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

Disclaimer

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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 today 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, as well as an 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 further medium-term economic development and job creation on energy efficiency improvement measures. There is also a high potential for energy conservation in the public lighting system.

Of particular importance to the application of the principle of energy efficiency is the fact that the public lighting in use today was mainly designed at a time when there was no highly effective lighting technique, and when electricity was significantly cheaper. Currently, public lighting systems are one of the main sources of electricity consumption, with 3.19% of global electricity production allocated to public lighting.
This amount is higher than the production of all hydro or nuclear plants and is equal to the production from natural gas. It is generally known that public lighting is a sector characterized by excessive and disproportionate energy consumption in relation to the quality and functionality of the service offered to citizens. Investing in optimal measures to improve the energy efficiency of public lighting systems has become strategic for the economic, technological and social development of cities.

Therefore, new public lighting needs to be designed and built in accordance with the principles of energy efficiency, and the existing ones, if at all possible,need to be adapted. Improving energy efficiency is one of the most important pillars of modern energy policy, and is the key and most economically effective mechanism for achieving the goals of sustainable development of the energy sector.
Improving energy efficiency reduces costs and contributes to the competitiveness of the national economy. Energy efficiency means consuming less energy for the same product or service. Energy efficiency offers many benefits, depending on the 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 labor,
- reduce the burden on budgets,
- increase economic competitiveness.

In order to assess the energy saving potential of public lighting, the existing situation must be defined. In other words, the following basic activities should be established:

- preparation,
- inspection / review,
- description of the current situation and identified measures,

- Á energy budget and,
- Á economic budget.

It is important to point out that energy efficiency should by no means be seen as energy saving. Namely, *saving*always implies certain sacrifices, while *efficiency*means maintaining, in this case, the given level of lighting with the use of a smaller amount of electricity.

The costs of public lighting are becoming an increasing burden on the budgets of various levels of government from year to year. Newer technologies and more economical lighting fixtures provide the possibility of savings while maintaining the existing or even improving the quality of lighting. With newer technologies, and with acceptable investments, municipalities can reduce allocations for the operation of public lighting systems, which will create opportunities for redirecting such saved funds to further expansion of 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 the EU under the 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 outdoor lighting they were adopted under the names:

- **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 calculation,
- **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 lamps 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

The municipality of Sapna is located in the northeastern part of Bosnia and Herzegovina (BiH) in Tuzla Canton (TC), which consists of the cities of Tuzla, Živinice, Srebrenik, Gradačac and Gračanica and eight other municipalities (Banovići, Čelić, Doboj Istok, Kalesija, Kladanj, Lukavac , Sapna and Teočak). The area of Tuzla Canton is 2,649 km^2, which is 10.15% of the area of the Federation of Bosnia and Herzegovina (FBiH), whose area is 26,110.5 km2, or 5.17% of the territory of BiH (51,209.2 km^2).
The municipality of Sapna consists of 14 local communities , namely: Baljkovica, Donji Zaseok, Goduš, Kobilići, Kovačevići, Kraljevići, Međeđa, Nezuk, Rastošnica, Sapna, Skakovica, Vitinica, Zaseok , Žuje and Šarci, and occupy an area of 201 km^2 which is 7.6% of the territory of Tuzla Canton, 0.77% of the territory of FBiH and 0.39% of the territory of BiH. The regional road R306 passes through the territory of the Municipality of Sapna (connects the border of the entity Priboj - Sapna - the border of the entity Karakaj); the road is 16 km long; R307 (connects Sapna - Kalesija, and its length is 14 km).
Thanks to the mentioned communications, the area of Sapna has a quality connection with the region and other parts of BiH. The average altitude of the area is 147 m with a temperate continental climate. The average annual air temperature is 10 ° C, with an average summer air temperature of 20 ° C.[1]
Agricultural lands cover an area of 4,163.42 ha, while forests cover about 40% of the total area of the Municipality. The official language in majority use is Bosnian language. Image 1 shows the position of the Municipality of Sapna in Tuzla Canton, FBiH and BiH.

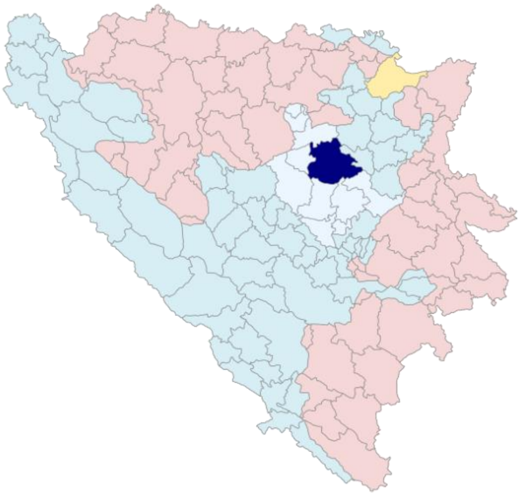

Image 1: Position of the Municipality of Laktaši in TC, FBiH i BiH2

[1] Strategija razvoja Općine Sapna za period 2014. – 2020. [Development Strategy of the Municipality of Sapna for the period 2014-2020]

[2] https://commons.wikimedia.org/wiki/File:Sapna_municipality.svg

5.2 Overview of the socio-economic situation

According to the 2013 census, the Municipality of Sapna has 11,178 inhabitants, while according to the Development Strategy of the Municipality of Sapna for the period 2014-2020, the estimated number is 12,136 inhabitants territorially organized in 14 local communities. The relative population density is about 103 inhabitants per 1 km^2. The estimate of the total population by age structure is 2,220 or 17.4% of young people under the age of 14, 9,052 or 70.9% of the population aged 15 -64 and 1,481 or 14.8% over the age of 65.

The natural increase rate in 2013 was 1.73, and the birth and death rates in 2010 were 8.71 and 6.38, respectively, while the natural increase rate for 2010 was 2.33. The current percentage of the population living in urban areas is 0%, as according to the 1991 census, which shows that 100% of the population lives in rural areas.

The migration balance from 2008 to 2013 was constantly negative and ranged between 55 and 130 inhabitants annually. The reason for the departure of the population (primarily to other countries) is most often the difficult economic situation. According to the 2013 census, the majority of the population is Bosniak, 96.9%, Serb 2.1%, Croat 0.002% and the others 1%.

In the area of the Municipality of Sapna in 2014, according to the collected data, 54 registered legal entities were active, of which 39 economic private activities and 15 public, and 70 registered natural persons and 498 registered family farms. Out of 39 registered companies, 17 of them have their headquarters in the Municipality of Sapna, while 22 branches or business units of companies are registered in other municipalities.

Out of 54 registered legal entities, 11 are active in the field of wholesale and retail trade, 1 in the field of catering, 10 in the field of transport (transport of goods and passengers), 17 in the field of service activities and 15 legal entities in the field of education, health, social protection and public administration. Out of 70 registered natural persons, 22 trade activities are active in the field of retail trade, 8 catering shops in the field of catering, 17 in the field of transport, carriers of goods and passengers and other crafts.

The total number of registered agricultural farms is 498 with 1441 members. Of the total available agricultural land in the Municipality of Sapna (4163.42 ha), 590.09 ha or 14.17% of was entered in the register of agricultural holdings.

According to available data, the gross domestic product (GDP) per capita for the Municipality of Sapna in 2013 amounted to 1,321.00 BAM. Although compared to 2012, GDP per capita increased by 2.9% (in 2012, GDP per capita amounted to 1,284.00 BAM), it is still significantly below the average GDP in the FBiH.

According to the data of the Agency for Statistics in the Municipality of Sapna, in 2013, goods and services were imported and exported in the total amount of 1,083,000 BAM. According to the available data, Image 2 shows the weak coverage of imports by exports. An indicator of the poor economic situation in the Municipality of Sapna is the amount of the average net salary in 2013, which is 90.7% of the average net salary in the FBiH.

While in 2018 the average salary in the Municipality of Sapna was 860 BAM, which is 97% of the average net salary in the FBiH.[3]

[3] Socioekonomski pokazatelji po općinama u FBiH, 2018. godine *[Socio-economic indicators by municipalities in the FBiH, 201*

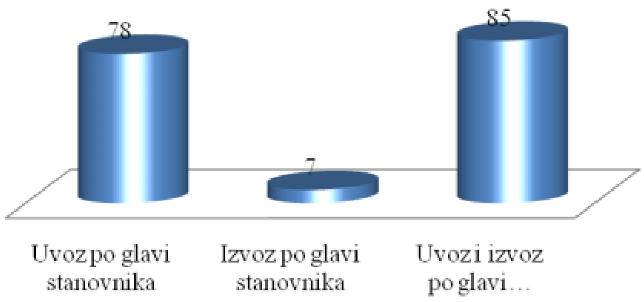

Image 2: Indicators of imports and exports of the Municipality of Sapna per capita in 2013[4]

In 2014, 588 people were employed in the Municipality of Sapna. A significantly larger number is employed by registered legal entities, i.e. 479 persons, while 109 persons are employed by registered natural persons. Classified by activities, the largest number of employed persons is in the field of education, health, social protection and public administration or 53.91%, service activities 17.69%, in wholesale and retail trade 17.52%, transport of goods and passengers 8.16 %, and catering 2.72%.

The number of employees in the Municipality of Sapna in 2013 was 594, which is by 4.8% more than in 2012 (567). Image 3 provides an overview of employees in the Municipality of Sapna from 2005 to 2013.

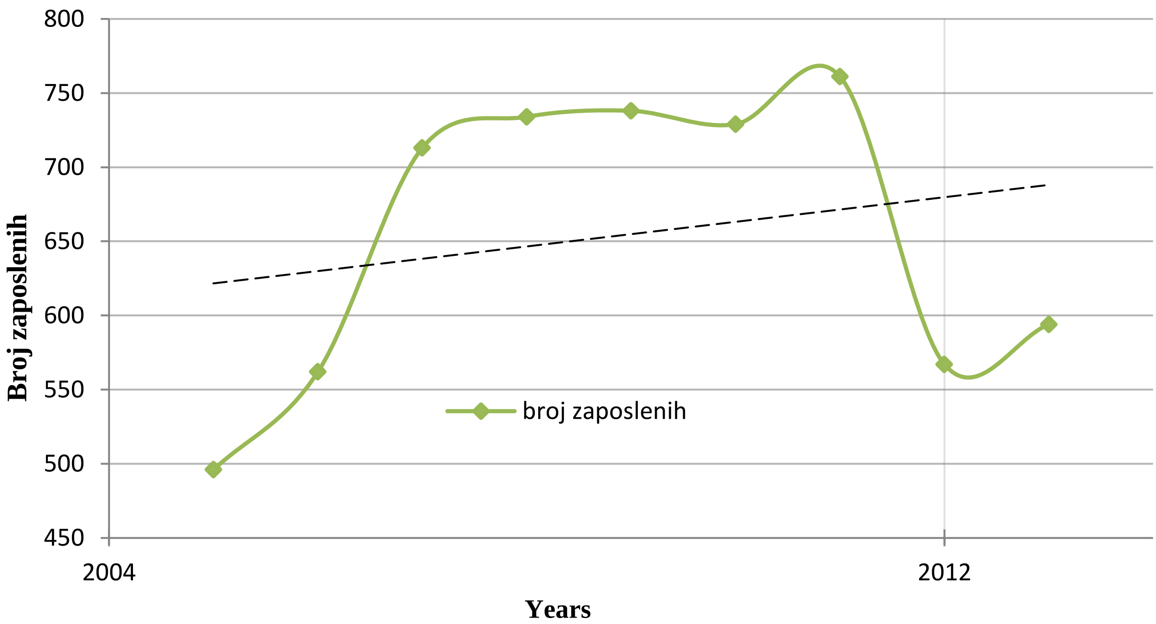

Image 3: Overview of employed persons in the Municipality of Sapna

[4] Federalni zavod za programiranje razvoja - Socioekonomski pokazatelji po općinama u FBiH za 2013. godinu [Federal Institute for Development Programming -Socio-economic indicators by municipalities in the FBiH for 2013]

In 2013, out of 3,183 persons of working population, 594 of them were employed, which is 18.7%, while the rest were unemployed (81.34%). The number of unemployed in the period from 2005 to 2013 ranged from 1,989 (62.5%) to 2,589 (81.34%).

According to the data from socio-economic indicators by municipalities from 2016 to 2019, the number of pensioners in the Municipality of Sapna is constantly increasing, so that in 2019 788 pension beneficiaries (old-age, disability and family) were registered, which is 3.55% more compared to 2016 (761).

The ratio of pensioners and the number of employees in 2019 is 1.29: 1, in favor of pensioners, which is extremely unfavorable from the aspect of providing financial sources from which pensions are paid (contribution to salaries). An increase in the number of pensioners with an insufficient increase in the amount of pensions, which in 2019 averaged about 276 BAM for old-age, 365 BAM for family and 147 BAM for disability pension.[5]

5.3 State of the public infrastructure electricity network

Electricity supply in the Municipality of Sapna takes place through JP "Elektroprivreda Bosne i Hercegovine" d.d. Sarajevo, Branch Elektrodistribucija Tuzla, Business Unit Sapna. Supply is made from the main supply substation TS 35/10 kV which is located along the regional road R307 Sapna - Kalesija.

The current condition of the electricity infrastructure is quite good, the entire low voltage network is wired with overhead SKS cables. The number of customers covered by the Sapna business unit, hereinafter (BU) is 2918, which is an increase compared to 2009 by 218 customers or 7.47%, and the total length of the LV network is about 170 km.[6]

The condition of LV networks is quite good, the whole network is covered with SKS cable, poles are a mixture of wood, impregnated and ABS, while the current number of electricity users in the Municipality of Sapna, covered by BU Teočak, is 197 connected customers.

The situation in the area covered by BU Teočak is such that there are currently 26,077 km of transmission lines (these are two parallel transmission lines from Sapna to Teočak that intersect this area, and connecting transmission lines for individual substations), 8 substations with 8 low voltage networks with a total length of 27 , 15 km. There are no underground networks in this area owned by ED Tuzla. BU Sapna, on the territory of the Municipality of Sapna, has the following electric power (EE) facilities; Substations:

- 35/10 kV substation (1 substation);
- 10/04 kV substation (32 substations)

Transmission lines (OHL):

- OHL 35 kV Kalesija - Sapna (length is 12 km) one part is in the Municipality of Sapna and most of it in the Municipality of Kalesija;
- OHL10 kV (length is 44 km).

The existing infrastructure can meet the applicable standards for this area, as well as the electricity needs in the municipality of Sapna. The problems are mainly of a property and legal nature because there are property disputes and claims for the rehabilitation or reconstruction of existing electricity facilities (EEO).

5 Federalni zavod za programiranje razvoja - Socioekonomski pokazatelji po op ǒnama u FBiH za 2019. godinu

6 Strategija razvoja Op ǒne Sapna za period 2014. - 2020.
[Development Strategy of the Municipality of Sapna for the period 2014-2020]

5.4 Analysis of socio-economic population research

5.4.1 Introduction

As part of the Feasibility Study for the installation of new energy efficient public lighting systems for the Municipality of Sapna, a survey of the population of the Municipality of Sapna was conducted with the aim of assessing citizen satisfaction with the quality of key dimensions of public lighting performance.
A survey questionnaire was chosen as the method for collecting primary data. The survey was conducted in the period from July 14 to September 1, 2020. The survey questionnaire was distributed in electronic (web) form with the aim of increasing the response of citizens.
The number of inhabitants of the Municipality of Sapna is 12,136, while 108 respondents participated in the survey, with a confidence level of 95% for the stated number of respondents and a confidence interval of 9.4. The research was conducted anonymously, and the respondents were previously informed about the goal of the research.

5.4.2 General respondents' data

Out of the total number of respondents (108), 56.48% of the respondents were males, while in the percentage of 43.52% they were females (Image 4).

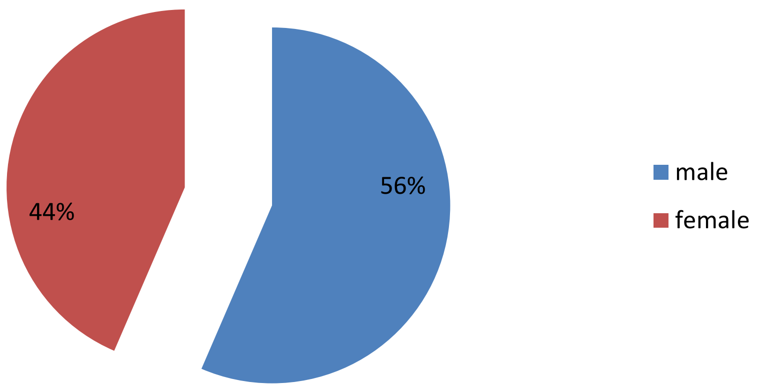

Image 4: Structure of respondents by gender

The age of respondents is categorized into four age groups: 18 - 29; 30 - 39; 40 - 49; 50 - 64; 65+. The most represented age group in the sample is the population aged 40-49 (33.33%), as well as the respondents aged 18-29 (28.7%), while the respondents aged 30-39 participated in the percentage of 24.07% .
The least represented group of respondents is in the age group of 65+ years (0.93%), while the respondents in the age group of 50-64 years participated in percentage of 12.96%. The stated structure of respondents by age shows that approximately the same percentage of respondents belonging to the young and older population participated in the survey, which satisfied the equality in terms of age groups.
The percentage of respondents who are employed is 86.11%, while the percentage of respondents who are unemployed is 13.89%. In addition, out of the total number of respondents, the largest number had a university degree / baccalaureate level of education 45.37%, while the percentage of respondents with completed high school is 24.07%. The percentage of respondents who have the status of higher education

is 5.56%, while respondents with a master's degree participated in percentage of 18.52%.Respondents who completed 6 years of study and have the title of MD did not participate in the survey, nor did respondents with the title of Doctor of Science. Respondents who have student status participated in percentage of 6.48% (Image 5)

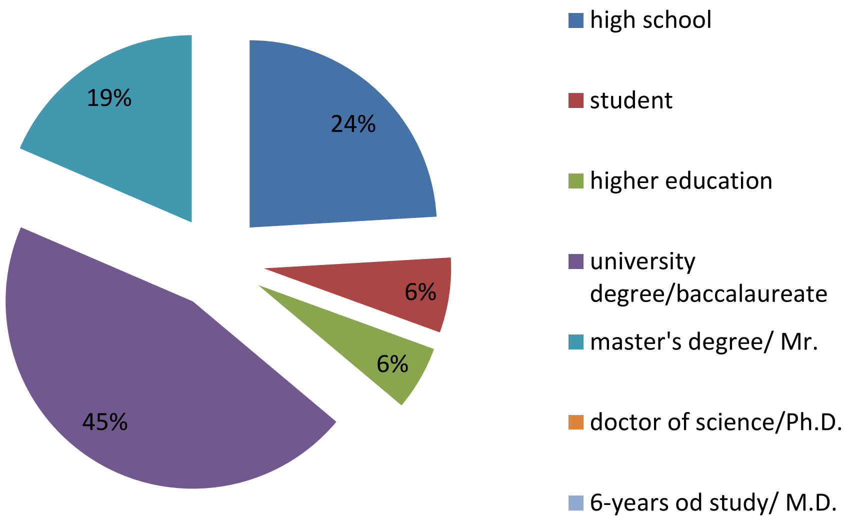

Image 5: Structure of respondents by level of education

5.4.3 Energy efficiency and population satisfaction with the quality of key dimensions of public lighting performance

Knowledge of energy efficiency is key to understanding the need to implement EE measures. Therefore, a set of 3 questions was formed which were created with the aim of identifying the existing knowledge of the respondents about energy efficiency. 97.22% of respondents answered that they are familiar with what is meant by the term energy efficiency, while 2.78% of them answered that they are not familiar with it.
98.15% of respondents who participated in the survey, answered that energy efficiency is associated with environmental protection, while 1.85% said it is not associated with environmental protection. However, when it comes to knowledge about the costs of public lighting in the Municipality of Sapna, most respondents or 70.37% are not aware of the costs of public lighting, while 29.63% of respondents are familiar with data on the costs of public lighting in the Municipality of Sapna (Image 6).

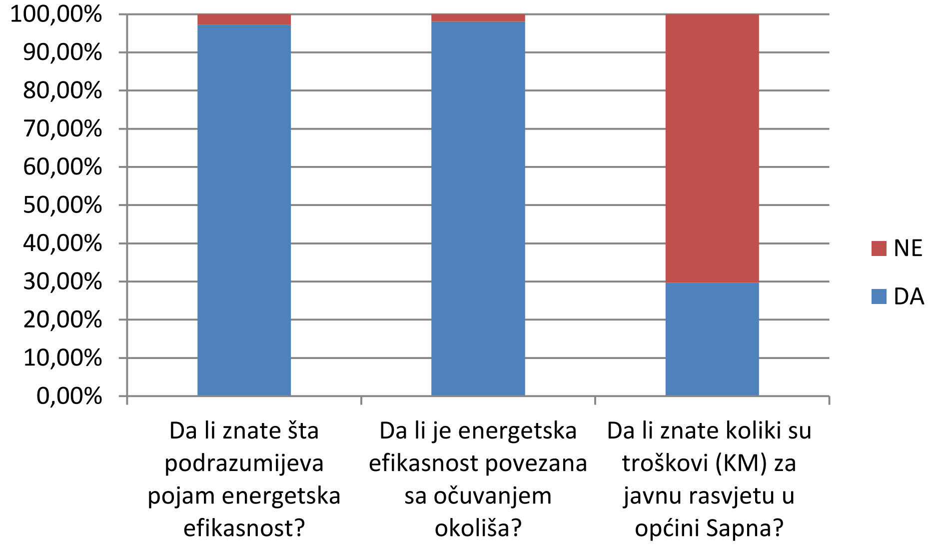

Image 6: Respondents' knowledge of energy efficiency

According to the respondents on whether the Municipality of Sapna is taking any of the energy efficiency measures, most respondents or 52.78%,answered that the measures are taken in the form of replacing existing lamps with LED lamps ,while 21.3% of respondents said no measures were taken. In addition, the respondents in the percentage of 19.44 mentioned the switching off of lamps as a measure implemented by the Municipality of Sapna , 4.63% of respondents stated that the Municipality of Sapna applies dimming as a measure of energy efficiency, and 1.85% stated that measures of dimming, turning on and off lamps on the motion sensor are applied (Image 7).

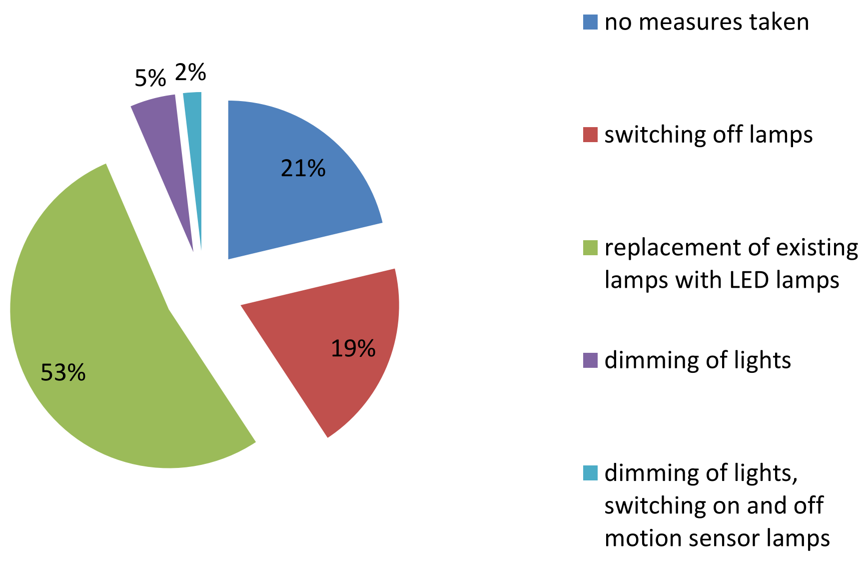

Image 7: Percentage share of respondents' answers to the question: In your opinion, does the Municipality of Sapna takes any of the energy efficiency measures?

Taking into account the instruction on Liker scale, where one = (minimum) to five = (maximum), the respondents expressed their satisfaction with the current public lighting. Out of the total number of respondents, 25.93% of respondents expressed their satisfaction with the current lighting with a grade of three, while 20.37% of respondents gave a grade of four to the current state of public lighting, and 17.59%

a grade of five. 18.52% gave the lowest assessment of the state of public lighting in the Municipality of Sapna (Image 8).

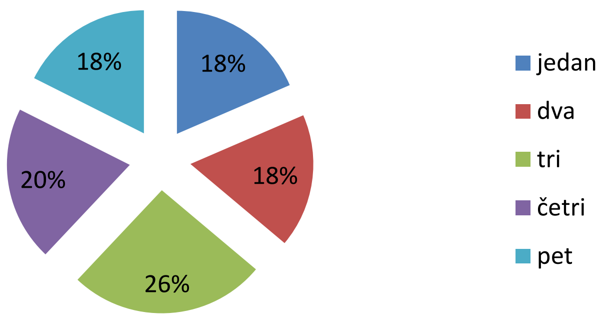

Image8. Percentage of respondents' answers to the question: Your level of satisfaction with the current publi lighting?

The majority of respondents or 25%, rated the maintenance of public lighting in the Municipality of Sapna with a grade of three, while 20.37% gave a grade of two, and the same percentage of respondents gave a grade of four. According to the above data, over 69% of respondents gave a rating of three, four or five to the maintenance of public lighting, while 10.19% gave the lowest grade, one (Image 9).

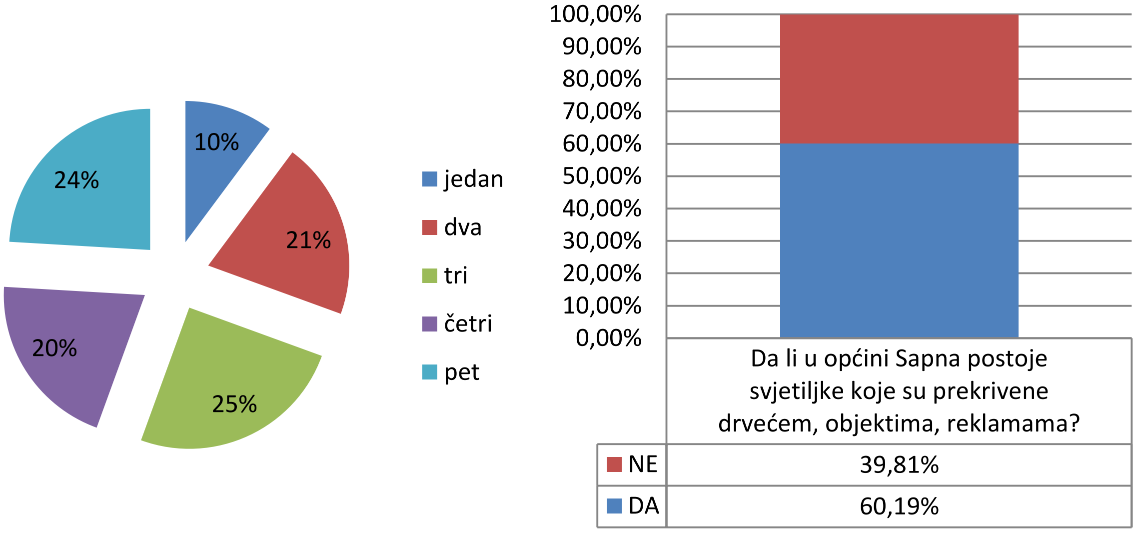

Image 9: Percentage of respondents' answers to the question: (Left Sapna Municipality regularly maintains public lighting? Right Does Sapna Municipality invest sufficiently in innovative technologies (in this case, for example, in LED lighting or in automatic control of public lighting system)?

According to the respondents, investing in innovative technologies in terms of public lighting in the Municipality of Sapna, the answer was mostly that it is level three, 36.11%, while 17.59% of them said that it is level two.

The lowest number of respondents, 9.26%, stated that the level of investment in innovative technologies in terms of public lighting is at the highest level, five. 60.19% of respondents stated that in the Municipality of Sapna there are lamps covered with trees, buildings, advertisements, while the rest of the respondents in the percentage of 39.81% stated that this is not the case (Image 9).

Respondents were also asked about the characteristics of current lighting through a survey, answering questions related to light pollution and glare. Respondents gave the highest percentage of three (35.19%) for the presence of lamps that cause light pollution, as well as the lowest grade, one (29.63%)

When it comes to the existence of lamps that cause the effect of glare, 82.41% of respondents, which represents the majority, gave a grade of one, two or three, while 17.59% of them gave a grade of four or five (Image 10).

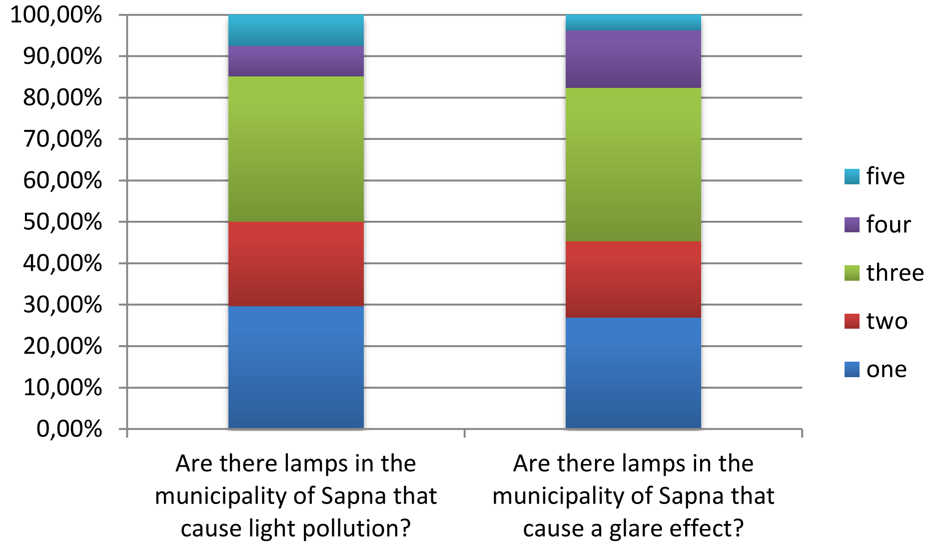

Image 10: Percentage share of respondents' answers to questions about the characteristics of current public lighting in the Municipality of Sapna

5.5 Review of energy efficient public lighting trends

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.

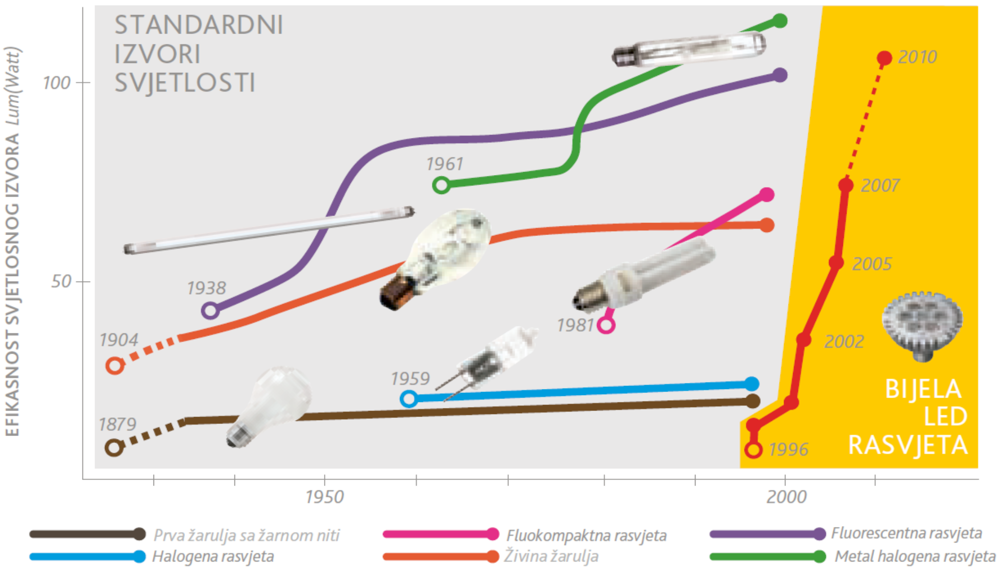

Image11: Development trend of individual light sources[7]

High pressure sodium lamp (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.

High-pressure sodium lamps are produced in a wide range of powers, different shapes and sizes. 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 high-pressure sodium lamp is 2012.

Image 12: High-pressure sodium lamp

[7] *[www.osram.hr]*

High pressure mercury lamp (HQL)

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-pressure mercury lamp

High pressure metal halide lamp (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 lamp

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

Fluorescentube (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 lamp

LED based lamp *(LED)*

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 lamp

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 / intelligent 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 MANAGEMENT CHARACTERISTICS

6.1 General

According to development strategy of City of Sapna, internal powers analysis, electronetwork and lighting is well developed. Main streets are illuminated , as most rural streets. However, existing public lighting has low energyefficiency. Table 1 gives general data on public lighting system, and table 2 gives a list of overviewed streets.

Amenable administration	Općina Sapna	Street	206.Viteške brigade Sapna	No.	bb
Contact person	Fatima Gušić	Phone	035/599-530, lokal 562		
Cell phone	060/3063755	Mail:	fata@opcinasapna.ba		
Public lighting (type) goal			Street lighting, walking zone lighting, suburb residental zone lighting		
First year of building					
Lamp operating system			√ Imagecell √ Time reley □ Timer switch		
Daily operating time (h)			Summer: 20:30-5:00 Winter: 16:30 - 7:00 Average: approx 11h		
Operating system			Not regulated		
Subject obligated/under contract for public lighting maintenance			JKP "Sapna" d.o.o. Sapna		
Contact person			Samir Smajlović		
Phone			035/597 -999; 062/285-365		
Electricity supplier			JP Elektroprivreda BiH		

Table 1: General informations on public lighting system

Ordinal No.	Street name
1	206. viteške brigade
2	Goduš
3	Patriotske lige
4	R456
5	Međeđa
6	Branilaca Kraljevića

Table 2: Streets listed for an overview[8]

[8] Informations given by Amenable Administrating Service

6.2 Energy characteristics analysis

City of Sapna does construction, management 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.

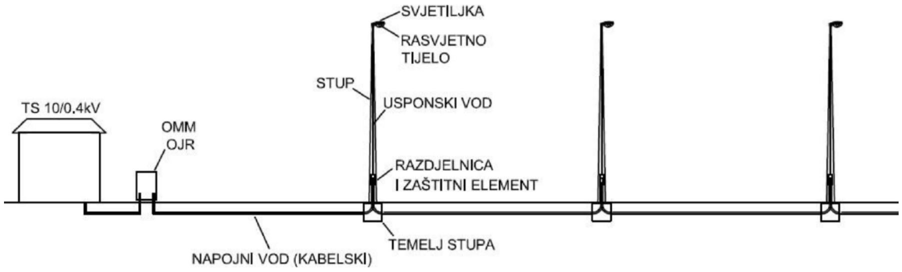

Image 20: Public lighting system elements

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 data are shown on the following pages.

6.2.1 Lighting source optical and technical characteristics

Subject part of public lighting Study in City of Sapna is installed mostly with mercury lamps and LED lamps. Lamp box is mostly built in a mechanical protection IP65 degree. Table 3 shows a lighting source overview on subject streets, partaking lighting sources are shown in image 21.

Ordinal No.	Street name	Lighting source type	Rated power per source (W)	Lighting sources (pcs)
1	206. viteške brigade	Mercury	250	4
2	206. viteške brigade	Mercury	250	21
3	206. viteške brigade	Mercury	250	14
4	Goduš	Mercury	250	20
5	Goduš	LED	50	2
6	Patriotske lige	Mercury	250	19
7	R456	Mercury	250	15
8	Međeđa	Mercury	250	13
9	Branilaca Kraljevića	Mercury	250	6
10	206. viteške brigade	Mercury	250	13
11	206. viteške brigade	Mercury	250	24
TOTAL				151

Table 3: Lighting types by subject streets

Image 21: Partaking lighting source types

Image 22 show an existing public lighting lamps overview in City of Sapna. 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: Mercury lamps

6.2.2 Geolocation 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 data, we get a mapped lamp overview (image 23).

Image 23: Laser measuring parameter example

Image 24: Pole and lamp mapping example

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. 23 shows a measuring example. Data on all measurings is shown in the following chapters.

6.2.3 Measuring points and substations

Total number of measuring points (OMM) in the system reffering to this study, there are 24 measuring points for measuring public lighting system energy consumption. Releys are installed in central building for controlling power of installed lamps. It is a partial convinient management 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 protected with automatic fuses usually Hager on which there are no signs of damaging on fuses. Main switches are operable and new. Switchboards fulfill current demands of the right standard STN.While operating, there is no greater risk of electric shock. Leading cables for all public lighting distributors are mechanically protected. Control and safety parts are mostly protected with casings in case of possible electric shock and they are not life threatening while maintaining.

bel OMM fficially based EE overview meration)	Substation name/label	OMM is located inside substation (yes / no)	Average lighting daily working hours (h)	Management type	Switching device functional (yes / no)	Luminous flux regulation (yes / no)	Regulation type	Regulation device functional (yes / no)	Public lighting power lines in OMM	Labe the circu
14977	PL Sapna Pijaca	no	12	Photo cell	yes	no	no regulation	-	1	1/A/
66597	PL 7066597 ALIJE IZETBEGOVIĆA R13	no	11	Time relay	yes	no	no regulation	-	6	2/A/ 2/A/
15027	PL Sapna 2	no	12	Photo cell	yes	no	no regulation	-	1	3/A/ 3/A/
54714	PL Goduš 2	no	12	Photo cell	yes	no	no regulation	-	1	4/A/ 4/A/
15000	PL Gornja Sapna	no	12	Photo cell	yes	no	no regulation	-	2	5/A/ 5/A/
65876	PL 7065876 GAZI HUSREFBEGOVA R14	yes	11	Time relay	yes	no	no regulation	-	3	6/A/ 6/A/

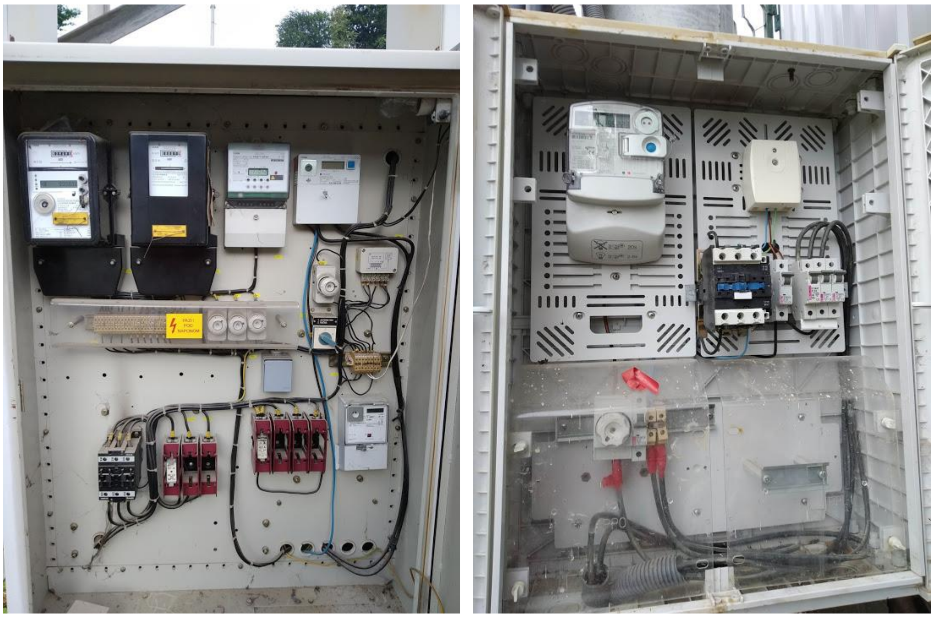

Image 25: OMM

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)	Management 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	8314977	PL Sapna Pijaca	no	12	Photo cell	yes	no	no regulation	-	1	1/A/1	underground
2/A	7066597	PL 7066597 ALIJE IZETBEGOVIĆA R13	no	11	Time relay	yes	no	no regulation	-	6	2/A/1 2/A/2	underground
02/A	8315027	PL Sapna 2	no	12	Photo cell	yes	no	no regulation	-	1	3/A/1 3/A/2	underground
03/A	8554714	PL Goduš 2	no	12	Photo cell	yes	no	no regulation	-	1	4/A/1 4/A/2	underground
04/A	8315000	PL Gornja Sapna	no	12	Photo cell	yes	no	no regulation	-	2	5/A/1 5/A/2	underground
6/A	7065876	PL 7065876 GAZI HUSREFBEGOVA R14	yes	11	Time relay	yes	no	no regulation	-	3	6/A/1 6/A/2	underground

Table 4: Data on measuring points (OMM)

6.2.4 Poles and support brackets

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 AB poles, metal poles and wooden poles.

Most poles are installed as one-sided. Existing steal poles are corroded on some places and it is necessary to protect adequately with protective coating and paint them. Supporting brackets on some places are smaller, which leads to uneven lighting. It is desirable to replace the wooden poles because of obsolescence.

Metal poles are made as an anchor, concrete poles are secured with concreate foundations, and the wooden ones are anchored and connected with concrete feet and a concrete plinth. Depending on zone and part of network, poles are set on green surfaces, as on walking and traffic surfaces. Lamps are mounted under 5 degrees with a console set on poles. Console length is from 0,5 to 1 m. Pole height varies from 3 and 9 m. Table 5 shows data on pole construction.

Ordinal No.	City	Metal (pcs)	Reinforced concrete (AB) (pcs)	Wooden (pcs)	Total
1	Sapna	50	96	5	151
		33,11%	63,58%	3,31%	100,00%

Table 5: Pole construction

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
				(m)		(m)		
1	206. viteške brigade	40	one-sided	8	yes	2	10	1
2	206. viteške brigade	40	one-sided	8	yes	0,3	10	1
3	206. viteške brigade	40	one-sided	8	yes	0,4	5	1
4	Goduš	40	one-sided	8	yes	0,4	5	1
5	Patriotske lige	40	one-sided	8	yes	0,4	5	1
6	R456	40	one-sided	8	yes	0,4	15	1
7	Međeđa	40	one-sided	8	yes	0,3	5	1
8	Branilaca Kraljevića	40	one-sided	8	yes	2	10	1
9	206. viteške brigade	40	one-sided	8	yes	0,4	10	1
10	206. viteške brigade	40	one-sided	8	yes	0,4	10	1

Table 6: Technical characteristics of geometry poles and consoles

Pogreška! Izvor reference nije pronađen. 26 and 27 show technical characteristics for pole geometry and consoles.

Image 26: Poles (Reinforced concrete - left, metal –middle, wooden-right)

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
				(m)		(m)		
1	206. viteške brigade	40	one-sided	8	yes	2	10	1
2	206. viteške brigade	40	one-sided	8	yes	0,3	10	1
3	206. viteške brigade	40	one-sided	8	yes	0,4	5	1
4	Goduš	40	one-sided	8	yes	0,4	5	1
5	Patriotske lige	40	one-sided	8	yes	0,4	5	1
6	R456	40	one-sided	8	yes	0,4	15	1
7	Međeđa	40	one-sided	8	yes	0,3	5	1
8	Branilaca Kraljevića	40	one-sided	8	yes	2	10	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
				(m)		(m)		
9	206. viteške brigade	40	one-sided	8	yes	0,4	10	1
10	206. viteške brigade	40	one-sided	8	yes	0,4	10	1

Table 7: 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 (concrete poles) and under ground (metal poles). Over ground conductors are isolated.

All cables are dimensioned accordant to installed power in a circuit and power demands (accordant with subject standards), long approx from 50 to 1.200 meters. Underground power cables are connected onto a divider on metal poles, by upright cable connection is made and asures lamp powering, lighting body. Lamps powered by air cable are connected directly onto grid. Lighting circuits (power cables) have up to 100 lighting spots, poles. Image 28 shows the way of cabling poles.

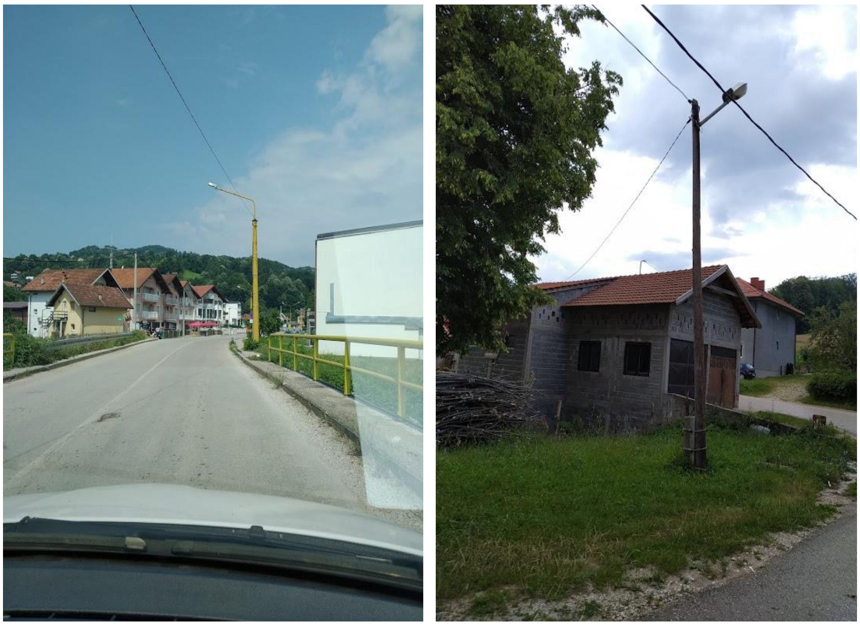

Image 28: Poles (under ground cabling – left, over ground cabling – right)

6.3 Measurings

6.3.1 Measuring electric parameters and electricity quality anaysis

Analysis is done based on measuring electric values (voltage, electricity, cosφ , power). Measurings of electric parameters are published accordant to Law of electricity in Federation Bosnia and Herzegovina (''Official Gazzete FBiH'', 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 powers 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 29 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 30 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.

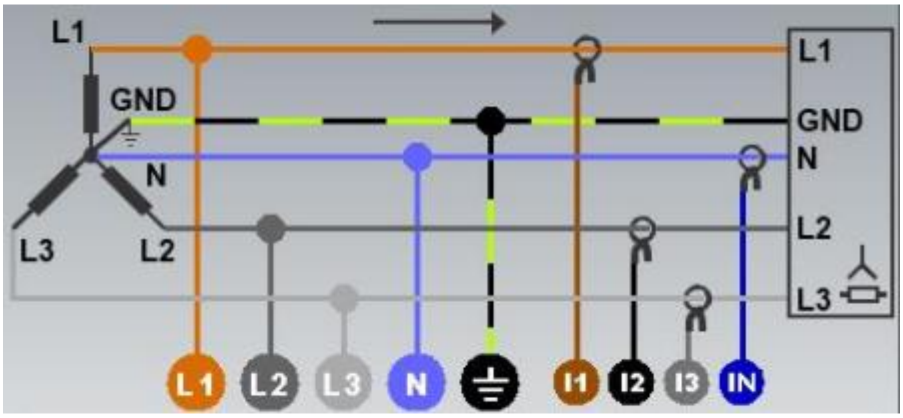

Image 30: Measuring instrument connection overview

Measuring voltage has generated sinus wave forms as image 31 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.

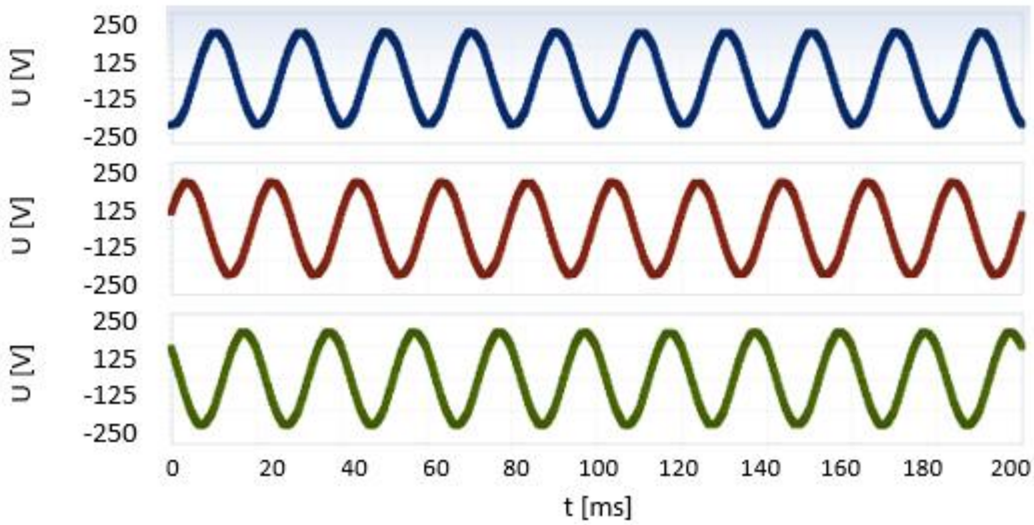

Image 31: Sinus wave form of measured voltage during 10 periods

Besides sinus wave form, a linear voltage overview is generated (image 32). 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.

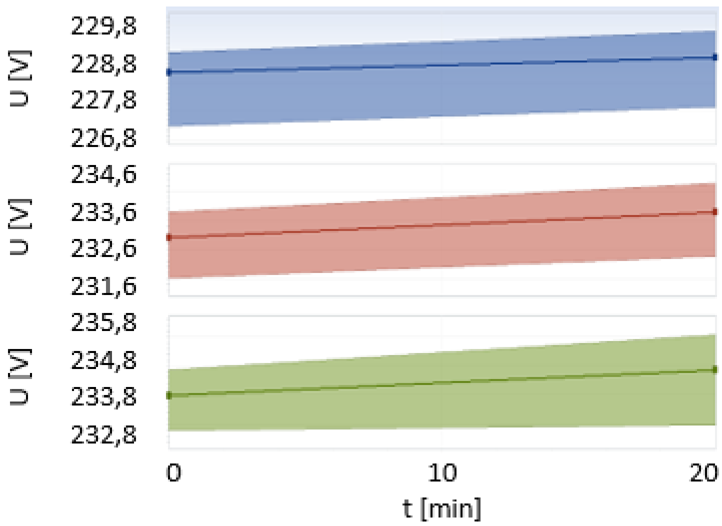

Image 32: Voltage effective values overview

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.

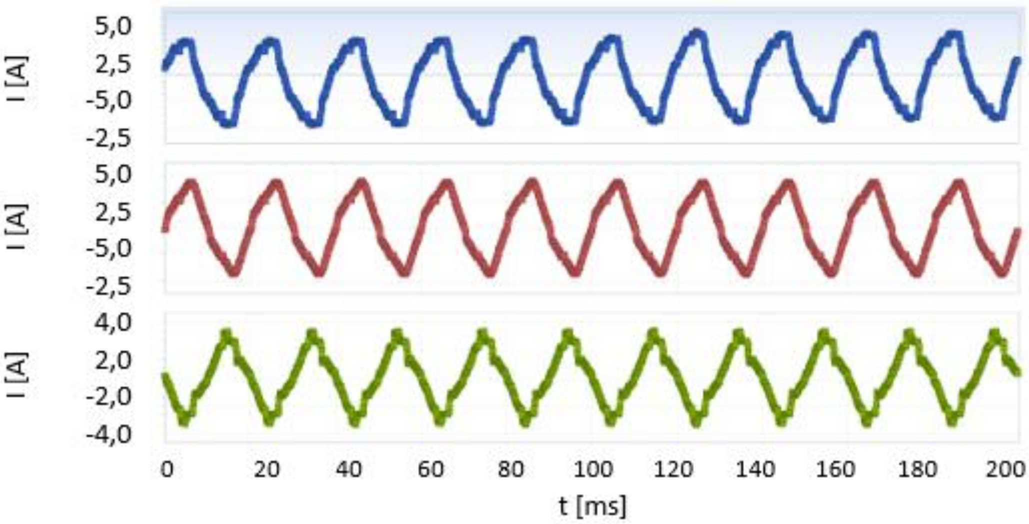

Image 33: Sinus wave form of measured voltage during 10 periods

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 34).

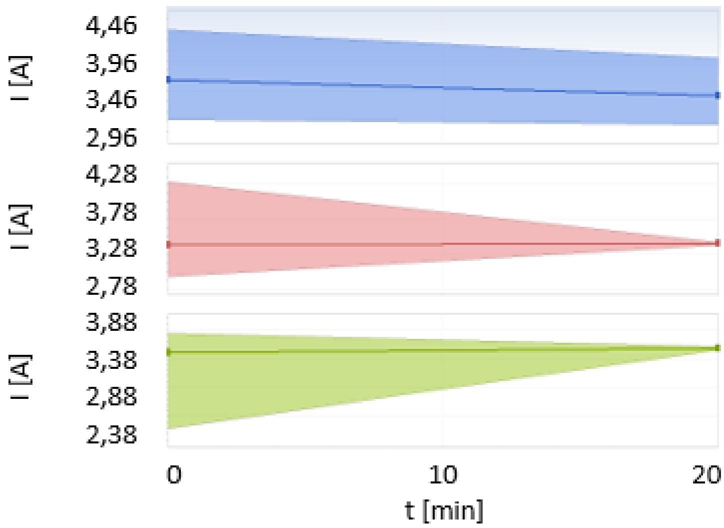

Image 34: Power effective value overview

During measuring voltage and power, effective display for active, reactive and apparent power triangle is generated. Great partaking in apparent power has a reactive power shown in image 35 which needs to be compensated due to measured cosφ is lower than 0,95.

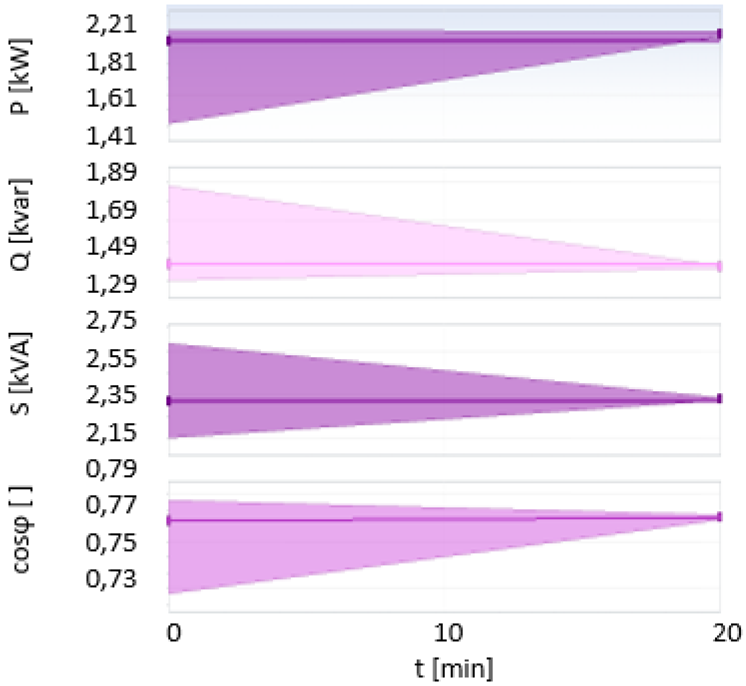

Image 35: : Active, reactive, apparent powers and cosφ overview

Measured active and reactive energy follows power values in measuring period shown in image 36.

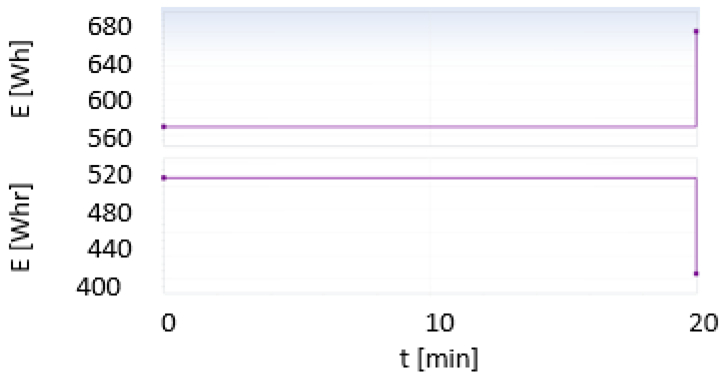

Image 36: : Radna i jalova energija

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 37 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.

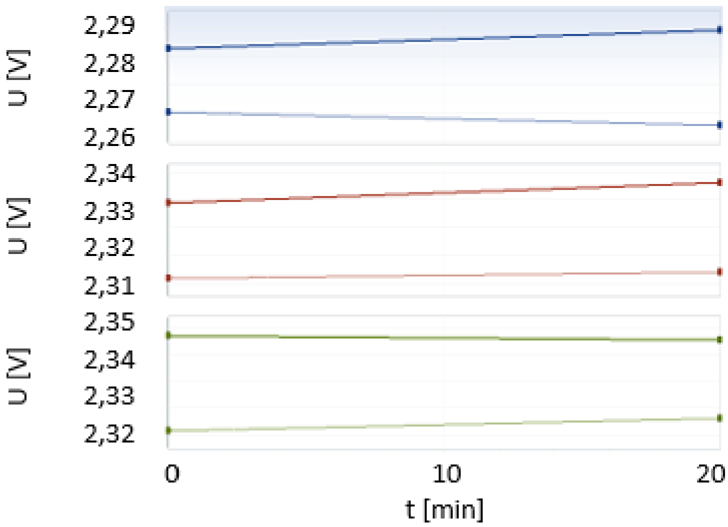

Image 38: : Maximum and average value of THDU

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 37th. Total harmonic deformation of power is approx 21%. Image 39 shows an overview of higher power harmonics up to 49th harmonic.

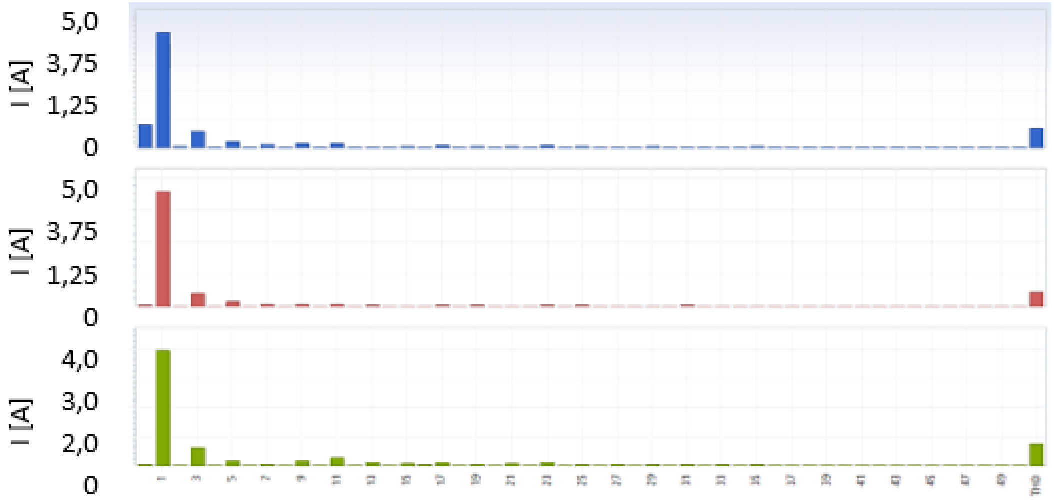

Image 39: : Column overview THDI

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

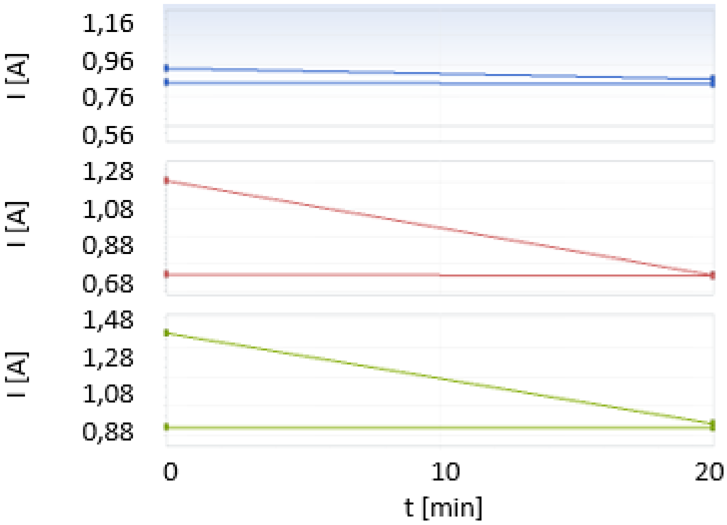

Image 40: : maximum and average value of THD

OMM name	Cable	Voltage (V)			Electricity (A)			Power (kW)			Cosϕ		
		L1	L2	L3	L1	L2	L3	L1	L2	L3	L1	L2	L3
PL Sapna Pijaca	4x10 m^2	227,9	233,3	233,6	2,28	2,34	2,36	0,384	0,388	0,402	0,74	0,71	0,73
PL Sapna 2	4x10 m^2	234,8	231,2	228,8	6,24	6,30	6,66	1,114	1,107	1,128	0,76	0,76	0,74
PL Goduš 2	4x10 m^2	233,3	230,9	230,3	1,18	1,29	1,19	0,212	0,212	0,206	0,77	0,71	0,75
PL Gornja Sapna	4x10 m^2	234,2	232,4	234,2	4,51	4,58	4,36	0,750	0,746	0,746	0,71	0,70	0,73
PL Međeđa	4x10 m^2	233,6	233,0	228,2	7,30	6,35	6,69	1,159	1,138	1,083	0,68	0,77	0,71
PL Sapna 1	4x10 m^2	228,8	233,6	234,8	3,46	3,28	3,38	0,593	0,589	0,627	0,75	0,77	0,79

Table 8: 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 41 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 (**Pogreška! Izvor reference nije pronađen.**).


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)
206. viteške brigade	Živa	250	4	4100	4715,00
206. viteške brigade	Živa	250	21	4100	24753,75
206. viteške brigade	Živa	250	14	4100	16502,50
Goduš	Živa	250	20	4100	23575,00
Goduš	LED	50	2	4100	471,50
Patriotske lige	Živa	250	19	4100	22396,25
R456	Živa	250	15	4100	17681,25
Međeđa	Živa	250	13	4100	15323,75
Branilaca Kraljevića	Živa	250	6	4100	7072,50
206. viteške brigade	Živa	250	13	4100	15323,75
206. viteške brigade	Živa	250	24	4100	28290,00
Total (kWh/annually)					176105,25
Lamp sources (pcs)					151,00
Specific annual consumption (kWh/per lamp source annually)					1166,26

Table 9: Calculated public lighting electricity consumption overview

From table 9 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 46 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)
Mercury	175633,75	149	1178,75	37357,30	19100,48
Total	175633,75	149	1178,75	37357,30	19100,48

Table 10:: Calculated consumption and unefficient public lighting electricity expenses overview

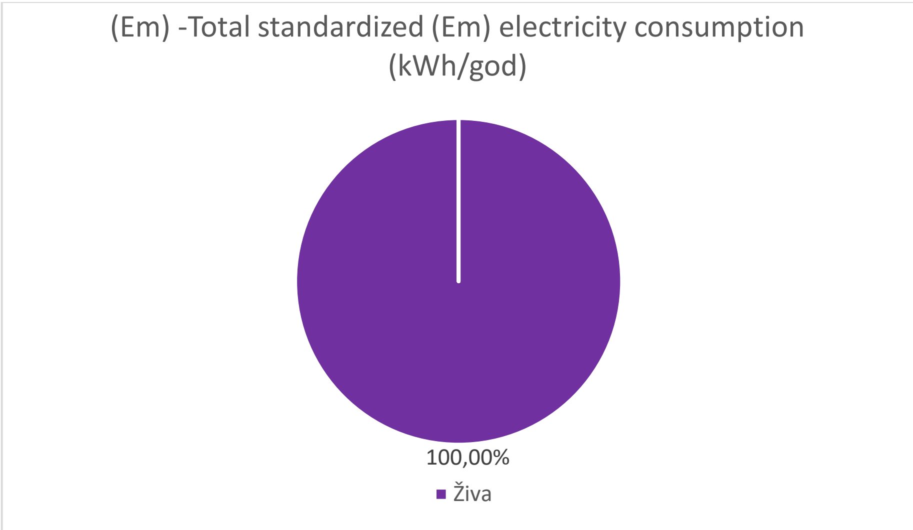

Image 43: Total standardized (Em) electricity consumption by unefficient public lighting types overview (kWh/annually)

Total standardized annual electricity consumption overview of unefficient public lighting per street classification from chapter ''Light - based technical requests and street classifications'' shown in table 11 while image 44 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)
M3/P1	24753,75	21	1178,75	5265,12	2692,01
M3/P2/P2	4715,00	4	1178,75	1002,88	512,76
M5	22396,25	19	1178,75	4763,68	2435,63
M5/P3	108445,00	92	1178,75	23066,25	11793,59
M5/P3/P3	15323,75	13	1178,75	3259,36	1666,49
Total	175633,75	149	1178,75	37357,30	19100,48

Table 11: Calculated consumption overview and electricity expenses of unefficient public lighting by street classifications

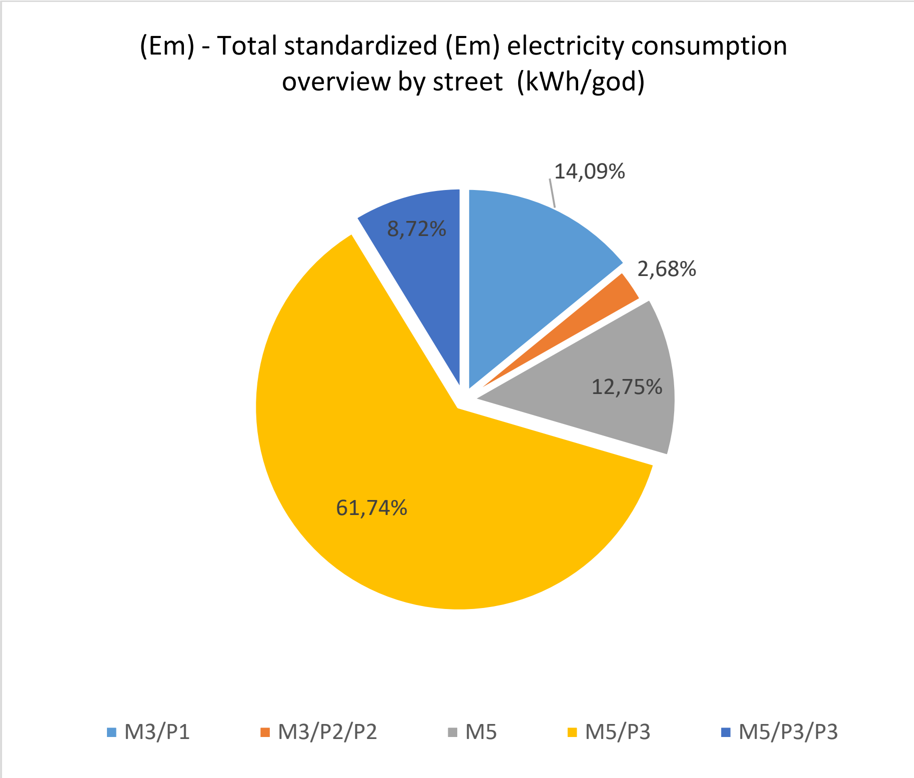

Image 44: Total standardized (Em) electricity consumption overview by street classifications of unefficient public lighting (kWh/annually)

6.5 System regulation and management analysis

In City of Sapna, there is no installed gear per OMM for central survilance and management over public lighting systems.

A way and type of management per OMM is shown in table from previous chapter ''Measuring points and substations''. Percentaged partaking of management devices per OMM (image cells, time releys, manual, etc.) is shown in image 45.

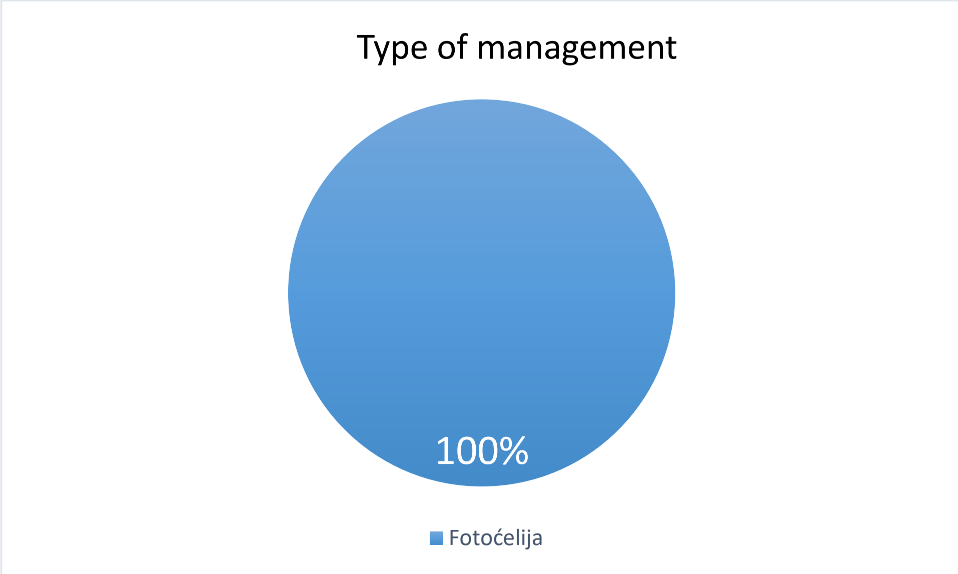

Image 45: Percentaged partaking overview of management device per OMM

6.6 Public lighting maintenance analysis

User self-initiatively and accordant to possibilities replaces lighting source. Table 12 shows an intervention overview and total annual maintenance u 2019.

/	Intervention name	KM/number	Description	Note
1	Annual maintenance expenses accordant to invoices	KM	No information	
2	Intervention number annually for lamp maintenance and total number of replaced complete lighting bodies	number	1-2 interventions per year	It is performed periodically when about 10 lamps are not in function
3	Total replaced lamp sources annually	number	up to 40 pcs per year	
4	Intervention number annually for electric installations maintenance	number	several interventions of el. distribution	
5	Number of lamp cleaning interventions annually due to dust contamination or other	number	During light bulb replacement, cleaning is also performed	
6	Intervention number annually due to other reasons (exp. cutting trees that block lamps)	number	a few	
7	Intervention number annually due to mistakes caused due to poor gear	number	a few	

Table 12: intervention overview and total annual public lighting maintenance

7 ANALYSIS OF ENERGY EXPENSES AND FORECASTING FUTURE CONSUMPTION

The analysis of electricity consumption was done on the basis of data from the bills received from the customers (UNDP) and City of Sapna for 2019. The tables and graphs in the following chapters show the electricity consumption for public lighting. Electricity is supplied from the public electricity distribution network, PC "Elektroprivreda BiH" ''Elektrodistribucija Bihać'', through 6 measuring points.

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

Electricity measuring point measures energy consumption, and it is measure consumption of active power. Total expenses for electricity are presented in the expenses balance, which is divided into two types (electricity and network charges) and tariff elements. The following tables provide an overview of electricity consumption and expenses by electricity measuring points.

The average price of electricity for the analyzed period is **0,2127 KM/kWh ili 0,108752 EUR/kWh**.

Month	01/A PL SAPNA - PIJACA 8314977	
	2019.	
	kWh	KM
January	1068	224,83
February	940	197,65
March	850	180,06
April	811	173,34
May	681	147,44
June	489	105,23
July	627	134,37
August	639	136,95
September	790	168,77
October	911	194,34
November	954	203,4
December	1086	231,27
Total	**9846**	**2097,65**

Table 13: Electricity consumption and expenses for the analyzed periodic measuring PL SAPNA - PIJACA

Month	02/A PL SAPNA 2 8315027	
	2019.	
	kWh	KM
January	968	203,47
February	860	180,98
March	757	160,35
April	733	156,74
May	616	132,05
June	452	97,41
July	623	133,52
August	616	132,05
September	749	160,13
October	846	180,61
November	890	189,89
December	1021	217,55
Total	**9131**	**1944,75**

Table 14: Electricity consumption and Expenses for the analyzed periodic measuring OMM PL SAPNA 2

Month	03/A PL GODUŠ 8554714	
	2019.	
	kWh	KM
January	716,63	151,16
February	641,79	135,58
March	493,82	105,3
April	513,53	110,41
May	446,89	96,35
June	348,64	75,59
July	360,67	78,13
August	368,08	79,7
September	357,31	77,42
October	458,88	98,88
November	527,24	113,31
December	602,76	129,24
Total	**5836,24**	**1251,07**

Table 15: Electricity consumption and Expenses for the analyzed periodic measuring OMM PL GODUŠ

Month	04/A PL GORNJA SAPNA 8315000	
	2019.	
	kWh	KM
January	1832	383,3
February	1569	328,56
March	1495	314,74
April	0	0
May	1269	269,91
June	964	205,51
July	1276	271,39
August	1251	266,12
September	1458	309,82
October	671	143,65
November	2741	580,69
December	2006	425,53
Total	**16532**	**3499,22**

Table 16: Electricity consumption and Expenses for the analyzed periodic measuring OMM PL GORNJA SAPNA

Month	05/A PL MEĐEĐA 7553897	
	2019.	
	kWh	KM
January	323,11	69
February	279,05	60,07
March	218,39	47,69
April	184,85	41,02
May	165,13	37,39
June	131,25	29,69
July	152,06	34,09
August	171,45	38,19
September	191,79	42,48
October	227,59	50,03
November	243,2	53,33
December	261,03	57,11
Total	**2548,9**	**560,09**

Table 17: Electricity consumption and Expenses for the analyzed periodic measuring OMM PL MEĐEĐA

Month	06/A PL SAPNA 1 7555334	
	2019.	
	kWh	KM
January	2329	488
February	1929	403,5
March	0	0
April	1716	364,41
May	1438	309,28
June	1095	233,18
July	1404	298,43
August	1414	300,54
September	1717	364,51
October	1941	411,8
November	1955	414,75
December	2118	449,17
Total	**19056**	**4037,57**

Table 18: Electricity consumption and Expenses for the analyzed periodic measuring OMM PL SAPNA 1

Month	2019.		
	kWh	KM	EUR
January	7236,74	1519,76	777,04
February	6218,84	1306,34	667,92
March	3814,21	808,14	413,20
April	3958,38	845,92	432,51
May	4616,02	992,42	507,42
June	3479,89	746,61	381,74
July	4442,73	949,93	485,69
August	4459,53	953,55	487,54
September	5263,1	1123,13	574,25
October	5055,47	1079,31	551,84
November	7310,44	1555,37	795,25
December	7094,79	1509,87	771,98
Total	**62.950,14**	**13.390,35**	**6.846,38**

Table 19: Total electricity consumption and Expenses for 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 Expenses, measures can be suggested to reduce or increase energy efficiency.

Image 46 shows a diagram of electricity consumption and its Expenses by months in 2019. 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. The electricity transmission tariff has not changed.

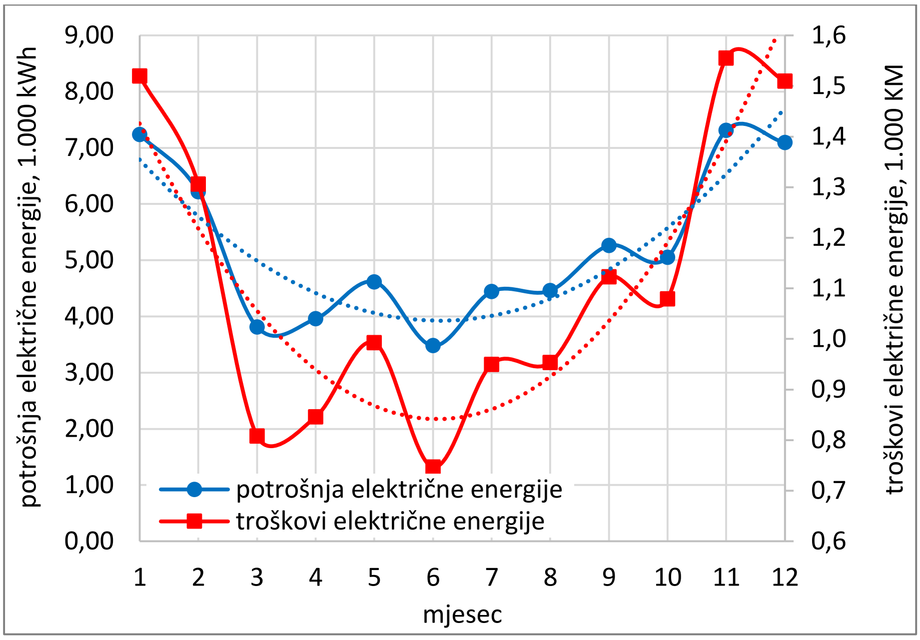

Image 46: Overview of total electricity consumption and Expenses during 2019. godine

The consultant did not receive invoices for other years.

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 relation:

$$MF = LLMF \times LSF \times LMF \ (\times SMF) \ \text{(outdoor areas)} \quad (4.)$$

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 lamps, without the need to clean the lamps 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 lamps 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 electricityand 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 data 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 lamps. 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 lamps 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

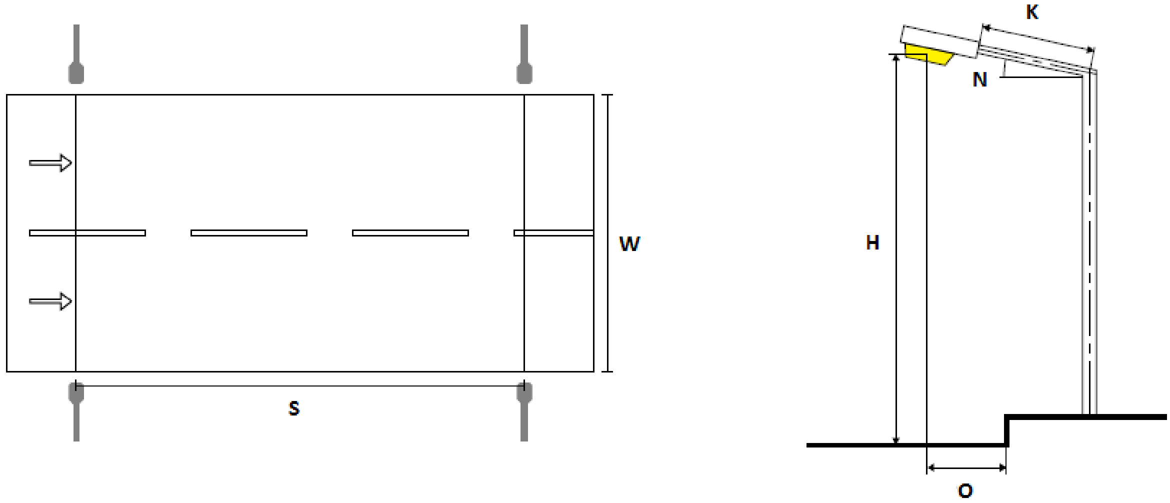

Image 47: Geometric display of characteristics parameters

Image 48 gives an example of photometric calculation and determination of street class in software.

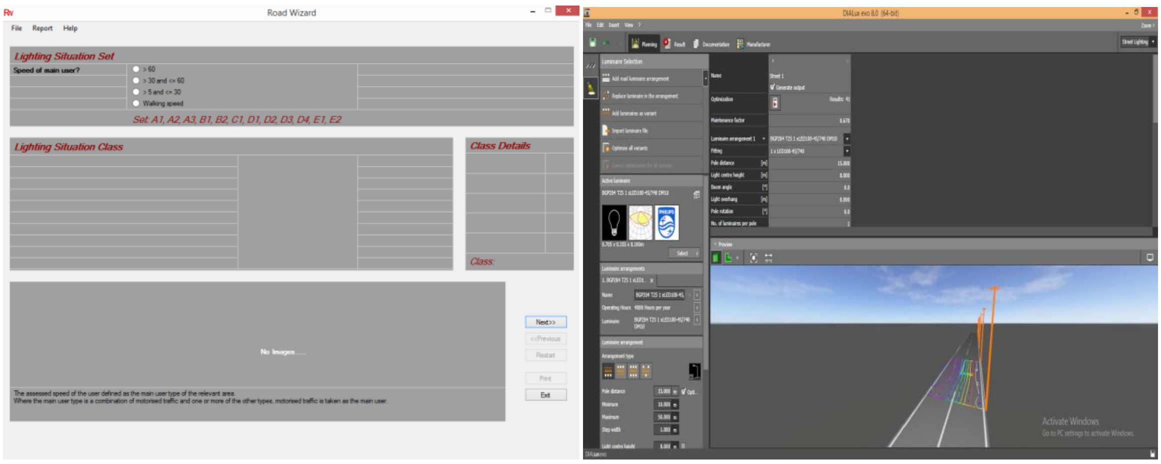

Image 48: Left - example of determining the class of the street in the software "Road Wizard", right - example of photometric calculation of the road in the software "Dialux "

"

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 15 gives certain classes of streets with all the input data necessary for photometric calculations.

Image 49, image 50, image 51 i image 52 show examples of a new lighting solution.

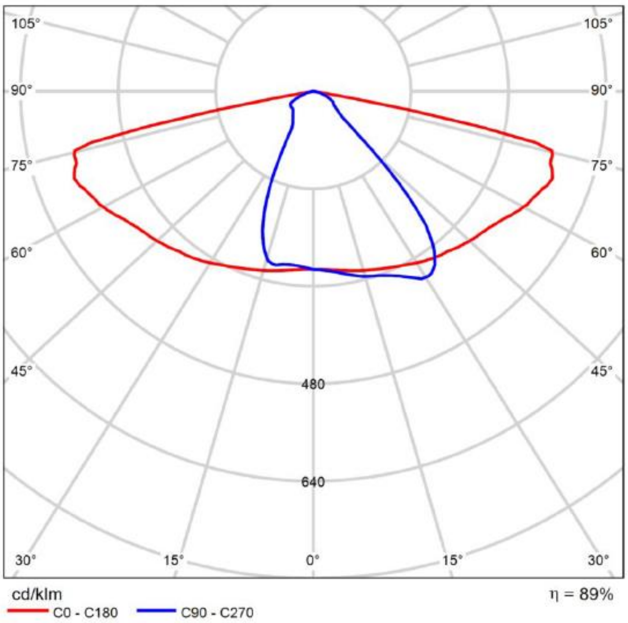

Image 49: Example of light emission calculation

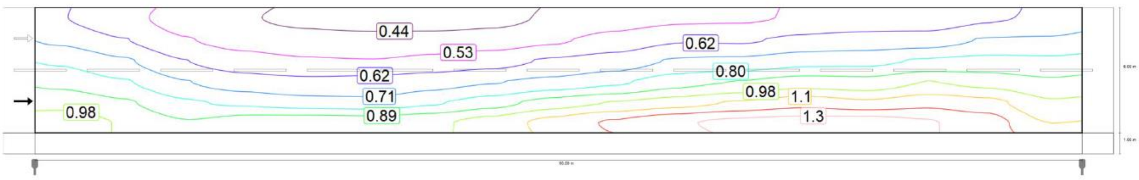

Image 50: Example of light intensity calculation and analysis results

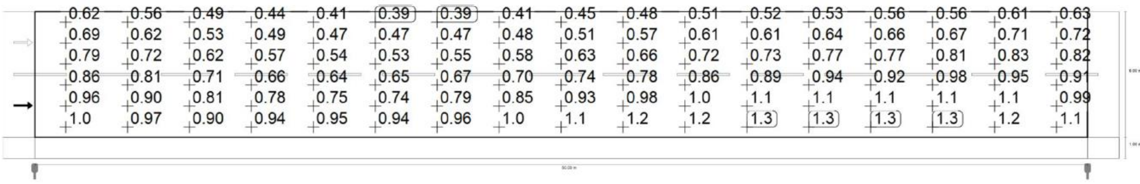

Image 51: Example of horizontal brightness calculation and analysis results

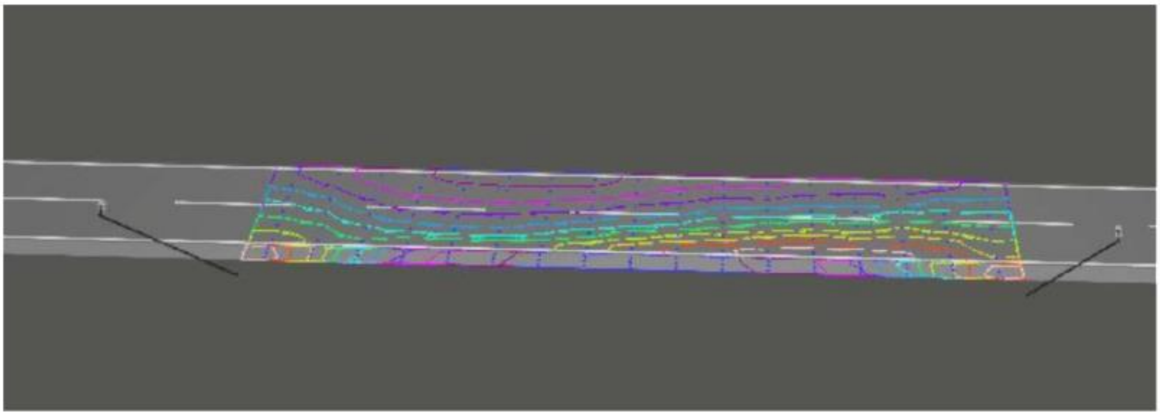

Image 52: Replacing the existing lighting with LED lighting

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	206. viteške brigade	40	2	6	1/1	40	one-sided	8	da	2	10	1	mixed	M3/P2/P2
2	206. viteške brigade	40	2	6	1/0	40	one-sided	8	da	0,3	10	1	mixed	M3/P1
3	206. viteške brigade	40	2	6	1/0	40	one-sided	8	da	0,4	5	1	mixed	M5/P3
4	Goduš	80	2	6	1/0	40	one-sided	8	da	0,4	5	1	mixed	M5/P3
5	Patriotske lige	80	2	6	1/0	40	one-sided	8	da	0,4	5	1	mixed	M5/P3
6	R456	80	2	6	1/0	40	one-sided	8	da	0,4	15	1	mixed	M5/P3
7	Međeđa	50	1	5	0/0	40	one-sided	8	da	0,3	5	1	mixed	M5
8	Branilaca Kraljevića	50	1	5	0/0	40	one-sided	8	da	2	10	1	mixed	M5

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	Lamp mounted on tine / console (yes/no)	Tine / console length	Inclination of the tine / console (%)	The distance of the light pole from the road	Type of traffic participants	Road class
								(m)		(m)	(%)	(m)		
9	206. viteške brigade	80	2	6	1/1	40	one-sided	8	da	0,4	10	1	mixed	M5/P3/P3
10	206. viteške brigade	80	2	6	0/0	40	one-sided	8	da	0,4	10	1	mixed	M5/P3

Table 20: 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 electricity while leaving quality of lighting intact. Besides direct profits (energy consumption savings, or electricityexpenses), 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. Based on imagemetry budget, replacement of existing energy, not efficient lamps with LED lamps is suggested. Lighting bodies overview is found in table 21.

Ordinal number	Street name	Lighting source type	TIP
1	206. viteške brigade	Type as PhilipsBGP283 LED119-4S/730 II DM10 D9 48/60S	T1
2	206. viteške brigade	Type as PhilipsBGP283 LED130-4S/730 II DM11 D9 48/60S	T2
3	206. viteške brigade	Type as PhilipsBGP307 LED54-4S/730 II DN10 D9 48/60S	T3
4	Goduš	Type as PhilipsBGP307 LED54-4S/730 II DN10 D9 48/60S	T3
5	Patriotske lige	Type as PhilipsBGP307 LED54-4S/730 II DN10 D9 48/60S	T3
6	R456	Type as PhilipsBGP307 LED54-4S/730 II DN10 D9 48/60S	T3
7	Međeđa	Type as PhilipsBGP307 LED45-4S/730 II DN10 D9 48/60S	T4
8	Branilaca Kraljevića	Type as PhilipsBGP307 LED45-4S/730 II DN10 D9 48/60S	T4
9	206. viteške brigade	Type as PhilipsBGP307 LED54-4S/730 II DN10 D9 48/60S	T3
10	206. viteške brigade	Type as PhilipsBGP307 LED54-4S/730 II DN10 D9 48/60S	T3

Table 21: Lighting bodies overview for which energyefficiency measures are suggested

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

9.1.1 Electricity consumption budget by applying replacement measures of existing lighting with LED technology

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

$$E_{m1}=(P_{isLED} + P_{gubLED}) * T_{ref} \quad (5.)$$

$$E_{m1}=P_{refLED} * T_{ref} \quad (6.)$$

where the following is:
Em1 – standardized annual electricity 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 energy efficiency enhancement measure found in table 22.

Street name	Lighting source type	PrefLED – Total reference power	Quantity	(Tref) - Working period	(Em1) - Total standardized annual consumption
		(W)	(pcs)	(h/annually)	(kWh/annually)
206. viteške brigade	Type as PhilipsBGP283 LED119-4S/730 II DM10 D9 48/60S	75	4	4100	1230
206. viteške brigade	Type as PhilipsBGP283 LED130-4S/730 II DM11 D9 48/60S	83	21	4100	7146,3
206. viteške brigade	Type as PhilipsBGP307 LED54-4S/730 II DN10 D9 48/60S	37	14	4100	2123,8
Goduš	Type as PhilipsBGP307 LED54-4S/730 II DN10 D9 48/60S	37	20	4100	3034
Patriotske lige	Type as PhilipsBGP307 LED54-4S/730 II DN10 D9 48/60S	37	19	4100	2882,3
R456	Type as PhilipsBGP307 LED54-4S/730 II DN10 D9 48/60S	37	15	4100	2275,5
Međeđa	Type as PhilipsBGP307 LED45-4S/730 II DN10 D9 48/60S	30,5	13	4100	1625,65

Street name	Lighting source type	PrefLED – Total reference power	Quantity	(Tref) - Working period	(Em1) - Total standardized annual consumption
		(W)	(pcs)	(h/annually)	(kWh/annually)
Branilaca Kraljevića	Type as PhilipsBGP307 LED45-4S/730 II DN10 D9 48/60S	30,5	6	4100	750,3
206. viteške brigade	Type as PhilipsBGP307 LED54-4S/730 II DN10 D9 48/60S	37	13	4100	1972,1
206. viteške brigade	Type as PhilipsBGP307 LED54-4S/730 II DN10 D9 48/60S	37	24	4100	3640,8
Total (kWh/annually)					26680,75
Lighting sources (pcs)					149
Specific annual consumption (kWh/per lighting source annually)					179,07

Table 22: Total electricity 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 Analiza upravljanja javnom rasvjetom

Lighting management 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 management cannot complete all requested lighting system functions. Considering a decision on turning on/off lights depends on a man, from a perspective of energyefficiency, this way of managing is especially inconvenient.

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 electricitysavings through lighting system automatization. In the following, measures of automatic lighting management 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 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 is considered with built in autonomous dimmer (Dynadimmer). Dynadimmer (image 51) 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 53: 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.

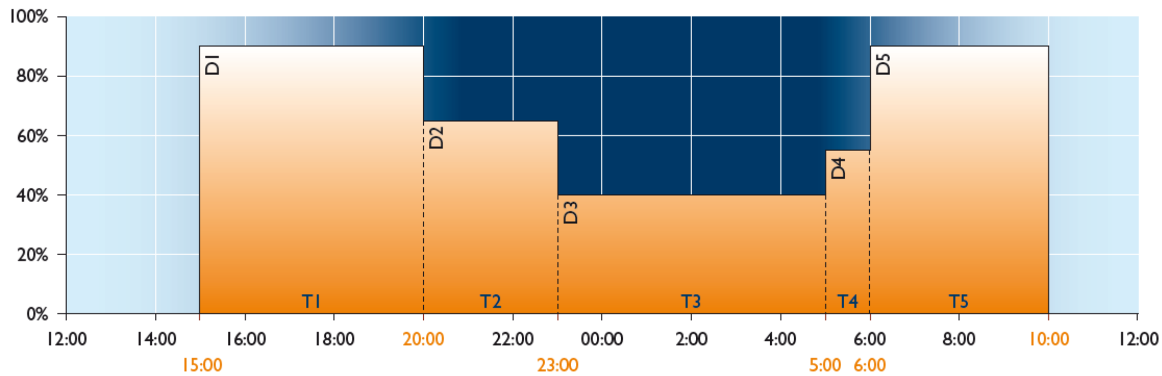

Image 54: Example of dimming luminous flux into 5 levels

For electricity 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 electricity consumption was done by equation:

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

Where the following is:
E_{m2} – standardized annual electricity consumption for considered M2 – measure 2 (kWh/annually);
E_{m1} – standardized annual electricity 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.

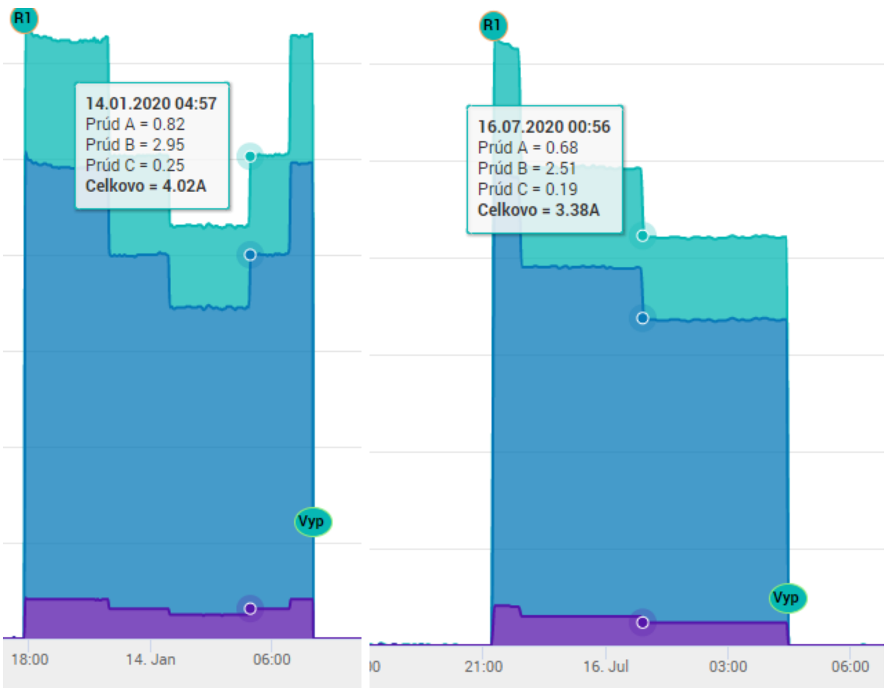

Image 55: Used model for dimming luminous flux for considered measure (left – diagram example for winter period, right – diagram example for summer period)

Table 23 shows a total electricity consumption applying measures based on a considered model

Ordinal number	Street name	Lighting source type with built in dimming device	(Em2) - Total standardized annual consumption (kWh/annually)
1	206. viteške brigade	Type as PhilipsBGP283 LED119-4S/730 II DM10 D9 48/60S– Dynadimmer DDR2 built in a lamp	954,57
2	206. viteške brigade	Type as PhilipsBGP283 LED130-4S/730 II DM11 D9 48/60S– Dynadimmer DDR2 built in a lamp	5546,04
3	206. viteške brigade	Type as PhilipsBGP307 LED54-4S/730 II DN10 D9 48/60S– Dynadimmer DDR2 built in a lamp	1648,22

Ordinal number	Street name	Lighting source type with built in dimming device	(Em2) - Total standardized annual consumption (kWh/annually)
4	Goduš	Type as PhilipsBGP307 LED54-4S/730 II DN10 D9 48/60S– Dynadimmer DDR2 built in a lamp	2354,60
5	Patriotske lige	Type as PhilipsBGP307 LED54-4S/730 II DN10 D9 48/60S– Dynadimmer DDR2 built in a lamp	2236,87
6	R456	Type as PhilipsBGP307 LED54-4S/730 II DN10 D9 48/60S– Dynadimmer DDR2 built in a lamp	1765,95
7	Međeđa	Type as PhilipsBGP307 LED45-4S/730 II DN10 D9 48/60S– Dynadimmer DDR2 built in a lamp	1261,62
8	Branilaca Kraljevića	Type as PhilipsBGP307 LED45-4S/730 II DN10 D9 48/60S– Dynadimmer DDR2 built in a lamp	582,29
9	206. viteške brigade	Type as PhilipsBGP307 LED54-4S/730 II DN10 D9 48/60S– Dynadimmer DDR2 built in a lamp	1530,49
10	206. viteške brigade	Type as PhilipsBGP307 LED54-4S/730 II DN10 D9 48/60S– Dynadimmer DDR2 built in a lamp	2825,52
Total (kWh/annually)			20706,17
Lighting sources (pcs)			149
Specific annual consumption (kWh/per lighting source annually)			138,97

Table 23: Total electricity 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 will not have any effect on functionality and safety with built in central technical survilance

Building techincal survilance known as ''telemanagement'' is an automatized digital management system consisting of few subsystems. Telemanagement 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). Telemanagement provides malfunction detection on a lamp, powering problems and etc., two-way communication between a lamp and management module where exists a feedback on a particular lamp status. A system consists of 3 main elements:
- gateway,
- controller,
- management software, recently ''Cloud''.

Remote management and control system of public lighting (telemanagement) 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 management system, collecting, analyzing and processing data. From this management 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 54, image 55, and image 56 show an interface overview, using software with possibilities and settings.

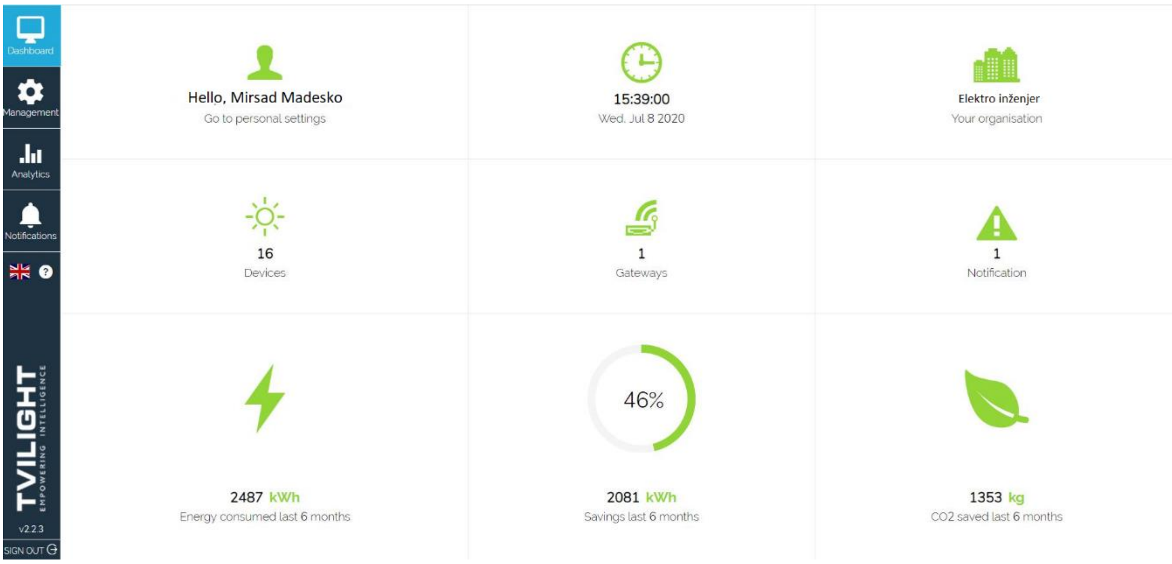

Image 56: Software interface overview

Image 57: Conducting analysis for electricity consumption example

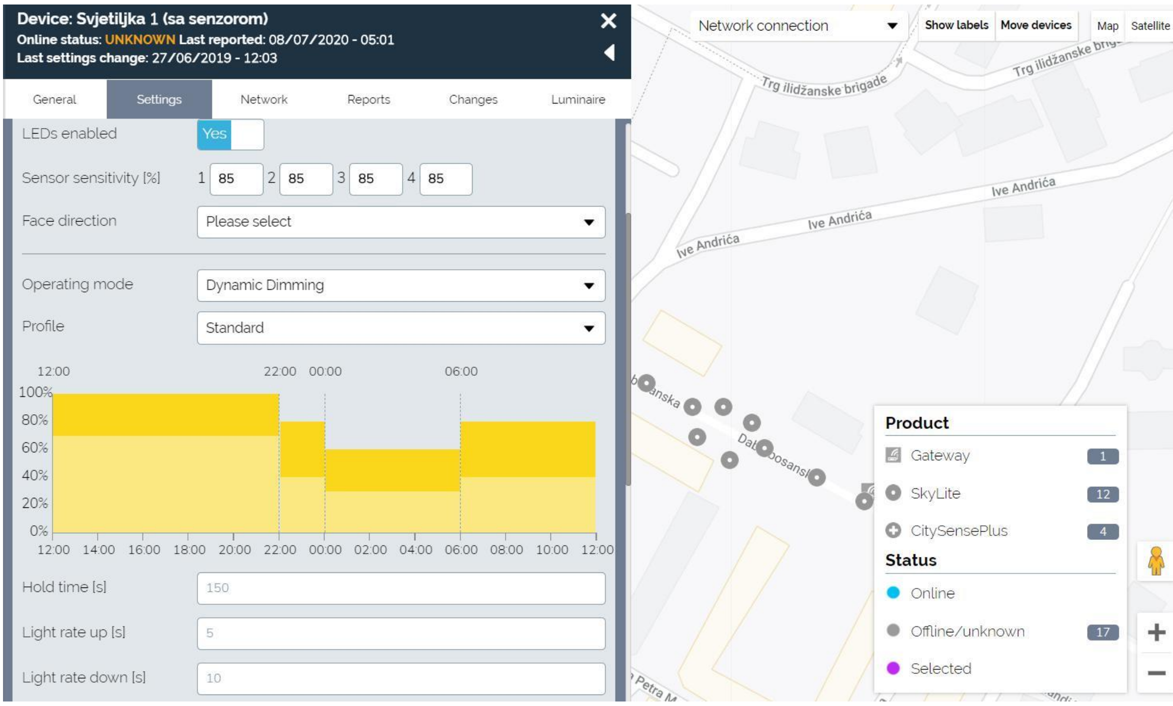

Image 58: Software settings example

For electricity 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 techincal survilance is an applied practice system. Standardized annual electricity consumption was made by:

$$E_{m3}=E_{m1} * k_{m3} \qquad (8.)$$

where the following is:

E_{m3} – standardized annual electricity consumption for considered M2 – measure 2 (kWh/annually);
E_{m1} – standardized annual electricity consumption from M1 – measure 1 (kWh/annually);
k_{m3} – coefficient applied from winter and summer period practice – 0,374

Table 24 gives a description of a decision with automatized lighting way of work. Electricitysavings 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	(Em3) - Total standardized annual consumption
Telemanagement system installation	set	DA	DA - Cloud	16702,15
Total (kWh/annually)				
Lighting sources (pcs)				
Specific annual consumption (kWh/per lighting source annually)				

Table 24: Total electricity 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 lighting 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 25 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)	(pcs)	(KM/annually)
1	206. viteške brigade	4715,00	1230,00	3485,00	4	871,25
2	206. viteške brigade	24753,75	7146,30	17607,45	21	838,45
3	206. viteške brigade	16502,50	2123,80	14378,70	14	1027,05
4	Goduš	23575,00	3034,00	20541,00	20	1027,05
5	Patriotske lige	22396,25	2882,30	19513,95	19	1027,05
6	R456	17681,25	2275,50	15405,75	15	1027,05
7	Međeđa	15323,75	1625,65	13698,10	13	1053,70
8	Branilaca Kraljevića	7072,50	750,30	6322,20	6	1053,70
9	206. viteške brigade	15323,75	1972,10	13351,65	13	1027,05
10	206. viteške brigade	28290,00	3640,80	24649,20	24	1027,05
TOTAL		**175633,75**	**26680,75**	**148953,00**	**149**	**999,68**

Table 25: Energy savings for lighting after replacing existing lighting with LED

10.1.1.2 Energy savings analysis by replacing existing lamps with dimmable LED lamps - 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 26.

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)	(pcs)	(KM/annually)
1	206. viteške brigade	1230,00	954,57	275,43	4	68,86
2	206. viteške brigade	7146,30	5546,04	1600,26	21	76,20
3	206. viteške brigade	2123,80	1648,22	475,58	14	33,97
4	Goduš	3034,00	2354,60	679,40	20	33,97
5	Patriotske lige	2882,30	2236,87	645,43	19	33,97
6	R456	2275,50	1765,95	509,55	15	33,97
7	Međeđa	1625,65	1261,62	364,03	13	28,00
8	Branilaca Kraljevića	750,30	582,29	168,01	6	28,00
9	206. viteške brigade	1972,10	1530,49	441,61	13	33,97
10	206. viteške brigade	3640,80	2825,52	815,28	24	33,97
UKUPNO		**26680,75**	**20706,17**	**5974,58**	**149**	**40,10**

Table 26: Energy savings for lighting after replacing existing LED lighting with Dynadimmer

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

Table 27 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)	(pcs)	(KM/annually)
Installation of telemanagement system	26680,75	16702,15	9978,60	149,00	66,97

Table 27: Calculation of potential electricity savings by installing a telemanagement system

10.1.2 Economic analysis

10.1.2.1 Analysis of economic savings of replacing exisiting lighting with LED

The calculation of electricity Expenses that would be after the implementation of this measure has been performed, and the results are found in table 28.

Ordinal No.	Street name	Expenses according to energy consumption Em	Expenses according to energy consumption Em1	Annual savings	Quantity	Annual savings per lamp
		(kWh/annually)	(kWh/annually)	(kWh/annually)	(pcs)	(KM/annually)
1	206. viteške brigade	1002,88	261,62	741,26	4	185,31
2	206. viteške brigade	5265,12	1520,02	3745,10	21	178,34
3	206. viteške brigade	3510,08	451,73	3058,35	14	218,45
4	Goduš	5014,40	645,33	4369,07	20	218,45
5	Patriotske lige	4763,68	613,07	4150,62	19	218,45
6	R456	3760,80	484,00	3276,80	15	218,45
7	Međeđa	3259,36	345,78	2913,59	13	224,12
8	Branilaca Kraljevića	1504,32	159,59	1344,73	6	224,12
9	206. viteške brigade	3259,36	419,47	2839,90	13	218,45
10	206. viteške brigade	6017,28	774,40	5242,88	24	218,45
TOTAL		**37357,30**	**5675,00**	**31682,30**	**149**	**212,63**
TOTAL (€/annually)		**19100,48**	**2901,58**	**16198,90**		**108,72**

Table 28: Expenses calculation after replacing existing lighting with LED

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

The calculation of electricity Expenses that would be after the implementation of this measure has been performed, and the results are found in table 29.

Ordinal No.	Street name	Expenses according to energy consumption Em1	Expenses according to energy consumption Em2	Annual savings	Quantity	Annual savings per lamp
		(KM/annually)	(KM/annually)	(KM/annually)	(pcs)	(KM/annually)
1	206. viteške brigade	261,62	203,04	58,58	4	14,65
2	206. viteške brigade	1520,02	1179,64	340,38	21	16,21
3	206. viteške brigade	451,73	350,58	101,16	14	7,23
4	Goduš	645,33	500,82	144,51	20	7,23
5	Patriotske lige	613,07	475,78	137,28	19	7,23
6	R456	484,00	375,62	108,38	15	7,23
7	Međeđa	345,78	268,35	77,43	13	5,96
8	Branilaca Kraljevića	159,59	123,85	35,74	6	5,96
9	206. viteške brigade	419,47	325,54	93,93	13	7,23
10	206. viteške brigade	774,40	600,99	173,41	24	7,23
TOTAL		**5675,00**	**4404,20**	**1270,79**	**149**	**8,53**
TOTAL (€/annually)		**2901,58**	**2251,83**	**649,74**		**4,36**

Table 29: Expenses calculation after installing the Dynadimmer system

10.1.2.3 Analysis of economic savings by replacing existing lamps with dimmable LED lamps - where dimming is possible and will not affect functionality and safety with the installation of central technical supervision

The calculation of electricity Expenses that would be after the implementation of this measure was performed, and the results are found table 30.

Measure name	Expenses according to energy consumption Em1	Expenses according to energy consumption Em3	Annual savings	Quantity	Annual savings per lamp
	(KM/annually)	(KM/annually)	(KM/annually)	(pcs)	(KM/annually)
Installation of telemanagement system	5675,00	3552,55	2122,45	149	14,24
	(EUR/god)	(EUR/god)	(EUR/god)	(kom)	(EUR/god)
	2901,58	1816,39	1085,19	149	7,28

Table 30: Calculation of Expenses after installing a telemanagement system

11 FINANCIAL ANALYSIS

In general, the implementation of EE measures on public lighting systems leads to the realization of various positive effects. In technical terms, there is an optimization of lighting capacities, a reduction in electricity consumption, the release of capacity for further expansion of public lighting systems, and a number of other positive effects.

These technical improvements, consequently, lead to improvements of the financial situation in the companies that manage public lighting systems as well as on the side of their users. Within the technical analysis, which was done with the aim of finding the optimal way to improve the public lighting system in the Municipality of Laktaši, the implementation of 4 EE measures was considered:

- Measure 0 - Preparatory works / dismantling of existing lighting fixtures
- Measure 1 Procurement and installation of new LED lamps;
- Measure 2 Procurement and installation of a ballast for autonomous wireless attenuation of light flux;
- Measure 3 Procurement and installation of telemanagement.

The financial effects of the implementation differ both for each of the above measures individually and for a combination of 2 or more measures. In order to select a measure or combination of measures that will lead to the greatest financial effects, 3 EE scenarios have been defined, as follows:

- Scenario 1 - includes procurement and installation of new LED lamps;
- Scenario 2 includes the procurement and installation of new LED lamps and the procurement and installation of a ballast for autonomous wireless attenuation of light flux;
- Scenario 3 includes the procurement and installation of new LED lamps and the procurement and installation of telemanagement.

The analysis of the financial justification of the above scenarios was done on the basis of cash flow projections for each scenario for a period of 15 years (2020 -2035), which served as a basis for calculating financial indicators: (i) internal rate of return (internal rate of return(IRR)), (ii) Net Present Value (NPV), (iii) Simple Payback Period, and (iv) Discounted Payback Period.

It is important to note that the amounts of investment costs for the proposed measures, as well as the amounts of operating costs and revenues are shown without value added tax (VAT). Taking into account their amounts, it is expected that the implementer of measures, regardless of whether it is a local self-government unit or a third legal entity, will be a registered VAT payer and thus have the right to deduct VAT.

Cash savings that will be realized as a result of the implementation of a certain scenario are considered as cash inflows, while investment costs and maintenance costs for a given scenario are considered as cash outflows. Also, within the financial analysis of the considered scenarios, a discount rate of 5% was used.

11.1. Investment costs (CAPEX)

Table 26 provides an overview of investment costs for the considered scenarios.

ITEM	AMOUNT	
Measures	BAM	EUR
M0 Preparatory works / dismantling of existing lighting fixtures	2.980	1.524
M1 Procurement and installation of new LED lamps	65.370	33.423
M2 Procurement and installation of a ballast for autonomous wireless dimming of light flow	4.023	2.057
M3 Procurement and installation of telemanagement	77.362	39.555
Scenarios		
Scenario 1 (M0+M1)	68.350	34.947
Scenario 2 (M0+M1+M2)	72.373	37.004
Scenario 3 (M0+M1+M3)	145.712	74.501

Table 31: Investment costs by scenarios

The assumption is that the investments in the considered scenarios will be realized during 2020, and that the municipality of Sapna will start realizing the financial effects from the implementation of the investment in 2021.

11.2. Financial savings

The financial savings that will appear as a result of the implementation of the considered scenarios are calculated on the basis of the existing electricity consumption for public lighting in the municipality of Sapna and the electricity consumption after the implementation of the considered scenarios. The price of electricity from the chapter Analysis of energy costs and forecast of future consumption of 0,2127 KM/kWh or 0,1088 EUR/kWh was used in the analysis. Table 27 gives an overview of financial savings according to the considered scenarios.

ITEM	UNIT	AMOUNT
Existing considered electricity consumption	kWh/year	175.634
Electricity consumption by scenarios		
Scenario 1	kWh/year	26.681
Scenario 2	kWh/year	20.706
Scenario 3	kWh/year	16.702
Electricity savings		
Scenario 1	kWh/year	148.953
Scenario 2	kWh/year	154.928
Scenario 3	kWh/year	158.932
Electricity price	BAM/kWh	0,2127
	EUR/kWh	0,1088
Financial savings		

Scenario 1	BAM/year	31.682,30
	EUR/year	16.198,90
Scenario 2	BAM/year	32.953,10
	EUR/year	16.848,65
Scenario 3	BAM/year	33.804,75
	BAM/year	17.284,09

Table 32: Financial savings

11.3. Operating costs (OPEX)

11.3.1. Maintenance costs

The equipment that will be installed within the considered scenarios will have a warranty for a period of 5 years, which implies that there will be no maintenance costs in the period of 2020-2025. After the 2025., it is assumed that the annual maintenance costs will be 0.5% of the investment costs for the given scenario, which in addition to the regular maintenance costs also include the costs for the necessary licenses. Table 28 gives an overview of maintenance by scenarios.

Scenario	UNIT	
	BAM	EUR
Scenario 1	341,75	174,73
Scenario 2	361,87	185,02
Scenario 3	728,56	372,51

Table 33: Maintenance costs

11.4. Cash flow projection

Based on the aforementioned investment costs and maintenance costs and expected financial savings, a cash flow projection was made for each scenario for the period 2020- 2035. Table 29, table 30 and table 31 provide an overview of cash flow for each scenario considered and the 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
CASH INFLOWS																		
Financial savings	KM			31.682,30	31.682,30	31.682,30	31.682,30	31.682,30	31.682,30	31.682,30	31.682,30	31.682,30	31.682,30	31.682,30	31.682,30	31.682,30	31.682,30	31.682,30
CASH OUTFLOWS																		
Maintenance costs	KM		0	0	0	0	0	0	342	342	342	342	342	342	342	342	342	342
Investment costs	KM		68.350	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NET CASH FLOW	**KM**		-68.350	31.682	31.682	31.682	31.682	31.682	31.341	31.341	31.341	31.341	31.341	31.341	31.341	31.341	31.341	31.341
CUMULATIVE CASH FLOW	**KM**		-68.350	-36.668	-4.985	26.697	58.379	90.062	121.402	152.743	184.083	215.424	246.764	278.105	309.445	340.786	372.126	403.467
IRR	%	46%																
NPV	KM	258.433,82																
Discounted return period	year	3																
Peyback period	year	3																

ITEM	UNIT	Amount	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
CASH INFLOWS																		
Financial savings	EUR		0	16198,904	16198,904	16198,904	16198,904	16198,904	16198,904	16198,904	16198,904	16198,904	16198,904	16198,904	16198,904	16198,904	16198,904	16198,904
CASH OUTFLOWS																		
Maintenance costs	EUR		0	0	0	0	0	0	175	175	175	175	175	175	175	175	175	175
Investment costs	EUR		34.947	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NET CASH FLOW	**EUR**		-34.947	16.199	16.199	16.199	16.199	16.199	16.024	16.024	16.024	16.024	16.024	16.024	16.024	16.024	16.024	16.024
CUMULATIVE CASH FLOW	**EUR**		-34.947	-18.748	-2.549	13.650	29.849	46.048	62.072	78.096	94.120	110.144	126.169	142.193	158.217	174.241	190.265	206.289
IRR	%	46%																
NPV	EUR	132.135,12																
Discounted return period	year	3																
Peyback period	year	3																

Table 34: Cash flow Scenario 1

ITEM	UNIT	Amount	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
CASH INFLOWS																		
Financial savings	KM			32.953,10	32.953,10	32.953,10	32.953,10	32.953,10	32.953,10	32.953,10	32.953,10	32.953,10	32.953,10	32.953,10	32.953,10	32.953,10	32.953,10	32.953,10
CASH OUTFLOWS																		
Maintenance costs	KM		0	0	0	0	0	0	362	362	362	362	362	362	362	362	362	362
Investment costs	KM		72.373	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NET CASH FLOW	KM		-72.373	32.953	32.953	32.953	32.953	32.953	32.591	32.591	32.591	32.591	32.591	32.591	32.591	32.591	32.591	32.591
CUMULATIVE CASH FLOW	KM		-72.373	-39.420	-6.467	26.486	59.439	92.392	124.984	157.575	190.166	222.757	255.349	287.940	320.531	353.122	385.714	418.305
IRR	%	45%																
NPV	KM	267.479,55																
Discounted return period	year	3																
Peyback period	year	3																

ITEM	UNIT	Amount	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
CASH INFLOWS																		
Financial savings	EUR		0	16848,652	16848,652	16848,652	16848,652	16848,652	16848,652	16848,652	16848,652	16848,652	16848,652	16848,652	16848,652	16848,652	16848,652	16848,652
CASH OUTFLOWS																		
Maintenance costs	EUR		0	0	0	0	0	0	185	185	185	185	185	185	185	185	185	185
Investment costs	EUR		37.004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NET CASH FLOW	EUR		-37.004	16.849	16.849	16.849	16.849	16.849	16.664	16.664	16.664	16.664	16.664	16.664	16.664	16.664	16.664	16.664
CUMULATIVE CASH FLOW	EUR		-37.004	-20.155	-3.306	13.542	30.391	47.240	63.903	80.567	97.230	113.894	130.558	147.221	163.885	180.549	197.212	213.876
IRR	%	45%																
NPV	EUR	136.760,12																
Discounted return period	year	3																
Peyback period	year	3																

Table 35: Cash flow Scenario 2

ITEM	UNIT	Amount	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
CASH INFLOWS																		
Financial savings	KM			33.804,75	33.804,75	33.804,75	33.804,75	33.804,75	33.804,75	33.804,75	33.804,75	33.804,75	33.804,75	33.804,75	33.804,75	33.804,75	33.804,75	33.804,75
CASH OUTFLOWS																		
Maintenance costs	KM		0	0	0	0	0	0	729	729	729	729	729	729	729	729	729	729
Investment costs	KM		145.712	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NET CASH FLOW	**KM**		**-145.712**	**33.805**	**33.805**	**33.805**	**33.805**	**33.805**	**33.076**	**33.076**	**33.076**	**33.076**	**33.076**	**33.076**	**33.076**	**33.076**	**33.076**	**33.076**
CUMULATIVE CASH FLOW	**KM**		**-145.712**	**-111.907**	**-78.102**	**-44.298**	**-10.493**	**23.312**	**56.388**	**89.464**	**122.540**	**155.617**	**188.693**	**221.769**	**254.845**	**287.921**	**320.998**	**354.074**
IRR	**%**	**22%**																
NPV	**KM**	**200.761,94**																
Discounted return period	**year**	**5**																
Peyback period	**year**	**5**																

ITEM	UNIT	Amount	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
CASH INFLOWS																		
Financial savings	EUR		0	17284,095	17284,095	17284,095	17284,095	17284,095	17284,095	17284,095	17284,095	17284,095	17284,095	17284,095	17284,095	17284,095	17284,095	17284,095
CASH OUTFLOWS																		
Maintenance costs	EUR		0	0	0	0	0	0	373	373	373	373	373	373	373	373	373	373
Investment costs	EUR		74.501	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NET CASH FLOW	**EUR**		**-74.501**	**17.284**	**17.284**	**17.284**	**17.284**	**17.284**	**16.912**	**16.912**	**16.912**	**16.912**	**16.912**	**16.912**	**16.912**	**16.912**	**16.912**	**16.912**
CUMULATIVE CASH FLOW	**EUR**		**-74.501**	**-57.217**	**-39.933**	**-22.649**	**-5.365**	**11.919**	**28.831**	**45.742**	**62.654**	**79.566**	**96.477**	**113.389**	**130.300**	**147.212**	**164.123**	**181.035**
IRR	**%**	**22%**																
NPV	**EUR**	**102.647,95**																
Discounted return period	**year**	**5**																
Peyback period	**year**	**5**																

Table 36: Cash flow Scenario 3

All considered scenarios have acceptable financial indicators. The IRR value for Scenario 1 is 46% and for Scenario 2 is 45%. The payback period and the discounted payback period for Scenario 1 and Scenario 2 is the same of 3 years. While NPV in Scenario 1 is 258 thousand BAM or 132 thousand EUR, and in Scenario 2 it is 267 thousand BAM or 136 thousand EUR. In Scenario 3, the value of financial indicators is less favorable compared to the first two scenarios, where the IRR is 22%, NPV is 200 thousand BAM or 102 thousand EUR, and the payback period and discounted period is 5 years.
Taking into account the above, it is recommended that the municipality of Sapna implements the EE measures proposed under Scenario 2,[9] given that they lead to the realization of the greatest financial effects in relation to the financial resources invested in their implementation.
Given that Scenario 3 has a payback period of 5 years, which is a favorable financial indicator for measures of this type, it is recommended that this scenario be proposed and nominated through other funds and organizations and implemented as a pilot project.

11.5. Analysis of funding sources

The municipality of Sapna has several different models and sources of funding available for the implementation of the proposed measures in the public lighting system.
First of all, it is necessary to consider the municipality of Sapna's own financial capacity to implement these measures. According to the data on the budget for 2019, the municipality of Sapna allocated an average of 0,2 million BAM for capital projects. The investment in the proposed EE measures is 72 thousand BAM which is 36% of the amount of money allocated for capital projects from the budget of the municipality of Sapna in the mentioned period. Therefore, it can be concluded that there is a financial capacity of the municipality of Sapna to implement the proposed EE measures from its own resources.

An additional possibility of financing the implementation of the proposed EE measures is through loans. The municipality of Sapna can provide credit funds with domestic commercial banks or international financial institutions (EBRD, WB, etc.).

The third possibility for financing EE measures is through public-private partnership (PPP), which is becoming an increasingly common practice in the realization of many public investments. The PPP model can be attractive to both the public and private sectors. Private financing can support increased investment in projects of social interest without additional public sector borrowing.At the same time, better private sector management systems, and their capacities leading to innovation, can lead to increased efficiency in the implementation and management of various projects of social interest.
On the other hand, the interest of the private sector exists primarily for financially viable projects that have the possibility of commercialization. Also, the involvement of the private sector through the PPP model can lead to additional benefits for the public sector, such as:

- Faster project implementation;
- Reduction of implementation and project management costs;

[9] In case the IRR value is the same or approximately the same for the variants / scenarios being compared, the NPV value is taken into account.

- Creation of added value and additional income.

In accordance with the Law on Public-Private Partnership in Tuzlaj canton,the municipality of Sapna is able to involve the private sector in improving the public lighting system through two PPP models:
-Basic model - according to which the payment of compensation to a private partner is made in whole or in part from the budget based on the availability of public services according to the agreed standards;
-Special model - according to which the payment of the fee to the private partner is made in full or in large part by the end users, based on the use of the public service according to the agreed standards.
In order to consider the possible costs and benefits of implementing EE measures through PPP, and to select the most acceptable PPP model, it is necessary to perform a detailed analysis of possible models of PPP implementation, taking into account the interests of the municipality of Sapna and potential private partners.

11.6. Least Cost analysis of public lighting systems

Least cost analysis of the public lighting system implies a comparison of possible public lighting systems from the financial aspect in relation to the proposed public lighting system. All public lighting systems use electricity to produce artificial light. So there are no alternatives between 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 by the technology and equipment they use. Taking into account the above, in the municipality of Sapna, it is possible to identify and compare 2 public lighting systems:

- Existing system - which uses fluorescent and sodium lamps to produce artificial light;
- Proposed system - which uses LED lamps with the possibility of dimming the light.

In order to compare the mentioned systems from the financial aspect, the calculation of unit costs per lamp for both systems was performed. Table 32 provides an overview of these costs.

ITEM	UNIT	Existing system	Proposed system
Number of lamps	piece	149	149
Electricity costs	BAM/year	37.357	4.404
	EUR/year	19.100	2.252
Maintenance costs	BAM/year	0	362
	EUR/year	0	185
Investment costs	BAM	0	72.373
	EUR	0	37.004
Electricity costs per unit	(KM/lamp)	251	30
	(EUR/lamp)	128	15
Unit maintenance costs	(KM/lamp)	0	2
	(EUR/lamp)	0	1
Unit investment costs	(KM/lamp)	0	43
	(EUR/lamp)	0	22
TOTAL UNIT COST	BAM	251	75
	EUR	128	38

Table 37:Unit costs of public lighting systems

Based on the previous table, it can be concluded that the proposed public lighting system is significantly more cost-effective for the municipality of Sapna, by 176 BAM or 90 EUR per lamp per year.

11.6.1. Sensitivity analysis

Sensitivity analysis includes an analysis of the impact of variables, which can lead to a change in either project costs or revenue, on the final result of the project. In this case, the variables that may affect the ultimate cost-effectiveness of implementing the selected scenario are investment costs (CAPEX) and operating costs (OPEX). For the purpose of making the sensitivity analysis, the changes of CAPEX and OPEX by +/- 5% were assumed and their impact on IRR, NPV, payback period and discounted payback period was analyzed.Table 33 shows the results of the sensitivity analysis.

Variable	Change	Result			
		IRR	NPV (EUR)	Payback period (yr.)	Discounted payback period (yr.)
CAPEX	-5%	48%	138.610	3	3
	0%	45%	136.760	3	3
	5%	43%	134.910	3	3
OPEX	-5%	45%	136.816	3	3
	0%	45%	136.760	3	3
	5%	45%	136.704	3	3

Table 38: Sensitivity analysis

Based on the results of the sensitivity analysis, it can be concluded that:

- Reduction of CAPEX by 5% leads to:
  - IRR increase by 3%;
  - NPV increase by 1850 EUR;
- Increasing CAPEX by 5% leads to:
  - IRR reduction by 3%;
  - NPV reduction 1850 EUR;

Reduction or increase of OPEX by 5% has no significant impact on the final profitability of the project.

12. ENVIROMENTAL AND SOCIAL ASSESSMENTS

12.1. CO_2 reduction analysis

Earth is a large greenhouse in space where instead of glass, heat is maintained by some of the gases in the atmosphere. They let in the heat of the Sun that reaches the ground, and then retain it and maintain the temperature on a planet suitable for life. On the other hand, when coal burns, carbon combines with oxygen from the air and thus forms carbon dioxide - CO_2. Carbon dioxide is a colorless and odorless gas, and in the atmosphere it is one of the greenhouse gases. Increasing its concentration causes a decrease in heat loss by radiation from the Earth's surface into space and therefore increases the temperature on Earth.

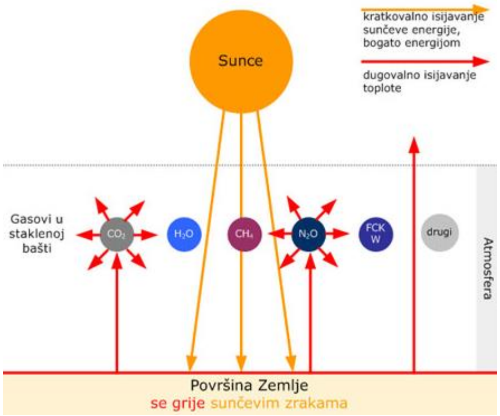

Image 59: Greenhouse effect

As CO_2 concentrations have increased over the last century the greenhouse effect is becoming more pronounced. The consequence is a global increase in average temperature which causes:

- melting of polar caps and glaciers,
- raising sea levels,
- climatic extremes,
- impact on agriculture.

According to the analysis of the current situation, at the locations in the municipality of Sapna that are the subject of this study, mostly sodium light sources are used, which are low-efficient in terms of electricity consumption, i.e. large consumers of electricity, which directly affects CO_2 greenhouse gas emissions.

CO_2 emissions from public lighting are indirect emissions from electricity consumption (emissions do not occur at the location of direct energy consumption), and data on annual electricity consumption and CO2 emission factor for electricity will be used as input data for the calculation.
Emission factor for electricity according to the Ordinance on the methodology for calculating the energy performance of buildings (Official Gazette of FBIH 81/19), which is obtained from the ratio of electricity produced from hydropower and thermal power plants depending on the structure of fossil fuels used (and other renewable sources) amounts to **0.7446 tCO2 / MWh.**

According to the analyses of energy consumption and measures recommended in Chapter 7, the results of the calculation of CO_2 emissions for the current situation, scenario 1, scenario 2 and scenario 3, reductions in electricity consumption and indirect CO_2 emissions resulting from the implementation of each of these measures presented below.

Parameter	Current situation	Scenario 1	Scenario 2	Scenario 3
Electricity consumption (kWh / year)	175.634	26.681	20.706	16.702
CO2 emissions (t/year)	130,78	19,87	15,42	12,44
Savings (kWh)	-	148.953	154.928	158.932
CO2 savings (t /year)	-	110,91	115,36	118,34
CO2 emission reduction (%)	-	84,81%	88,21%	90,49%

Table 39: Electricity consumption for public lighting on the analyzed coverage and associated CO_2 emissions

Based on the results of the calculation, the annual indirect CO_2 emissions of public lighting in the municipality of Sapna for the current situation amount to 130,78 tCO_2/year, with an annual electricity consumption in the amount of 175.634 kWh/year. By implementing the measures proposed by the project, it is possible to achieve an overall reduction in emissions of 84,81% by applying scenario 1, 88,21% by scenario 2 and 90,49% by scenario 3. By applying scenario 3, the largest reduction in electricity consumption is achieved, and thus indirect CO_2 emissions compared to the current situation.

The reduction of harmful components into the atmosphere is in line with the tasks that BiH needs to fulfill in terms of implementing international obligations. As a signatory to a number of international agreements and conventions related to environmental protection and renewable sources (Southeast European Energy Community Treaty, Framework Convention on Climate Change, Kyoto Protocol, Espoo Convention, etc.) and the Stabilization and Association Agreement itself, Bosnia and Herzegovina is committed to respect the same.

The members of the Energy Community have committed themselves to the implementation of a number of EU directives, including Directives 2001/77 / EC, 2003/30 / EC and 2009/28 / EC. The mentioned directives refer to the obligations of the EU member states, that is, the signatories, that they will work on the development and wider application of various renewable energy sources in the energy sector and transport.

In particular, Directive 2009/28 / EC provides a framework for the harmonization of activities and legislation related to the application of green technologies.[10]Adherence to the provisions of the

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

2009 Directive would mean for BiH that the share of renewable sources will increase by 2% in the next two years, or by more than 6.5% in 2020 (to 33%) .
By signing the Agreement on the Common Energy Market of Southeast Europe, BiH, like other members, has committed itself to transposing the acquis communautaire in the field of energy and environmental protection.
The aim of establishing the Community, in addition to creating a single energy market, was to increase energy efficiency and the use of renewable energy sources.

BiH ratified the UN Framework Convention on Climate Change (UNFCCC) on December 6, 2000. As we are not a developed country (we do not belong to Annex I), we do not have a strict obligation to reduce greenhouse gases, but we have general obligations related to calculating annual greenhouse gas emissions, implementing measures to regulate anthropogenic emissions and measures to adapt to climate change, adoption and development of technologies that limit and reduce greenhouse gases.

12.2. Waste disposal

During the implementation of the project, the Investor is obliged, in accordance with the provisions of Article 19 of the Law on Environmental Protection and the provisions of Article 19 of the Law on Waste Management, to take adequate waste management measures and provide basic measures to prevent waste generation, recycling and waste treatment. reuse, extraction of raw materials and possible energy and safe disposal. Considering that the project includes the dismantling of existing lamps which according to the Rulebook on waste categories with lists ("Official Gazette of FBiH", No. 09/05) are classified as hazardous waste, and which includes any waste that has one or more characteristics that cause danger for human health and the environment by their origin, composition or concentration, as well as those wastes that are listed in the waste list as hazardous and regulated by an implementing regulation.
Therefore,the current legislation defines the manner of disposal of this type of waste, i.e. the operator / owner of waste is obliged to enter into a contract with an authorized company that deals with the collection and final disposal of this type of waste and with the prescribed documentation to hand it over. Also, the authorized company is obliged to give feedback to the owner of hazardous waste that the waste has been disposed of in the prescribed manner.

In order to minimize waste generation, during the implementation of project activities to replace existing lamps, it is necessary to take measures to prevent waste generation. One of the goals of waste management is controlled waste disposal, prevention of irresponsible waste management, controlled procurement of funds and education on waste management and safe disposal of waste while taking all necessary measures to protect human health and the environment.

Table 35 shows the waste flow of the Investor with a description of waste management practices, which the Investor is obliged to implement and the regulations according to which each measure is implemented.

No.	Emission	Description of the waste stream management procedure	Final disposal	Relevant regulations in FBIH that prescribe it
1.	Electronic waste from the removal of existing lamps	Proper temporary storage in a specially designated place and special containers -Removal by special vehicles by an authorized company -Handing it over to an authorized company for further management	Authorized company for this type of waste with which the Investor will enter into a contract	-In accordance with the Law on Waste Management ("Official Gazette of FBiH", No. 33/03, 72/09, 92/17) -In accordance with the Regulation on Selective Collection and Labeling of Waste ("Official Gazette of FBiH", No. 38 / 06), - In accordance with the Rulebook on the conditions for the transfer of waste management obligations from producers and sellers to the Investor of the waste collection system ("Official Gazette of FBiH", No. 9/05)

Table 40: Waste management procedures in accordance with regulations in FBiH and EU legislation

12.3. Light pollution

Light pollution includes any unnecessary emission of artificial light in a space outside the zone that needs to be illuminated. The main causes of this type of pollution include mainly improper installation and design of lighting fixtures and therefore when installing new lighting fixtures or designing a new public lighting network, it is important to adjust the design that will have the least negative impact.

In addition, light pollution can be avoided by using environmentally friendly lighting fixtures that do not scatter light outside the space that needs to be illuminated. According to the data of the First World Atlas of Light Pollution from 2001, 82% of the population in Bosnia and Herzegovina is exposed to clear skies whose light is greater than the natural light of the night sky: threshold bp which determines that the night sky is polluted [i.e. when the light of the artificial sky is greater than 10% of the natural light of the night sky above 45 ° altitude (Smith 1979)[11]

[11] 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

Image 60: Satellite image of Europe at night[12]

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

- Artificial light should be directed where it is needed and emissions outside the coverage area should be minimized
- Depending on the purpose, it is necessary to ensure that the illumination does not exceed the required minimum
- Whenever possible, it is necessary to use light of warm tones and continuous spectrum, and avoid sources that emit a lot of light energy in the blue, purple and near UV range of the spectrum.

If we compare the current lighting fixtures and the project proposed lamps, the current lighting fixtures in the municipality of Sapna are designed to emit light in almost all directions, and the efficiency of emitted light to illuminate the desired area is only 10- 30%.

This type includes all those lighting fixtures in which the glass ball or hemisphere is "thrown" out of the luminaire housing. The use of these lighting fixtures is usually extremely energy inefficient, i.e. 30- 40% of electricity is wasted unnecessarily, which is also shown in the earlier chapters in which the comparison of electricity consumption was made.

Unlike existing lighting fixtures, the project envisaged alternative environmentally friendly lighting fixtures that are fully shaded and have the ability to control light emission and not allow light to be scattered into the environment.

Such luminaries have flat glass on the underside, and the cheaper versions are without glass and illuminate only the target area, without unnecessarily emitting light to the side and towards the sky. The implementation of measures to replace inefficient lighting fixtures in the municipality of Sapna achieves a significant reduction in light pollution and reduces the risks that this type of pollution has on the health and safety of residents.

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

13. COMPARATIVE ANALYSIS OF PUBLIC LIGHTING ENERGY CONSUMPTION INDICATORS

When analyzing electricity consumption, it is necessary to provide consumption indicators in order to identify and analyze energy consumption in the system, compare consumption before and after the implementation of energy efficiency measures, and ultimately make comparisons on an annual level or with similar systems of other Cities / Municipalities. Energy consumption indicators are values derived from parameters that describe or provide information on the state of energy consumption of the system.

They appear as indices (a set of aggregated parameters or parameters with weight fractions), or as parameters (value measured or evaluated). Without energy consumption indicators in the field of energy, energy management is inconceivable, precisely because they provide a link between human activities, energy changes, but also the effects of measures.
Indicators allow individual systems to be compared with other or to be monitored over a longer period of time. Therefore, the indicators will be used to analyze the energy consumption of the system.

Energy consumption indicators can be expressed as ratios of produced / consumed energy per lamp unit or some similar criterion.

Therefore, the indicator of annual energy consumption can be presented through the ratio of total annual energy consumption (P, kWh) of the system and e.g. by the number of light sources (Br, number), for which the following equation is used:

$$E = \frac{P}{B_{\mathrm{r}}} \qquad (9.)$$

Apart from the number of light bulbs, energy consumption can be expressed by the total area of the Municipality / City or the considered part of the public lighting system or by other specifics that have an impact on energy consumption, and this energy consumption indicator can be presented by the ratio of total annual electricity consumption. (City, Municipality, Street, etc.) and considered areas (City, Municipality, Street, etc.):

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

In addition to these, there are other ways of expressing electricity consumption indicators, so in the case of this system, the indicators of actual electricity consumption are provided in earlier chapters.

13.1. Indicators of electricity consumption for the current situation

In order to compare and analyze the consumption of electricity for public lighting, it is necessary to provide indicators of energy consumption in the public lighting system. Electricity consumption indicators can depend on many factors such as geographical location, degree of utility of the system and the like.

For the purpose of analysis of electricity consumption for public lighting, the most important indicators are given below, which will be analyzed even after the possible implementation of the proposed energy efficiency measures, i.e. the realization of the optimal scenario. By having indicators for the current state of energy consumption, and indicators of energy consumption after the proposed energy efficiency measures, a comparative analysis of these indicators is possible.

Thus, the following energy consumption indicators will be considered:

- Number of light sources (pcs),
- Required electricity for public lighting (kWh / year),
- Specific annual consumption (kWh / light source /yr).

The most relevant and most frequently analyzed indicator is the consumption of electricity for public lighting by light source (kWh / pc per year).
The specific consumption of electricity, i.e. the need for electricity for public lighting, depends on the size of the system, i.e. the number of light sources. The listed indicators of electricity consumption for public lighting for the current situation are given in Table 36.

Indicator	Value
Number of light sources (pcs)	149
Required electricity for public lighting (kWh / year)	175633,75
Specific annual consumption (kWh / light source year	1178,75

Table 41: Overview of electricity consumption indicators for public lighting for the current condition of the building

It can be seen that required public lighting electricity for the current state is 175633,75 kWh / year. If this value is divided by the considered number of light sources, it is obtained that the specific annual consumption is 1178,75 kWh / light source per year.

13.2. Electricity consumption indicators after the implementation of energy efficiency measures

Following the implementation of the proposed measures to increase energy efficiency, electricity consumption for public lighting would be reduced. This reduction in electricity consumption is represented by the energy indicators provided in Table 37, according to the optimal scenario described earlier in the document.

Indicator	Value
Number of light sources (pc)	149
Electricity required for public lighting (kWh /year)	20706,17
Specific annual consumption (kWh / light source/ yr)	138,97

Table 42: Overview of electricity consumption indicators for public lighting after the implementation of the proposed measures

It can be seen from the table that the electricity needs would be 20706,17 kWh/ year, and thus the specific electricity consumption per light source on an annual basis would be reduced to 138,97 kWh/ light source per year.

13.3. Comparative analysis of electricity consumption indicators and electricity needs for the current situation and after the 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 38.

Indicator	Current situation	After the measures Implementation
Required electricity for public lighting (kWh / year)	175633,75	20706,17
Specific annual electricity consumption (kWh/light	1178,75	138,97

Table 43: Overview of indicators before and after the implementation of the proposed measures to increase energy efficiency

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 88,21%, and thus the specific annual consumption from 1178,75 kWh / light source to 138,97 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 0,2127 BAM/ / 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 88,21%.The investment would pay off in 3 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, lighting fixtures and BMP

15.2. Photometric calculations of new lighting with LED technology on streets

15.3. Specification of equipment and public lighting works bill of quantities