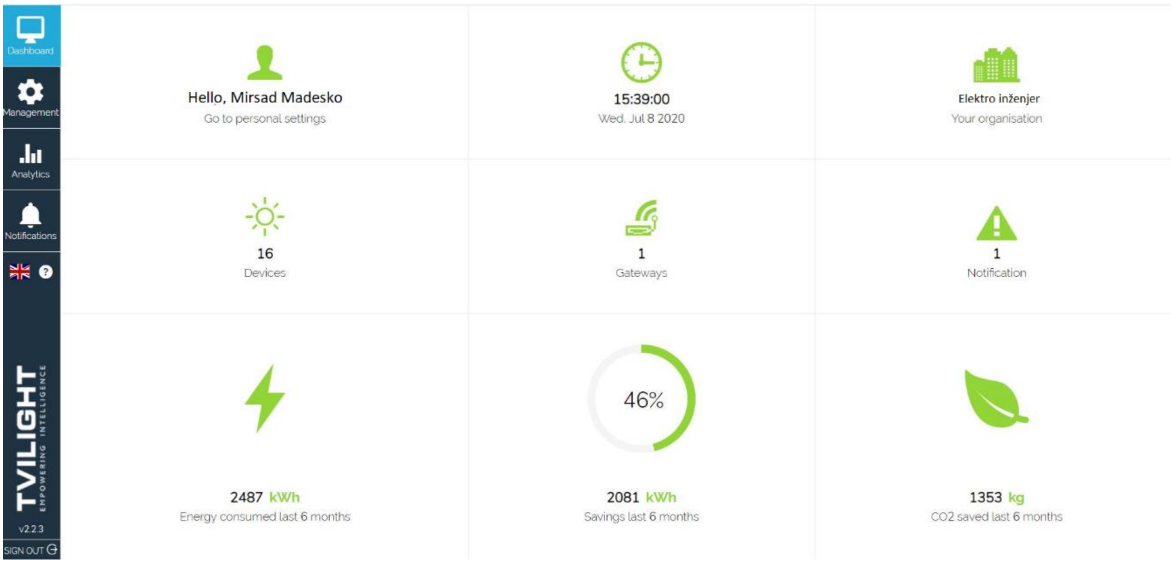


Image 59: Software interface overview

Image 60: Conducting analysis for electric energy consumption example

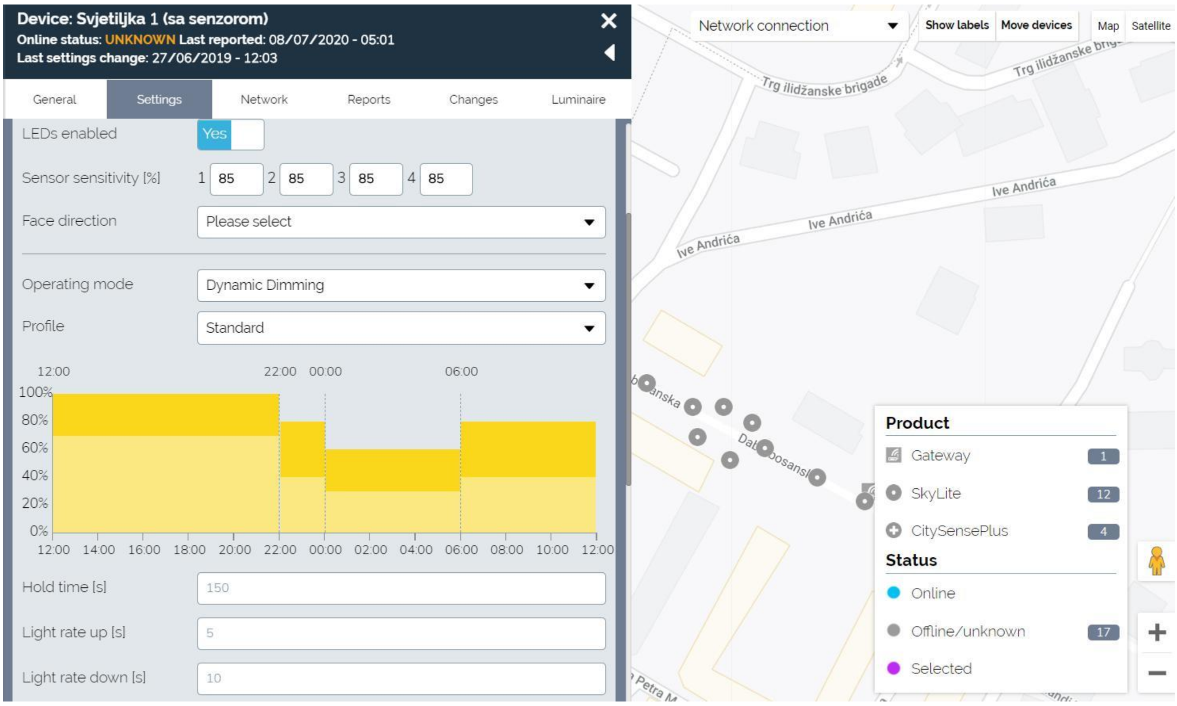


Image 61: Software settings example

For electric energy consumption budget by applying replacement measures of existing lamps with LED lamps with a possibility of dimming – where dimming is possible and will not have any effect on funcionality and safety with built in techinical survilance is an applied practice system. Standardized annual electric energy consumption was made by:

$$E_{m3}=E_{m1} * k_{m3} \tag{8.}$$

where the following is:

E_{m3} – standardized annual electric energy consumption for considered M2 – measure 2 (kWh/annually);

E_{m1} – standardized annual electric energy consumption from M1 – measure 1 (kWh/annually);

k_{m3} – coefficient applied from winter and summer period practice – 0,374

Pogreška! Izvor r gives a description of a decision with automatized lighting way of work. Electric energy savings move up to 40% - achieved by combination of 3 mentioned principles:

1. maintaining constant luminous flux installation level – savings up to 10%,
2. lighting power source regulation – savings up to 25%,
3. regulation depends on traffic density – savings up to 40%.

Measure name	Quantity	Wireless	Control room operable	Consumption (kWh/annually)
Telemanagment system installation	set	Yes	Yes - Cloud	4897,07
Ukupno (kWh/god)				4897,07
Total (kWh/annually)				66
Lighting sources (pcs)				74,20

Specific annual consumption (kWh/per lighting source annually)	

Table 15: Total electric energy consumption for public lighting after implementing measures with technical survilance

10 ANALYSIS OF ENERGY AND ECONOMIC EFFECTS OF THE SUGGESTED MEASURES

10.1 Quantitative analysis of energy and economizing

In this chapter, an analysis of the economic savings of the measures suggested in the previous chapter is performed.

10.1.1 Energy savings analysis

10.1.1.1 Analysis of energy savings by replacing existing lightining with LED

The calculation of electricity that would be needed after the implementation of this measure was performed, and the results are found in table 21 for each individual roadway. The annual number of working hours is 4100 according to the standard BAS CEN / TR 13201-1: 2016.

Ordinal No.	Street Name	(Em) - Total standardized annual consumption	(Em1) - Total standardized annual consumption	Annual savings	Quantity	Annual savings per lamp
		(kWh/annually)	(kWh/annually)	(kWh/annually)	(pieces)	(KM/annually)
1	Ulica Senada Mehdina Hodžića	3465,53	2324,70	1140,83	21	54,33
2	25. novembar ZAVNO-BiH	3536,25	910,20	2626,05	6	437,68
3	Sarajevska ulica	990,15	664,20	325,95	6	54,33
4	Sarajevska ulica	1414,50	356,70	1057,80	2	528,90
5	Muhamed age Hadžiefendića	1414,50	356,70	1057,80	2	528,90
6	Kapetana Hajre Mešića	3795,58	2546,10	1249,48	23	54,33
7	Naselje Palavre	990,15	664,20	325,95	6	54,33
TOTAL		**15606,65**	**7822,80**	**7783,85**	**66**	**117,94**

Table 16: Energy savings for lighting after replacing existing lighting with LED

10.1.1.2 Energy savings analysis by replacing existing luminaires with dimmable LED luminaires – where dimming is possible and will not affect functionality and safety

The calculation of electricity that would be needed after the implementation of this measure was performed, and the results are found in table 22.

Ordinal No.	Street name	(Em1) - Total standardized annual consumption	(Em2) - Total standardized annual consumption	Annual savings	Quantity	Annual savings per lamp
		(kWh/annually)	(kWh/annually)	(kWh/annually)	(pieces)	(KM/annually)
1	Ulica Senada Mehdina Hodžića	2324,70	2115,48	209,22	21	9,96
2	25. novembar ZAVNO-BiH	910,20	810,08	100,12	6	16,69
3	Sarajevska ulica	664,20	604,42	59,78	6	9,96
4	Sarajevska ulica	356,70	310,33	46,37	2	23,19
5	Muhamed age Hadžiefendića	356,70	310,33	46,37	2	23,19
6	Kapetana Hajre Mešića	2546,10	2316,95	229,15	23	9,96
7	Naselje Palavre	664,20	604,42	59,78	6	9,96
TOTAL		**7822,80**	**7072,01**	**750,79**	**66**	**11,38**

Table 17: Energy savings for lighting after replacing existing LED lighting with Dynadimmer

10.1.1.3 Analysis of energy savings by replacing existing luminaires with dimmable LED luminaires – where dimming is possible and will not affect functionality and safety with the installation of central technical supervision

Table 18 shows the total realized electricitysavings by installing a telemanagement systems.

Measure name	(Em1) - Total standardized annual consumption	(Em3) - Total standardized annual consumption	Annual savings	Quantity	Annual savings per lamp
	(kWh/annually)	(kWh/annually)	(kWh/annually)	(pieces)	(KM/annually)
Installation of telemanagement system	7822,80	4897,07	2925,73	66	44,33

Table 18: Calculation of potential electrcity savings by installing a telemanagement system

10.1.2 Economic analysis

10.1.2.1 Analysis of economic savings of replacing existing lighting with LED

The calculation of electricity costs that would be after the implementation of this measure has been performed, and the results are found in table 24.

Ordinal No.	Street name	Costs according to energy consumption Em	Costs according to energy consumption Em1	Annual savings	Quantity	Annual savings per lamp
		(kWh/annually)	(kWh/annually)	(kWh/annually)	(pieces)	(KM/annually)
1	Ulica Senada Mehdina Hodžića	577,09	445,18	131,91	21	6,28
2	25. novembar ZAVNO-BiH	588,86	174,30	414,56	6	69,09
3	Sarajevska ulica	164,88	127,19	37,69	6	6,28
4	Sarajevska ulica	235,55	68,31	167,24	2	83,62
5	Muhamed age Hadžiefendića	235,55	68,31	167,24	2	83,62
6	Kapetana Hajre Mešića	632,05	487,58	144,47	23	6,28
7	Naselje Palavre	164,88	127,19	37,69	6	6,28
TOTAL		**2598,85**	**1498,07**	**1100,78**	**66**	**16,68**

TOTAL (€ / a n n) u a	**1328,77**	**765,95**	**562,82**		**8,53**

Table 19: Cost calculation after replacing existing lighting with LED

10.1.2.2 Analysis of economic savings by replacing existing luminaries with dimmable LED luminaires – where dimming is possible and will not affect functionality and safety

The calculation of electricity costs that would be after the implementation of this measure has been performed, and the results are found in table 25.

Ordinal No.	Street name	Costs according to energy consumption Em1	Costs according to energy consumption Em2	Annual savings	Quantity	Annual savings per lamp
		(KM/annually)	(KM/annually)	(KM/annually)	(pieces)	(KM/annually)
1	Ulica Senada Mehdina Hodžića	445,18	345,49	99,69	21	4,75
2	25. novembar ZAVNO-BiH	174,30	135,27	39,03	6	6,51
3	Sarajevska ulica	127,19	98,71	28,48	6	4,75
4	Sarajevska ulica	68,31	53,01	15,30	2	7,65
5	Muhamed age Hadžiefendića	68,31	53,01	15,30	2	7,65
6	Kapetana Hajre Mešića	487,58	378,40	109,18	23	4,75
7	Naselje Palavre	127,19	98,71	28,48	6	4,75
TOTAL		**1498,07**	**1162,61**	**335,46**	**66**	**5,08**
TOTAL (EUR/annually)		**765,95**	**594,43**	**171,52**		**2,60**

Tabela 20: Cost calculation after installing the Dynadimmer system

10.1.2.3 Analysis of economic savings by replacing existing luminaires with dimmable LED luminaires – where dimming is possible and will not affect fuctionality and safety with teh installation of central technical supervision

The calculation of electricity costs that would be after the implementation of this measure was performed, and the results are found in table 26.

Measure name	Costs according to energy consumption Em1	Costs according to energy consumption Em3	Annual savings	Qua ntit y	Annual savings per lamp

	(KM/annually)	(KM/annually)	(KM/annually)	(pieces)	(KM/annually)
Installation of telemanagement system	1498,07	937,79	560,28	66	8,49
	(€/annually)	(€/annually)	(€/annually)	(pieces)	(€/annually)
	765,95	479,48	286,47	66	4,34

Table 21: Calculation of costs after installing a telemanagement system

11 FINANCIAL ANALYSIS

In general, implementation of energy efficiency measures on public lighting systems leads to the realization of different positive effects. In technical sense, it leads to the optimization of light capacities, reduction of electricity spending, releasing capacities for further expansion of public lighting system, and a number of other positive effects.
Mentioned technical improvements, consequently, lead to the improvement of financial state in companies managing public lighting systems, as well as its users.
Within technical analysis that was done with the aim to find the best way to improve public lighting system in the Municipality of Kalesija, the implementation of four energy efficiency measures was discussed:

- Measure 0 – Preparation works/dismantlement of existing light fixtures;
- Measure 1 – Procurement and installation of new LED light bulbs;
- Measure 2 – Procurement and installation of pre-junction machine for autonomous wireless damping of the light flow;
- Measure 3 – Procurement and installation of telemanagement.

Financial effects of the implementation differentiate for each of the mentioned measures individually, as well as for the combination of two or more measures. Three scenarios of the energy efficiency were defined in order to choose measures or combination of measures that will lead to the best financial effects, and they are:

- Scenario 1 – includes procurement and installation of new LED light bulbs;
- Scenario 2 – includes procurement and installation of new LED light bulbs, and procurement and installment of pre-junction machine for autonomous wireless damping of the light flow; the telemanagement.

Analysis of the financial validity of above mentioned scenarios was done on the basis of projections of a money flow for every scenario for 15-years period (2020-2035) which served as the basis to calculate financial indicators: (i) Internal Rate of Return (IRR), (ii) Net Present Value (NPV), (iii) Simple Payback Period, and (iv) Discounted Payback Period.

It is important to mention that the amount of investment cost for proposed measures, and amounts of operational costs and income are showed without the value added tax (VAT). Considering these amounts, it is expected that an implementer of the measures, whether it is an unit of local management or the third legal entity, will be registered VAT taxpayer and in that way they will have the right to VAT deduction.
Money savings that will be achieved as a result of the implementation of a certain scenario are seen as the money inflow, while an investment cost and maintenance cost for the certain scenario are seen as the money outflow. Also, the discount rate of 5% was used within the financial analysis of the considered scenarios.

11.1 Investment cost (CAPEX)

Table 22 gives the overview of the investment cost for the considered scenarios.

ITEM	AMOUNT	
Measures	KM	EUR
M0 - Preparation works/dismantlement of existing light fixtures	1.320	675
M1 - Procurement and installation of new LED light bulbs	28.000	14.316
M2 - Procurement and installation of pre-junction machine for autonomous wireless damping of the light flow	1.782	911
M3 – Procurement and installation of telemanagement	35.782	18.295
Scenarios		
Scenario 1 (M0+M1)	29.320	14.991
Scenario 2 (M0+M1+M2)	31.102	15.902
Scenario 3 (M0+M1+M3)	65.102	33.286

Table 22: Investment cost according to scenarios

It is assumed that the investments in the considered scenarios will be implemented within 2020, and that the Municipality of Kalesija will begin to realize financial effects of the investment implementation in 2021.

11.2 Financial savings

Financial savings that will be a result of the implementation of the considered scenarios are counted on the basis of the current spending of the electricity for the public lighting in the Municipality of Kalesija, and the spending of the electricity after the implementation of the considered scenarios. In the analysis was used the price of the electricity from the chapter Analysis of Energy Cost and Predictions of Future Spending worth 0,1915 KM/kWh or 0,0979 EUR/kWh.Table 23 gives the overview of the financial savings according to the considered scenario.

ITEM	UNIT	AMOUNT
Existing considered spending of electricity	kWh/year	15.607
Spending of electricity according to the scenarios		
Scenario 1	kWh/year	7.823
Scenario 2	kWh/year	6.071
Scenario 3	kWh/year	4.897
Electricity saving		
Scenario 1	kWh/year	7.784
Scenario 2	kWh/year	9.536
Scenario 3	kWh/year	10.710
Electricity price	KM/kWh	0,1915
	EUR/kWh	0,0979
Financial savings		
Scenario 1	KM/year	1.490,61
	EUR/year	762,14
Scenario 2	KM/year	1.826,07
	EUR/year	933,65
Scenario 3	KM/year	2.050,88
	EUR/year	1.048,60

Table 23: Financial savings

11.3 Operational cost (OPEX)

11.3.1 Maintenance cost

Equipment that will be installed within the considered scenarios will have five-year guarantee period, which implies there will no maintenance cost in the period 2020-2025. After 2025, it is assumed that the maintenance cost will annually amount to 1% of the amount of the investment costs for given scenario, which in addition to regular maintenance cost include and cost of necessary licenses. The table 29 gives the overview of the maintenance according to scenarios.

Scenario	UNIT	
	KM	EUR
Scenario 1	293,20	149,91
Scenario 2	311,02	159,02
Scenario 3	651,02	332,86

Table 24: Maintenance cost

11.4 Money flow projection

On the basis of previously mentioned investment cost and maintenance cost, and expected financial savings, a projection of money flow for each scenario was done for the period 2020-2035. The table 30, the table 31 and the table 32 give the overview of money flow for each considered scenarios and values of IRR, NPV, payback period and discounted payback period (DPP).

ITEM	UNIT	AMOUNT	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
CASH INFLOW																							
Financial savings	KM			2.990,61	2.990,61	2.990,61	2.990,61	2.990,61	2.990,61	2.990,61	2.990,61	2.990,61	2.990,61	2.990,61	2.990,61	2.990,61	2.990,61	2.990,61	2.990,61	2.990,61	2.990,61	2.990,61	2.990,61
CASH OUTFLOW																							
Maitenance costs	KM		0	0	0	0	0	0	308	308	308	308	308	308	308	308	308	308	308	308	308	308	
Investment costs	KM		29.320	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
NET CASH FLOW	**KM**		**-29.320**	**2.991**	**2.991**	**2.991**	**2.991**	**2.991**	**2.683**	**2.683**	**2.683**	**2.683**	**2.683**	**2.683**	**2.683**	**2.683**	**2.683**	**2.683**	**2.683**	**2.683**	**2.683**	**2.683**	**2.991**
CUMULATIVE CASH FLOW	**KM**		**-29.320**	**-26.329**	**-23.339**	**-20.348**	**-17.358**	**-14.367**	**-11.684**	**-9.001**	**-6.319**	**-3.636**	**-953**	**1.730**	**4.412**	**7.095**	**9.778**	**12.461**	**15.143**	**17.826**	**20.509**	**23.191**	**26.182**
IRR	**%**	**5%**																					
NPV	**KM**	**-141,13**																					
Discontinued payback period	**year**	**16**																					
Payback period	**year**	**11**																					

ITEM	UNIT	AMOUNT	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
CASH INFLOW																							
Financial savings	EUR		0	1529,0732	1529,0732	1529,0732	1529,0732	1529,0732	1529,0732	1529,0732	1529,0732	1529,0732	1529,0732	1529,0732	1529,0732	1529,0732	1529,0732	1529,0732	1529,0732	1529,0732	1529,0732	1529,0732	1529,0732
CASH OUTFLOW																							
Maintenance costs	EUR		0	0	0	0	0	0	157	157	157	157	157	157	157	157	157	157	157	157	157	157	0
Investment costs	EUR		14.991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NET CASH FLOW	**EUR**		**-14.991**	**1.529**	**1.529**	**1.529**	**1.529**	**1.529**	**1.372**	**1.372**	**1.372**	**1.372**	**1.372**	**1.372**	**1.372**	**1.372**	**1.372**	**1.372**	**1.372**	**1.372**	**1.372**	**1.372**	**1.529**
CUMULATIVE CASH FLOW	**EUR**		**-14.991**	**-13.462**	**-11.933**	**-10.404**	**-8.875**	**-7.346**	**-5.974**	**-4.602**	**-3.231**	**-1.859**	**-487**	**884**	**2.256**	**3.628**	**4.999**	**6.371**	**7.743**	**9.114**	**10.486**	**11.858**	**13.387**
IRR	**%**	**5%**																					
NPV	**EUR**	**-72,16**																					
Discontinued payback period	**year**	**16**																					
Payback period	**year**	**11**																					

Table 25: Cash flow for Scenario 1

ITEM	UNIT	AMOUNT	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
CASH INFLOW																							
Financial savings	KM			3.326,07	3.326,07	3.326,07	3.326,07	3.326,07	3.326,07	3.326,07	3.326,07	3.326,07	3.326,07	3.326,07	3.326,07	3.326,07	3.326,07	3.326,07	3.326,07	3.326,07	3.326,07	3.326,07	3.326,07
CASH OUTFLOW																							
Maitenance costs	KM		0	0	0	0	0	0	327	327	327	327	327	327	327	327	327	327	327	327	327	327	327
Investment costs	KM		31.102	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NET CASH FLOW	**KM**		**-31.102**	**3.326**	**3.326**	**3.326**	**3.326**	**3.326**	**2.999**	**2.999**	**2.999**	**2.999**	**2.999**	**2.999**	**2.999**	**2.999**	**2.999**	**2.999**	**2.999**	**2.999**	**2.999**	**2.999**	**2.999**
CUMULATIVE CASH FLOW	**KM**		**-31.102**	**-27.776**	**-24.450**	**-21.124**	**-17.798**	**-14.472**	**-11.472**	**-8.473**	**-5.473**	**-2.474**	**526**	**3.525**	**6.525**	**9.524**	**12.524**	**15.523**	**18.523**	**21.522**	**24.522**	**27.521**	**30.521**
IRR	**%**	**6%**																					
NPV	**KM**	**1.445,63**																					
Discontinued payback period	**year**	**14**																					
Payback period	**year**	**10**																					

ITEM	UNIT	AMOUNT	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
CASH INFLOW																							
Financial savings	EUR		0	1700,5914	1700,5914	1700,5914	1700,5914	1700,5914	1700,5914	1700,5914	1700,5914	1700,5914	1700,5914	1700,5914	1700,5914	1700,5914	1700,5914	1700,5914	1700,5914	1700,5914	1700,5914	1700,5914	1700,5914
CASH OUTFLOW																							
Maintenance costs	EUR		0	0	0	0	0	0	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167
Investment costs	EUR		15.902	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NET CASH FLOW	**EUR**		**-15.902**	**1.701**	**1.701**	**1.701**	**1.701**	**1.701**	**1.534**	**1.534**	**1.534**	**1.534**	**1.534**	**1.534**	**1.534**	**1.534**	**1.534**	**1.534**	**1.534**	**1.534**	**1.534**	**1.534**	**1.534**
CUMULATIVE CASH FLOW	**EUR**		**-15.902**	**-14.202**	**-12.501**	**-10.800**	**-9.100**	**-7.399**	**-5.866**	**-4.332**	**-2.798**	**-1.265**	**269**	**1.802**	**3.336**	**4.870**	**6.403**	**7.937**	**9.471**	**11.004**	**12.538**	**14.071**	**15.605**
IRR	**%**	**6%**																					
NPV	**EUR**	**739,14**																					
Discontinued payback period	**year**	**14**																					
Payback period	**year**	**10**																					

Table 26: Cash flow for Scenario 2

ITEM	UNIT	AMOUNT	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
CASH INFLOW																							
Financial savings	KM			3.550,88	3.550,88	3.550,88	3.550,88	3.550,88	3.550,88	3.550,88	3.550,88	3.550,88	3.550,88	3.550,88	3.550,88	3.550,88	3.550,88	3.550,88	3.550,88	3.550,88	3.550,88	3.550,88	3.550,88
CASH OOUTFLOW																							
Maintenance costs	KM		0	0	0	0	0	0	684	684	684	684	684	684	684	684	684	684	684	684	684	684	684
Investment costs	KM		65.102	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NET CASH FLOW	**KM**		**-65.102**	**3.551**	**3.551**	**3.551**	**3.551**	**3.551**	**2.867**	**2.867**	**2.867**	**2.867**	**2.867**	**2.867**	**2.867**	**2.867**	**2.867**	**2.867**	**2.867**	**2.867**	**2.867**	**2.867**	**2.867**
CUMULATIVE CASH FLOW	**KM**		**-65.102**	**-61.551**	**-58.000**	**-54.449**	**-50.898**	**-47.347**	**-44.480**	**-41.613**	**-38.745**	**-35.878**	**-33.011**	**-30.143**	**-27.276**	**-24.409**	**-21.541**	**-18.674**	**-15.807**	**-12.939**	**-10.072**	**-7.205**	**-4.337**
IRR	**%**	**-4%**																					
NPV	**KM**	**-32.380,34**																					
Discontinued payback period	**year**	**21**																					
Payback period	**year**	**21**																					

ITEM	UNIT	AMOUNT	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
CASH INFLOW																							
Financial savings	EUR		0	1815,5382	1815,5382	1815,5382	1815,5382	1815,5382	1815,5382	1815,5382	1815,5382	1815,5382	1815,5382	1815,5382	1815,5382	1815,5382	1815,5382	1815,5382	1815,5382	1815,5382	1815,5382	1815,5382	1815,5382
CASH OUTFLOW																							
Maintenance costs	EUR		0	0	0	0	0	0	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350
Investment costs	EUR		33.286	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NET CASH FLOW	**EUR**		**-33.286**	**1.816**	**1.816**	**1.816**	**1.816**	**1.816**	**1.466**	**1.466**	**1.466**	**1.466**	**1.466**	**1.466**	**1.466**	**1.466**	**1.466**	**1.466**	**1.466**	**1.466**	**1.466**	**1.466**	**1.466**
CUULATIVE CASH FLOW	**EUR**		**-33.286**	**-31.470**	**-29.655**	**-27.839**	**-26.024**	**-24.208**	**-22.742**	**-21.276**	**-19.810**	**-18.344**	**-16.878**	**-15.412**	**-13.946**	**-12.480**	**-11.014**	**-9.548**	**-8.082**	**-6.616**	**-5.150**	**-3.684**	**-2.218**
IRR	**%**	**-4%**																					
NPV	**EUR**	**-16.555,81**																					
Discontinued payback period	**year**	**21**																					
Payback period	**year**	**21**																					

Table 27: Cash flow for Scenario 3

Scenario 2 has acceptable financial indicators. The value of IRR for the Scenario 1 is 5% and for the Scenario 2 it is 6%.
Payback period for the Scenario 1 is 11 years, and the discounted payback period is 16 years, while for the Scenario 2 the payback period is 10 years, and discounted payback period is 14 years.

NPV in the Scenario 1 is -141,13 KM or -72,16 EUR, and in the Scenario 2 it is 1445,63 KM or 739,14 EUR.

In the Scenario 3, the value of financial indicators is unfavorable, with IRR being -4%, and payback period 21 years and discounted payback period 21 years.

Taking into consideration already mentioned it is recommended that the Municipality of Kalesija implements energy efficiency measures proposed within the **Scenario 2**, considering it will lead towards the realization of the best financial effects compared to the invested funds in their implementation.

11.5 Analysis of funding sources

The Municipality of Kalesija has at its disposal several different models and sources of financing for the implementation of proposed measures on the public lighting system.

First, it is necessary to consider **own financial capability of the Municipality of Kalesija** for the implementation of mentioned measures. According to the information on the budget of the Municipality of Kalesija for 2018, 2019 and 2020, the Municipality of Kalesija is allocating on average 2.3 million KM annually for capital projects. The investment in the proposed energy efficiency measures is 8.000 KM, which is 0,3% of the amount of money allocated for capital projects from the budget of the Municipality of Kalesija in the mentioned period. Therefore, it can be concluded there is financial capacity of the Municipality of Kalesija for the implementation of the proposed energy efficiency measures from their own funds.
Additional possibility of financing the implementation of the proposed energy efficiency measures is **by a loan**. The Municipality of Kalesija can provide loan funds with local commercial banks or international financial institutions (EBRD, WB, etc.).
The third option for financing the energy efficiency measures is through public-private partnership (PPP) that is becoming more frequent practice in the realization of many public investments. PPP model can be attractive both for public and private sector. Private financing can support increase of investments in projects of social interest without additional borrowing of the public sector. At the same time, better management system in the private sector and its capacities leading towards innovation can lead to better efficiency in the implementation and management of different projects of the social interest.
On the other side, the interest of the private sector is present primarily for (financially) cost effective projects that have the possibility of commercialization. Moreover, including private sector via PPP model can lead to the realization of additional benefits for the public sector, such as:

- Faster implementation of projects;
- Reduction of implementation and project management costs;
- Creating additional values and additional revenues.

In accordance with the Law on public-private partnership in the Canton of Tuzla, the Municipality of Kalesija has the possibility to include private sector in the improvement of public lighting system through two models of PPP:

- Basic model – private partner would have an obligation of the implementation of energy efficiency measures, and the Municipality of Kalesija would pay them reimbursement from its budget in accordance with agreed conditions;
- Special model – private partner would implement the energy efficiency measures and manage public lighting system, and they would charge the Municipality of Kalesija the service of providing public lighting.

With the aim to perceive possible cost and benefits of the implementation of the energy efficiency measures via PPP, with the purpose to choose the most acceptable model of the PPP, it is necessary to carry out detailed analysis of possible realization models of the PPP taking into account interests of the Municipality of Kalesija and potential private partners.

11.6 Least Cost analysis public lighting system

Least cost analysis of the public lighting system implies comparison of possible public lighting systems from a financial viewpoint compared to a proposed public lighting system. All public lighting systems are using the electricity for the production of the artificial light. Thus there are no alternatives among public lighting systems when it comes to the energy they use. Therefore, the only segment in which it is possible to compare different public lighting systems is a technology and equipment used. Taking into account the mention, two public lighting systems can be identified and compared in the Municipality of Kalesija:

- Existing system – using fluorescent and natrium light bulbs to produce artificial light;
- Proposed system – using LED light bulbs with the possibility to dim the light.

An estimate of a unit cost per a light bulb for both systems was done in order to compare the mentioned system from the financial point of view. The table 33 gives an overview of these costs.

Item	Unit	Existing system	Propose system
Number of light bulbs	pcs	66	66
Electricity costs	KM/year	2.989	1.163
	EUR/year	1.528	594
Maintenance costs	KM/year	1.500	311
	EUR/year	767	159
Investment costs	KM	0	31.102
	EUR	0	15.902
Unit electricity costs	(KM/light bulb)	45	18
	(EUR/light bulb)	23	9
Unit maintenance costs	(KM/light bulb)	23	5
	(EUR/light bulb	12	3
Unit investment costs	(KM/light bulb)	0	41
	(EUR/light bulb)	0	21
TOTAL UNIT COST	KM	68	64
	EUR	35	33

Table 28: Unit costs of the public lighting system

On the basis of this table it can be concluded that the proposed public lighting system is significantly more cost effective for the Municipality of Kalesija by 4 KM or 2,05 EUR per a light bulb annually.

11.6.1 Analysis of sensibility

Analysis of the sensibility includes the analysis of variables influence which can lead to a change whether in costs or revenues of the project, affecting final result of the project. In this case, variables that can influence the final cost effectiveness of the implementation of chosen scenario are investment costs (CAPEX) and operational costs (OPEX). For the purpose of making the analysis of the sensibility changes to CAPEX and OPEX by +/-5% were assumed and their influence on IRR, NVP, payback period and discounted payback period were analyzed. The table 34 is showing the results of the analysis of the sensibility.

Variable	Change	Result			
		IRR	NPV (EUR)	Payback period (year)	Discounted payback period (year)
CAPEX	-5%	7%	1.582	10	13
	0%	6%	787	10	14
	5%	5%	-8	11	16
OPEX	-5%	6%	835	10	14
	0%	6%	787	10	14
	5%	6%	739	10	14

Table 29: Analysis of sensibility

Based on the result of the analysis of the sensibility it can be concluded that:

- CAPEX reduction by 5% leads to:
  - Increase of IRR by 1%;
  - Increase of NPV by 795 EUR;
  - Reduction of discounted payback period by 1 year;
- CAPEX increase by 5 % leads to:
  - IRR reduction by 1%;
  - NPV reduction by 795 EUR;
  - Increase of discounted payback period by 2 years;
- Reduction or increase of OPEX by 5% does not have significant influence on the final cost effectiveness of the project.

12 ENVIRONMENT AND SOCIAL ESTIMATES

12.1 Analysis of CO_2 reduction

The Earth is a big greenhouse in the Universe in which instead of the glass the heat is maintained by some of gases in the atmosphere. They are letting trough Sun's heat that reaches the ground, and then they hold it and maintain the temperature on the planet suitable for life. On the other hand, when the coal burns down, the carbon connects with the oxygen from the air and in that way forms the carbon dioxide – CO_2. The carbon dioxide is the gas without color and smell, and it is one of the greenhouse gases in the atmosphere. Increase of its concentration causes the reduction of the heat loss by radiation from the Earth's surface into the space thus increasing the temperature on the Earth.

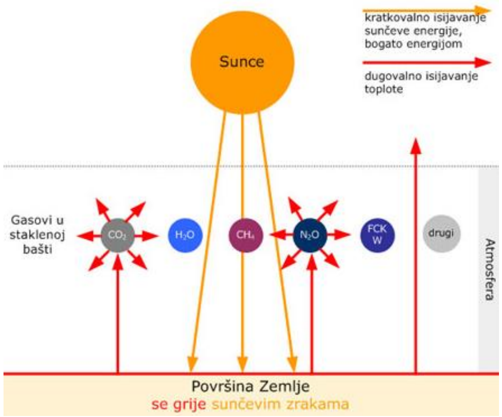


Image 62: Greenhouse effect

The greenhouse effect is more pronounced as the CO_2 concentration increased during the last century. The consequence is global increase of an average temperature which causes:

- melting of polar ice caps and glaciers,
- sea level increase,
- climate extremes,
- Influence on the agriculture.

According to the analysis of the current state, at locations in the Municipality of Kalesija which are the subject of this study, sodium light sources are mostly used which, from the electricity spending viewpoint, have low efficiency, that it, they are big spenders of the electricity and it is directly reflected on the emission of the greenhouse gas CO_2.

CO_2 emissions from public lighting are indirect emission made by electricity spending (emissions are not created at a location of immediate spending of the energy), and as an entry data for the estimate will be used data on annual spending of the electricity and emission factor of CO_2 for electricity. Emission factor for the electricity according to the Rulebook on minimum requirements for energy characteristics of buildings (Official Gazette of FBiH 81/19), obtained from the ratio of produced electricity from hydro power plants and thermal power plants depending on a structure of used fossil fuel (and other renewable sources) and it is **0,7446 tCO_2/MWh**.

According to the analysis of the energy spending and measures recommended in the chapter 7, what follows are results of estimates of CO_2 emission for the existing state, the scenario 1, the scenario 2, the scenario 3 and the scenario 4 of the reduction of electricity spending and indirect CO_2 emission being the result of the implementation of each of mentioned measures.

Parameter	Existing state	Scenario 1	Scenario 2	Scenario 3
Electricity spending (kWh/year)	15.607	7.823	6.071	4.897
CO_2 emission (t/year)	11,62	5,82	4,52	3,65
Savings (kWh/year)	-	7.784	9.536	10.710
CO_2 savings (t/year)	-	5,80	7,10	7,97
CO_2 emission reduction (%)	-	49,88%	61,10%	68,62%

Table 30: Spending of the electricity for the public lighting on analyzed coverage and associated CO_2 emission

Based on results of estimates the annual indirect CO_2 emissions of the public lighting of the Municipality of Kalesija for the existing state amount 11,62 tCO_2/year with annual electricity consumption of 15.607 kWh/year. By implementing the measures propose by the project it is possible to achieve the total reduction of emissions in the percentage of 49,88% by implementing the scenario 1, 61,10% by the scenario 2, 68,62% by the scenario 3 and 65,09% by the scenario 4. The implementation of the scenario 3 gives the biggest reduction of electricity consumption, and thus of indirect CO_2 emission compared to the existing state.

Reducing harmful particles in the atmosphere is in accordance with tasks BiH needs to fulfill when it comes to the implementation of international obligations. As the signatory of a number of international agreements and conventions related to the environment protection and renewable sources (the Agreement on the Energy community of Southeast Europe, Framework Convention on Climate Changes, Kyoto Protocol, Espoo Convention and the like) and the Stabilization and Association Agreement, BiH committed itself to respecting them. Member states of the Energy Community are committed to implementing a number of EU directives, including directives 2001/77/EC, 2003/30/EC and 2009/28/EC. The mentioned directives relate to obligations of EU member states, that is, signatories that they will work on the development and wider use of different renewable energy sources in the energy sector and transport.

The directive 2009/28/EC especially gives the framework for the harmonization of activities and legislatives related to the implementation of green technologies.[6] Complying with provisions of the Directive 2009 for BiH would mean that a part of renewable sources will increase by 2% in the next two years, that is by more than 6,5% in 2020 (to 33%). By signing the Agreement on Joint Energy Market of Southeast Europe, BiH, like other member states, took the obligation to adopt European acquis in the area of the energy and environment protection. The aim of the Community formation, in addition to creating single energy market, was to increase the energy efficiency and a level of using energy renewable sources. BiH ratified the United Nations Framework Convention on Climate Change (UNFCCC) on December 6,2000. As BiH is not developed country (does not belong to the

[6] Energy Community, Study of the Implementation of the New EU Renewables Directive in the Energy Community, June 2010., p. 6., www.energy-community.org

Annex I), it does not have the strict obligation to reduce greenhouse gases, but it does have general obligations that are related to estimates of annual emissions of greenhouse gases, implementation of measures for regulation of anthropogenic emissions and measures for adaptation to climate changes, acceptance and development of technologies limiting and reducing greenhouse gases.

12.2 Waste disposal

During the implementation of the project, the Investor is obliged, in accordance with provisions of the Article 19 of the Law on Environment Protection and provisions of the article 19 of the Law on Waste Management, to take appropriate measures for waste management and provide basic measures with the aim to prevent creating waste, recycling and treating waste for re-use, extracting raw materials and possible energy, and definitely disposal. Considering the project includes dismantling of existing light fixtures which according to *the Rulebook on Waste Categories with Lists* *(*''Official Gazette of FBiH'', no.09/05) are listed as dangerous waste, and it includes any waste that has one or more characteristics causing danger to the health of people and environment because of their origin, composition or concentration, as well as the waste listed in the list of waste as dangerous and being regulated by implementer provision.

Legal regulations in force define a way of taking care of this kind of waste, that is, an operator/owner of the waste is obliged to make a contract with authorized company dealing with gathering and disposal of this kind of waste and with proper documentation carry out its handover. Authorized company is obliged to give feedback to the owner of dangerous waste that the waste was disposed in proper manner.

With the aim to minimize waste during the implementation of project activities of replacing existing fixtures, it is necessary to take measures to prevent creation of the waste. One of the aims of waste management is controlled waste disposal, prevention of irresponsible waste management, controlled procurement of funds and training on waste disposal and safe waste disposal by taking all necessary measures to protect the health of people and the environment.

Table 31 gives the overview of waste flow of the investor, with a description of practices in the waste management, which the Investor is obliged to carry out the regulations according to which some measure is being implemented.

No.	Emission	Description of procedure of waste flow management	Final disposal	Relevant regulations in FBiH prescribing
1.	Electric waste from removing existing light fixtures	-Proper temporary storage at specially provided place in special containers - transport by special vehicles by an authorized company - handover to the authorized	The authorized company for this kind of waste with which the Investor will make contract	- in accordance with the Law on Waste Management (''Official Gazette of FBiH'', no. 33/03, 72/09, 92/17) -In accordance with the Provision on selective gathering and marking of waste (''Official Gazette of FBiH'', no. 38/06), - U accordance with the Regulation on conditions for the transfer of obligations for waste management

No.	Emission	Description of procedure of waste flow management	Final disposal	Relevant regulations in FBiH prescribing
		company for further management		from a producer and seller to the Investor of the waste gathering system ("Official Gazette of FBiH", no. 9/05)

Table 31: Procedures for waste management in accordance with regulations in FBiH and EU legislation

12.3 Light pollution

Light pollution includes any unnecessary emission of artificial light in the area outside of a zone that needs to be light up. Main causes of this kind of pollution include mostly incorrect installation and design of light fixtures, therefore it is important to adjust design that will have the smallest negative impact when installing new light fixtures or designing new network of public lighting. In addition, the light pollution can be avoided by using environmentally friendly bodies which do not strew the light out of an area which needs to be enlightened. According to the data of the first world Atlas of Light Pollution from 2001, 82% of the population in BiH is exposed to clear sky which light is higher than the natural light of the night sky: the threshold bp to consider the night sky polluted, i.e. when the artificial sky brightness is greater than 10% of the natural night sky brightness above 45 ° of elevation (Smith 1979).[7]

Image 63: Satellite image of Europe during night[8]

If we take into account that the light pollution cannot be completely avoided, it is necessary to influence minimizing negative impacts by applying simple principles and measures. Also, compared to other types of pollution, results of implementation of measures to reduce the light pollution are visible immediately, at least on local level. Efficient measures for reduction are based on following principles:

[7] The first World Atlas of the artificial night sky brightness, P. Cinzano, F. Falchi, C.D. Elvidge, December 2001, Monthly Notices of the Royal Astronomical Society, Volume 328, Issue 3, December 2001, Pages 689–707

[8] http://www.savethenight.eu/Lights%20in%20Europe.html

- Artificial light needs to be directed where necessary, and emissions outside of a reach area need to be reduced as much as possible.
- Depending on a purpose, it is necessary to provide that the brightness is not bigger than minimum required.
- Whenever possible, it is necessary to use the light of warm tones and continuous spectra, and avoided sources broadcasting a lot of light energy in blue, purple and UV close spectrum area.

If we compare current light fixtures and project proposed light fixtures, the current light fixtures in the Municipality of Kalesija are design to broadcast the light in almost all directions, and usability of broadcasted light to light up desired surface is only 10-30%. This includes all light fixtures that have glass globe or half-globe outside of lamp housing. The use of mentioned light fixtures is most often distinctly ineffective energy-wise, i.e. 30-40% of electricity is being lost unnecessarily, which was shown in previous chapters in which was done comparison of electricity consumption.

Unlike current light fixtures, the project envisions replacement with environmentally friendly light fixtures which are full cutoff and they have the possibility of controlling light emission and do not allow waste of light in the environment. These light fixtures have flat glass from the bottom side, and cheaper ones are without the glass and enlighten only aimed surface, without unnecessary emission of the light to a side and towards the sky. By implementing the measures of replacement of inefficient light fixtures in the Municipality of Kalesija would be achieved significant reduction of the light pollution and reduce risks that such pollution has on the health and safety of residents.

13 COMPARATIVE ANALYSIS OF INDICATORS OF PUBLIC LIGHTING ENERGY CONSUMPTION

It is necessary to give consumption indicators during the analysis of the energy consumption in order to identify and analyze the energy consumption in a system, compare the consumption before and after implementation of the energy efficiency measures, and finally compare on annual level or with similar systems of Cities/Municipalities. Energy consumption indicators are values taken from parameters describing or giving information on state of the energy consumption of a system. They appear as indexes (a set of aggregated parameters or parameters with weight ration) or as parameters (value that is measured or assessed). Energy management would be unthinkable in the field of energy without energy consumption indicators, precisely because they make connection between human activities, change of energy, and also effects of measures. Indicators enable comparison between individual systems or one system for a longer time period. Therefore, energy consumption of the system will be analyzed with the help of indicators.

Energy consumption indicators can be expressed as ratios of produced/consumed energy per unit of a light fixture or similar criterion.

According to that, the indicator of annual energy consumption can be presented with the ratio of total annual energy consumption (*P*, kWh) of the system and, e.g., a number of light sources (*Br*, number), by using following equation:

$$E = \frac{P}{B_r} \quad (9.)$$

Except per number of light bulbs, energy consumption can be expressed by a total surface of a Municipality/City or considered part of public lighting system or other specifies impacting energy consumption, and that energy consumption indicator can be presented with the ratio of total annual electricity consumption of a system (City, Municipality, street, etc.) and considered surface (City, Municipality, street, etc.):

$$E = \frac{P}{A} \quad (10.)$$

In addition to there, there are other ways of expressing electricity consumption indicators, thus in the case of this system the indicators of real electricity consumption were given in previous chapters.

13.1 Indicators of electricity consumption for current state

It is necessary to give indicators of energy consumption in the public lighting system in order to compare and analyze energy consumption for the public lighting. Indicators of the electricity consumption can depend on many factors such as geographical location, level of usability of the system and the like. For the purpose of the analysis of the electricity consumption for the public lighting, what follows are the most important indicators to be analyzed and after possible implementation of energy efficiency measures, that is, realizing optimal scenario. With the existence of indicators for current state of energy consumption and indicators of energy consumption after proposed energy efficiency measures it is possible to compare analyses of mentioned indicators.

Following indicators of the energy consumption will be taken into consideration:
- Number of sources of light (pcs),
- Needed electricity for the public lighting (kWh/year),
- Specific annual consumption (kWh/light source annually).

The most relevant and the most often analyzed indicator is the electricity consumption for the public lighting per light source (kWh/pcs year).

Specific electricity consumption, that is, the need of the electricity for the public lighting, depends on a size of a system, that is, a number of sources of light. The table 37 gives mentioned indicators of electricity consumption for the public lighting for current state.

Indicator	Value
Number of light sources (pcs)	66
Needed electricity for public lighting (kWh/year)	15606,65
Specific annual consumption (kWh/light source year)	236,46

Table 32: Overview of indicators of electricity consumption for public lighting for current state

It can be seen that needed electricity of the public lighting for the current state 15606,65 kWh/year. If this value is divided with considered number of light sources, one gets that the specific annual consumption is 236,46 kWh/light source year.

13.2 Indicators of electricity consumption after implementation of energy efficiency measures

Electricity consumption for the public lighting would be reduced after the implementation of proposed measures. This reduction of the electricity consumption is presented by the energy indicators given by the Table 38, according to the optimal scenario described earlier in the document.

Indicator	Value
Number of light sources (pcs)	66,00
Needed electricity for public lighting (kWh/year)	6071,05
Specific annual consumption (kWh/light source year)	91,99

Table 33: Overview of electricity consumption indicators for public lighting after implementation of proposed measures

It can be seen from the table that electricity needs would be reduced and amount 6071,05 kWh/year, and thus the specific electricity consumption per light source on an annual basis would be reduced to 91,99 kWh/light source per year.

13.3 Comparative analysis of indicators of electricity consumption and needs for electricity for current situation and after implementation of measures

The comparative analysis established the state of electricity needs for public lighting before and after the implementation of energy efficiency measures. As expected, the electricity needs after the implementation of energy efficiency measures would be reduced. An overview of indicators before and after the implementation of energy efficiency measures is given in Table 39.

Indicator	Current situation	Situation after
Electricity needed for public lighting (kWh/year)	15606,65	6071,05
Specific annual production (kWh/light source year)	236,46	91,99

Table 39: Overview of indicators before and after implementation of proposed EE measures

Comparing the relevant indicators before and after the implementation of energy efficiency measures (according to the optimal scenario), it is obvious that the electricity needs are reduced by 61,10%, and thus the specific annual consumption from 236,46 kWh/ light source to 91,99 kWh / light source/ yr.

14 CONCLUSION

Through the preparation of the Study for the replacement of existing lighting fixtures with LED lighting, the key aspects that are important in the implementation of such a project were considered and analyzed. The identification of the initial state of the lighting system was done, which determined the basis for further conceptual design of the system. It was determined that such solutions make sense and that the effects after the implementation of the project are positive both financially and environmentally.

The first part of the study focused on the analysis of the current state of light sources, electrical characteristics and electricity consumption. A field visit revealed that the lamps are of very low energy efficiency.

The second part of the study included an analysis of the electricity consumption of the public lighting system. It has been established that the costs for electricity in the last three years amount to 0,1915 KM/kWh.

The third part of the study is the one in which the proposed measures are as follows:

- Replacement of existing lighting fixtures with LED lighting
- Replacement of existing lamps with LED lamps with dimming ability - where dimming is possible and will not affect functionality and safety
- Replacement of existing lamps with LED lamps with possibility of dimming - where dimming is possible and will not affect the functionality and safety with the installation of central technical supervision.

The fourth part of the study is the one in which the cost-effectiveness analysis of all proposed measures was performed. All measures are cost-effective within acceptable deadlines. Combinations of measures (scenarios) have been proposed and it has been shown that the optimal scenario is scenario 2. In addition, the reduction of CO_2 emissions has been calculated if any of the scenarios is realized.

If the measures are carried out according to the optimal scenario, it is possible to achieve energy savings of 61,10%. The investment would pay off in 10 years according to current electricity prices.

15 APPENDICES

- Geolocation coordinates of poles and lighting fixtures
- Photometric calculations of new lighting with LED technology on the streets
- Specification of public lighting works

15.1 Geolocation coordinates of poles, light fixtures and BMP

15.2 Photometric estimates of new lighting with LED technology per streets

15.3 Specification of equipment and overview of public lighting works