SMART EPC

next generation of energy performance contracting

METHODOLOGY FOR DETAILED ENERGY AUDIT OF PUBLIC LIGHTING SYSTEM

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Content

Glossary

Brackets and arms are parts of the luminaire holder, most often fitted onto street luminaire posts;

Billing metering point (BMM) is the element for measuring the public lighting energy consumption;

CCT (Correlated Colour Temperature) is the colour temperature compared to the temperature of an ideal black-body radiator. The temperature of an ideal black body expressed in degrees Kelvin, at which the same light as the measured source light is emitted, is called the correlated colour temperature of that light source.

CRI - Colour Rendering Index;

CLO (Constant Lumen Output) is a luminaire property maintaining the same value of the lumen output throughout the luminaire lifetime where the active power of the luminaire does not exceed the maximum allowed active power prescribed by the technical documentation of the luminaire manufacturer;

Dimming is the adjustment of the electric power of a luminaire and consequently the luminous flux of the luminaire by decreasing the luminous flux of the LED module.

Dimming regime means the information on the percentage of active power regulation and the output luminous flux of one or more luminaires in relation to the Normed active power of the luminaire in one or more time periods as defined by the Contracting Entity; it must be able to go from a minimum of 25% to 125% of the Normed active power of the luminaire;

Driver is a luminaire component that supplies the LED light source with adequate voltage and current. It converts input alternating current to direct current for supplying the LED light sources;

GIS (Geographic Information System) is a computer system for managing spatial data and the attributes of that data.

Illuminance is a physical value used to describe the amount of light falling onto a given surface area (unit: lux (lx)); Lux (lx) is a derived unit of the SI system which represents the illuminance of 1 square meter of surface onto which falls an equally distributed one-lumen luminous flux;

Lamppost is a part of a public lighting system that performs the function of public lighting, i.e. the supporting element of luminaire, suspensions, consoles and similar elements that perform the function of supporting element of a luminaires and/or supply cable of a public lighting.

Light pollution is a change in the level of natural light in night conditions caused by the emission of light from artificial light sources which has a detrimental effect on human health and threatens traffic safety due to glare, direct or indirect emission of light to the sky, interferes with the life and/or migration of birds, bats, insects and other animals and disrupts plant growth, compromises natural balance, interferes with professional and/or amateur astronomical observations, unnecessarily consumes energy and affects the night landscape;

Luminaire is an electrical device (fixed or portable) that has one or more light sources built into it; and it is intended for directing; filtering or transmitting light.

Light source is a part of the luminaire converting a certain form of energy into light;

Lighting classification are requirements for illumination of public traffic areas and other public areas in accordance with EN 13201 – wherever it is stated, it means the overall norm of EN 13201; EN 13201-2:2015; EN 13201-3:2015; EN 13201-4:2015; EN 13201-5:2015 and CEN/TR 13201-1:2014 or equivalent.

M: motorized vehicles on traffic routes (sometimes also on residential roads) at low to very high driving speeds urban or not urban motorized traffic, the values of L (illuminance) can be calculated, M1 to M5; C: = Conflict areas occur wherever vehicle streams intersect each other or run into areas frequented by pedestrians, cyclists, or other road users [1]. Areas showing a change in road geometry, such as a reduced number of lanes or a reduced lane or carriageway width, e.g. at a bus or tram stop in commercial areas, roundabouts, C0 to C5 classes; P+HS pedestrian areas and pedal cyclist use; SC EV: Semicircular class and vertical according to EN 13201-2015

LOR (Light Output Ratio) – the ratio between the luminous flux emitted by the luminaire, including the losses in the optics and the protective glass, and the total luminous flux emitted by the LED module;

Optical system (unit) or optics is a part of the luminaire whose purpose is to set the lighting quality conditions for the proper functioning of the luminaire, i.e. proper distribution of the produced lumen output;

Pole or column is the part of the lamppost that holds and bears the weight of the brackets, arms or the luminaire.

Public Lighting is external lighting used for illuminating public areas;

Road lighting is outdoor lighting that is used to illuminate roads and other traffic areas.

Ripple control receiver is a device which receives the signal from the electric grid which determines the ignition of electricity supply of the public lighting system.

Street Lighting Distribution Cabinet means a demarcation point between the power distribution network and the public lighting system, comprising the elements for metering the power consumption of the public lighting system; public lighting management and protection system;

Surge Protection Device or SPD is part of the public lighting system designed to protect the luminaires from the harmful effects of increased voltage (surge) in the distribution network or public lighting feeder lines;

Supply cables are part of the public lighting system that transmits energy from the point of collection to the end elements (lamps).

Upward Light Output Ratio (ULOR) is the ratio of light distribution to the upper hemisphere, i.e. the portion of the light output ratio indicating the emission of light into the upper hemisphere.

1 Preamble

This Methodology is prepared within the 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 lighting 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.

The main goal of the public lighting energy audit is to collect all the necessary data for:

- modernization of the public lighting system through the Energy Performance Contract;
- implementation of non-revenue related measures (smart city);
- implementation of additional revenue-based services like e-charging or 5g;
- implementation of the measures for light pollution protection.

The purpose of the Methodology is to formulate the requirements for the energy audit by proposing the procedure and the minimum set of baseline data that is needed for decision making and feasibility calculations of public lighting reconstruction.

Some countries defined obligation of producing an energy audit of public lighting by law[1], but this Smart EPC Methodology is not part of the legislative framework and it is suggested that Smart EPC Methodology needs to be adjusted to national or local legislation framework (if existing).

The basic phases of the implementation of a detailed energy audit of the public lighting system are listed below:

Figure 1 Energy audit phases

[1] Regarding countries of Smart EPC project partners Public lighting energy audit is obligatory only in Croatia, and in Spain, France and Poland there is no legislatinal defined obligation

Public lighting owner/operator has the right to supervise the implementation of any energy audit phases. After the completion of the last phase and before the printing and submission of the Report, the public lighting owner/operator has the right to review the completeness and accuracy of the collected data. If it turns out that the data are not complete and / or accurate, the energy auditor is obliged to supplement them at his own expense in order to meet the requirements specified in this Methodology.

2 Minimum capacity requirements

2.1 Energy auditors' minimum capacity requirements

Energy audit of the public lighting system must be performed by a certified electrical engineer. Since the part of the energy audit foreseen the measurements on the supply lines under voltage the person conducting these measurements must be trained for safe operation under voltage. The energy auditor is obliged to coordinate all activities of the energy audit and collect all necessary data required in this Methodology, which includes coordination with the public lighting owner/operator, maintainer, electricity distributor and all other stakeholders.

2.2 Required energy auditors' equipment

For the detailed energy audit the Energy auditor is suggested to have at least the following equipment at his disposal:

- Camera with a resolution of 5 MP or higher with an integrated GPS receiver with the ability to geolocate and tag photos (geotagging).
- Personal computer with software with the ability to read and process * .xls and * .csv files used in the analysis of collected data as well as a program to elaborate reports (.docx or similar);
- Laser measuring device for measuring distances (measuring the height of the lamppost, the width of the pavement, pavement, etc.) with the possibility of measuring distances up to 40 meters;
- Device for measuring electrical power, energy and quality of electricity with a valid certificate accuracy class S or A in accordance with IEC 61000-4-30 with a accuracy tolerances of + / - 2.5% or less. The device must be able to measure current, voltage, real power, reactive power, apparent power, power factor (cos ϕ).

2.3 Preparation for the existing baseline data collection

This chapter describes the necessary activities that the energy auditor is obliged to undertake as well as the data that he is obliged to collect before field work. The owner of the public lighting system is obliged to make available to the energy auditor upon request all data he owns on the public lighting system as well as basic data on the public lighting system maintainer, distribution system operator, electricity supplier, etc.

A list of available data is included in the annex of this document.

The documentation that the Energy auditor is obliged to check (if available) in the preparation phase refers to:

- Project designs or similar project documentation for the modernization, reconstruction or construction of a public lighting system that has been completed or is planned to be completed in the next 24 months;
- Existing public lighting baseline data (elements, lighting classification, etc.);
- Existing energy audit;
- Information on implemented and/or planned modernizations through the maintenance of public lighting in the past and/or the next 12 months;
- Detailed data on electricity consumption in the last 3 years from billing metering points;

- Last available bill for electricity of public lighting or other source for actual electricity price information;
- Data on the costs and content of maintaining the public lighting system in the last 3 years;
- Data about the public lighting system stakeholders (maintainer, distribution system operator, electricity supplier and other possible stakeholders).

This information and documentation must be elaborated within the report.

3 Instructions for data collection

Public lighting is lighting that illuminates public areas to ensure the safe movement of pedestrians and vehicles on roads and a safe and pleasant atmosphere in squares and public spaces in a period when there is no natural light. The basic elements that perform the function of public lighting are:

- place of demarcation of the electricity network and public lighting – lighting distribution cabinet or public lighting field in transformer stations with billing metering point and protective equipment (hereinafter: OMM);
- supply cables (overhead or underground lines);
- lamppost;
- luminaires with light source and ballasts;
- centralized monitoring and control system (if existing).

The following figure shows the disposition of the basic elements of public lighting buildings supplied by underground lines (Figure 1).

Figure 2 Visualisation of public lighting system basic elements

Within this chapter it is described all the necessary data needed for implementation of Energy performance contract, road classification in accordance with EN 13 201, smart city, additional energy related services and light pollution protection. Methodology is organized in the way if data foreseen for collecting already exists it can be use only part of the Methodology where additional data collecting is described in order to supplement data that are already in possession (Figure 3).

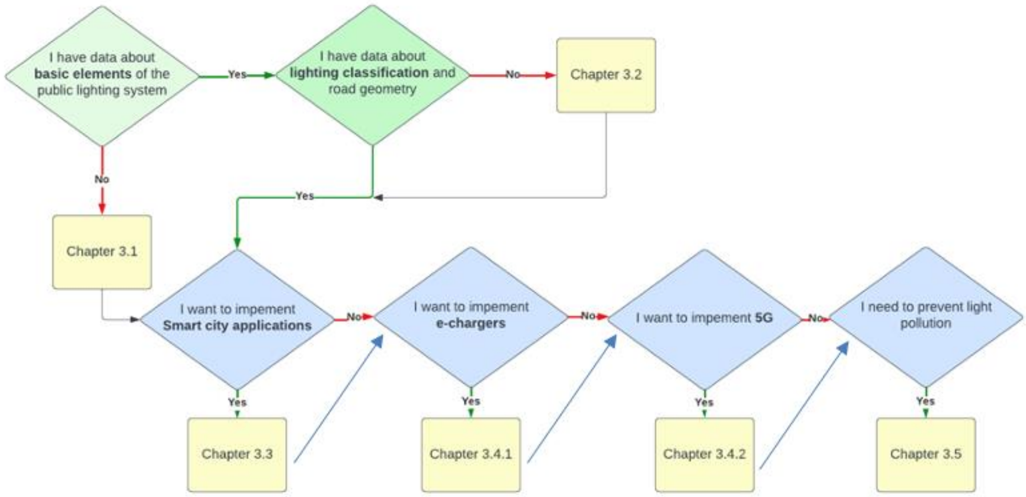
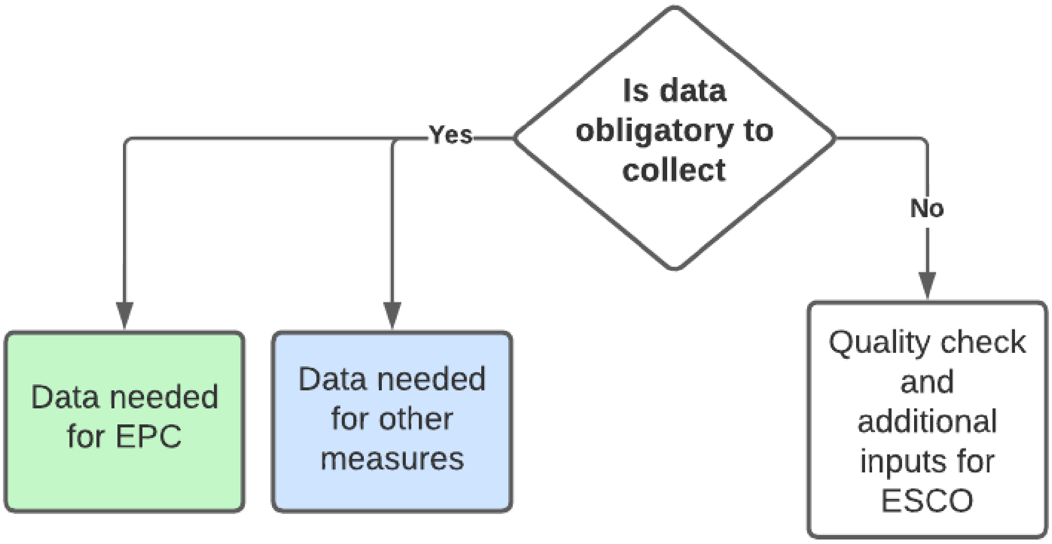


Figure 3 Modularity of data collection

Data that needs to be collected are divided into two main groups. First set of data needs to be collected for EPC contract implementation. Second set of data is data that serves as additional data that is not obligatory to collect and is used for checking the quality in later stages of energy audit or EPC contract.
First set of data is obligatory for collecting (without this data EPC is not possible) while second set of data is just recommendation.



3.1 Elements of the public lighting system

If there is no data about elements of the public lighting system, or existing data are obsolete or incomplete then the data stated in the chapter 3.1 of the Methodology shall be collected.

3.1.1 Public lighting distribution cabinet

The public lighting distribution cabinet can be located inside the transformer station (then it is the public lighting field in the transformer station) or it can be separated in a separate public lighting cabinet. The public lighting cabinet usually has several outlets for powering public lighting (power lines). The supply lines are connected to the distribution board in the lighting pole (in the case of underground water) or via a plug directly to the lamp on the lighting pole in the case of overhead water.

The data about public lighting cabinet includes the data about following elements:
- billing metering point;
- management and regulation system;
- protection system;
- supply lines.

It is necessary to determine the geolocation for each cabinet of the public lighting system.

a) Basic data

It is necessary to provide a brief technical description and specification of the connection point to the electricity network (official electricity distributor number for the billing metering point, energy meter number, energy supply contract, type of supply and type of the contract). It is necessary to describe the position of the cabinet, ie whether it is located inside the transformer station or in a separate (separate) cabinet, and the type of device used to calculate electricity consumption. It is also necessary to state the approved connection power in accordance with the electricity approval (maximum power of the electricity consumers according to the electricity distributor company that are connected to the respective billing metering point).

b) Management and regulation (turning on and off the lighting)

It is necessary to determine the type of on / off device of the public lighting system (device that puts supply line under voltage) and the functionality of the device (photoelectric cell/astronomic watch/centralized system). In addition to the basic function of switching the public lighting system on and off, the control system may also include a control (dimming) system. Public lighting control refers to a device that regulates the luminous flux of a luminaire through the regulation of luminaire power in order to reduce electricity consumption (eg reducing luminous flux in energy saving mode, usually in the late hours of the night when nominal luminous flux is not required). If there is a control system in the cabinet, it must be described.

c) Protection system

During the energy audit of the system, it is necessary to briefly describe the protection against indirect and direct contact. It is necessary to determine the type of low voltage network according to EN 60 364-1. It is necessary to establish whether the existing system has built-in overvoltage protection in the cabinet of public lighting and the characteristics of that protection. Short-circuit and overload protection must be described. The number, type and rated current for all fuses used for public lighting must be stated.

d) Determining the luminaires powered from cabinet

The energy auditor is obliged to determine exactly which lamps are powered from which cabinet. When switching on the public lighting system the energy auditor needs check which lamps have turned on and note that respectively – link between the luminaire and cabinet data is obligatory.

e) Instructions for collected data structuring

The public lighting cabinet includes the attributes of the following elements of the public lighting system:

Table 1 List of attributes to be collected for lighting cabinet

Attribute name	Description
Public lighting cabinet ID	Assigned by energy auditor (or local authority) and is the basis for linking to other collected data and elements
Address of the public lighting distribution cabinet	
Nr. of the transformer station	Code of the transformer station from official electricity distributor database
Official code of the billing metering point	Code of the metering point from official electricity distributor database
Energy consumption in the last 36 months (kWh)	As detailed as possible, based on the bills or other measurements
Public lighting management device	Description about type of management device (time based, luxmeter based, remote control,…) and working regimes
Overvoltage protection	Is overvoltage built-in, if yes its basic characteristic
Placement of cabinet	Is cabinet placed in transformer station or in separate standalone cabinet
Critical parts of the cabinet	Description of the broken, malfunctioned or other critical element of the cabinet
Control measurement made	Are measurement described in chapter 3.1.4 made
Does cabinet power anything else besides lighting	Describe consumers (type, power and working regime) that are powered from respective cabinet
Note	
X coordinate	
Y coordinate	

3.1.2 Lamppost

The lamppost includes data on the following elements:

- public lighting poles;
- luminaires with light source and ballast.

It is also obligatory to describe the poles that do not have a lamp installed on them, but at least one of the 4 neighbouring poles has a lamp installed on them). No data relating to the lamp and the light source shall be entered for the above poles.

For each public lighting pole, it is necessary to determine the geolocation and display it graphically.

a) Poles

Poles used for public lighting can also be electricity poles (owned by electricity distributors) or poles intended exclusively for public lighting (usually owned by a local government). All other suspension elements (consoles on the walls of buildings, suspension cables, etc.) that serve as supporting elements for luminaires are also considered as the public lighting poles.

It is necessary to specify the type of lamp holder (suspension, pole, console on the facade, etc.). Pole ownership must be determined. It is also necessary to record the public lighting poles located in the geographic area of the public lighting owner and which are supplied from the cabinets owned by another owner (other city/municipality) and to mark them accordingly. It is necessary to record all the other purposes that pole is used for (e.g. electricity distribution, traffic lights, tram power line, etc.).

It is necessary to determine the basic technical characteristics of the poles (material, height, existence of grounding, type of pole), including the description of the arm / bracket (length, slope estimate). During the energy audit it is necessary to assess the condition of the poles in terms of:

- the need to apply minor additional protection measures such as corrosion protection;
- necessary replacement of the complete pole (in case of very poor, critical condition of the pole, disturbed mechanical stability, etc.).

It is necessary to determine the geolocation for each public lighting pole.

b) Luminaire and light source

It is necessary to determine and indicate the name of the luminaire manufacturer and type. It is also necessary to determine or evaluate the basic technical characteristics of the luminaires such as the age of the luminaire, the number of luminaires on the pole, the type and power of the light source, the description of the ballast/driver (electronic or electromagnetic) and the design of the protective glass/optics. If the control and regulation is not performed centrally in the cabinet but is integrated in the luminaire, it is necessary to describe working regime of luminaire. If there are several luminaires on the lamppost, it is necessary to record whether they illuminate the same surface or different ones (e.g. road and sidewalk).

It is necessary to assess the condition of the luminaire (excellent /good /bad) in such a way that the luminaires whose condition is excellent are luminaires with flat protective glass, in fully functional condition and not older than 8 years. Luminaires in good condition are luminaires in functional condition but older than 8 years. Luminaires in poor condition are non-functional luminaires, such as luminaires with heavily soiled protective glass through which not enough light penetrates, faulty luminaires, etc.

During the field trip, the power of the light source and the type of ballast/driver are recorded. In the subsequent analysis, the losses in the ballasts/driver must be included in the calculation of the luminaire power. Losses in luminaires need to be estimated with respect to luminaire performance technology. In older luminaires with electromagnetic ballasts, the losses amount to 21% of the power of the light source, while in the case of lamps with electronic ballasts the losses amount to 11% of the power of the light source. With LED luminaires there is no need to record power of the LED module but only overall power of LED luminaire including power losses in driver. It is recommended that losses in the supply line and transformer be calculated as 4% of the total power of the light source. If different amounts than the recommended ones are used, it is necessary to state the source, ie the reason for using other values.

It is necessary to indicate which surface the luminaire illuminates (road, sidewalk, etc.). It is necessary to indicate whether a luminaire with a roto-symmetric light distribution or a luminaire with an asymmetric light distribution with respect to the illuminated surface is required. It is necessary to record if during the reconstruction should be installed specially designed luminaire (e.g. with a decorative element to fit into the landscape-urban environment, with antivandal protection, reflector etc).

c) Detection of critical points and unjustified locations

Within the energy audit, it is necessary to detect critical points of the public lighting system. The critical points are, among others:

- the pole is bent;
- rotten pole;
- necessary to apply corrosion protection;
- lamps with spherical fittings – light pollutants;
- soiled protective glass;
- other.

Unjustified public lighting locations are places that are illuminated even though they are not public places and/or there is no need to ensure the basic function of public lighting, i.e. safe movement and comfortable feeling of pedestrians and vehicles on roads and safe and pleasant atmosphere in squares and public spaces. Unjustified locations are, among others, if:

- a pole more than 5 m away from the road;
- a luminaire illuminates mainly private property;
- the luminaire illuminates areas that do not need to be illuminated, i.e. the luminaire does not contribute to the preservation of social and traffic safety (e.g. only motor traffic outside the settlement, green areas that are not used at night, etc.) – relocation or suppression of these luminaires are going to be considered;
- Poles have nonoptimal geometries for the surface they illuminate (too low / too high, placed too close/too far apart).

If an individual pole or luminaire represents an unjustified location, it is necessary to record it with an appropriate description.

d) Instructions collected data structuring

If more than one lamp is present on the pole, it is necessary to fill in the data for each lamp.

The following attribute data must be collected for public lighting poles:

Table 2 List of attributes to be collected for lamppost

Attribute name	Description
Luminaire ID	Assigned by an energy auditor or local authority and is the basis for linking to other collected data and elements
Public lighting cabinet ID	Represents the link to public lighting cabinet that powers the respective luminaire
Illuminated surface ID	Represents the link to the illuminated surface and all attributes of the illuminated surface in accordance with the chapter 3.2.1
Characteristic profile ID	Represents the link to the described characteristic profile according to the chapter 3.2.2
Luminaire location in relation to the illuminated surface (in case it illuminates several types of surfaces)	One-sided, one-sided on the side of the sidewalk, opposite the sidewalk, two-sided, central, alternating, between the pavement and the sidewalk, etc.
Distance of the pole from the edge of the road (m)	
Pole and luminaire height (m)	
Pole construction material	
Ownership of the pole and whether it is used for other purposes	
Is electricity distribution network placed on the pole	
Critical point	
Unjustified location	
Pole grounded	
Need to increase mechanical stability	If obvious
Luminaire functional	
Luminaire height (m)	
Length of the arm/bracket (m)	
Tilt of the luminaire optical axis (°)	
Number of luminaires on pole (pcs)	
Luminaire type	
Luminaire producer	
Luminaire age (years)	< 10 y., 10-20 y., > 20 y.
Type of the optical/protective glass	Weather is it curved or flat
Type of the ballast	Is it electromagnetic or electric

Is luminaire in individual dimming regime	If not regulated via cabinet but individually in luminaire regime should be recorded
Number of light sources in luminaire (pcs)	
Overall number of light sources	
Light source type	
Nominal power of the light source (W)	
Power of luminaire (W)	Included ballast / driver losses
Decorative luminaire	It is necessary to record if during the reconstruction should be installed a luminaire with a decorative element to fit into the landscape-urban environment
Roto-symmetric luminaire	Is a luminaire with a roto-symmetric light distribution or a luminaire with an asymmetric light distribution with respect to the illuminated surface necessary
Note	
X coordinate	
Y coordinate	

3.1.3 Pole without luminaire

The following table provides instructions for collecting data on pole locations where there is no luminaire installed (**Error! Reference source not found.**). Only the poles implied in the lighting system in a way, or another are to be included.

Table 3 List of attributes to be collected for pole without luminaire installed

Attribute name
Pole ID
Public lighting cabinet ID
Illuminated surface ID
Characteristic profile ID
Pole height (m)
Pole ownership
Electricity distribution network on pole
Critical point
Pole grounded
Need to increase mechanical stability
Note
X coordinates
Y coordinates

3.1.4 Control measurement

During the implementation of the energy audit, it is necessary to carry out control measurements of the load of the public lighting system at all billing metering points to which the public lighting is connected.

Control measurements under load, for safety reasons, are performed exclusively by a certified electrical engineer. Based on the collected data, the certified electrical engineer prepares and certifies the Report on the results of short-term operational load measurements. The energy inspector is obliged to use the data from the Report on the results of short-term operational load measurements and enclose the same with the Report on the conducted detailed energy audit. It is recommended that the energy auditor needs to provide all the conditions necessary for the safe control measurements, such as:

- ensure the escort of employees of the electricity distributor company (e.g. for those billing metering points located within distribution transformer stations);
- all consent requirements and other documents for conducting measurements.

When performing control measurements, the authorized electrical engineer is obliged to measure the engaged power of the lamps connected to the public lighting cabinet in question (billing metering point). It is necessary to measure with devices with a valid certificate of accuracy class S or A in accordance with IEC 61000-4-30 with a workforce measurement of 2.5 or more accurate, i.e. permissible deviations are + / - 2.5% or less.

For each supply line, the workforce is determined by measurement. When measuring, it is important to record the voltage conditions at the measuring points as well as the power factor (cos fi). After the measurement, it is necessary to determine the total workforce for each supply line (circuit) and billing metering point.

When performing control measurements, the authorized electrical engineer is obliged to collect the following data for each supply line:

- output current per phase (A);
- phase voltage (V);
- active power per phase (W);
- reactive power output per phase (VAr);
- apparent power output per phase (VA);
- power factor cos ϕ per phase;
- logs of the measuring device with which the stated parameters were measured for each billing measuring point with the recorded date and time of measurement.

Based on the measured data, it is necessary to show the amount of power that remained available for use in relation to the measured power (per phase of the supply line) and in relation to the leased power (according to OMM).

If the absolute difference between the calculated electrical power of luminaires that are in operation and connected to the metering point with all losses included and the measured power is greater than 15% then this is a significant power difference and therefore necessary determine the reason for the deviation.

In the event of a significant difference, several cases are possible:

- error in data collection of the power of the luminaires connected to the supply line;
- error in data collection of the number of luminaires connected to the supply line;

- error in data collection of the link between luminaire and cabinet (some luminaires powered from other cabinet);

If necessary (i.e. not linked only to the actual power of all luminaires), a field visit to locations where there is a significant difference between the measured and calculated power and in contact with the maintainer of the public lighting system is necessary to determine the reason for the deviation of power.

If the field inspection and in contact with the maintainer of the public lighting system determines that the above errors have not occurred, it is possible:

- **the existence of parasitic consumers involved at the time of measurement;**
- **irregular maintenance of the public lighting system (non-functional lamps and/or lamp parts at the time of measurement).**

The Energy auditor is obliged to address the billing metering points where significant deviations between the measured and calculated lamp power were observed and is obliged to explain in detail the reason for the deviation.

3.1.5 Photo documentation

Elements of the public lighting system must be photographed in their entirety and in the parts listed below:

1. each cabinet of public lighting outside and inside (protection, timer, other installed equipment);
2. any lighting location that is a critical point;
3. any lighting location that is an unjustified location;
4. any lighting location that is suitable for the installation of a e-charging station;

Each photograph must have geolocation information (geo-marked photograph) in order to be able to relate to an element of the public lighting system.

3.1.6 Determining the geolocation of elements of the public lighting system

During the field trip, it is necessary to spatially record, i.e. determine the geolocation coordinates for Cabinets of public lighting, supply lines and lighting points. The coordinates must be in the official coordinate system. Manual entry of the public lighting element on the map is also allowed using some of the proposed cartographic bases (digital orthophoto, copy of the cadastral plan or special geodetic base). Geolocations must be shown in the tabular presentation of each of the elements of the public lighting system, except for power lines which are a linear spatial element.

For the purposes of conducting an energy audit, it is not necessary to determine the position of lighting points with geodetic accuracy. The positions of lighting points with an accuracy of up to 2 meters ensure a satisfactory level of accuracy for the use of the collected data in the geoinformation system of public lighting.

3.2 Illuminated surfaces

If there is no data regarding illuminated surfaces which are important for determining the lighting quality standards in accordance with the EN 13 201 and/or are no defined lighting classes for illuminated areas than data stated in chapter 3.2 of the Methodology shall be collected.

3.2.1 Lighting classes

The energy auditor determines the classification of the illuminated surface in accordance with the standard HRN EN 13 201-1: 2015 from which the maximum allowable reduction of the output luminous flux will be interpreted (in the event lamps).

When classifying illuminate areas, a certified electrical engineer is obliged to adhere to the following principles:

- classification of roads with motor traffic, city streets and residential settlements, traffic areas with pedestrian and bicycle traffic and promenades in parks to be performed according to EN 13 201-1: 2015;
- the classification of intersections should be determined on the basis of a certain classification of public lighting of the major road at the intersection (e.g. main road at the intersection of classes M1, intersection of classes C0, further M2 / C1, M3 / C2, etc.);
- the classification of the pedestrian crossing must correspond to the classification of the road on which the pedestrian crossing is located according to the Class Comparison (HRN EN 13201) (e.g. the classification of public lighting on a class M2 road at a pedestrian crossing should meet the conditions of public lighting class C2, etc.);
- For roads classified as M1, it is not necessary to define a pedestrian crossing classification.

For each illuminated area it is necessary to enter the parameters on the basis of which the classification of illuminance is determined (traffic speed, traffic volume, traffic composition, separation of traffic lanes, intersection density, presence of parked vehicles, ambient illumination, possibility of navigation) all according to CEN / TR 13201 -1: 2014 (Table 4.3). If the luminaires illuminate surfaces that are not classified according to the specified standard (lighting of facades, sports fields, etc.), it is necessary to describe the area that is illuminated without determining the classification of illumination.

Table 4 Example of lighting class calculation

Design speed or speed limit	High	70 < v < 100 km/h
Traffic volume	Moderate	35%-65% of maximum capacity
Traffic composition	Mixed	
Separation of carriageway	Yes	
Junction density	Moderate	≤3 per km
Parked vehicles	Not present	
Ambient luminosity	Moderate	Normal
Navigational task	Easy	
Lighting class	**M4**	

The energy auditor is obliged to introduce the classification of illuminated areas into the energy audit in such a way that each luminaire is linked to the area illuminated by that respective luminaire and its lighting class. If the luminaire illuminates an area that is not classified in accordance with CEN / TR 13201-1: 2014, the Energy auditor is obliged to describe that area (e.g. playground, parking lot, building facade, etc.).

The lighting objective can be functional or ambiental. The former offers road traffic safety and pedestrian safety, (prevents accidents). Moreover, this functional lighting enhances confidence for night activities. The latter, provides comfort, attracts to these areas and facilitates night leisure activities when its hours increase.

Table 5 List of attributes to be collected for lighting class calculation

Illuminated area ID	A unique number that will serve as a link between public lighting elements and illuminated surface	
Name of the illuminated area	Name of the street, road, square, park etc	
Type of the illuminated area	Road without sidewalk, sidewalk, road with sidewalk on the opposite side of the pillar, road with sidewalk on the side of the pillar, road with sidewalk, side of the building, sports field, park, parking lot, promenade, square, green area or similar ..	
Classification of roadway	According to CIE 30-2 and CIE 66 wherein R1- concrete pavement with 80% aggregate additives protruding from the asphalt mass R2 - new cast asphalt, with 60% aggregate additives that have a grain size of up to 10mm R3 - worn rough asphalt, grain size up to 10 mm R4 - smooth asphalt, worn asphalt	
Type of the road	state / county / local / unclassified	
In case of motorized traffic (M)		
	Normal usage	Lower usage
Hours (from – till)		
Design speed or speed limit		
Traffic volume	If available	
Traffic composition		
Separation of carriageway		
Junction density		
Parked vehicles		
Ambient luminosity		
Navigational task		
Lighting class		
In case of pedestrians and low speed areas (P)		
	Normal usage	Lower usage
Hours (from – till)		
Travel speed		
Use intensity		
Traffic composition		
Parked vehicles		
Ambient luminosity		
Lighting class		

The classification, at the end, is decided by the local authority. If one illuminated area differs according to the classification, the respective area should be divided into as many units as there are different classifications (e.g. Street X has 2 zones, where the first zone is classified as M3, the second zone as M2 - Street X should be divided into Street X -1, Street X-2). It should be noted that the name of the illuminated area is indicated in the same way (with unique ID) in the part of the classification of the illuminated area and in the part of entering the luminaire attribute, since each lamp must be associated with the classification attribute through the name of the illuminated area. The energy auditor is obliged to determine the illuminated area and assign the classification exclusively to the illuminated area (e.g. if the luminaire illuminates only the road and not the sidewalk behind the lamp, then the illuminated area is exclusively the road, while the classification of sidewalks is not entered!). If the luminaire illuminates both the road and the sidewalk, it is necessary to enter the classification of both surfaces.

If the luminaire illuminates an area that is not classified in accordance with CEN / TR 13201-1: 2014, the Energy auditor is obliged to describe the area (e.g. playground, parking lot, building facade, etc.).

3.2.2 Characteristic profiles of illuminated area

As a part of energy audit characteristic profiles of illuminated surfaces shall be determined. The characteristic profile is determined by the geometric characteristics of the illuminated surfaces. The data to be collected are listed in the table below.

Table 6 List of attributes to be collected for characteristic profiles determine

Name of the attribute
Illuminated surface ID
Road width
Number of pavement lanes
The width of the sidewalk closer to the luminaire
The width of the sidewalk further the luminaire
Other measures important for determining the characteristic profile (eg width of the central green area, etc.)

One characteristic profile includes illuminated surfaces of similar geometric characteristics, **where a similar geometric characteristic is defined as surfaces where the average luminance (in the case of road surfaces) or the average illuminance (in the case of pedestrian surfaces) does not deviate by changing one or more parameters for more than 10% from the average luminance (in the case of road surfaces) or average illuminance (in the case of pedestrian surfaces) of a characteristic profile**.

If a change in one or more geometric characteristics in the characteristic profile results in a change in the mean illuminance of the surface by more than 10% of the mean illuminance of the characteristic profile, the energy inspector is obliged to determine another characteristic profile.

It is necessary to determine the characteristic profiles for all illuminated areas in the administrative area of the city.

3.3 Implementation of other measures

3.3.1 Overview

Existing public lighting infrastructure offer an ideal point from which a diverse range of Smart City IoT applications and collecting an array of data can be fostered. Intelligent lampposts don't just offer instant energy savings and maintenance cost reductions but play an important role as one of the IoT infrastructures. It can be equipped with weather station, wireless AP, camera, LED display, public help terminal, online speaker, charging pile and other devices. Smart lamppost becomes the data collecting sensors of Smart City, and share to each responsible department, ultimately achieving a more efficient and integrated city management.

For easier planning and decision making for smart city infrastructure implementation it is necessary to collect additional data about public lighting elements that represents technical requirements for implementing of measures stated in this chapter.

Table 7 List of attributes to be collected for Smart city decision making

Attribute name	Description
Lamppost ID	It is obligatory to link all additional attributes with other basic attributes of public lighting elements
Available communication network on the spot	LoRa, NBIoT, LTE, Optics, etc.
Luminaire illuminates pedestrian crossing	

3.3.2 E-charging

Residential urban areas with multiapartment buildings present example of locations where there of the lack of private parking spaces (or private garages) leads to citizens having limited access to charging infrastructure for charging their vehicles overnight oppose to private parking spaces or garages in houses. Public lighting infrastructure can provide solution to this problem. Public lighting infrastructure is already developed throughout urban city areas and reaches majority of public parking spaces. However, further retrofit for EV charging adoption is needed.

Not all public lampposts are suited for EV charging. Problems like distance between the lamppost and parking lot or pedestrian pathways between lampposts and parking lots can present some of the obstacles in EV charging development. Also, state and available power reserve of existing power supply cables can limit the number and power of EV charging points that can be implemented on some section of public lighting infrastructure. Power supply contracts, management of public lighting and power supply of public lighting, such as round the clock power availability, as well as influence or possible disturbance in power network that can be caused by installing EV charging also need to be analysed. Another major challenge for EV charging integrated in public lighting infrastructure derives from different ownership and management structures of public lighting infrastructure across different EU countries that in some cases generates rather complex needed technical interventions.

It is necessary to give a brief description of the supply lines of the public lighting system that supply the luminaires, not counting the connection of the public lighting cabinets with the first lighting pole. Each supply line must be plotted on a geographical base map. If there are underground lines, the route should be determined using the available documentation, cadaster of lines, etc. If the data do not exist, the route is determined according to the on-site inspection.

Table 8 List of attributes to be collected for e-charging decision making

Attribute name	Description
Additional cabinet info	
Cabinet ID	Unique number that serves as a ling with other basic data about public lighting cabinet
Available power for the cabinet (kW)	Power leased from the electricity distributor for respective cabinet
Circuits (phases) in use for lighting (pcs)	
Maximum possible number of circuits (phases) in cabinet	
Supply cable type	
Type of electricity installation	According to the HD 60364-1
Supply cable ID	Unique number that serves as a ling with other basic data about public lighting cabinet
Additional supply cable info	
Supply cable ID	Unique number that serves as a ling with other basic data about public lighting cabinet. Each supply cable must have a unique label that contains the code of the billing metering point and the code of the supply line (e.g. 0129483273343-01).
Type of supply cable	For each public lighting supply line, it is necessary to determine the type of power cable (not counting the connection of the public lighting cabinet with the first lighting pole).
Supply cable cross section	For each underground supply line of public lighting, it is necessary to determine the number of cores, material and cross section (not counting the connection of the public lighting cabinet with the first lighting pole).
Supply cable age	<10y; 10y< and <30y; >30y
Additional lamppost info	
Luminaire ID	Link with luminaire basic data
Supply cable ID	Link with the supply cable data
The location of the pole is suitable for a charging station	Distance from the parking space <1m, without sidewalk between the filling station and the parking space, near a residential building without the possibility of charging the vehicle (without yard)

Lamppost inner diameter	Collection of attributes only if the location of the pole is suitable for an electric charging station - it is necessary to record whether it is possible to install a min 110 mm diameter charging station inside the pole

Each supply cable must be plotted on a geographical base map. Supply cable information must be provided in a shapefile zip file with * .shp, * .shx and * .dbf files and in a spreadsheet file (* .csv or * .xlsx).

3.3.3 5G and other communication protocols

With huge uptake of users number and user requirements cellular networks are faced with overload which is sometimes hard to solve by the network planner in urban, highly populated areas.

This explains how the public lighting infrastructure could play an important role in deployment of high frequency spectrum (like 5G), but also with other communication protocols. Additionally, higher frequencies have a harder time penetrating buildings, resulting with poor indoor coverage. 5G connectivity is most useful in big cities where there's a higher concentration of cellular devices (and greater demand for high-speed, low latency Internet).

Not all public lampposts are suited for communication infrastructure. Availability of basic infrastructure (power and communication cable infrastructure) can present one of the major obstacles in communication network development. Barriers can be summed up to legal (deployment depended on national strategies and concession rules), financial (bankability of a larger scale deployment can prolong the wider market presence), and technical (non-existing power and communication infrastructure).

Table 9 List of attributes to be collected for communication infrastructure deployment

Attribute name	**Description**
Additional cabinet info	
Cabinet ID	Unique number that serves as a ling with other basic data about public lighting cabinet
Available power for the cabinet (kW)	Power leased from the electricity distributor for respective cabinet
Circuits (phases) in use for lighting (pcs)	
Maximum possible number of circuits (phases) in cabinet	
Supply cable type	
Type of electricity installation	According to the HD 60364-1
Supply cable ID	Unique number that serves as a ling with other basic data about public lighting cabinet
Available free surface for installation of additional equipment	
Additional supply cable info	

Supply cable ID	Unique number that serves as a ling with other basic data about public lighting cabinet. Each supply cable must have a unique label that contains the code of the billing metering point and the code of the supply line (e.g. 0129483273343-01).
Type of supply cable	For each public lighting supply line, it is necessary to determine the type of power cable (not counting the connection of the public lighting cabinet with the first lighting pole).
Supply cable cross section	For each underground supply line of public lighting, it is necessary to determine the number of cores, material and cross section (not counting the connection of the public lighting cabinet with the first lighting pole).
Supply cable age	
Attribute name	**Description**
Additional lamppost info	
Luminaire ID	Link with luminaire basic data
Supply cable ID	Link with the supply cable data
Is pole suitable for antenna based on regulatory requirements	E.g. distance from the schools, hospitals
Available space for communication antenna	Available space in height on the pole for the installation of antenna
Available space for grounding cable	
Is optic cable available on 1m diameter from the pole	
Is optical cable available in 50m diameter	

3.4 Light pollution protection

Public lighting can make a positive contribution to safety and security; however, those lights affect not only the intended area but spread out uncontrolled into the surrounding areas and into the sky is an annoyance to society. The term used to describe this negative aspect of lighting is light pollution. It may be a danger for road users and disturb residents, wildlife and the growth of vegetation. It may also disturb both professional and amateur astronomers in their research work and make it impossible for all of us to see the stars. Professional, carefully designed lighting should bring the light to only where it is really needed, only as much as is needed, and only when it is really needed. Only then can the right balance be achieved between the positive effects of lighting and the negative impacts of that lighting on the environment. In most of the EU countries there is act that regulates protection against light pollution, which usually includes measures for protection against light pollution, determines the maximum permissible photometric values, restrictions and prohibitions on lighting, conditions for planning, construction, maintenance and reconstruction of outdoor lighting. Environmental lighting and other issues in order to reduce light pollution and the consequences of light pollution. Mostly used restrictions are regarding corelated colour temperature (CCT) of the light source (e.g. must be bellow 3000K), upward light output ratio (e.g. ULOR<3) and maximum average illuminance.

Table 10 List of attributes to be collected for measures of light pollution protection

Attribute name	Description
Luminaire ID	Link with luminaire basic data
ULOR (Upper Light Output Ratio)	The ratio of the luminous flux emitted by a luminaire above the horizontal to that emitted by the lamp.
CCT of the light source	Nominal CCT from the technical sheet (no need for measurement)
Lighting environmental zone	According to IESNA 1999 (E0, E1, E2, E3, E4 details explained in Annex 1)

3.5 Instructions for collected baseline data systematisation

All collected data must be recorded as an electronic tabular file, while all textual descriptions and explanations must be recorded in the Report on the detailed energy audit. The draft content of the * .xls file must be in accordance with this Methodology, i.e. it must contain all the data that must be collected in accordance with this Methodology.

4 Technical and financial baseline data analysis

4.1 Lighting regimes

It is necessary to determine the operating modes of the public lighting system (annual number of operating hours of the public lighting system) as well as the diming regimes of luminaires. If there are more than one operating mode and more than one dimming regime it is necessary to determine and describe each of them.

4.2 Active electrical power of the public lighting system

a) Installed active power of the public lighting system

It is necessary to calculate the active power of the luminaires by adding the nominal powers of all installed luminaires (whether or not they are in operation). All losses must be included in the calculation of the total installed power (losses in the ballasts, driver, supply cable etc.).

It is recommended that in the case of luminaires with magnetic ballasts, the losses are counted as 21% of the power of the light source, while in the case of electronic ballasts and others, they are counted as 11% of the power of the light source. It is recommended that losses in the supply line be calculated as 4% of the total power of the light source.

If it is not possible to determine the installed active power of a luminaire that is not in function (e.g. a light source is missing, etc.), the power of the nearest lamp in function and connected to that supply cable shall be used.

b) Simulated active power of the public lighting system

When analysing energy parameters, it is necessary to calculate the power that the system assuming that the minimum lighting requirements are met in accordance with EN 13 201.

The simulated power is calculated as the total power of the luminaires that would be achieved by adding lighting points to each existing unused pole position (without installed lamps). The power and performance of the luminaires with which the simulated work force is calculated must correspond to the stated technical parameters of most luminaires on that section.

Note: An unused pole position means a pole position where there is no lamp and the lamp is located on the first or second pole position next to it. An unused pole location does not indicate a pole location where there is a string with more than 5 pole locations without a lamp.

The energy indicator of the simulated state is the sum of the existing installed workforce of the luminaires and the workforce of the newly added luminaires. The simulated workforce also includes all losses in the lighting system, which are calculated as well as losses when calculating the installed workforce.

The energy indicators of the simulated state are identical to the existing installed working power of the luminaires only if a luminaire is installed at each pole in the existing public lighting. If the above conditions are not met, the energy indicators of the simulated workforce are increased in relation to the existing installed workforce by the amount of power of the newly added simulated luminaires.

The actual work force of the correct lamps, the actual work force of the faulty lamps, their sum and the simulated work force must be shown for each OMM.

In case where public lighting system is in accordance with requirements specified in EN 13 201 then simulated active power is equal to installed active power of public lighting system.

4.3 Electric energy consumption

In order to determine the baseline energy parameters, it is necessary to analyse the electricity consumption of public lighting. Electricity consumption is divided into:

a) actual electricity consumption;
b) standardized electricity consumption;
c) simulated electricity consumption.

The analysis of electricity consumption must be performed for each billing metering point. A description of the methodology for calculating the above electricity consumptions is given below.

a) Actual electricity consumption

Actual consumption is identical to the consumption recorded in the electricity supply and distribution bills.

The electricity bills for the last 3 years shall be provided to the Energy auditor. The energy auditor is obliged to determine which of the last 3 years best shows the current state of the public lighting system and state that year as the baseline consumption.

b) Standardized annual electricity consumption

Standardized annual electricity consumption is the consumption of the public lighting system that would be realized in the conditions of standardized operation of the public lighting system. Standard operating conditions refer to the functionality of all existing luminaires throughout the year and the number of standardized operating hours per year.

The standardized annual electricity consumption is calculated as follows:

$$E_{norm} = P_{inst} * T_{ref}$$

where:

E_{norm} – standardized annual electricity consumption (kWh);
P_{inst} – installed active power of public lighting system (kW);
T_{ref} – standardized number of annual operating hours (e.g. 4 100 h);

If a luminaire has dimming regimes the reference number of operating hours must be corrected in accordance with the respective dimming regime.

c) Simulated annual electricity consumption

If the luminaires are not installed at each existing pole location and distance between two neighbour luminaires is more than x, it is assumed that the existing public lighting system does not meet the minimum lighting requirements in accordance with HRN EN 13 201. In this case it is necessary to simulate the electricity consumption when meeting minimum lighting requirements in accordance with the specified standard. The simulated annual electricity consumption is calculated by multiplying the simulated electric power by the reference number of operating hours of public lighting throughout the year.

$$E_{sim} = P_{sim} * T_{ref-kor}$$

Where:
E_{sim} – simulated annual electricity consumption (kWh);
P_{sim} – simulated active power of the public lighting system (kW);
T_{ref} – standardized number of annual operating hours (for Croatia 4 100 h);

If a luminaire has dimming regimes the reference number of operating hours must be corrected in accordance with the respective dimming regime.

In case where public lighting system is in accordance with requirements specified in EN 13 201 then simulated active power is equal to installed active power of public lighting system and simulated annual electricity consumption is equal to standardized annual electricity consumption.

d) Comparison of annual electricity consumption, installed system power and number of operating hours of the public lighting system

The energy auditor is obliged to compare the actual annual electricity consumption (consumption according to electricity bills) with the calculated electricity consumption (calculated as a product of the calculated power of the public lighting system and the determined actual operating mode of the public lighting system). If the difference between the calculated consumption and the actual consumption is less than or equal to 15% of the actual consumption, this is a negligible difference. If the difference is greater than 15%, it is a significant difference that needs to be explained.

When explaining the existing deviations, it is necessary to take into account the measurements of the installed power of the lamps. If the measurements of the installed power have proven the accuracy of the entered data (quantity and power of lamps), it is necessary:

- examine whether there have been changes in that part of the public lighting system in the period from which the electricity consumption bills are available (upgrade, change of operating regime, modernization, etc.);
- examine with the owner and maintainer of the public lighting system the possibility of the existence of parasitic consumers;
- check with the owner and maintainer of the public lighting system the appearance of non-functional lamps and/or lamp parts.

Within the energy audit, the Energy auditor is obliged to address the billing metering points where significant deviations between the actual and calculated annual electricity consumption have been observed, and it is obliged to explain in detail the reason for the deviation.

4.4 Operating costs of a public lighting system

a) Electricity costs

The price of electricity must be calculated according to the current price of electricity. The current price is taken from the electricity bill. The current price is used in the calculation of the actual cost of electricity, the standardized cost of electricity and the simulated cost of electricity.

Cost of electricity is calculated by multiplying the current price of electricity with:

- Actual electricity consumption;
- Standardized electricity consumption;
- Simulated electricity consumption.

In order to calculate actual, standardized and simulated electricity costs.

b) Maintenance costs

The owner of the public lighting system is obliged to give the maintenance costs for at least last 12 months to the Energy auditor. In the total maintenance costs, it is necessary to distinguish between the costs of regular maintenance (repair of non-functional elements of public lighting) and the costs of investment maintenance (replacement with new luminaires/poles and expansion of public lighting).

c) Overall operating costs of public lighting

The operating costs of the public lighting system include the costs of electricity and the costs of maintenance. It is necessary to calculate the actual operating costs (as the sum of the actual cost of electricity and the actual maintenance costs).

5 Energy audit report content

The energy audit report should include:

1. Introduction
2. Methodology and scope
3. Control centre
4. Roadways and classification
5. Luminaires
6. Energy efficiency measures for the lighting system and/or other systems

The report on the performed energy audit should include appropriate attachments:

- Excel spreadsheet with data on each individual element of the public lighting system, which must contain the following sheets:
    - Public lighting cabinet - all necessary data on public lighting cabinets where one row represents one public lighting cabinet and one column represents one attribute of public lighting cabinets;
    - Supply line - all necessary data on the supply line of public lighting where one row represents one supply line of public lighting and one column represents one attribute of the supply line of public lighting;
    - Lighting location - all necessary information about the lighting location where one row represents one lighting location and one column represents one attribute of the lighting location
    - Pillar place without lamp - all necessary data on the pillar place without lamp where one row represents one pillar place and one column represents one attribute of the pillar place without lamp;
    - Characteristic profile - all data on the characteristic profile where one row represents one characteristic profile and one column represents one attribute of the characteristic profile;
    - Classification of illuminance - all necessary data for determining the illuminance class of the surface, where one row represents one illuminated surface and one column represents one attribute on the basis of which the classification of illuminance is determined;
- Spatial data (Shapefile) exclusively for supply lines of public lighting systems;
- Photos in digital format on electronic media, cloud or sent to the client's mail;
- Logs from the measuring device in digital format on electronic media, cloud or sent to the customer's mail.

It is advisable to elaborate a summary of the basic parameters of the public lighting system elements in free form. It is necessary to determine the baseline electricity power, lighting regimes and the electricity consumption of the public lighting system. It is necessary to give an overview of possible differences between the actual state and the baseline data.

All collected data must be recorded in an electronic tabular presentation, while all textual descriptions and explanations must be recorded in the Report on the conducted detailed energy audit.

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Annex 1 Lighting environmental zones

ZONE	NAME	AREA	CRITERIA
E0	Areas of natural light	Close to larger professional observatories Dark sky parks Natural areas of open space Areas of nature outside the boundaries of settlements important for the conservation of wild species sensitive to light pollution, with special emphasis on strictly protected species Protected areas - Strict reserves, special reserves and zones of strict and targeted protection within nature parks and national parks Wildlife shelters Parts of landscape and landscape infrastructure	Areas where outdoor lighting seriously and negatively affects the natural environment. Impacts include disrupting the biological cycles of flora and fauna and / or preventing people from enjoying and respecting the natural environment. Human activity is subordinate to nature. The vision of people and users is adapted to the darkness and they expect to see little or no light. Natural areas of open space - forest areas; meadows and pastures; natural and artificial water bodies - e.g. rivers, lakes, ponds, ponds, irrigation ponds, ponds important for bird conservation. Areas around important underground bat shelters (at least 100 m) - corridors of movement from the shelter to hunting habitats are not illuminated; green bridges on the upper side and at least 300 m on each side of the entrance of the green bridge important for the migration of strictly protected species and their prey; crossings for wildlife. The whole area of a strict reserve. Special reserves in cases where outdoor lighting impairs the properties for which they were declared. Areas of strict and targeted protection within nature parks and national parks, unless a special regulation governing the protection and preservation of protected areas provides otherwise. Parts of the landscape in settlements important for the conservation of wild species sensitive to light pollution with particular emphasis on strictly protected species (unlit parts of large parks and gardens that continue to rivers, lakes, streams, etc.). Parts of landscape infrastructure that enable the preservation of significant and characteristic features of the landscape, which are based on their linear or continuous structure or function essential for migration, spread and genetic exchange of wild species sensitive to light pollution (birds, bats, pollinators, etc.). When not needed, the lights should be turned off.

E1	Dark sky areas	Rural and urban areas and areas with limited night activity Buildings within natural areas of open space Long-distance local roads are mostly unlit Protected areas outside the boundaries of settlements other than protected areas in E0 Protected areas within the boundaries of settlements important for strictly protected species if the habitats and shelters within the settlement are key in the settlement area Shelters and habitats of wild species sensitive to light pollution within settlements	Areas where outdoor lighting negatively affects the flora and fauna or significantly disrupts the character of the area. Rural and urban areas with limited nocturnal activity outside the boundaries of settlements important for light species sensitive to light pollution with special emphasis on strictly protected species if the area is key habitats and shelters outside the settlement related to human activity. Parts of rural and urban green / landscape infrastructure that enable the preservation of significant and characteristic features of the landscape, which are based on their linear or continuous structure or function essential for migration, spread and genetic exchange of wild species sensitive to light pollution (birds, bats, pollinators, etc.) . Buildings in areas outside settlements with limited human activity within natural areas of open space. Shelters of wild species sensitive to light pollution within the settlement are not directly lit and dark corridors to key habitats (food, drinking water, migration) are provided, while avoiding direct lighting of the shelter exit and leaving a dark corridor between the shelter and the hunting habitat. The view of residents and users is adjusted to the levels of low light. Outdoor lighting can be used for safety and atmosphere, but is not necessarily uniform or continuous. In late night, most lighting should be turned off or dimmed according to the declining activity level.
E2	Areas of low ambient light	Construction areas of settlements Residential zones Protected areas except for parts that are in zones E0 and E1 Zones of use within nature parks and national parks	Areas of human activity in which the vision of people and users is adapted to moderate lighting. Zone of use within settlements located in nature parks and national parks related to road safety and public lighting and other protected areas within the boundaries of settlements related to road safety and public lighting. Outdoor lighting can be typically useful for safety and atmosphere, but is not necessarily uniform or continuous. In late night, outdoor lighting can be turned off or dimmed according to declining activity levels.

		Protected areas within the boundaries of settlements	
E3	Areas of medium ambient light	Industrial and commercial zones as separate construction areas outside settlements Industrial and commercial zones within the settlement Transport infrastructure	Areas of human activity in which the vision of people and users is adapted to moderate to medium levels of illumination. Public roads for motor vehicles as part of the traffic infrastructure inside and outside the construction area of the settlement, except for the roads covered by the lighting zone E2 in the construction areas of the settlement and zones E0 and E1. Outdoor lighting is generally needed for safety, atmosphere, comfort and is often uniform and / or continuous. In late night, outdoor lighting can be turned off or dimmed according to declining activity levels.
E4	Areas of high ambient light	Urban areas of commercial character with a high degree of night activity	Areas of human activity in which the vision of people and users is adapted to moderately high levels of illumination. Outdoor lighting is generally needed for safety, atmosphere, comfort and is often uniform and / or continuous. In daylight, lighting can be reduced in most areas as activity levels decrease.