



next generation of energy performance contracting

PUBLIC STREETLIGHT RENOVATION ACTION PLAN (2023 –2030?)

October 2022, v1

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D3.1c Standardised SMART EPC concept documentation: Public streetlight renovation action plan draft



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Abstract

Public streetlight renovation action plan (in the text: Action Plan) is the key strategic document used to analyse the current state of infrastructure and renovation potential, as well as the optimal coverage and models of public streetlight financing. Public streetlight renovation action plan is developed within SMART EPC project. The main objective of Smart EPC project is to enable transition towards smart sustainable cities and municipalities of the future by utilizing energy efficiency as a key for unlocking potentials of new, emerging technologies and services. Refurbishment of old and inefficient public streetlight units with integration of IoT technology and Smart City components will pave the way for a wide range of energy and non-energy services and applications, including public safety, traffic management, EV charging, environmental monitoring, and next generation of cellular communications (e.g. 5G). The Action Plan is a document which indicates a method for artificial lighting of roads, parks and other public areas with the purpose of meaningful planning of construction and renovation of the public streetlight system and represents a strategic document of the local authority in terms of developing the public streetlight system in the period till 2030 and supporting the climate neutrality targets for 2050 by significantly reducing the energy demand.

As a part of the Action Plan, the analysis of the existing situation of the public streetlight system was done for the purpose of defining the overall construction and upgrade needs, renovation potential and method for infrastructure operation and management. It was made based on the collected and processed data from the conducted energy audit of the public streetlight system, which cover the entire system infrastructure. In addition to the technical aspects, the analysis of the maintenance and construction of the public streetlight system, as well as the energy balance of the electricity consumption was carried out.

The existing public streetlight system is in a relatively good condition due to good management and regular maintenance, but mostly technologically outdated and energy inefficient. The Action Plan presents potentials of renovation in terms of energy and cost savings. It should be emphasized that, apart from the renovation of existing luminaires, the technical solutions proposed by the Action Plan also include additional renovation with the aim of achieving the current lighting standards (minimum light technical parameters in accordance with norm EN 13201) as well as renovation for the purpose of the alignment with the legislative framework of light pollution limitations. The Action Plan provides an optimum coverage of the financial model of construction, extension and renovation.

1. Preamble

Nowadays, the human need for mobility has generated the necessity of high-quality public streetlight of urban areas and roads throughout the night through artificial light sources. Public streetlight at night enables safer road traffic, unhindered performance of various social and economic activities, gatherings, sports, socializing and entertainment, which is especially pronounced and necessary in urban areas. Construction, extension, renovation and maintenance and management of this infrastructure is one of the most important tasks and responsibilities of local self-government units. Also, given the importance of issues related to climate change, the issue of energy renovation of public buildings and infrastructure emerges as one of the unavoidable topics when thinking about sustainable development.

The importance of this issue is also recognized at the level of the European Union, which is visible through a series of documents and directives that express the political will and determination to position Europe as a global leader and an example to other countries of the world. In particular, the recent REPowerEU Plan presented in May 2022, the Commission proposed to raise the ambition further to reduce the EU's reliance on fossil fuel imports. In 2018, as part of the '[Clean energy for all Europeans package](#)', the amending [Directive on Energy Efficiency](#) (2018/2002) was agreed to update the policy framework to 2030 and beyond. Its key element is a headline energy efficiency target for 2030 of at least 32.5%.

In order to encourage concrete steps by member states (national, regional and local levels), the European Commission supports public and private investments in projects that contribute to the stated goals through initiatives and funds. The action plan represents the continuation of the adoption of strategic and planning documents of the Municipality for the purpose of planning specific sustainable development activities and *//add other strategic documents*. The purpose of the Action Plan is to define the total needs of *the Municipality* in order to ensure the full functionality of the public streetlight system and the optimal model of financing the necessary activities.

In addition to the regular maintenance of the public streetlight system in order to ensure the illumination of public areas and meet the conditions regarding the reduction of light pollution, one of the basic analysis of the Action Plan is the analysis of improving the energy efficiency of the public streetlight system. Increasing energy efficiency and reducing electricity consumption is the obligation accordance with *the Integrated National Energy and Climate Plan*. The action plan considers technical solutions that can improve the energy efficiency of the public streetlight system, while meeting the lighting requirements. Public streetlight can generally be divided into road lighting (street lighting), urban lighting (lighting of squares, pedestrian zones, etc.), lighting of facades of buildings of cultural and architectural heritage, and lighting of other public areas (sports fields, public parking lots, etc.).

According to the analysis of the public streetlight system, on the basis of the Report on energy audits, the classification of traffic area lighting it can be concluded that the majority of the public streetlight system (about X%) minimum standardized lighting requirements according to EN 13 201-2:2015 are met. In the remaining part of the system (about X%), the reason for not meeting the standard is (i.e. insufficient luminaire power or insufficient density of luminaires, which results in unsatisfactory lighting conditions (most often the level or minimum uniformity of luminance).)

The municipality responsible recognize the importance of implementing energy efficiency measures and reducing light pollution in the public streetlight system. The municipality has developed strong efforts during the last years to renovate the old streetlight by more efficient

units, but still additional efforts can be done. New LED units, additional smart systems or better operation and maintenance can help to reduce the energy demand and the municipal energy bill.

Additionally, there is interest in knowing innovative financing opportunities for the public streetlight system (that might include investment for the renovation and maintenance costs) in order to reach the required level of standards and obligations, ensuring quality public service, reducing lifetime costs and obtaining the highest value for taxpayers' money, has been in recent years increasingly pronounced. The possible limitations regarding available financial resources in the annual budgets of local authorities for streetlight renovation, as well as assuming long-term obligations through classic loans, lead local authorities to consider alternative financing models as Energy Performance Contracting (EPC) and the so-called PPP model (Public Private Partnership). Alternative financing models and methods for projects realization are explained in more detail in this Action Plan. These alternative contracting models differ, apart from financing, in the approach to project implementation. In addition to the listed alternative models, it will be introduced other potential sources of financing renovation and construction works from EU funds (primarily through the next financial perspective from 2021-2027).

In order to determine the total costs of the public streetlight in the *municipality*, it is necessary to estimate the costs along the lifetime of the system, that is, an LCC analysis (Life Cycle Costs). LCC include the investment costs for building/upgrading the public streetlight system (including the streetlights, low voltage electric assets - as cabinets or wires- , streetlight monitoring or management system, innovative smart systems included, etc) , end of life costs (recycling or waste disposal) operation and maintenance costs, electricity costs, public streetlight, costs of risks associated with the mentioned activities, public streetlight and financing costs. For this purpose, the Action Plan includes a public streetlight LCC over a 15-year period, considering the useful lifetime of the assets and the fast technology changes public streetlight, to assess the viability of the project and also the financing needs. A sensitivity analysis with several scenarios will be analysed in order to determine the life-cycle costs and make a judgment on the optimal scope and method of financing.

2. Current state of the public streetlight system

2.1. Reasons and objectives for the public streetlight system renovation

In order to determine the current state and the viability of the public streetlight system renovation public streetlight, it is necessary to make an assessment about the needs, the potential and limitations of public streetlight renovation. Rational energy management represents an important segment of the sustainable development of local communities. As part of the European Green Deal, the Commission proposed in September 2020 to raise the 2030 greenhouse gas emission reduction target, including emissions and removals, to at least 55% compared to 1990. It looked at the actions required across all sectors, including increased energy efficiency and renewable energy, and started the process of making detailed legislative proposals by July 2021 to implement and achieve the increased ambition. The key targets for 2030 include at least 40% cuts in greenhouse gas emissions (from 1990 levels), At least 32% share for renewable energy and at least 32.5% improvement in energy efficiency.

Moreover, certain light sources with a high content of active mercury (e.g. mercury luminaires - HPM, replacement sodium luminaires HPS) represent dangerous waste and a significant environmental problem at the end of their life and exploitation. In addition to the above, these luminaires consume significantly more electricity with the same light intensity and are usually used for the reason that the purchase price is many times lower compared to other light sources.

The purpose of the Action Plan is to define the overall needs for the construction, extension and renovation of the public streetlight system in order to ensure the full functionality, but also compliance with the conditions defined by law. Additional goals of the public streetlight renovation are increasing the safety of citizens, more energy efficiency and cost savings, improving lighting in commercial or industrial areas to benefit the local economy, etc. The necessity of modernizing and renovating public streetlight also stems from the fact that current lighting contributes to the light pollution.

The causes of light pollution related to the public streetlight system are primarily:

- installing luminaires that have a low-quality reflector or no reflector at all (such luminaires are often called "non-ecological luminaires");
- placing luminaires at an inadequate angle (of 15° or more) in relation to the horizon;
- installation of the light source partially or completely outside the housing of the light fixture and
- installation of luminaires with inadequate correlated light colour temperature (more than 3000 K).

The consequences of light pollution, caused by the installation of non-ecological luminaires or at a bad angle, are multiple:

- due to poor light direction, 20-40% of electrical energy is unnecessarily wasted on illuminating surfaces that do not need to be illuminated;
- increased general level of illumination (especially in a period with low traffic intensity) causes unnecessary energy consumption and light pollution;
- the level of safety in traffic is significantly reduced due to glare, just as in the case of alternating unlit and intensely lit zones (due to slow eye accommodation);
- negative impact on the daily biorhythm of plant and animal species (intense lighting of certain areas or unnecessary lighting of nature has a devastating effect on populations of birds, turtles, bats, fireflies, insects and other animals, and insects enter luminaires that do not have high-quality dust protection);

- the impossibility of astronomical observations, where the light has a negative effect on the observer (inadequate accommodation of the eye), the visibility of the observation object (stars fade and disappear due to a decrease in the light-dark contrast, details are lost or become unrecognizable, the background of the sky is brightened) and observation instruments (strong parasitic light).

The problem of light pollution can be significantly reduced in several ways:

- by installing luminaires in which reflectors are installed, which direct the light in the desired direction, with minimal scattering of light on the surrounding area (so-called full cut-off luminaires);
- by installing luminaires at an appropriate angle (ideally 0 degrees);
- choosing luminaires in which the light source is placed deeper into the housing of the reflector, which reduces glare and directs the light more easily;
- by choosing luminaires with a low correlated light colour temperature;
- using lighting intensity regulators, which reduce the intensity of lighting in times of significantly reduced traffic.
- planning of the of lighting needs and rethinking of the existing public streetlight disposition;

The improved quality of public streetlight directly affects numerous factors:

- reduction of operational costs (electricity consumption and maintenance) and consequently emissions of harmful gases into the atmosphere;
- limiting light pollution and the impact on the living world (primarily humans, insects and plants) due to the use of luminaires with better quality reflectors and the use of an appropriately correlated light colour temperature;
- an increased level of safety in traffic (both for traffic participants and for the safety of people when moving through pedestrian zones);
- crime prevention (reduction in the number of car thefts, burglaries, street attacks, etc.);
- contribution to culture and tourism by highlighting cultural monuments, parks and other representative cultural features of the city, and shaping the attractive night vision of the city.
- reduction in breakdowns in the public streetlight system (decreased standard of public service);
- dilapidated pillars as a potential danger for citizens and material goods (static stability);
- uneconomical luminaires and light sources with poor light technical characteristics, resulting in scattering of light on unwanted surfaces (light pollution).

2.2. Public streetlight system baseline data

2.2.1. Energy consumption and cost data

This chapter provides an overview of the current state of the public streetlight system through a description of the technical and technological solutions used. All elements of the public streetlight system were analysed, from cabinets to the streetlight supply lines, luminaire posts, luminaires and light sources. The analysis was carried out based on the information available at the municipality and the energy audit developed within SMART-EPC project. In addition to the technical aspects, an analysis of the design, maintenance and materials of the public streetlight system was carried out, as well as an energy balance of electricity consumption for the needs of public streetlight.

As a reference consumption, the energy demand (MWh), energy cost - according to the electric bills for the public lighting -, maintenance costs, operation costs and other costs (all costs in €/year VAT included) for the last three years are summarized in the following table:

	2020	2021	2022	2023 (forecast)
Energy - MWh/year				
Energy - €/year				
Maintenance materials - €/year				
Maintenance men work- €/year				
Operation - €/year				
Other costs- €/year				
Total costs - €/year				

2.2.2. Basic technical parameters of the current system

Cabinets

Based on collected and processed data from energy audits below is a summary of the current state of the public streetlight system. Public streetlight system is connected to the power distribution network by means of X cabinets, of which X cabinets (X%) are located inside transformer stations and the remaining X are independent cabinets (X%)., (Table 2.1). The distribution of cabinets with regard to the location is shown in the figure below (Figure 2.2). The management of public streetlight system (on/off) in most cases (over X%) is solved by network tone frequency control.

Table 2.1.1 Basic technical info about location of cabinets

Location of the cabinet	Number
Inside transformer station	
Standalone cabinet	
Overall	

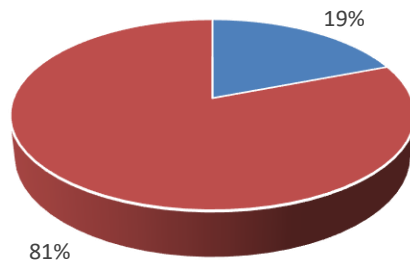


Figure 2.1.1 Distribution of public streetlight cabinets

Supply cables

The supply cables are X% underground and Y% overhead, owned by ZZZZZ and in general good? conditions. (ownership, types, length, condition etc) (Figure 2.3).

Table 2.1.2 Supply cables type

Supply cable type	Length (km)	Owned by local authority	Owned by electricity distributor
Overhead supply cables			
Underground supply cables			
Overall			

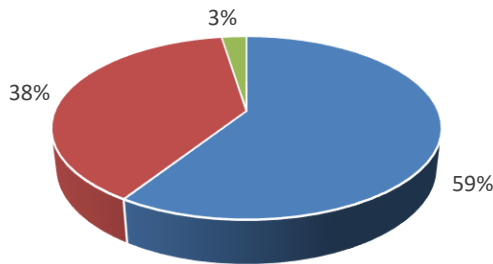


Figure 2.1.2 Distribution of ownership of public streetlight supply cables

Luminaire posts

The luminaire posts luminaire postare mainly made of steel (x%) and concrete (X%) columns, a smaller part is made of wooden columns (X%) and other load-bearing elements (suspension on cables, wall brackets, floor or ceiling luminaires) (X%) (Table 2.3).

Table 2.1.3 Basic data on luminaire postluminaire posts

Type and ownership of luminaire post	Number of luminaire postluminaire posts	Share in overall number of luminaire posts (%)
Steel		
Concrete		
Wood		
Overall		

Description on ownership and legislation framework for luminaire postluminaire posts

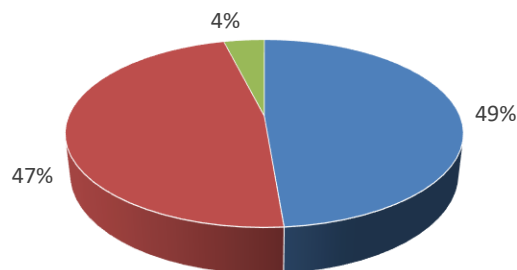


Figure 2.1.3 Lamppost ownership distribution

Description about technical conditions of luminaire postluminaire posts, need for renovation, upgrade etc.

Table 2.1.4 Share of the luminaire postluminaire posts based on height and type

Luminaire post height (m)	Number of steel luminaire postluminaire posts	Number of concrete luminaire postluminaire posts	Number of wooden luminaire postluminaire posts	Number of other types of luminaire post
<3.99				
4 - 5.99				
6 - 7.99				
8 - 9.99				
10 – 11.99				
12 – 15.99				
16– 19.99				
> 19.99				
Overall				

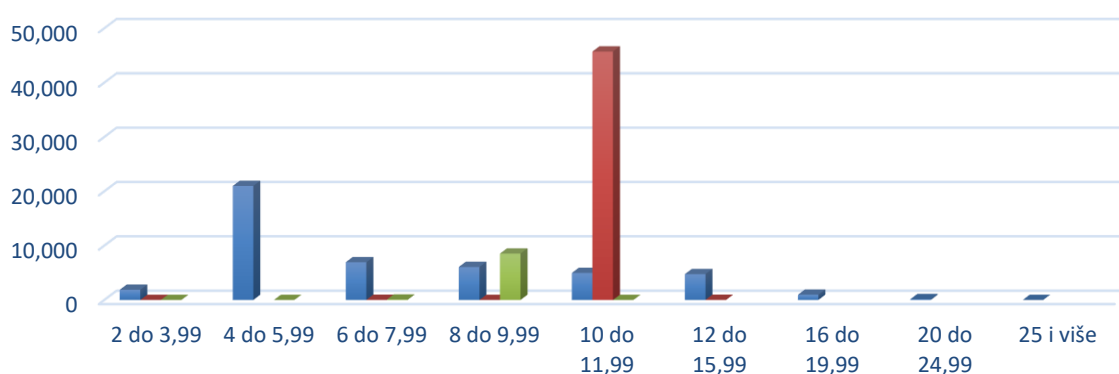


Figure 2.1.4 Overview of the lamppost height and type

Luminaires

Description on luminaires (number, overall power), light sources (share of types).

Table 2.1.5 Overview of the light sources used

Type of light source	Number of luminaires	Share of luminaires (%)	Installed power (kW)	Share (%)
LED luminaire				
LED only bulb				
HPS (Sodium HP)				
LPS (Sodium LP)				
MV (Mercury)				
MH (Metallic Halides)				
CFL (Compact Fluorescent)				
Halogen				
Incandescent				
Others				
Overall				

//Description of legislation regarding phasing out of some type of existing luminaires (containing toxic substances like mercury), share of luminaires that needs to be replaced according to that criteria

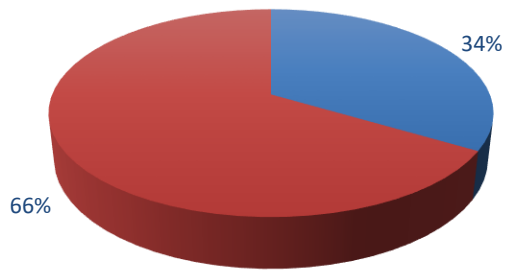


Figure 2.1.5 Distribution of light pollution compliant luminaires

2.2.3. Lighting classes by use

//Description on source of data about lighting classification
 //Description on share of luminaires that lights roads, parks, walk paths etc.
 //Description on share of luminaires and lighting classes

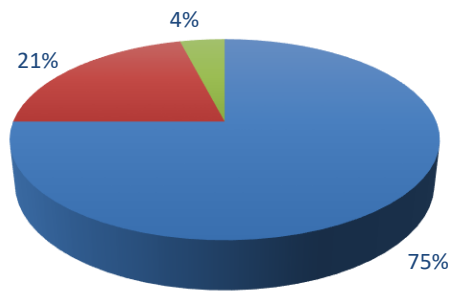


Figure 2.1.6 Luminaire distribution according to illuminated surfaces

Table 2.1.6 Basic luminaire data that illuminate exclusively roads

Road lighting class	Number of luminaires	Share (%)	Installed power (kW)	Share in overall power (%)
Overall				

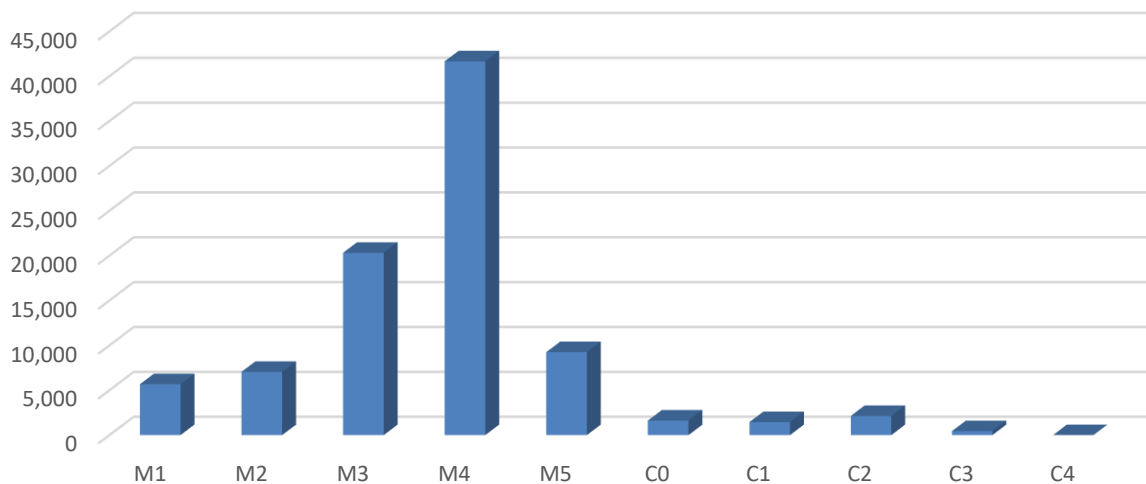


Figure 2.1.7 Luminaire distribution according to the road lighting classification

The distribution of luminaires that illuminate exclusively pedestrian zones is given below.

Table 2.1.7 Basic luminaire data that illuminate exclusively pedestrian zones

Pedestrian lighting class	Number of luminaires	Share (%)	Installed power (kW)	Share in overall power (%)
Overall				-

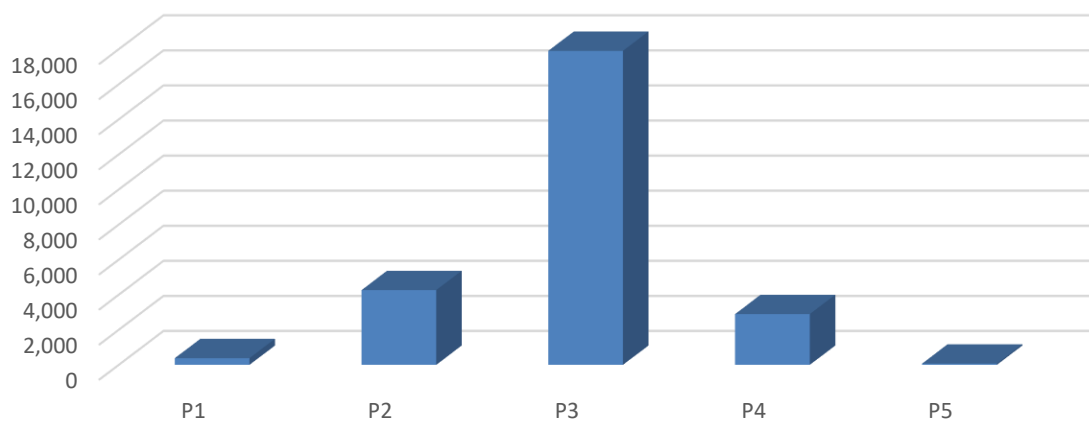


Figure 2.1.8 Luminaire distribution according to the pedestrian lighting classification

//Description on areas that are lighted by public streetlight but not classified according to EN 13 201 (outdoor working places, sport facilities etc) – number of luminaires, power etc.

2.2.4. Energy costs of the public streetlight system

//Description about source of data, commenting possible difference in yearly consumption in last 3 years, describe which years are included and referent, reference on average number of not working luminaires (under reparation).

Table 2.1.8 Consumption and energy cost data for public streetlight

Year	Consumption (GWh)	Average electricity price per unit (EUR/kWh with VAT)	Energy costs (EUR with VAT)
2019. year	74,9	0,63	47.187.000
2020. year	74,8	0,65	48.620.000
2021. year	75,9	0,76	57.684.000
Projection for 2022.	75,9	0,86	65.274.000
Projection for 2022. With nonfunctional luminaire	78,5	0,86	67.510.000

//Description of methodology of calculating baseline consumption costs (reference year + newly added luminaire + nonfunctional luminaires or similar).

//Defining baseline consumption, baseline costs of energy per unit and overall consumption costs of public streetlight

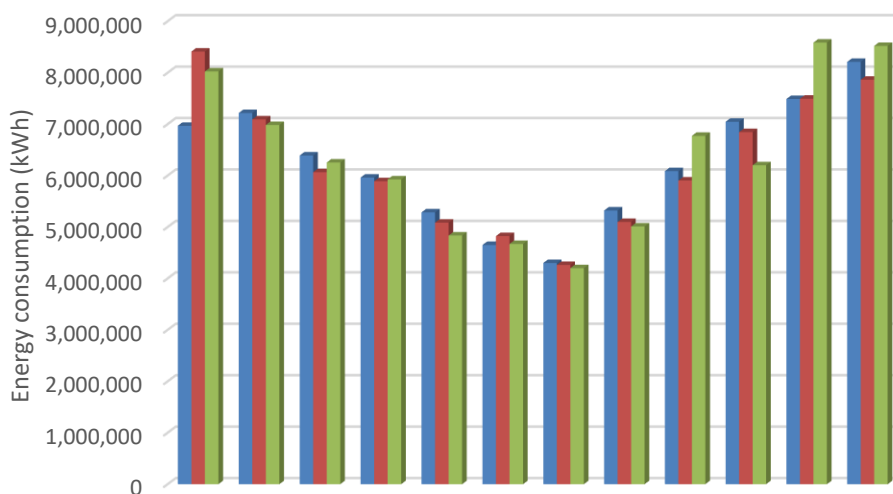


Figure 2.1.9 Consumption on the last 3 years

//Commenting the costs of electricity in last 3 years, cost per unit

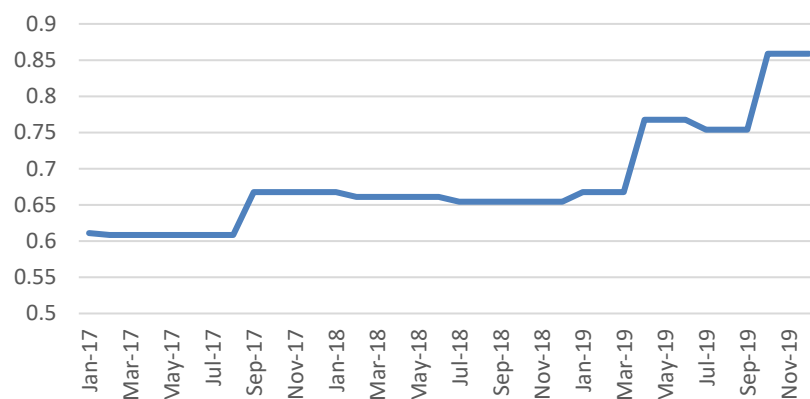


Figure 2.1.10 Presentation of the unit price of electricity for public streetlight for period 2019-2022.

//Description on source of data for maintenance costs, commenting possible difference in yearly costs in last 3 years

Table 2.1.9 Data on the costs of regular maintenance of public streetlight in the past three years

	Maintenance costs – work (EUR)	Maintenance costs – material (EUR)	Maintenance costs – other (EUR)	Overall (EUR)
2019. year				
2020. year				
2021. year				
Baseline maintenance costs				

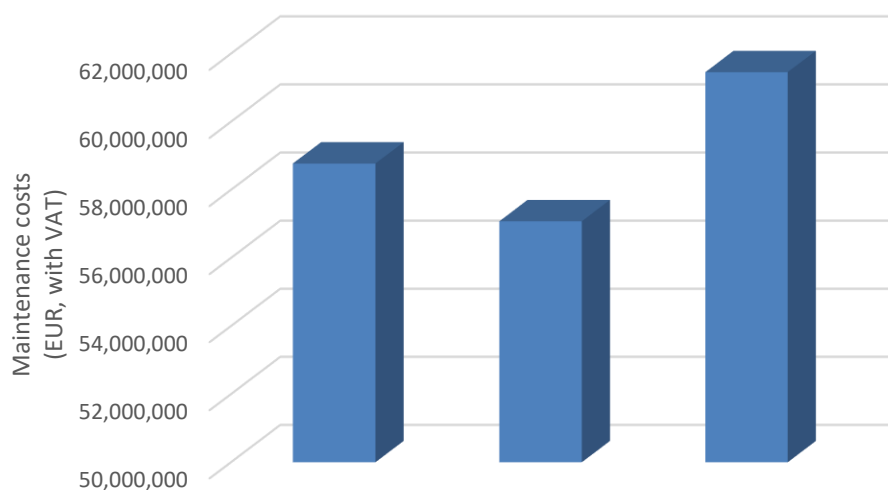


Figure 2.1.11 Costs of regular maintenance of the public streetlight system in the last three years

//Defining baseline operational costs (electricity, maintenance). (Table 2.1.10).

Table 2.1.10 Summary of public streetlight operation and maintenance costs

Summary of public streetlight system operational costs	Average last 3 years	Foreseen 2022
Energy costs		
Maintenance costs (staff)		

Investment maintenance costs (equipment and materials)		
Operation costs		
Overall (EUR)		

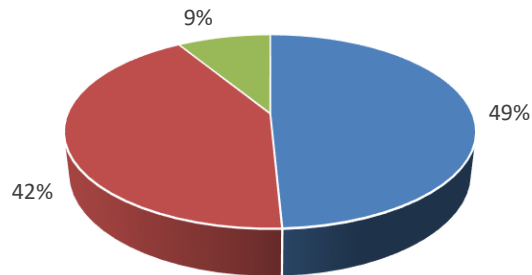


Figure 2.1.12 Share of cost categories in operational costs

//Description of difference between budget for public streetlight and baseline operational costs (which public streetlight costs are not included, or which are foreseen but not in budget..)

3. Needs and possibilities of improving the public streetlight system

The analysis of needs and possibilities for improving the existing public streetlight system is based on the following assumptions:

- construction and extension needs for increasing traffic safety (compliance with the EN 13 201 standard);
- needs for renovation in order to ensure the basic functionality and availability of the existing system (e.g. replacement of dilapidated underground supply cables);
- needs for renovation in order to comply with the light pollution protection legislative;
- possibilities of improving the public streetlight system from the aspect of increasing energy efficiency by replacing existing light sources and luminaires with more efficient ones with the application of regulation of luminaire power;
- the possibility of improving the public streetlight system by applying digitization and supervision system and implementation of Smart City application.

The analysis of needs and possibilities is based on a 15-year period mainly for the purpose of encompassing relevant works and needs during the economic lifetime of the basic public streetlight system elements. Only the needs of construction and extension of the public streetlight system for the purpose of increasing traffic safety (compliance with EN 13:201) are observed in a five-year period due to the impossibility of quantifying annual needs over a longer period of time. The analysis is done with the help of the Analytica tool developed as part of the Smart-EPC project based on the collected data within the energy audit. It should be noted that all analyses are based on the last indicators (attributes) of the public system derived from the energy audit. In case of attribute changes (e.g. major extension, renovation, modernization, etc.), it will be necessary to recalculate analysis using the Analytical tool. It is also important to note that all analyses are based on the latest current prices of electricity as well as the prices of services, equipment and works (date), and in case of significant changes in the prices it is necessary to do new analysis using the Analytical tool. All amounts stated in the description of individual scenarios of this Action Plan are rounded for the purpose of simplification, presented in euro with VAT included, and do not include the costs of engineering services or the costs of implementation risks.

3.1. Increasing traffic safety (Scenario A)

It is assumed that the public streetlight system will maintain the same growth as in last 3 years trend in the period of next five years. In accordance with this a uniform need for the construction and extension of the public streetlight system is assumed in the annual amount of X million EUR. The construction and extension does not result in energy and cost savings, which is why only estimates of investment (capital costs) are given below. The basic financial indicators of the estimated annual growth of the public streetlight system are given in the table below (Table 3.1).

Table 3.1 Costs of the public streetlight system extension on an annual basis

Data on the annual extension of the public streetlight system	
Number of luminaires	
Investment (EUR)*	

*Investment includes services, works and all required material needed for implementing an extension with VAT included

Overall five-year needs are stated in the table below.

Table 3.2 Costs of public streetlight system construction at the five-year basis

Data on the five-year extension of the public streetlight system	
--	--

Number of luminaires	
Investment (EUR)*	

*Investment includes services, works and all required material needed for implementing an extension with VAT included

The primary function of the public streetlight system is to ensure the safety of the traffic and people through public traffic areas at night. Creating appropriate visual conditions for traffic participants in conditions of low visibility is possible only by meeting the minimum lighting standards, i.e. by observing the minimum light technical parameters defined by standards in the field of light technology (EN 13 201). In order to harmonize the existing public streetlight system with the light technical standards it is necessary to upgrade and reconstruct the existing public streetlight system, respectively to expand the system by adding about **XY** new luminaires (about **X%** of the existing number) with an average specific cost of about **XY** EUR, or a total of about **XY** million EUR. The total need for building and upgrading the system in order to increase traffic safety is estimated at around **XY** million EUR and includes the construction of **XY** new luminaires and the addition (expansion) of around **XY** luminaires in order to comply with the EN 13 201 standard.

Table 3.3 Costs of additional extension and construction of lampposts

Data on the five year construction and extension of the public streetlight system	
Number of luminaires due to extension of system on new areas	
Investment (EUR)	
Number of luminaires due to extension of system for complying with standards	
Investment (EUR)	
Overall (EUR)	

*Investment includes services, works and all required material needed for implementing an extension with VAT included

3.2. Ensure the basic functionality and availability of the existing system (Scenario B)

During the analysis of the existing public streetlight system conditions from energy audits, several critical parts of the infrastructure of the public streetlight system were addressed, which in order to ensure the basic functionality and availability of the system, needs to be reconstructed in the near future. Those parts refer to:

- Public streetlight fields located in transformer stations owned by the distribution system operator and dilapidated public streetlight cabinets;
- Dilapidated underground supply cables of the public streetlight system;
- Dilapidated luminaire post/luminaire posts (threatened static stability and safety).

//Description on specific needs for renovations (number, percentage, reasons, costs)

Table 3.4 Needs for basic functionality and availability ensuring

Description	
Public streetlight cabinets renovation	
Supply cables renovation	
Lampposts renovation	
...	
Overall	

*Investment includes services, works and all required material needed for implementing an extension with VAT included

3.3. Comply with the light pollution protection legislative (Scenario C)

The purpose of the Action Plan is to determine the current needs and ensure the financing of activities to align the public streetlight system with the legislative framework. The Action Plan is document based on which the local authority unit defines the need in terms of maintenance and renovation of the public streetlight system with the aim of ensuring the conditions defined by the legislation.

//Describe specific requirements and deadlines for the public streetlight/luminaires defined by legislation

//Describe the scope of the renovation needed to comply with the legislation, number of luminaires, costs..

Table 3.5 Light pollution complying costs overview

Description	
Investment in order to comply with the light pollution protection legislative	
Overall	

*Investment includes services, works and all required material needed for implementing an extension with VAT included

3.4. Increasing energy efficiency of the public streetlight system (Scenario D)

The analysis of improving the energy efficiency of the public streetlight system is one of the basic objectives of the Action Plan. The purpose of the Action plan, based on the analysis of the current lighting system is to determine the scope of the financially profitable renovation of the public streetlight system. Increasing energy efficiency and reducing electricity consumption is the obligation in accordance with the national policies and regulation. The Action plan considers technical solutions that can improve the energy efficiency of the public streetlight system, while meeting the lighting requirements. The total coverage of the renovation of the system, which defines the financially profitable part of the renovation (in which the renovation of the existing luminaires is paid from the achieved energy/cost savings in the economic life of the luminaire, i.e. 15 years) is about XY% of the existing public streetlight system, the capital value of which is estimated at about XY million EUR (including VAT). The implementation of the project would generate annual savings in electricity costs in the amount of about XY million EUR (including VAT) with a simple investment return period of about X years. In addition to the savings in electricity costs, the implementation would also generate savings in the maintenance costs of the public streetlight system. The presentation of the cost estimate of the costs in question is given in the table below (Table 3.6).

Table 3.6 Energy efficiency increasing costs overview

Description	
Investment in financially profitable renovation	
Overall	

*Investment includes services, works and all required material needed for implementing an extension with VAT included

3.5. Smart City application with digitization of public streetlight system (Scenario E)

Today's cities strive to ensure greater efficiency, safety, reliability and quality of public streetlight systems while achieving savings in operating costs. A smart city is an urbanistic method of city development in the direction of increasing the comfort and standard of living through advanced solutions that enable information and communication technologies (ICT) and the Internet of Things (IoT).

ICT and IoT technologies bring many advantages and improvements in the management and optimization of the public services, such as transport and parking, public streetlight, monitoring and maintenance of public areas, waste collection, maintenance of hospitals and schools, rain and pollution sensors but also in ensuring the development of advanced communication platforms. Furthermore, the availability of various data collected with ICT and IoT technologies can also be used to increase transparency and promote the actions of local government towards citizens through increasing awareness of the current position and status of the city and primarily the quality of the public service provided.

Smart cities require high automation, the connection of a large number of devices to a data network and its management in a smart city platform. The increased number of devices and sensors that will enable the development of smart cities and autonomous vehicles requires the construction of high-quality and robust stationary and mobile communication infrastructure. The development of future communication systems will depend on the architecture of the fifth generation of mobile networks (5G), which will ensure greater capacity, extremely low communication delays, high transmission speeds and low energy consumption.

In order to achieve the stated goals, it is essential to incorporate the public streetlight management system, which enables the management of the luminaires, the measurement of operation parameters, the optimization of the operation of an individual luminaire or group of luminaires, and the implementation of advanced analysis for the purpose of optimizing the maintenance, renovation or expansion process of the public streetlight system. Management systems enable the illumination level control, which is extremely useful in cases of changes in requirements for the minimum or maximum permissible level of illumination (eg. legislative changes or the case of changes in requirements for the classification of road illumination).

The basic elements of the modern public streetlight control and monitoring system can be divided into hardware and software parts. The hardware part includes a luminaire equipped with an appropriate driver, standardized connectors for sensors and equipment for sending data from the luminaire to the software, while the software part includes a programming interface for remote control, monitoring and management. The program interface is connected to the luminaires and other parts of the system via network protocols and standards.

The software interface provides the possibility to review the status of the public streetlight system, energy parameters of the luminaires in real time and warns of possible errors and malfunctions in the system (with a precise description of the fault, an overview of all relevant attributes and the exact position of the fault/luminaire). In order to enable communication between individual components in the public streetlight system and the management and control center, and to enable the subsequent connection of system components (new luminaire, sensors, etc.) from different manufacturers and it is mandatory to use open protocols for communication.

In order to ensure interoperability between the control and monitoring center and public streetlight system elements, in which hardware and software solutions from a larger number of manufacturers are used, it is necessary to define the minimum technical specifications of the basic components of the system, such as:

- Driver - a physical device that contains control and monitoring features applied to the luminaire. It has the ability to identify electrical faults, measure various electrical parameters and manage the level of illumination;
- Communicator – a physical device that is connected to driver and other components of the luminaires and that enables communication with the control and monitoring center;
- Socket for sensors – a physical part of the luminaire housing that is wired to other components of the luminaire (driver, communicator) and to which sensors can be connected without the need for additional hardware or software installations (plug and play);
- Network component – a tool / device or service that enables communication between the luminaire (communicator) and the software tool (Control - monitoring center);
- Control and monitoring center – a software tool that communicates with communicators through network components to enable remote configuration and control of luminaires.

In order to implement the control center of public streetlight, it is necessary to include the following elements during the renovation:

- Procurement of luminaires with integrated basic communication components or procurement of separate communication components for existing luminaires;
- Programming or procurement of a software solution for the management control center;
- Expect additional operational costs for communication services between the luminaire and the software tool.

//Additional description on specific requirements, smart city application, costs, expected revenues or additional services etc.

3.6.Overall needs and possibilities of public streetlight system upgrade or renovation

The analysis developed in the previous sections conclude that over the next 15 years, the replacement of dilapidated infrastructure and the replacement of dilapidated luminaires that do not meet the requirements of the legislation will definitely have to be carried out, and that the cost of the aforementioned activities will be considerable (they will probably require an increase in part of the budget which refers to the construction and costs of investment maintenance of the public streetlight system). Analysing the maintenance and renovation activities of the public streetlight system that the local authority will definitely have to undertake , it is evident that some overlap and that it is desirable and rational to coordinate them in order to optimize the process and not to duplicate certain costs (Figure 3.2).

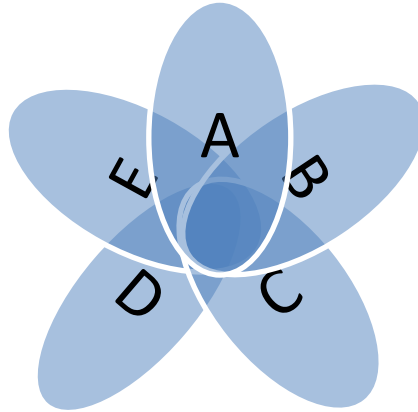


Figure 3.1 Overall needs and possibilities for public streetlight renovation

For the defining of the total needs during the economic lifetime of the basic parts of the public streetlight system, the needs and costs over a 15-year period were observed. The exception to this time period of consideration is the needs of construction and extension of the public streetlight system, which were considered in a period of 5 years (due to great uncertainty and lack of knowledge of long-term needs and the dynamics of public streetlight system construction).

To analyse the financial indicators of the financing model, it was necessary to define the optimal scope of the project, respectively to divide the public streetlight system into functionally and technically connected units whose realization could be considered separately. Units are defined in such a way that they satisfy:

- construction and extension needs for increasing traffic safety (compliance with the EN 13 201 standard);
- renovation needs for ensuring the basic functionality and availability of the existing system (e.g. replacement of dilapidated infrastructure);
- renovation needs for compliance with the legislation on light pollution protection;
- possibilities of improving the public streetlight system (from the aspect of increasing energy efficiency by replacing existing light sources with more efficient ones);
- possibilities of improvement through the application Smart city applications and digitization of the public streetlight system.

//Description of functional-logical units (example in table below) and priorities

Table 3.7 Functional units overview

Unit	Description of the unit	Cost estimation (EUR)
1.	<p>Replacement of existing luminaires, which do not comply with the legislation and/or are energy inefficient and are located on poles that do not need to be replaced, with new more energy efficient luminaires with integrated Smart City components and a software solution for monitoring and managing the public streetlight system.</p> <p>Quantity: about X% of luminaires</p>	

2.	<p>Replacement of the remaining existing luminaires with integrated Smart City components that are not included in unit 1 and do not comply with the legislation and/or are energy inefficient, replacement of dilapidated luminaire postluminaire posts, relocation of lighting cabinets from transformer stations, renovation of part of the existing public streetlight cabinets, replacement of part of the underground supply cables of the public streetlight system.</p> <p>Amount: about X% of luminaires about X% of luminaire posts X% of cabinets in the transformer station X% of independent public streetlight cabinets X% of underground lines.</p>	
3.	<p>Extension of the public streetlight system due to meeting the minimum light technical conditions and construction of new lighting positions due to the expansion of the public streetlight system. The expansion cost includes the assumed expansion needs over the next 15 years</p> <p>Quantity: expansion with around X lighting positions per year (luminaire + luminaire post) Addition of around X luminaires in order to meet the minimum requirements</p>	
Overall		

According to the analysis the estimated investment, i.e. the cost of meeting the overall needs of the public streetlight system over the next 15 years (realization of all three above mentioned units) amounts to about XY EUR (including VAT). All amounts stated in the description of the financing model, for the purpose of simplification, are rounded and presented in EUR with VAT included, and do not include the costs of engineering services or the costs of implementation risks. Chapter X of this Action Plan contains an analysis of financial indicators of the scope and implementation model for the purpose of determining the optimal financing model.

4. Analysis of financing models, opportunities and financial indicators

4.1. Introduction to energy performance contracting

In recent years, energy performance contracting has become an increasingly frequent form of realization of public projects, all for the purpose of reducing total costs and increasing the quality of public service. The fiscal capacities of local authorities rarely allow new debts (long-term liabilities), i.e. project financing with loans. The traditional model of project implementation, which is based on the use of own budget funds or loans, shows a number of limitations, among which the following can be highlighted:

- risks associated with the poor quality of project documentation and execution of extension, construction or renovation works, which causes potentially high unplanned construction costs (e.g. extra-budgetary works or unforeseen quantities) and higher operational costs (mainly reactive maintenance);
- the possibility of financing through own funds is often insufficient for the realization of larger projects (e.g. holistic renovation of the public streetlight system) in a relatively short period of time (even with the use of EU funds). Likewise, the financing of projects through loans/credits represents an increase in the indebtedness of the public sector;
- the expected availability of generous allocations in the form of grants for the co-financing of projects from the 2021-2027 financial perspective for the traditional implementation model will be significantly less compared to the allocation in the period 2014-2020.

As a result, the public sector, based on the limitations of the traditional implementation model, is considering alternative ways of project implementation. Alternative models can be characterized as procurement models such as Energy Performance Contracts, Public-Private Partnerships, Leasing, etc. Basically, these models represent a type of performance-based project implementation service provision (Performance base contracts or also Service level agreements). The basic feature of performance-based models is that the private party, which is the service provider, undertakes to finance and perform all works and guarantee the agreed standards during the duration of the contract (e.g. availability of space, energy savings, etc.). In these types of contractual relationships, the service provider is paid exclusively in accordance with the standard of the service provided. During the duration of the contract, the provider is forced to constantly prove that it provides the agreed standard and not reaching the standards results with the reduction in the payment of the fee.

The implementation of public streetlight renovation projects for improving energy efficiency through Energy Performance Contracts is different from traditional financing. The basic feature of EPC is that the private party, which is the contractor, undertakes design, finance and execute of all works and guarantee the agreed standards during the duration of the contract. By contracting the EPC model, four procurement procedures are combined:

1. design and engineering phase: energy audit, engineering and designing of project documentation for construction;
2. construction phase: purchase of equipment and materials, installation and commissioning
3. Financing: providing of own or external financing, and management of subsidies;
4. guaranteeing of performance: availability of equipment/measures (maintenance within the warranty period) and operation with a certain energy demand reduction and/or renewable production

From a financial point of view, it can be concluded that the greatest benefit of implementing public streetlight renovation projects through an EPC contract lies in the fact that the project is realised without the need to secure additional sources of financing, that the project does not

reduce the loan potential, and that the project is fully financed from the energy savings achieved without increasing expenditures in the budget. Also, in relation to the traditional way of implementing the project, through the energy performance contract, public clients have the option of reducing the compensation payable to the ESCO company (service provider), in contrast to the traditional way where public clients must in any case pay due obligations on loans. In the traditional model, possible penalties due to defective equipment must be proven and claimed from the contractor or supplier of the equipment after the contract has been executed, or most often after the warranty period has expired.

With the condition that the Energy Performance Contract is in accordance with EUROSTAT's guidelines, it is not considered an increase in public debt for the public sector. EPC model offer security in terms of guaranteeing results (eg. expected energy savings) where all risks related to guaranteed savings in energy consumption are allocated to a private partner (ESCO company). Most of the issues arising from the traditional method of procurement, which are related to the capabilities and strength of the bidder and bidder's guarantees, the quality of the works performed, the technical performance of the procured goods, the proof of the contracted standards, the prosecution and penalization of the bidder or the executor of the contract, have been practically solved by the implementation of the EPC model of contracting.

In this way, innovative solutions are encouraged, as well as the quality of the works performed and installed equipment, because without them the private partner does not achieve the desired results and does not receive compensation for the energy service (EPC compensation). Given that the private partners (ESCO companies) finance all the works and goods in the project themselves, reductions in compensation due to compensation provided below the contracted standards practically mean that the private partners will be left without a part of the planned income (profit). EPC contracts, with all their advantages, also have limitations in their application. Namely, as their name suggests, they are contracts on energy performance and thus are tied to renovation measures that result in energy savings. In accordance with EUROSTAT's guidelines, it is necessary to meet the condition that the EPC fee is equal to or less than the savings achieved by reduced energy consumption.

4.2. Analysis of procurement models

4.2.1. Applicability of the on-balance and off balance sheet

To be able to analyse the different procurement models, it was necessary to define the needs. In chapter 3.6, the overall needs and possibilities for improving the public streetlight system are defined and they are divided into 3 different units according to technical and functional nature.

In the traditional way of realizing the project, the selection of different parts of the system as separate entities has no special influence. Considering the very nature of the traditional method of realization, where modernization/renovation is first designed, then works are carried out and equipment is procured, it is possible to do the same for any number of luminaires and elements of the public streetlight system, and it is possible to separately replace lampposts, supply cables, and separately tender luminaires. As stated in the previous chapter, this model implies that the local authority consequently assumes a greater part of the risk in the project.

Model of contracting energy services through an energy performance contract if it is to be treated as a so-called off balance sheet for the municipality, i.e. if it does not want to be treated as public debt in accordance with EUROSTAT's guidelines, it is characterized by the limitation that the cost of modernization/renovation of the project, i.e. the scope of the project must be fully financed from savings achieved through reduced energy consumption.

This limitation, in the public streetlight off balance sheet renovation, means that the scope of the project, which would include the replacement of underground supply cables or luminaire post of the public network system, cannot be carried out, because the cost of replacing them is multiple in relation to the cost of replacing only luminaires (and savings in energy consumption are primarily achieved by replacing luminaires). Payback periods are too long so such scope of the project cannot be financed from electricity savings.

4.2.2. Traditional financing model

Economic parameters and financing in traditional projects

The overall capital investment costs for the project include Describe the scope of renovation and expected investment (design, works, material, risks, guarantees and insurances)

Regarding the sources for capital expenditures for the project in a traditional model, the implementation of the project based on the traditional financing model is can be done by financing totally or partially with long-term obligations (loan), or by direct financing from existing own sources in the municipal budget.

If the project were to be realised through a long-term loan, then, it could be financed (i.e.) with the assumption of repayment of the loan over a period of 15 years, in such a way that 1/2 of the total investment is realised annually in the first two years and that the same is later repaid over 15 years with an interest rate of 2%, financing costs (total amount of interest costs), amounted to about XY million EUR.

Regarding the dynamics of payments, i.e. the increase in budget expenditures, would mean that the total expenditures for the public streetlight system (energy, maintenance and loan annuity) would gradually decrease from X million EUR to X million EUR after 2 years. Such reduced annual expenses of around X million EUR, or total annual expenses for the public streetlight system of X million EUR, would have to be provided for the payment of loans, electricity and maintenance for the next 15 years.

By paying off the loan until the end of the analysed period (25 years), the reduced expenses would amount to about X million EUR compared to the reference ones, that is, the total annual expenses for the public streetlight system would amount to 110.4 million HRK (Figure 4.3).

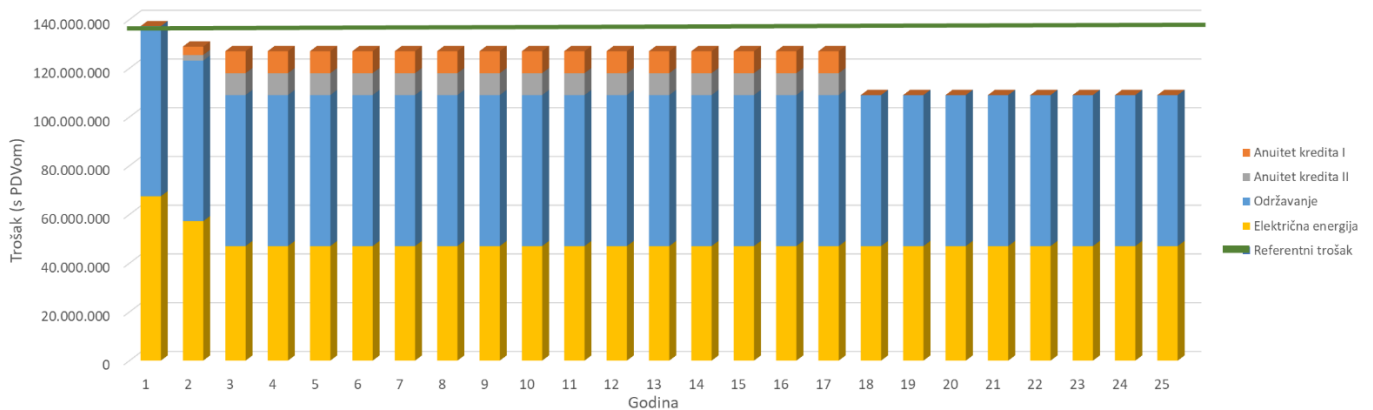


Figure 4.1 Expenditure dynamics - realisation through a loan

In absolute terms, this means a reduction of the total planned expenditures for the public streetlight system in the 25 years by about X million EUR, i.e. it means a potential reduction of the total expenditures for the public streetlight system from the reference X million EUR (with VAT) from 2020. to around X million EUR (including VAT) in 2022.

On the other hand, with direct financing from the own sources from the municipal budget, it would be necessary to ensure an average annual increase in expenditures of around X million EUR in the first two years of implementation (2021 and 2022), after which savings would be realised in regular budget expenditures for management and maintenance. public streetlight system compared to the reference state in the amount of X million EUR (Figure 4.4). In absolute terms, this increase of around X million EUR means an increase in total annual expenditures for the public streetlight system from the reference X million EUR (including VAT) to around X million EUR (including VAT) in 2021. and to around X million EUR (including VAT) in 2022.

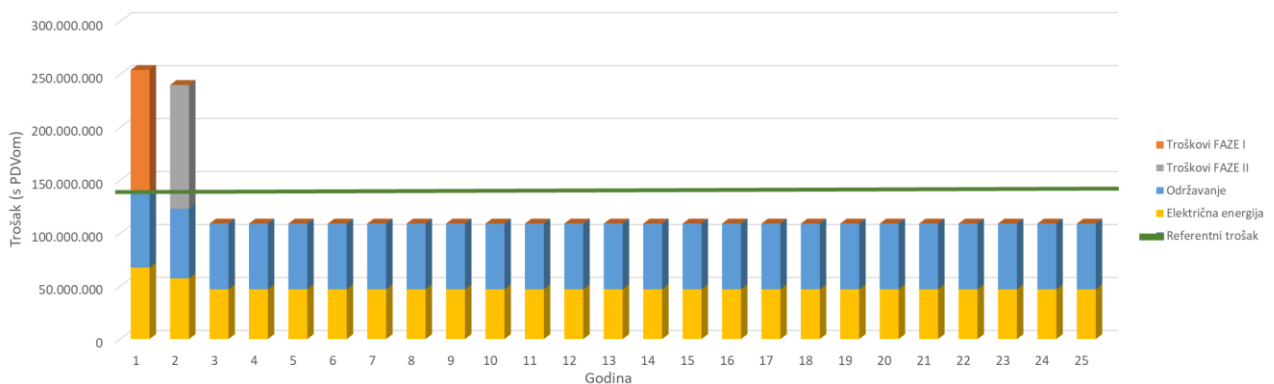


Figure 4.2 Expenditure dynamics - realisation through a local authority budget

By implementing the renovation of the public streetlight system, the potential of annual savings of around X million EUR will be realised, of which it is estimated that X million EUR are savings in electricity consumption and around X million EUR are savings in maintenance costs. The simple payback period of the investment in question is about X years. From the analyses carried out, it can be concluded that the simple return period of the investment (capital cost) is shorter than the expected lifetime of the luminaires (the lifetime of the luminaires is declared to be 100,000 hours or about 25 years).

Design and Build Model- D&B

In a turnkey project a single entity—a contractor—works with a project owner under a single contract to complete all stages of a project from detail engineering through construction.

The basic difference between the turnkey model and the Design and Build model (hereinafter: D&B) stems from the fact that the D&B model combines two procurement procedures (design of project documentation and implementation of works and equipment). This very fact is the basis for achieving greater value for taxpayers' money (the possibility for a private partner to optimize technical and technological solutions). During the implementation of procurement for construction, extension and renovation in the D&B model only the standards (project goals) are prescribed but not technical solutions to achieve the standard (e.g. cost items), which results in allowing the elaboration of technical solutions to bidders. The future contractor performs the works (designs and selects technical/technological solutions) and temporarily finances the execution of the works (independently or through loans), in this way it is possible to implement advanced solutions that would most likely not be included in classical design (a priori rejected

as expensive or unavailable). In addition to the above, in the D&B model there are no unexpected "out-of-budget works", because the contractor undertook to design and perform the works when contracting, thereby assuming the risk of the occurrence of unforeseen quantities or works entirely on himself. This means that every D&B contract is actually a contract concluded under the so-called to the "turnkey" model, and payment to contractor is denied until all obligations are fulfilled. Precisely based on these advantages, in the case of a decision to implement a project through a traditional financing model (budgetary funds or through a loan), it is recommended to use the design and build model with the aim of achieving greater value for money and simplifying the contracting and project implementation process. The method of closing the financial construction for project realization based on the design and build model is identical to that described for traditional sources of financing (budget funds or loans).

4.2.3. Energy Performance contract (EPC) model

The advantage of alternative procurement models as EPC , compared to the traditional model of project implementation based on budget funds or a loan, lies in the fact that the private partner offers the implementation of the project according to the so-called turnkey model that includes:

- design of project documentation with optimization of equipment and technological solutions in relation to given criteria (standards);
- financing, supply of equipment and performance of works based on project documentation;
- the service of guaranteed functional operation of installed equipment (in the EPC model) and guaranteed energy and cost savings (assuming relevant project risks).

An energy performance contract (EPC) is one of the possible solutions for financing the renovation of the public streetlight system, which is carried out in such a way that a private partner/ESCO company (Energy Service Company) independently finances and performs works on the renovation of public streetlight. Realised cost savings, which occur after the renovation of the existing luminaires, are used to cover the costs of the investment and the costs of providing the energy service. After the expiration of the EPC contract, the public partner benefits from the implemented renovation due to energy and financial savings that are realised even after the expiration of the contractual relationship with the ESCO company. Energy service contracting is defined by the Regulation on contracting and implementation of energy services in the public sector. With regard to the Budget Law, the Regulation and EUROSTAT's interpretation, EPC contracts are not considered public debt if all prescribed assumptions and requirements are met. It is important to point out that according to the Regulation, if the fee for the service is less than the guaranteed savings, the EPC contract is not considered a public debt in the sense of the Budget Law. In the case of project implementation based on the EPC model, the scope of the project may consist primarily of luminaires on poles that do not change, as explained in chapter 4.2.1.

The proposal for the scope of the renovation of the public streetlight system through the EPC model includes the replacement of about X% of the existing luminaires that do not comply with the Law and/or are energy inefficient and that are located on poles that do not need to be changed with new, more energy-efficient and controllable luminaires and the introduction of a public streetlight management system (procurement of a management control center and controllable luminaires), i.e. the implementation of Unit 1 of the Public streetlight System from chapter 3.6. The scope of renovation of the public streetlight system is the same as in chapter 4.2.2. Since the scope of the renovation is equal to the scope analysed in chapter 4.2.2, they represent comparable scenarios. For the purpose of creating indicative indicators of the project's implementation through the energy performance contract, the cost of capital, i.e. the level of the interest rate in the amount of 4%, is assumed. The duration of the contract is expected to be 17 years, considering that the replacement of the luminaires, i.e. the performance of the renovation works, should be carried out in a period of 2 years.

Furthermore, the assumptions used in the calculation of the indicative indicators of project implementation through the EPC model are:

- The scope of the project is equal to the scope analysed in the previous chapter;
- The time schedule for the execution of the works is equal to the schedule for the realization of the project in the traditional way;
- Savings in the capital costs of the project of 15% compared to the traditional way;
- Savings in electricity costs after the renovation are about ?% higher compared to the project realised in the traditional way, that is, the luminaires are more efficient by about 40%;
- Savings in maintenance costs are about 10% higher compared to a project realised in the traditional way;
- Share of the private partner's own investment (equity) around 20%;
- Interest on a long-term private partner loan (ESCO) of 4%.

Based on the analysis of the implementation of the project through the EPC model (energy performance contract) and based on the above assumptions, the indicative indicators indicate the potential for savings in annual operating costs of around X million EUR during the first 15 years of use of the reconstructed public streetlight system, i.e. around 3 X million EUR after the contract expires about the energy performance in relation to the traditional way of implementing the project with a loan. In absolute terms, this reduction of about X million EUR compared to the traditional way of realizing the project means a reduction of total expenditures for the public streetlight system from the reference X million EUR (with VAT) to about X million EUR (with VAT). The annual cost of the EPC fee is X million EUR (including VAT), i.e. a total of X million EUR during the 17-year period of the EPC contract (2 years of renovation and 15 years of use).

After the expiration of the Energy Performance Agreement (after the 15-year payment period), a reduction of total expenditures for the public streetlight system in the amount of X million EUR (including VAT) is anticipated, i.e. a reduction of total expenditures for the public streetlight system is anticipated from the reference X million EUR (including VAT) to around X million EUR (including VAT) (Figure 4.5).

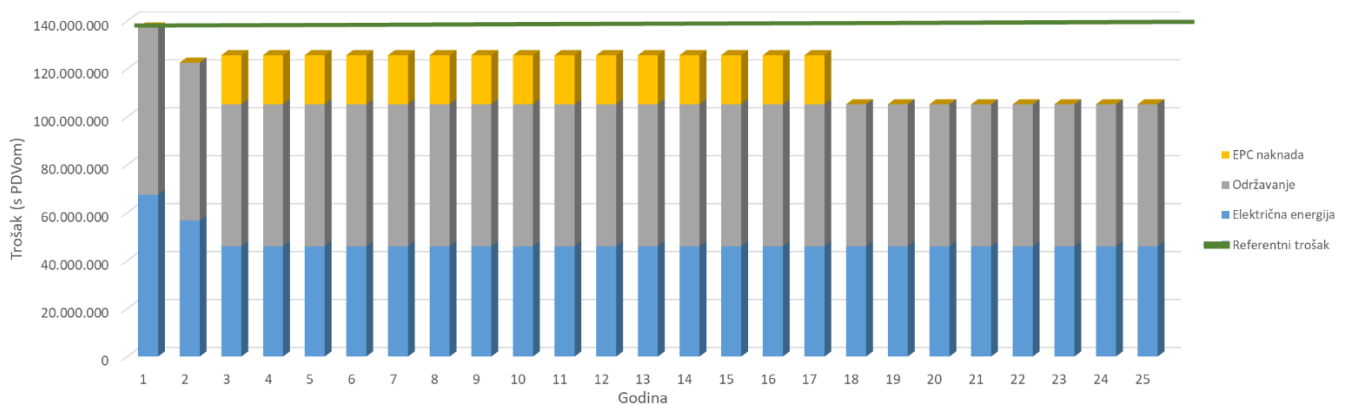


Figure 4.3 Expenditure dynamics - realisation based on financing with the Energy Performance Contract

As in the previous chapter, it was assumed that this reduction will be used to increase investment maintenance, which would be used for the gradual realization of part of the needs defined in Unit 2, that is, the needs for upgrading defined in Unit 3 of the public streetlight system.

4.3. Proposal of the optimal scope and financing model

Based on the analyses carried out (especially analysing the technical and technological aspects of the Public streetlight system renovation), the optimal solution is the scenario in which the renovation is carried out (replacement of around X% of the existing luminaires with controllable, more energy-efficient luminaires and the implementation of connected lighting and of a public streetlight management system) through the energy performance contract model while the renovation of Unit 2 and the extension of public streetlight system from Unit 3 are carried out in the traditional way (reinforced investment maintenance or loan).

Bearing in mind the increased needs for the construction and extension/renovation of other existing infrastructure and public buildings (administrative buildings, schools, hospitals, kindergartens, roads, etc.), this Action Plan analysed the possibilities of realizing the need for modernization, renovation and extension of the public streetlight system, primarily guided by the principle of retaining existing budget expenditures. Within the aforementioned limitation and bearing in mind the increased needs for construction and extension/renovation of other infrastructure, the scenario of realization of the renovation/modernization of Unit 1 through the energy performance contract model is considered the optimal solution. The conducted analysis determined that by implementing the renovation/modernization of Unit 1 of the public streetlight system through the energy performance contract model, additional annual savings of around X million EUR (X million EUR more than the traditional one) would potentially be achieved during the duration of the EPC contract (period of 15 years). Also, with additional savings, this implementation model ensures that the planned renovation/modernization is carried out, without increasing the public debt or indebtedness of the local authority and thus not reducing the fiscal capacity.

The analysis showed that the renovation of the scope defined by Unit 2 can be fully financed from budget funds.

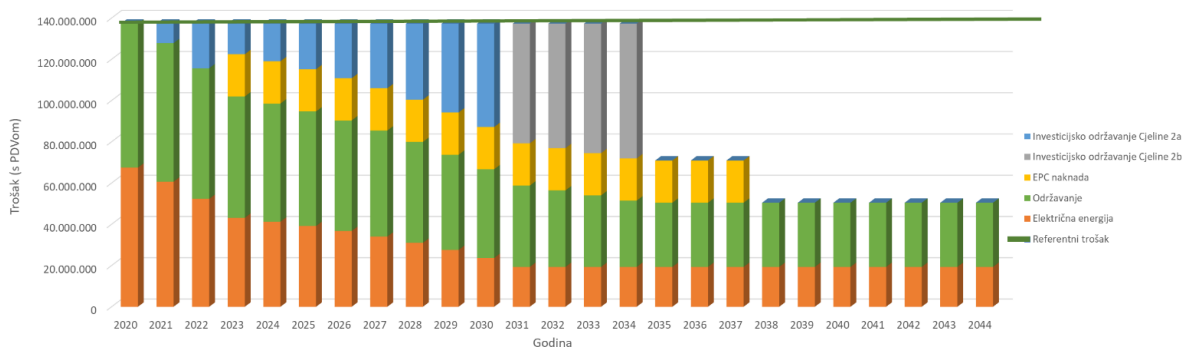


Figure 4.4 Expenditure dynamics – Unit 1 and 2

The analysis carried out showed that after the implementation of the renovation, the reduction of budget expenditures due to savings in energy consumption and regular maintenance amounts to X million EUR. For the renovation of Unit 2 to be fully financed from the budget, all the savings achieved as well as the budget funds foreseen for the major renovation of the existing lighting systems (around X million EUR) must be redirected to investment maintenance. The total amount of savings and the regular cost of investment maintenance would amount to X million EUR in the first year after the renovation of the public streetlight system (Unit 1) via the EPC model. At the same time, in order to achieve the greatest possible cost savings, it is recommended to start with the renovation of Unit 2a, which shows a greater potential for achieving cost savings, which in the coming years can again be redirected to investment maintenance.

The annual amount proposed to be channelled into the investment maintenance item increases from X million EUR in the first year to around X million EUR in the fourteenth year. At the same time, investment maintenance is invested in Unit 2a for the first ten years in order to bring the luminaires in into compliance with the legislation, and then investment maintenance is invested in Unit 2b in the following four years. Budget expenditures remain at the same level of reference expenditures of HRK X million EUR per year until 2034, after which they decrease by about X million EUR. After 2038, total expenditures will decrease by around X million EUR. The analysis did not take into account the increase in the price of electricity, nor the increase in the price of materials and services.

It is assumed that the extension of public streetlight system (Unit 3) will be carried out as in the previous period from the budget funds related to the costs of the extension or construction of new lighting. In the coming period, the possibility of financing the renovation and extension of Unit 2 and Unit 3 of the public streetlight system from available EU funds should certainly be monitored. At the time of writing this Action Plan, there are no available sources of EU funding through which the renovation and extension works of Unit 2 and Unit 3 could be financed. Based on all of the above, a summary of the optimal scope of construction, extension and renovation of the public streetlight system, as well as a financing proposal, is given below.

Unit 1**SCOPE**

Renovation X% of existing luminaires (X pcs)

OPTIMAL FINANCING MODEL

Energy performance contract

PERIOD OF IMPLEMENTATION

2023.-2024. renovation

2024.-2039. Service providing

Unit 2a**SCOPE**

Renovation X% of existing luminaire (X pcs)

Renovation X% of steel luminaire postluminaire posts (X pcs)

OPTIMAL FINANCING MODEL

Budget financing (primarily from the cost savings resulted from Unit 1)

PERIOD OF IMPLEMENTATION

2023.-2030. renovation

Unit 2b**SCOPE**

Public streetlight cabinet renovation (X pcs)

Renovation of underground supply cables (X pcs)

OPTIMAL FINANCING MODEL

Budget financing (primarily from the cost savings resulted from Unit 1 and Unit 2a)

PERIOD OF IMPLEMENTATION

2023.-2034.

Unit 3**SCOPE**

Construction of X luminaire postluminaire posts per year

Extension of X luminaires per year

OPTIMAL FINANCING MODEL

Budget financing

PERIOD OF IMPLEMENTATION

2023.-2037.

4.4. Potential sources of financing for the public streetlight renovation

//Describe available sources, preferential loans etc.

4.4.1. EU funds

4.4.2. National funds

5. Implementation schedule of the construction, extension and renovation of the public streetlight system

The implementation of the project of construction, extension and renovation of the public streetlight system is divided into four basic phases:

PHASE A

Preparation of legal and technical documentation for the realization of the renovation Units 1 of the public streetlight system (year 2020);

PHASE B

Renovation of Units 1 of the public streetlight system (2021-2022.);

PHASE C

Detail analysis for Unit 2 and Unit 3 (analysis of needs, procurement models, feasibility study (2020-2021. godina)

PHASE D

Renovation Unit 2 and Unit 3 of public streetlight system (2022-2034.)

Detailed schedule of the renovation of Unit 1.

The first part of the project implementation (renovation of Unit 1 of the public streetlight system) includes the following preparatory activities:

PHASE A-I //Divide and describe phases

PHASE A-II

PHASE A-III .

Table 5.1 PHASE A implementation schedule

	2023											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
PHASE A-I												
PHASE A-II												
PHASE A-III												

The second part of the project implementation includes activities related to the implementation of the installation of designed equipment and materials in the public streetlight system (Table 6.2). The implementation of the project is divided into basic phases:

PHASE B-I *financial closure;*

PHASE B-II Design (ESCO);

PHASE B-III Implementation of renovation (ESCO);

PHASE B-IV Takeover of the implemented works;

PHASE B-V Use phase

IV

PHASE B-

V

Table 5.2 PHASE B implementation schedule

	2024											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
PHASE A-III												
PHASE B-I												
PHASE B-II												
PHASE B-III												
PHASE B-IV												
PHASE B-V												

		2025											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
PHASE A-III													
PHASE B-I													
PHASE B-II													
PHASE B-III													
PHASE B-IV													
PHASE B-V													

		2026											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
PHASE A-III													
PHASE B-I													
PHASE B-II													
PHASE B-III													
PHASE B-IV													
PHASE B-V													

6. Conclusion

The action plan for the construction, extension and renovation of the public streetlight system represents the key basis of the strategic investment project, used for the purpose of analysing the current state and potential, as well as the optimal coverage and financing model of public streetlight. As part of the creation of the Action Plan, an analysis of the current situation was carried out with a presentation of the potential of energy and cost savings and the necessary capital investments in the renovation of the public streetlight system. It should be emphasized that in addition to the renovation potential of the existing luminaires, the Action Plan also analysed the need for extensions in order to achieve minimum light technical parameters (in accordance with EN 13 201) as well as the need for construction to expand the public streetlight system.

Based on the Report on the conducted energy audits, the public streetlight system consists of X metering points, about X km of lines and about X lighting points with about X luminaires with a total installed power of about X MW. As a reference consumption of electricity, the consumption from 2019 was assumed, increased by the consumption of non-functioning luminaires throughout the year and increased by the consumption of the upgraded public streetlight system (increase in the number of luminaires during 2019 and projections for 2020). The reference electricity consumption of the public streetlight system, in accordance with the above, amounts to X GWh per year. The reference price of electricity used in this Action Plan is the price of electricity from December 2019 (X HRK/kWh including VAT). The reference costs of electricity in accordance with the reference unit price and reference consumption amount to X million EUR (including VAT). The average cost of maintenance in the period from 2017 to 2019 was taken as the reference cost of regular maintenance of the public streetlight system, and it amounts to about X million EUR (including VAT). The total operating costs of the public streetlight system also include investment maintenance costs, which for 2019 amounted to around X million EUR. According to the above, the total annual operating costs of the public streetlight system (cost of electricity and maintenance) amount to around X million EUR (including VAT). The stated operating costs do not include the costs of delivery, assembly and disassembly of holiday lighting and decorative elements at lighting positions, for which the local authority annually allocates around X million EUR (including VAT).

The analysis of the needs and possibilities of improving the existing public streetlight system, carried out as part of the Action Plan, was based on the needs of construction and extension in order to increase traffic safety (harmonization with the EN 13 201 standard), the needs of renovation in order to ensure the basic functionality and availability of the existing system (e.g. replacement of dilapidated underground infrastructure), the need for renovation in order to comply with the legislation, the possibilities of improving the public streetlight system from the aspect of increasing energy efficiency, and the possibilities of improvement by applying digitization in the public streetlight management and supervision system with the application of the so-called Smart City aspects. The conducted analysis of needs and possibilities was based on a 15-year period, and all for the purpose of encompassing relevant needs during the economic and lifetime of the basic parts of the infrastructure of the public streetlight system. Only the needs of construction and additions for the purpose of increasing traffic safety (compliance with EN 13 201) are observed in a five-year period due to the impossibility of quantifying annual needs over a longer period of time.

According to the analysis carried out, to meet the overall needs of the public streetlight system over the next 15 years, the estimated investment is about X billion EUR (including VAT) and does not include the costs of engineering services or the costs of implementation risks. In order to analyse the financial indicators of the financing model, it was necessary to define the optimal scope of the project to divide the public streetlight system into functionally and technically

connected units whose implementation could be considered separately. Units are defined in such a way that they comply with:

- construction and extension needs for the purpose of increasing traffic safety (compliance with the EN 13 201 standard);
- renovation needs for the purpose of ensuring the basic functionality and availability of the existing system (e.g. replacement of dilapidated underground infrastructure);
- renovation needs for the purpose of compliance with the legislation (mainly for the purpose of reducing the share of stray light and limiting the correlated light colour temperature);
- possibilities of improving the public streetlight system (from the aspect of increasing energy efficiency by replacing existing light sources and luminaires with more efficient ones with the application of active work regulation);
- possibilities of improvement through the application of digitization in the system of management and supervision of public streetlight and the construction of basic so-called Smart City infrastructure.

By analysing specific limitations, primarily of a technical nature, meeting the overall needs of the existing public streetlight system can be logically separated into three main units. Unit 1 refers to the part of the system characterized primarily by the replacement of existing luminaires with new ones. Unit 2 refers to the part of the system that requires the replacement of supply cables and luminaire postluminaire posts together with luminaires, which must be performed simultaneously due to the rationalization of costs. Unit 3 refers to the extension of the public streetlight system in order to meet the lighting technical conditions. What the mentioned units have in common is that they all provide for the installation of luminaires that are interoperable with the so-called Smart City platform so that through their realization the uniformity of technology and readiness for later upgrading with Smart City components. On the basis of the analyses carried out (especially analysing the technical and technological aspects of the renovation of the public streetlight system), the optimal solution is a scenario in which the renovation of Unit 1 of the public streetlight system is carried out (it includes the replacement of about X% of the existing luminaires (about X luminaires) with controllable and more energy-efficient luminaires and the introduction of the public streetlight management system) through the energy performance contract model, while the renovation of Unit 2 and the extension of Unit 3 are assumed to be implemented in the traditional way (reinforced investment maintenance from the financial savings generated by the implementation of Unit 1 or through a loan).

The recapitulation includes Unit 1, i.e. the basic details related to the costs and savings of the optimal scope of the public streetlight system renovation project:

- a) The scope is about X% of the total number of luminaires (about X luminaires in the scope);
- b) The existing cost of electric energy of the luminaires in the scope is about X million EUR;
- c) The renovation is carried out through the Energy Performance Agreement, which is concluded for a total duration of X years, of which:
 - X years planned for design and execution of works, and
 - X years of providing lighting services;
- d) Estimated capital investment amounts to about X million EUR (about X million EUR);
- e) The total cost of the Energy Performance Contract (includes the listed capital costs, but also the cost of financing, the cost of renewal, the cost of an extended warranty, the cost of a bank guarantee for all 15 years, the cost of improving the control and monitoring center, as well as the costs of data traffic for all 15 years for the purpose of communication luminaires) amounts to about X million EUR (about X million EUR);
- f) The estimated annual EPC fee is X million EUR;
- g) The estimated electricity savings after the renovation is about X million EUR (based on the savings in electricity costs, the EPC fee will be paid to the private individual).

Bearing in mind the increased needs in the construction and extension/renovation of other existing infrastructure and public buildings (administrative buildings, schools, hospitals, kindergartens, roads, etc.), this Action Plan analysed the possibilities of realizing the need for modernization, renovation and extension of the public streetlight system, primarily guided by the principle of retaining existing budget expenditures. Within the aforementioned limitation and bearing in mind the increased needs for construction and extension/renovation of other infrastructure, the scenario of realizing the renovation/modernization of Unit 1 through the energy performance contract model is considered the optimal solution. The contract on energy performance is implemented in such a way that the private partner/ESCO company (Energy Service Company) independently finances and performs works on the renovation of public streetlight. Realised cost savings, which occur after the renovation of the existing luminaires, are used to cover the costs of the investment and the costs of providing the energy service. After the expiration of the EPC contract, the local authority benefits from the renovation due to energy and financial savings that are realised even after the expiration of the contractual relationship with the ESCO company. Energy service contracting is defined by the **Regulation on contracting and implementation of energy services in the public sector**. With regard to the legislation and EUROSTAT's interpretation, EPC contracts are not considered public debt if all prescribed assumptions and requirements are met. It is important to point out that according to the Regulation, if the service fee is less than the guaranteed electricity savings, the EPC contract is not considered public debt in the sense of the **Budget Act**.

The advantage of alternative procurement models, i.e. contracts on energy performance, in relation to the realization of the project using the traditional model through budget funds or a loan, lies in the fact that the private partner (ESCO company) offers the implementation of the project according to the so-called to the turnkey model, which includes the optimization of equipment and technological solutions in relation to the given criteria (standards), creation of project documentation, financing, supply of equipment and performance of works, service of maintenance and guaranteeing the functional operation of the public streetlight system, and guaranteed energy and cost savings (taking over relevant project risks). By contracting the construction, extension and renovation of the public streetlight system according to the so-called the turnkey model eliminates the possibility of unforeseen quantities or out-of-budget works, which significantly simplifies the planning and management of total expenditures. In addition to the above, the advantage of implementing alternative procurement models, i.e. engaging a private partner, is the realization of the overall potential of more efficient project management (especially the supply chain in all stages of the project) and better risk management in the project, which of course has an impact on the overall cost of the infrastructure.

The total capital costs of the public streetlight system renovation project (Unit 1) are estimated at around **X million EUR** (including VAT) in terms of traditional financing. In addition to the costs of purchasing equipment, performing works, installing the management control center (a total of about **X million EUR** (including VAT), there are also costs for engineering services (design, design of the control center, expert supervision, project management, and measurement and verification) and risk costs and extended warranty costs on luminaires. The assumption is that the total costs of engineering services are worth about 5% of the investment, i.e. about **X million EUR** (including VAT), risk costs in the design and execution phase (they relate primarily to unforeseen costs and works) worth about 8% of the capital investment, or about **X million EUR** (with VAT) and the costs of the extended warranty on luminaires for a 15-year period of 2% of the capital investment, or about **X million EUR** (with VAT).

The analyses determined that the implementation of the renovation/modernization of Unit 1 of the public streetlight system through the energy performance contract model would potentially result in annual savings of around **X million EUR** during the EPC contract (15-year period). In absolute terms, the implementation of the renovation/modernization of Unit 1 will generate a

reduction in total expenditures for the public streetlight system from the reference **X million EUR** (including VAT) to around **X million EUR** (including VAT). The annual cost of the EPC fee is **X million EUR** (including VAT), i.e. a total of **X million EUR** over the 17-year period of the EPC contract (2 years of renovation and 15 years of use). Realization of the renovation of Unit 1 of the public streetlight system through the contract on energy performance ensures that the project is implemented without increasing the public debt or indebtedness of the local authority and thereby not reducing the fiscal capacity. Funds in the amount of **X million EUR** will need to be planned for the payment of the EPC fee, electricity and maintenance of the public streetlight system after the renovation. After the expiration of the Energy Performance Agreement (after the 15-year period of payment of the EPC fee), a reduction of total expenditures for the public streetlight system in the amount of **X million EUR** (with VAT) is anticipated, i.e. a reduction of total expenditures for the public streetlight system is anticipated from the reference **X million EUR** (including VAT) to around **X million EUR** (including VAT). According to the conducted analyses, the indicative indicators point to the potential of achieving greater value for taxpayers' money, and it is suggested that the project be launched through the Energy Performance Agreement model. The implementation of the project (Unit 1) will achieve savings in electricity consumption in the amount of about **X%** (for the part covered), i.e. about **X GWh** per year, while the implementation will also result in a reduction of carbon dioxide emissions by about **X tons** on an annual level. The implementation of the renovation of Unit 1 of the public streetlight system will fully achieve the goals defined by the Action Plan for Energy Sustainable Development and Adaptation to Climate Change (SECAP).

Considering the requirements of the legislation against Light Pollution, luminaires that do not comply with the legislation must be brought into line within a defined period. The scope included in Unit 2 refers to the remaining luminaires that are not included in Unit 1 and are not in accordance with the Law and/or are energy inefficient, replacement of dilapidated luminaire postluminaire posts, relocation or renovation of public streetlight cabinets and replacement of part of the underground supply cables. With regard to potential cost savings, Unit 2 can be divided into a more potent part related to luminaires and poles, where significant cost savings are realised immediately upon renovation (hereinafter referred to as Unit 2a), and a less potent part in terms of potential savings that refers to public streetlight cabinets and underground supply cables (further on in the text Unit 2b). The analysis showed that after the implementation of the renovation of Unit 1, the reduction of budget expenditures due to savings in energy consumption and regular maintenance amounts to **X million EUR**. In order for the renovation of Unit 2 to be fully financed from the budget, all the savings achieved as well as the budget funds provided for the renovation of the existing lighting system (around **X million EUR**) must be redirected to investment maintenance. The total amount of savings and the regular cost of investment maintenance would amount to **X million EUR** in the first year after the renovation of the public streetlight system (Unit 1) via the EPC model. At the same time, in order to achieve the greatest possible cost savings, it is recommended to start with the renovation of Unit 2a, which shows a greater potential for achieving cost savings, which in the coming years can again be redirected to investment maintenance. The annual amount that is proposed to be channelled into the investment maintenance item increases from **X million EUR** in the first year to around **X million EUR** in the fourteenth year (due to the realization of savings by implementing the renovation every year). At the same time, investment maintenance is invested in Unit 2a for the first ten years in order to bring the luminaires into compliance with the legislation, and then investment maintenance is invested in Unit 2b in the following four years. In accordance with the above, budget expenditures must be kept at the same level of reference expenditures of **X million EUR** per year until 2034, after which they decrease by about **X million EUR**. The analysis did not take into account the increase in the price of electricity, nor the increase in the price of materials and services. It was assumed that the extension of Unit 3 will be carried out as in the previous period from the budget funds related to the costs of the extension or construction of new lighting. In the coming period, the possibility of financing the renovation and extension of Unit 2 and Unit 3 of the public streetlight system from available EU funds should certainly be

monitored. At the time of the creation of this Action Plan, there are no available sources of EU funding through which the renovation and extension works of Unit 1, Unit 2 or Unit 3 could be financed. However, at the EU level, a new period of EU funding from 2021 to 2027, during which the areas eligible for EU co-financing will be defined. In this regard, the public streetlight system and its components could certainly be interesting in terms of the potential of using the so-called Smart City solutions, but also energy efficiency and potential impacts on the climate.

From the analysis carried out as part of the Action Plan for the construction, extension and renovation of the public streetlight system of the local authority, it can be concluded that:

- a) Estimated savings in electricity consumption (X million EUR per year) are equal to the estimated annual cost of the EPC fee (X million EUR HRK), which implies that the costs of the project will be financed exclusively from the achieved energy savings. In the public procurement procedure according to the EPC model, it is allowed to accept only bids that achieve equal or greater savings than the defined with an equal or lower value of the EPC fee than defined in the Procurement Documentation (cost of project implementation);
- b) Maintenance savings that are certain to occur (given that the ESCO company guarantees the full functionality of the luminaires for the duration of the EPC contract) remain in the city budget and, in accordance with the Action Plan, will be necessary in order to bring the remaining infrastructure of the public streetlight system into line with the legislative regulations;
- c) Bearing in mind the increased needs for the construction and extension/renovation of other existing infrastructure and public buildings (administrative buildings, schools, hospitals, kindergartens, roads, etc.), the Action Plan analysed the possibilities of realizing the need for modernization, renovation and additions to the public streetlight system, primarily guided by the principle of retaining existing budget expenditures. Within the aforementioned limitation and bearing in mind the increased needs for the construction and extension/renovation of other infrastructure, the scenario of realization of the renovation through the energy performance contract model is considered the optimal solution. The contract on energy performance is implemented in such a way that the private partner/ESCO company (Energy Service Company) independently finances and performs works on the renovation of public streetlight. Realised cost savings, which occur after the renovation of the existing luminaires, are used to cover the costs of the investment and the costs of providing the energy service. After the expiration of the EPC contract, local authority benefits from the renovation due to energy and financial savings that are realised even after the expiration of the contractual relationship with the ESCO company. Energy service contracting is defined by the legislation. With regard to the Budget Law, the Regulation and EUROSTAT's interpretation, EPC contracts are not considered public debt if all prescribed assumptions and requirements are met. It is important to point out that according to the Regulation, if the service fee is less than the guaranteed electricity savings, the EPC contract is not considered public debt in the sense of the Budget Law;
- d) The implementation of the project will achieve savings in electricity consumption in the amount of about X% (for the part covered), i.e. about X GWh per year, while the implementation will also result in a reduction of carbon dioxide emissions by about X tons on an annual basis. The implementation of the renovation of the public streetlight system will fully achieve the goals defined by the Action Plan for Energy Sustainable Development and Adaptation to Climate Change (SECAP);
- e) At the time of the creation of the Action Plan, there are no available sources of EU funding through which the works of renovation and upgrading of the public streetlight system could be financed. However, a new EU funding period from 2021 to 2027 is being negotiated and discussed at the EU level, during which the areas eligible for EU co-financing will be defined. In this regard, the public streetlight system and its components

could certainly be interesting in terms of the potential of using the so-called Smart City solutions, but also energy efficiency and potential impacts on the climate.

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Annex 1 Compliance of the Action Plan with the legislative and strategic framework

EU legislation	SOURCE
Zahtjevi za ekološki dizajn Direktiva 2009/125/EC	
(EC) No 245/2009 Transitional methods of measurement and calculation: 2014/C 22/02	http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1521114161802&uri=CELEX:32009R0245
Guidelines – July 2015	https://ec.europa.eu/energy/sites/ener/files/documents/Implementation%20Guide%20Lighting.pdf
Amended by (EU) No 347/2010	http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1521114224818&uri=CELEX:32010R0347
Impact Assessment [SEC(2009) 324]	https://ec.europa.eu/energy/sites/ener/files/documents/sec_2009_324_impact_assesment_en.pdf
Impact Assessment Summary [SEC(2009) 325]	https://ec.europa.eu/energy/sites/ener/files/documents/sec_2009_325_impact_assesment_summary.zip
(EU) No 1194/2012	http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1521114050010&uri=CELEX:32012R1194
Impact Assessment [SWD(2012) 419]	http://ec.europa.eu/governance/impact/ia_carried_out/docs/ia_2012/swd_2012_0419_en.pdf
Impact Assessment Summary [SWD(2012) 418]	http://ec.europa.eu/governance/impact/ia_carried_out/docs/ia_2012/swd_2012_0418_en.pdf
Communication on the market assessment on the mains-voltage luminaires COM/2015/0443	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2015:443:FIN
Transitional methods of measurement and calculation:: 2014/C 22/02	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.C_.2014.022.01.0017.01.ENG
Guidelines – July 2015	https://ec.europa.eu/energy/sites/ener/files/documents/Implementation%20Guide%20Lighting.pdf
(EU) 2015/1428 (amending Regulations (EC/EU) 244/2009, 245/2009 and 1194/2012)	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2015.224.01.0001.01.ENG
Oznake energetske učinkovitosti Uredba (EU)2017/1369	https://eur-lex.europa.eu/legal-content/hr/TXT/?uri=CELEX:32017R1369
(EU) No 874/2012	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32012R0874
Harmonised standards : (2014/C 22/02)	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.C_.2014.022.01.0017.01.ENG
Guidelines – July 2015	https://ec.europa.eu/energy/sites/ener/files/documents/Implementation%20Guide%20Lighting.pdf
EU strategic documents	SOURCE
Strategija Europa 2020	http://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf
Europsko inovativno partnerstvo za pametne gradove i zajednice (EIP-SCC - European Innovation Partnership on Smart cities and Communities)	http://ec.europa.eu/eip/smartcities/

Strategic Implementation Plan (SIP)	http://ec.europa.eu/eip/smartcities/files/sip_final_en.pdf
Operational Implementation Plan (OIP)	https://www.smartcities.at/assets/Uploads/operational-implementation-plan-oip-v2-en.pdf
National legislation	SOURCE
National strategic documents	SOURCE
Local strategic documents	SOURCE