ICT TECHNOLOGY MARKET ASSESSMENT

REPORT

SMART EPC

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About Smart EPC

- Call: H2020-LC-SC3-EE-2020-2
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Next generation of energy performance contracting

The main objective of Smart EPC project is to enable transition of local public authorities towards smart sustainable cities of the future by utilizing existing energy efficiency services as a key for unlocking potentials of new, emerging technologies and services. By creating advanced and smart concepts for modernization of public lighting in European cities, Smart EPC project will enable large-scale energy efficiency programs while strengthening the know-how of regional/national key stakeholders.

Executive Summary

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 (e.g., 5G).

Market Overview

The current EPC schemes across the EU face several challenges which have led to a partial accomplishment of their initial objectives: lack of accuracy, a gap between theoretical and real consumption patterns, absence of proper protocols for inclusion of smart and novel technologies, little convergence across Europe, lack of trust in the market and very little user awareness related to energy efficiency.

The average ESCO market of the European Union has been on a steady rise for the last decades. In general the ESCO markets are on a growth path, although this growth is not as widespread across countries. The national ESCO markets attract both local companies and, in many cases, international/multinational actors. The composition of the national ESCO markets varies significantly across Europe; nevertheless, companies from outside Europe are not typical. The total EU market was estimated at $2.7 billion (€2.4 billion) ESCO revenue in 2015, with a forecasted growth to $3.1 billion (€2.8 billion) in 2024 at a 1.7% compound annual growth rate (Talon and Gartner 2015). The EU ESCO market growth is expected to be driven by demand for capital to overcome the challenges of deferred maintenance, mounting regulatory and policy pressures, and growing interest in more comprehensive energy management strategies.

In their latest review of the European ESCO market (Bertoldi et al. (2014)) the sizes of the national ESCO markets in qualitative terms across Europe were reviewed and found that Germany, France, Austria, the Czech Republic, and the UK were the most active markets in 2013 (see Figure 1). Germany is regarded as the champion amongst the European ESCO markets in terms of maturity and market development (with strong institutional context, including legal background, associations, facilitators, etc.). Italy, Belgium, and Denmark were found to have medium size markets, while the ESCO markets of Estonia, Malta and Cyprus were found as non-existent. All other European markets were identified as small.

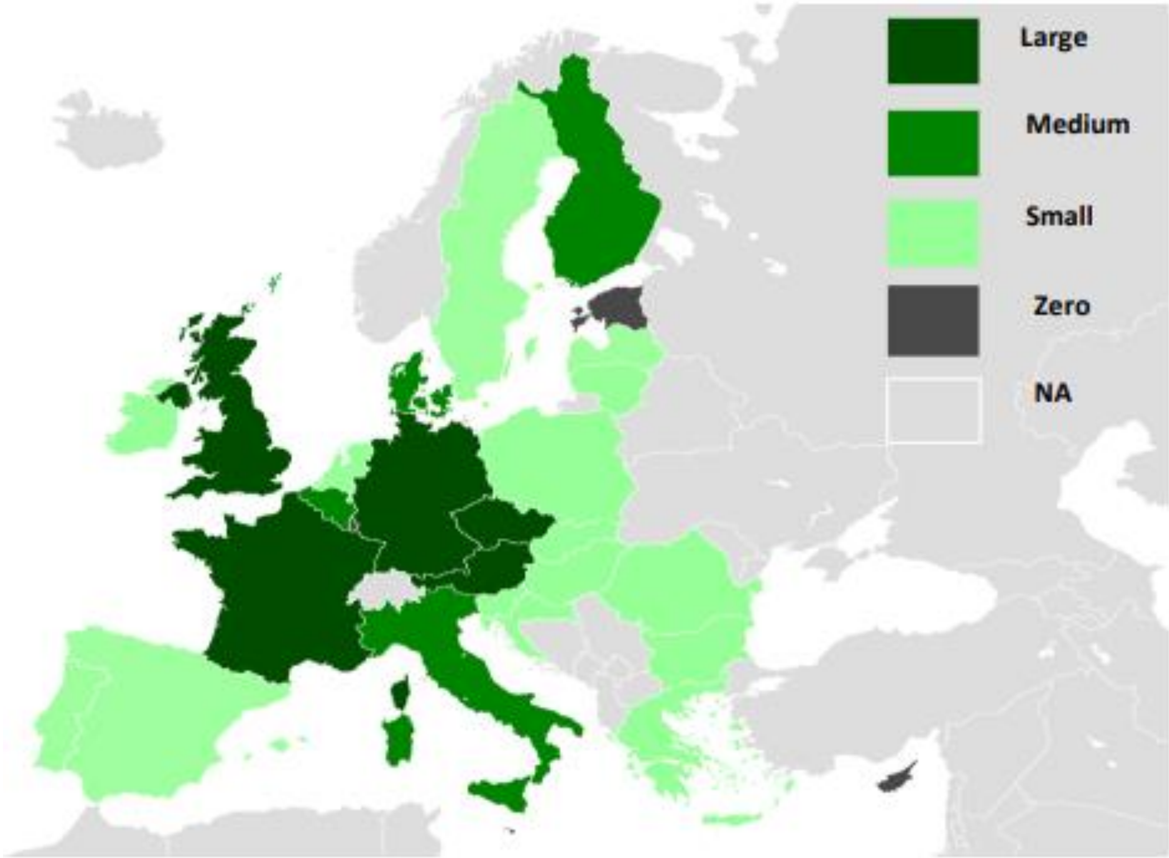

Figure 1 - The relative size of the national ESCO markets across the EU based on the assessment in Bertoldi, Boza-Kiss, Panev, & Labanca (2014)

Smart EPC Product Concept

Energy Performance Contracting (EPC) is a form of 'creative financing' for capital improvement which allows funding energy upgrades from cost reductions/savings. Under an EPC arrangement an external organization (ESCO) implements a project to deliver energy efficiency and uses the stream of income from the cost savings to repay the costs of the project.

The EPC approach is based on the transfer of technical risks from the client to the ESCO based on performance guarantees given by the ESCO. In EPC ESCO remuneration is based on demonstrated performance; a measure of performance is the level of energy savings or energy service.

In recent years, the concept of smart sustainable cities has come to the fore as a promising response to the challenge of urban sustainability. This transition towards Smart Cities requires profound changes not only on the economic perspective, such as implementing alternative financial models to overcome financial barriers, but also fostering cooperation between all actors involved, paying particular attention to innovative and market ready technology providers.

The main objective of Smart EPC project is to enable transition of local public authorities towards sustainable cities of the future by utilizing existing energy efficiency services as a key for unlocking potentials of new, emerging technologies and services. By creating advanced and smart concepts for modernization of public lighting in European cities, Smart EPC project will enable large-scale energy efficiency programs while strengthening know-how of regional/national key stakeholders.

The potential of Energy Efficiency services (e.g., Energy Performance Contracting - EPC) have remained largely untapped throughout Europe as ESCOs and cities have not recognized opportunities for bundling and integration of energy with non-energy services. By adapting to market and overall system needs, information, and communication technologies (ICT) can enable this integration in order to reach additional target groups, sectors and mobilize financial resources for triggering additional revenue streams. Amidst the coronavirus pandemic, European Commission proposed a new recovery instrument, Next Generation EU, to answer challenges emerging from the COVID-19 pandemic and support design and deployment of a long-term EU budget. One of the Next Generation EU pillars is Kick-starting the economy and helping private investment, an instrument which will support investments in key sectors and technologies, such as 5G technology, renewable energy and cleaner transport, which are highlighted as one of the crucial areas for green transition and digital transformation required to relaunch and modernize EU’s economy.

The Smart EPC project aims to integrate several key directions of the European Green Deal and Next Generation EU instrument to draw in and engage industry in providing quality public service. Use of EPC model will help in bringing together stakeholders from public and private sector to collaborate on public projects, bringing in value for money and subsequently improving the quality of life. Refurbishment of old and inefficient public lighting will lead to reducing energy costs, increasing energy efficiency, and reducing emissions and light pollution. In addition to the benefits, integration of IoT technology and Smart City components with the infrastructure refurbishment can pave the way for a wide range of energy and non-energy services and applications, including public EV charging service, traffic management, environmental monitoring, and extended Wi-Fi and next generation of cellular communications (e.g. 5G, LoRA etc.).

Market Drivers, Opportunities, Challenges and Risks Factors Analysis

Industry trends

All ESCOs measure and verify the energy savings over the projects' lives—as demanded by the customer and as the essence of energy performance contracting. The purpose of monitoring energy savings over time is to ensure that those savings persist and to identify immediately any anomalies in consumption patterns that may occur. It also serves to ensure the quality and effectiveness of ongoing maintenance, entailed in most ESCO projects.

The development of standardized procedures for the measurement and verification of savings has helped stakeholders to understand this key dimension of performance contracting.

U.S. ESCOs have adopted the U.S. Department of Energy's (DOE) International Performance Measurement and Verification Protocol (IPMVP). This protocol is also often used in EU countries as the industry standard approach to measurement and verification.

Public lighting plays a very important role in smart and sustainable cities of the future and plays a pivotal role in development of most of the Smart City systems by providing physical and electrical infrastructure suitable for communication and smart engagement devices (e.g. sensors, cameras, detectors, communication base stations, signalling devices, loudspeakers, displays etc.). In recent years a lot of development was invested in public lighting systems in order to enable maximum energy efficiency, minimum environmental load, high level of connectivity and embedded intelligence as well as to enable it function as energy and communications backbone to Smart City devices to be installed on its infrastructure. There is a variety of Smart City pilots and projects worldwide tailored around public lighting systems.

In short modern cities face challenges with:

- Energy balance;
- Environmental sustainability;
- City management;
- Citizen wellbeing;
- Global city branding and positioning;
- Communication services.

The concept behind Smart EPC is to exercise the most out of the smart public lighting infrastructure to be able to monetize on additional services such as street level 5G base stations, environmental monitoring etc.

The proposed case would be the following:

- Connected lighting infrastructure powered by the standard grid;
- Street side 5G base station solutions for mobile connectivity, mounted on light poles;
- EV charging solutions mounted within the light poles.

Environment sensors mounted on the light poles provide a grid of sensors that will give a clear picture (heat map) of air quality, noise level, or temperature level.

Market drivers

The prime purpose of modern cities is to provide high level of wellbeing to its citizens while not deteriorating environment of surrounding areas. This way, the city gets well positioned globally in an everlasting competition with other urban centres worldwide.

The number one challenge of modern cities is the sustainable balance of the total energy provided to the city with the one consumed by the city. This challenge gets more and more important each day.

The other very important factor is environmental sustainability. A very important task is to reduce waste generation load by every system used in modern cities, especially the one related to hazardous and polluting substances. The other important aspect is the issue of light pollution in modern cities, affecting human health, stability of biological ecosystems and preservation of dark skies environment important to astronomical observation, wellbeing of citizens and tourism.

As much as the life of modern person gets increasingly complex and multidimensional, the overall management of City life gets more and more complex each year as well in all of it aspects. The city management requires complex and smart integrated IT backbone, open and interactive to citizens as well as to all the city management service organizations. The city also needs to be interconnected with the whole country and global people, information, goods, and energy networks. This Management system needs to be live and interactive flexible system growing, adapting, and developing with the city.

Citizen wellbeing means that the city life is adjusted to citizen life in terms of all their daily needs, sensing life of the citizens, adapting to it, and interacting with it. Modern city needs to adapt to daily rhythms and movement patterns of its citizens.

By providing a high level of citizen wellbeing and a healthy integration within its own county and international community, the city advances in its global positioning and branding. This is also highly interconnected with the spirit of uniqueness and creativity expressed by the city and its citizens. The better the City's global perception and positioning the quicker prosperity of the city.

Market challenges and restraints

When thinking about the complete solution (connected lighting with additional service infrastructure) common question arise:

- How to deploy the additional infrastructure (sensors and 5G antennas) fast and with simplicity?
- How to secure power infrastructure for the additional services?
- How to deploy non-intrusive infrastructure (e-charging)?

The questions above present a challenge when we think on how to improve and enrich EPC projects.

Although the installation of connected public lighting might seem fairly simple, because it only envisions replacement of traditional light poles, the case is that this in the beginning is not an easy project. Detailed construction and development plans need to be constructed in order to meet the regulatory, legal, and planning demands.

Additionally, every additional service needs to take into consideration the following assumptions, prerequisites, and constraints.

Street side 5G solutions

Communications service providers are challenged on footprint, rent, and OPEX of macro sites, and those challenges are even more present at street level. New street and outdoor small-cell solutions can be mounted on existing infrastructure. They are fast to install, with a subtle footprint, and secure the 5G experience. Delivering industry-leading innovations is no small feat in the mobile operators' industry. The questions that arise with urban 5G roll-outs are:

- How to acquire sites with minimum rental?
- How to deploy fast and with simplicity to maximize 5G user experience?
- How to deploy non-intrusive 5G sites and how to best utilize all frequency layers?

As 5G network rollouts continue globally, the need for network densification will continue to grow. According to the Ericsson Mobility Report 2016, cellular data traffic is expected to grow nine times by 2020, placing a unique demand on mobile network operators to provide the necessary infrastructure and density required to serve the market. On top of this, operators are struggling to acquire new cell sites in public areas to provide the best possible mobile broadband coverage for their customers.

Environment monitoring

Air pollution, often referred to as the "Invisible killer", is one of the biggest public health risks worldwide. According to Harvard University, the presence of harmful gases and particles in the atmosphere results in 8.7 million premature deaths per year, roughly 20% of all deaths.

Tourism and travelling have become an important part of modern-day life, but they, among many positive, have a number of negative consequences. Environmental impact is probably the most obvious one. It consists of many different aspects, such as depletion of natural resources like water and land, discharging waste, pressure on endangered species, noise pollution, carbon footprint and many others. One of the aspects which is hard to notice at first is the impact on the air quality.

When monitoring environmental parameters in urban areas, the following questions arise:

- How to deploy sensors fast and with simplicity?
- How to secure power infrastructure?
- How to deploy non-intrusive sensors to best utilize existing infrastructure?

EV Charging

There are a number of reasons why the lamppost is in the spotlight for EV charging. It is existing infrastructure, ubiquitous and common throughout most urban spaces. Streetlights are already connected to a power supply and, in residential areas especially, where space is at a premium it makes sense to utilize street furniture that has already been installed, rather than further adding to street clutter.

A key reason that EV charging facilities are being retrofit into streetlights, is that it is significantly cheaper than new on-street charge points and their connection to the power grid. This, combined with the drive for EV take up where more electric cars are anticipated on the street, means there must be a charging infrastructure in place that can support it. Since pavements don’t have the capacity to accommodate additional applications, streetlights hold the answer.

The key challenge here is to separate the electric supply that is used for public lighting, other services, and EV charging. The architecture should be done in way that it protects all the assets in case of failure or overload. Additionally, the EV charging stations can be retrofitted only to the locations where it makes sense to put a parking place for EV to charge.

Smart lighting

Lighting controls for electric lighting have advanced beyond the simplistic on-off switch. Various lighting control strategies such as dimming, occupancy sensing, daylight harvesting, and scheduling not only improve the occupant experience within a building, but also provide energy and cost savings. A connected lighting system with integrated sensors and controllers allows for the transmission of data and communication within a lighting system. Although this market is still in its infancy, the benefits of a connected lighting system provide the driver for the growth of these systems.

Other barriers (such as cost, staffing challenges, and lack of standardization) can hinder the adoption of connected lighting systems. However, if organizations ensure there are fewer complex systems and provide comparisons of these systems as well as training, the burden of understanding these systems can be lessened.

Technology Segmentation

5G network infrastructure

Technology overview

5G is the fifth generation of cellular network technology. It delivers higher speeds, wider bandwidth, lower latency, and more advanced capabilities than its predecessors. Mobile Network Operators (MNOs) began rolling out 5G networks in 2019, and it's expected to become the primary cellular network in the coming years. 5G networks are vastly improving high-speed Internet connectivity around the globe and opening the door to a revolution on the Internet of Things (IoT). 5G networks are designed to achieve a peak download speed of 20 Gbps and peak upload speed of 10 Gbps. The average rates are 100 Mbps for downloads and 50 Mbps for uploads. In other words, 5G's average data speed is five times faster than 4G. It also has much lower latency as well (the time it takes to relay requests and responses from one device to another through a network). In a 5G network, the average latency is four milliseconds, and it can be as low as one millisecond for some applications, making 5G's latency more than 10 times lower than 4G. Advanced IoT applications like self-driving cars, smart farming equipment, and remote healthcare will rely on 5Gs low latency and greater bandwidth. 5G technology is changing the Internet of Things by offering significantly wider bandwidth and greater flexibility regarding how bands get used, enabling stable connectivity for a far greater number of devices in a concentrated area. 5G networks can facilitate connectivity on low frequencies below 1 GHz, mid frequencies from 1 GHz to 6 GHz, and high frequencies from 6 GHz to over 100 GHz. Additionally, a 5G network can connect devices over both licensed and unlicensed bands, giving providers greater flexibility with how they use the radio frequency spectrum. For comparison, commercial 4G networks can only use bands between 600 MHz and 3 GHz.

Implementation best practices

Current telecom infrastructure needs ramping up to address the predicted growth in global mobile data traffic. This is creating a need for increased mobile network densification, as well as the tighter integration of products on traditional macro sites and small cells. Service providers need more site options, presenting a significant site acquisition challenge. With macro site installation already close to the limit, gaining approval for a new site is a lengthy process. Meanwhile, the requirements for camouflage and multi-application sites are becoming increasingly stringent. 5G technology have addressed these challenges by producing integrated site solutions that cover a variety of expansion and installation options such as: RAN macro sectors, strand mounts, light pole sites, zero sites, street furniture sites, and vault sites. These facilitate site acquisition and reduce site rental costs by enabling service providers to share site space, use existing infrastructure, or fit more radio capacity into their existing footprint. Ericsson Integrated Site Solutions comprise a combination of cost-efficient, high-performance ERS products. The service provider benefits from fast time to market, easy installation, and a higher level of product and infrastructure integration. With our complete overview of each solution and in-depth ERS product knowledge – including thermal behaviour, radio frequency and antenna patterns along with material needs, camouflaging and compact integration – we can ensure exceptional performance and a very high level of integration.

Technology trends

Three new generations of wireless technology have been introduced in little more than a decade. Subscribers' hunger for mobile broadband is as insatiable as ever, and the stream of fresh, increasingly complex mobile use cases and applications entering the market seems never-ending. Connected cars, mission-critical connectivity, and new virtual or augmented reality sport and gamming applications are among the latest on offer. Total global mobile data traffic continues to increase. It is now expected to reach 131 exabytes (EB) per month by the end of 2024. We estimate that by then, the 5G subscriptions figure will have hit the 1.9 billion mark, and 35 percent of mobile traffic will be carried by 5G networks. We also foresee that up to 65 percent of the global population could be covered by 5G at that same point – which would make it the fastest generation of mobile technology ever to be rolled out on a global scale. This phenomenal growth is placing significant new demands on service providers and networks alike. It is creating a pressing need for additional capacity and functionality, as well as increasingly complex radio sites – especially for 5G. This in turn has prompted a call for the expansion of traditional tower and rooftop sites, as well as for the establishment of new smaller-cell sites at street level. A clear picture of the capabilities, capacity and performance of sites at any given time will be required to ensure their efficient operation and management. A fast, effective response to overloads, faults and failures will also be necessary to maintain service performance with minimal "manual" effort.

SWOT Analysis - 5G technology

Strengths	Weaknesses
1. Facilitates bulk-site approvals for cities, 2. Enables site permits in difficult areas, 3. Overcomes site acquisition issues, deploys in one day and reduces OPEX 4. Supports all technologies as well as micro, macro, Wi-Fi/camera/environmental sensors, fiber, antenna, and MINI-LINK are possibilities. 5. Houses equipment both inside and under the lamppost. Tailored to city infrastructure to ease acquisition, invisible connectivity appreciated by citizens 6. Generates energy savings of 50%-70% through efficient LED lighting 7. Provides better quality of light – besides an LTE/5G or other connection 8. Strengthens mobile broadband coverage in cities and seamless communication in dense areas inside city	1. Regulatory requirements regarding spectrum lease 2. Potentially increased CAPEX 3. Usability 4. Resilience
Opportunities	**Threats**
1. Regulatory requirements regarding spectrum lease 2. Potentially increased CAPEX 3. Usability 4. Resilience	1. Qualified workforce available on the market 2. Public perception on health concerns 3. Capital investments 4. Technology advancement

Economic viability

Based on technology advancement, PR & Marketing and trends, it feels like 5G is everywhere. In reality, 5G has three major constraints hindering widespread distribution: spectrum, energy, and money.

5G needs small cells and macro cells which, like the Wi-Fi modems in your home or office, wirelessly connect devices to the core network. Unlike retail Wi-Fi modems, small cells and macro cells commercially connect many devices within a given radius.

The difference between small cells and macro cells is scale: macro cells require 1000 watts to cover a 1000-meter radius, while small cells require 100 watts to cover a 100-meter radius. For consistent power supply, power hubs are housed in outside plant cabinets, like those metal boxes that you might find on a sidewalk near a streetlamp.

Small cells and macro cells also need an inefficient linear power amplifier, to boost the signal, which needs a large heatsink. Heatsinks represent wasted power: heat absorbed by the heatsink is power lost. As equipment moves into higher order QAMs to save on spectrum usage, the power efficiency of the amplifier has gone down with each generation, requiring a larger heatsink over time.

One of the most critical pieces of protecting infrastructure investments is ensuring that new platforms, products, or upgrades can be seamlessly integrated with existing systems. Street Radios connect to the Ericsson family of basebands, whether they reside in a hub or at the site location, via various backhaul options including fibre and microwave.

The Ericsson Street Radio 4402 is compatible with the 360 million streetlights that light our roads, towns and villages around the world. The Street Radio plugs into a global standard photocell socket (NEMA) and includes a revenue-grade meter that complies with local utility regulatory requirements.

The Street Radio's real-time GPS and integrated tilt and vibration sensors provide pole-asset data to let mobile operators and utilities detect failed or downed streetlights. After events like storms or blackouts, these sensors can save critical time and costs. Operators can assess damage remotely to quickly determine the best response to a failed asset.

The low profile and power consumption of these units is another key aspect of the product and can help contribute to CSP sustainability goals. All the existing bulbs on the light poles can be replaced with LED lights as a part of the deployment.

The ability to inventory and check the health of a pole remotely allows workers to attend to any outages or identify maintenance tasks remotely. All these activities result in less driving to the site for maintenance crews, helping contribute to the reduction in carbon footprint.

A mobile operator's TCO for 5G NR introduction in a RAN area includes both capital expenses (one-time costs) and operating expenses (recurring costs). Typical capital expenses include radio/RAN and transport equipment, site construction, installation costs and site acquisition. Typical operating expenses include costs for a leased line, dark fibre rental, spectrum for wireless transport, site rental, energy consumption, operation and maintenance costs and vendor support. Since the RAN area type and deployment solution alternatives affect the TCO, it is useful to compare the TCO of the deployment solution alternatives in different RAN areas.

Based on Ericsson customer price information and internal analysis, Figure 2 presents the relative operator TCO covering all capital expenses and operating expenses for an urban local RAN area in a high-cost market. Different regions and customers have variations in cost structure. The largest cost components are transport rent cost, site rental, energy consumption and radio/RAN equipment. The graph indicates that using self-built transport in the local RAN area is a much more cost-efficient approach than using a leased line to every site, both in DRAN and CRAN architectures (Figure 2).

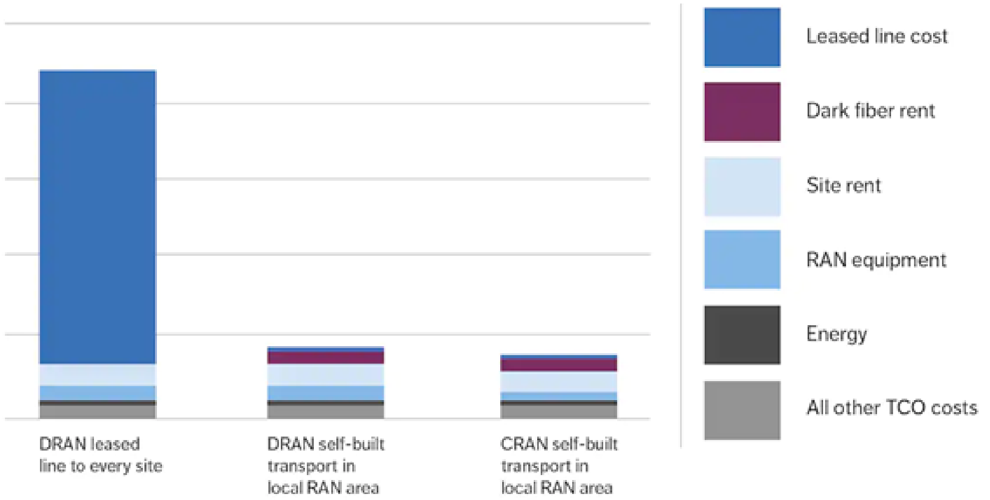

Figure 2 - Street side solution TCO overview

EV Charging

Technology overview

The increase in the use of electric vehicles (EV) in Europe has led to an increase in the demand for adequate places to charge them with electricity. Standard charging stations do not meet the required capacities in the context of the ratio of the number of charging stations to charging stations.

There are two ways an EV charging station can be integrated into a public lighting system. The first way is to install an isolator inside the lighting pole, which will enable two actions to take place without interruption, namely street lighting and vehicle charging. It is also the cheapest way of integration because it is performed on the existing infrastructure. Another way is to modernize public lighting by installing new models of smart lighting. This includes the installation of new public lighting poles that are equipped with new technologies.

Innovative solutions offer new charging methods and technologies that reduce the lack of supply for the service in question. One of such technologies is the method of charging through the existing public lighting system. In this way, owners and users of electric vehicles are given the opportunity to charge closer to their place of residence or workplace. With this technology, the amount of electricity used can be monitored in order to maintain a reliable supply of electricity. It also enables the release of parking spaces that are currently set aside as dedicated spaces for charging electric vehicles. This results in a reduced number of street furniture, as well as less excavation for installing new chargers[1].

For street lighting to have a multi-functional function, providing simultaneous illumination and charging capacity, the electrical infrastructure inside the light pole must be adapted. Although the light poles have the function of providing a public service, they still belong to the private property of a local self-government unit. In this case, an adequate transition from private to public supply must be ensured, which will provide access to electricity to the necessary users. In this context, the cooperation of all stakeholders is needed to ensure safe public access to this technology.

Conventional street lighting is powered according to the "ground-up" method, i.e., from the ground up. This means that the public lighting pole is supplied with electricity from the distribution network operator from the foundation, through the pole, to the lighting fixture (Figure 3).

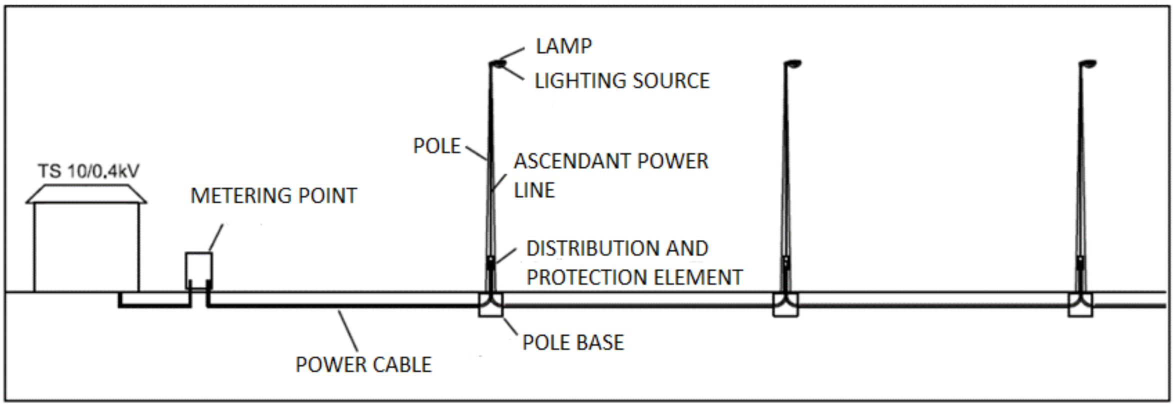

Figure 3 - Power supply option for street light mount

This power supply is properly isolated and controlled to ensure that sufficient power is delivered to the lighting fixture. Given that the bottom of the pole is at street level, this is where electric vehicle charging solutions are integrated by integrating a secondary supply isolator inside the street light pole, which can manage and protect the current. It is important to disconnect the power supply to the lamp from the charging point to ensure continuity of operation in the event of a fault or overload. When upgrading street lighting, possible national or local regulations must be considered.

In the UK are used Lucy Zodion isolators, which enable the smooth operation of especially the EV charger and especially the lighting system inside the light pole. One of the isolator models is shown in the following picture (Figure 4).

Figure 4 – Lucy Zodion isolator

The installation of a charging terminal at the customer's premises is a typical example of shared infrastructure. When EV's charging is active, it is considered as a new load added to the domestic electrical network. The resulting requested power must be compatible with the capacity of the electrical network of the considered user. As the level of penetration of EVs on the market increases, shared infrastructures will have to be upgraded. In order to accommodate the additional demand on the network, a smart control of the fluctuating availability power is necessary. During the day, when the lamps are turned off, the capacity of Public Lighting System (PLS) infrastructures is not exploited. That is why additional solutions are needed that will enable this. It is important to balance the loads connected to the transformer in order to avoid the increase of current on the neutral in order to prevent any service disruption.

The calculation measuring point, i.e., the device for power supply and distribution, is the place from where the lighting system is switched on and off. The low-voltage lighting switchgear can be in the distribution transformer station (older generation) or outside it (newer generation). Inside the distribution transformer stations there is a special low-voltage field from which the lighting circuits are powered, and it is possible to power other consumers as well. Outside the transformer station, there may be the following low-voltage distribution devices: free-standing lighting distribution cabinet, lighting distribution cabinet in the tunnel, distributor for lighting power supply. Electricity is distributed from the point of the connecting cable in the pole to the light source on the pole via a distribution board. The distributor in the column usually has only clamps and fuses, but also ballasts. For public lighting, overhead and installation lines and cables are used. In the case of overhead lines, a cable bundle consisting of a three-phase and neutral aluminium conductor, a steel load-bearing rope and appropriate insulation is most often used. Installation lines are used for distribution in lighting poles and in distribution devices. Cables are most often laid in the ground and in a concrete channel. The section and type of cables and lines is determined in accordance with the permanent permissible load current and the permissible voltage drop. The conditions for laying cables and lines, the limiting factors of protective measures, the characteristics of devices for protection against short circuit and overload, and the temperature of the connection points are important. Columns that have a distributor on them have a special opening of appropriate dimensions that allow access to the distributor. This opening is located at the bottom of the pole approximately 1 meter from the ground or at the top when the lighting is powered by a self-supporting cable bundle. The EV charging device is installed exactly where the opening provides access to the distributor. In this way, an easier connection to the necessary electricity is possible, and at the same time it is the most convenient place considering the distance of the EV.

In the norms of the HRN EN 61 851 series, the external equipment of charging stations for power supply and methods of charging electric vehicles are specified. There are four types of electric vehicle charging, which depends on the charging speed and thus the type of charging station. Mod 1, 2 and 3 are appropriate for integrates lamppost EV charging applications.

- The first method (Mod 1) of charging is from an ordinary socket (single-phase or three-phase). It is a slow charge and there is no communication between the outlet and the vehicle because the charger and the battery monitoring system are located in the vehicle;
- The second method (Mod 2) is similar to the first and is also slow charging from a regular socket with an ICCB (In Cable Control Box) control device in the power cable. In this case, the control device is not in communication with the charging socket, and the charger is in the vehicle;
- The third method (Mod 3) involves slow or fast charging via alternating current through a type 2 socket on the charger and with a special cable to the vehicle. Communication has been established between the charging station and the vehicle, and the charger is in the vehicle. This method is most suitable for charging via a public lighting pole.

Almost all EVs have a built-in converter that converts AC to DC. Therefore, many manufacturers choose the Type 2 cable, which is the most suitable in this case. It is a single-phase or three-phase connection with two contacts. Maximum 32A (63A), 230/400 V.

A public lighting pole with the additional function of charging electric vehicles must be placed in an adequate place (in proximity of public parking lots). The most suitable places are existing and prescribed parking places (vertical, diagonal and longitudinal) that ensure traffic at rest. The most common length of the EV charging cable ranges from 3-5 m. It is also the most convenient length that enables smooth charging. Longer lengths are more expensive and dysfunctional to use. Therefore, it is essential that public lighting poles with chargers be near the parking space in order to ensure all the necessary prerequisites for smooth charging of EVs.

For the safety of vehicle charging, the charging system must perform several safety actions and connect to the vehicle during connection and charging. There are current sensors on the filling stations that detect when contact is established[4].

Their role is also to disconnect the connection when the electric vehicle is no longer charging. If there were no current sensors, it could be dangerous to suddenly disconnect the vehicle from the charging station[4].

Safety sensors can be[4]:

- A current sensor that maintains the connection if the measured current value is within the permitted limits,
- A sensor in the form of a single pin inside a special multi-pin connector that works on the principle of a feedback signal.

Setting up charging stations for electric vehicles and their expansion due to the increasing use of electric vehicles requires thorough planning, which unfortunately is often not carried out in practice. This then has a negative impact on parts of the distribution system such as, for example, the public lighting infrastructure, as this lack of thorough planning can cause overload and power imbalance in the system. In this case, it is necessary to carry out appropriate analyses in order to reduce this negative impact.

Most of the streetlights are controlled by photocells and timers located in a service panel board, which means that the lighting poles are only energized at night. In order to host EV charging stations, each lighting pole has to have an independent control so it can be energized 24 hours a day 7 days a week. The lighting infrastructure of most of the cities is quite old and for that reason, its technical information is not available. Also, some cities have found that the electrical installations are deteriorated (conductors without proper insulation, broken conduits, etc.). This has made many cities discard certain locations that would be potentially useful for the users. Some of the cities are taking advantage of the retrofits that telecommunications companies are doing to the light poles. These companies are adding antennas to increase the mobility coverage and by doing this they are modifying the lighting poles to be energized 24 hours a day, 7 days a week, which is also a requirement for the electric vehicle charging stations. Moreover, during that retrofit, they are adding electric capacity to support these stations. There is a wide variety of EV charging stations suppliers that can adapt to the project requirements[6].

Once the areas of focus were identified, the next step was to select the location of light poles that would have the EVSE. To accomplish that objective defining the service panel was the priority. To define them the following steps were followed:

1. Review the inventory of the City's electrical light pole infrastructure.
2. Understand the physical status of the existing infrastructure.
3. Filtering the existing service panels that could be more suitable for the project.
4. Analysing the load capacity of the panels pre-selected.
5. Calculating the voltage drop on the light poles of the panels selected[6].

Due to the complexity of the integration of filling stations into the common infrastructure, it is necessary to minimize its impact and determine what needs to be done in order to reduce these impacts. Therefore, monitoring and control of public lighting systems are essential parts of the integration of filling stations in order to be able to carry out reliable analyses, timely evaluations, predict future events and effectively plan changes to the installation of filling stations. An energy management system can also help reduce the impact of installing charging stations by providing ways to connect to public lighting to reduce waste and excessive energy consumption. In order to achieve all this, it is necessary to modernize public lighting systems in cities. The result of this modernization is smart public lighting, the use of which contributes to the quality of life of citizens. The first step to establishing smart lighting is to replace existing lamps with LED lamps that can be intelligently controlled in a timely manner. This will result in a reduction in electricity consumption, but by integrating additional functions into the lamp post, it will increase power usage. With its modular LED design, the Light and Charge streetlight is more energy-efficient than conventional street lighting and provides more effective illumination. It can be installed anywhere, and its modular design can be tailored to different locations. Up to four LED modules can be used to provide night-time lighting on main roads, while one or two modules are sufficient to provide acceptable lighting on side streets and in residential areas. As is already the case with vehicle headlights, LED technology allows more targeted light distribution with less unnecessary and ecologically undesirable "scatter"[5].

Using the example of the City of Koprivnica, an analysis was made of the possibility of integrating charging stations for electric vehicles and the photovoltaic system into the public lighting system. That analysis showed that the photovoltaic system and charging stations can be integrated into the public lighting system without negatively affecting voltage, line load or power losses[18].

An analysis of the possibility of integrating the maximum number of filling stations with public lighting was also made. The analysis consisted of two parts. In the first part, the power flow and voltage profile were analysed when there were no integrated charging stations for public lighting. The result of the analysis showed that all lines were loaded below 5% of the permitted value, which indicated a large unused capacity of the network. After that, using the methodology for determining the maximum number of charging stations that can be integrated into public lighting in the specific example, it was calculated that a maximum of 9 charging stations can be integrated into that public lighting infrastructure, that is, 3 charging stations per phase. In the second part, the power flows after the integration of those 9 filling stations were analysed. The lines were loaded below 90% when all filling stations were working, and the voltage profile shows that the voltage values are within the permitted limits[18].

If the public lighting infrastructure does not use its full capacity and therefore offers the possibility of integrating slow charging stations for electric vehicles. By using the formula (Figure 5), the number of filling stations that can be integrated into the public lighting system per phase can be calculated. The formula considers the number and rates current of the lamps, the rated current of the chargers and the rated current of the cable[18].

$$n \le \frac{\sqrt{I_r^2 - (m \cdot I_L \cdot \sin\varphi_L)^2} - m \cdot I_L \cdot \cos\varphi_L}{I_{CS}}$$

Figure 5 - Formula for calculating the number of filling stations that can be integrated into the streetlamp

The results of the analysis show that in all three examples with different bulbs, the lines were loaded below 90% when all charging stations are operating at rated capacity. It can also be seen in all the voltage profiles that the voltage values at all points of public lighting are within the permitted limits. It follows that slow charging stations can easily be integrated into the hitherto relatively unused public lighting infrastructure[18].

Installing EV charging stations in the light poles would imply two major changes to be considered:

- city needs to add a metering device for energy consumption of the EV charging stations;
- a change in the public lighting tariffs a city is currently using for the lighting fixtures. This would only apply to the lighting fixtures that belong to the service panel where the charging station will be implemented[6].

There are two ways of performing the charging station. One is by installing the socket in the public lighting pole (see Figure 6), and the other is by placing the device on the pole (see Figure 7 and 8). Such a charging station must have any device through which measurements, billing and other actions will be performed. The German company Ubitricity has both two performance methods in its offer. The difference is that if only a socket is installed without a device, then there must be an additional device in another place. In the case of Ubitrcity, this device is located on the charger cable itself. In this case, users must have a specific cable that has a device on it. There is another way with this performance, and that is to make any smartphone that device. In this case, it is necessary to download the application through which all the necessary steps will be performed. In the second case, no additional investment in the device is needed because it already exists on the pole. Likewise, any cable can be connected to it, as long as it is Type 2.

Figure 6 - Simple installation - cable only

Figure 7 - Installation with EV charging device

Figure 8 - Installation with the EV charging device on the cable

For users to receive the charging service, it is necessary to install an app that will enable it. By registering and logging into the app, users are given access to the charging station and can start the charging service. EV driver connects to the charging point and pays via their mobile phone. All money owned for EV charging is paid directly into the EV hosts bank account on a monthly basis[8].

Implementation best practices

The objectives of the European Union are aimed at better, more efficient and sustainable management of urban and rural areas. Local self-governments have recognized the purpose of such management and, by applying the observed technology, have helped in its realization. In the continuation of this section, several examples of good practice in the use of this technology are listed.

Ubitricity is a leading manufacturer of smart street charging solutions for electric vehicles (EVs) that enable charging on existing infrastructure. Together with partner Lucy Zodion, they created a solution for charging electric vehicles on existing public lighting poles in London. The main challenge in that project was to make the transition from public lighting that serves only for street lighting to multi-purpose lighting in accordance with all regulations. Lucy Zodion's task was to manufacture and deliver several thousand secondary insulators in order to ensure the protection of the 32 A power supply and the insulation that is placed on the street light pole. An additional 25 A protection is also provided for equipment used to charge 5.8 kW EVs, along with 6 A protection for lighting fixtures. In this way, a product called Lucy Zodion Trojan Midi was created (see Figure 9).

Figure 9 - Lucy Zodion Trojan Midi with 32 A disconnector

With this project solution, all the set goals have been met because the installation of this type has been successfully certified and approved. Based on this, all London municipalities have the opportunity to meet all targets aimed at reducing harmful emissions by applying this solution.

Ubitricity is also active on the German and French markets. In their offer, they have different types of chargers that are adapted to their markets, which can be seen in the following table.

Country	Name	Picture
UK	Chelsea	
Germany	Heinz	

France	Étoile	

Figure 50 - Different types of lamppost integrated EV chargers as per country

A solution specifically for the French market was developed with Ubitricity's "Simple Socket Éoile." The two sockets, Type 2 and Type E (Schuko, CEE 7/5) could be used to charge electric vehicles with a standard charging cable (Type 2, Mode 3). Users would only need to scan a QR code with their smartphone and can start a charging process with just a few clicks.

Sabinov, Slovakia is a town of about 12,000 inhabitants in the Prešov region. In search of more efficient energy management, Sabinov was looking for innovative solutions. With the increase in the number of electric vehicles by residents and visitors to the city, there has been an increase in the demand for places to charge such vehicles. Seak Energetics, in cooperation with Vaisal, created a smart solution for the stated purpose of improving energy efficiency. The pilot project of this solution was the installation of new public lighting in a public parking lot near the city centre. Each streetlamp is integrated with a weather transmitter, an air quality transmitter and a LUMiCHARGER EV charger. This type of technology has put Sabinov on the map of smart cities with the help of using this type of technology.

Pilot project is installed in the public parking lot near the residential zone and the wall of the medieval fortifications of the city. This car park is used by locals as well as visitors to the centre. New luminaires with smart lighting control and integrated EV chargers are installed on the public parking lot. Thanks to this pilot project, the citizens and visitors can charge their electric cars. The city gets accurate data about energy savings achieved by controlling the light intensity. New lamps are equipped with sensors to monitor the environmental data including air pollution (Figure 11).

Figure 11 - Installation in Sabinov

All Smart City technologies installed in this pilot project are managed centrally thanks to INVIPO smart city platform. This platform links data from different technologies and systems into a holistic view and offers efficient management of city technologies to the town hall. The INVIPO platform offers Sabinov citizens access to public data from sensors and information about the current occupancy of charging stations.

Lighting always has priority; the rest of the power capacity is automatically evenly distributed among charging cars according to their charging needs. Drivers just sign in and start charging using an app (Figure 12).

Figure 126 - Seak Solution for EV Charging

Technology trends

Target of the EU is to cut CO2 emissions from cars by 55% and vans by 50% by 2030. It also proposes to completely cut emissions from cars and vans by 2035. A significant increase in the uptake of electric vehicles will be needed to achieve these goals[9] (Figure 13).

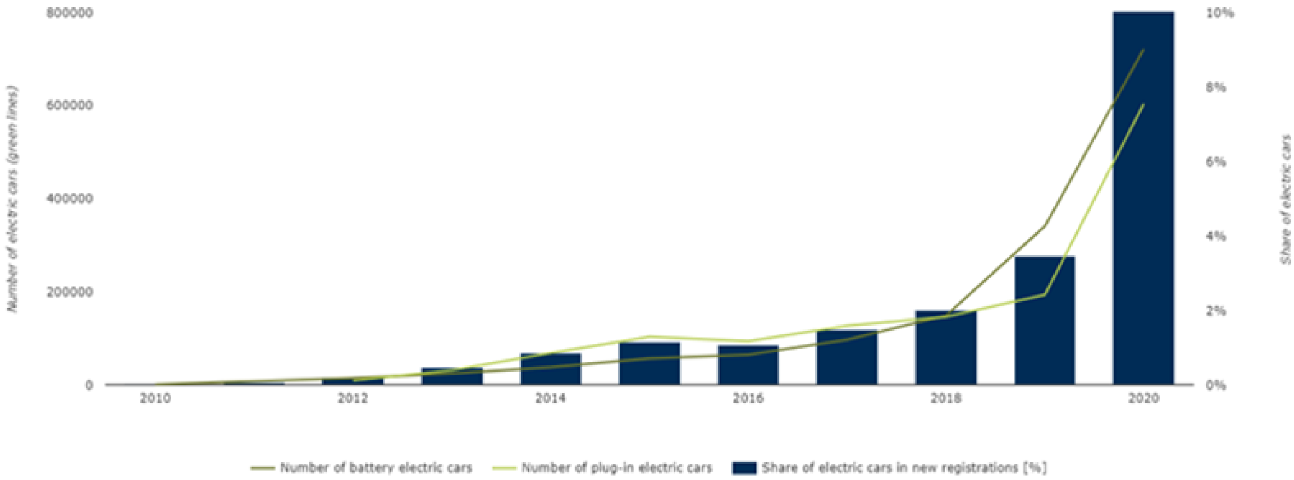

Figure 13 - EV Future trends

Electric cars — battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) — are gradually penetrating the EU market. There has been a steady increase in the number of new electric car registrations annually, from 700 units in 2010 to about 550,000 units in 2019 (3.5% of new registrations). In 2022, electric car registrations surged, accounting for 12% of newly registered passenger cars[9].

The Green Deal is the latest in a series of EU policy documents on the development of alternative fuels infrastructure. The added value of EU action in this field is that alternative fuels infrastructure is a trans-national challenge, but individual Member States do not have the necessary tools for pan-European coordination. Each Member State is responsible for preparing and implementing its own domestic alternative fuels policy under the framework set by the EU legislation. This may include measures such as tax breaks or subsidies for the purchase of electric vehicles and the construction of charging infrastructure. The 2014 directive on alternative fuels infrastructure (AFID)10 is a key policy tool within the overall EU strategy to develop publicly accessible electrical charging infrastructure. It aims to overcome a market failure best described as the 'chicken-and egg' problem: on the one hand, vehicle uptake will be constrained until charging infrastructure is available, while on the other, investments in infrastructure require more certainty of vehicle uptake levels. The deployment of charging infrastructure in step with EV uptake patterns is an essential part of the switch to alternative fuels. In its 2017 action plan on alternative fuels infrastructure, the Commission estimated that up to €3.9 billion would be required for electrical charging infrastructure by 2020 and possibly an additional €2.7 to €3.8 billion per year, as of 2021 depending on the share of fast-charging infrastructure. The Connecting Europe Facility (CEF), directly managed by the Commission, provides financial support for alternative fuels infrastructure. Further CEF calls to support the deployment of public charging infrastructure are expected after 2020, as part of the Green Deal. Moreover, one highlight of planning under the Recovery and Resilience Facility for the 2021-2027 multiannual financial framework is EU support for building of 1 million public charging points by 2025[11].

SWOT Analysis - EV charging

<table>
<tr><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>1. Quick installation (in some examples up to 1 h);
2. Integration with the existing infrastructure - Space-saving, no extra street furniture;
3. Easy charge;
4. Energy grid-friendly;
5. Can be planned at short notice;
6. Easy to relocate if required;
7. Have low investment and operating costs;
8. Network-compatible;
9. Easy access to charge points, especially for people without private parking spaces;
10. Variety of payment options;
11. Can be usable with type 2 standard cable;
12. Charging while the EV is parked anyway;
13. Fully standard-compliant.</td><td>1. If cable would need to be stretched across the footpath onto the road this would cause a potential trip hazard;
2. Challenge with the amount of power available;
3. Slow charging;
4. High costs for the option of installing smart lighting;
5. There's no way to tell if a charger is available at any given time (without dedicated parking).</td></tr>
<tr><th>Opportunities</th><th>Threats</th></tr>
<tr><td>1. Strong increase in EVs in Europe (40 million EVs in 2030);
2. Expansion of bans for combustion engine cars in major cities;
3. Strong expansion of urban charging infrastructure necessary;
4. Cities will need significantly more public, quickly scalable and easily accessible charging stations soon;
5. Electricity is already available all around us;
6. Funds and policies of the European Union.</td><td>1. Many lamp posts may not even be suitable for charging equipment;
2. A long distance from the public lighting pole to the parking lot;
3. Measuring of the charge points;
4. Laws and regulations;
5. Required permits;
6. Vandalism.</td></tr>
</table>

Economic viability

Entry costs	
Type of cost	**Price (€)**
Wall box charging hardware[13]	1000 – 3000
Lamppost integrated EV charging station	800 – 1000
Installation price	Depending on the contractor

In the Republic of Croatia, local self-government units use electricity for public lighting from the distributor HEP Operator of the distribution system. In its offer, HEP has a price list of services that depends on different usage models and categories of customers. The public lighting system belongs to the category of entrepreneurship, low voltage and Yellow model. The price list is shown in the following table.

Low voltage – Yellow Model	**Price (€/kWh)**			**Total (€/kWh)**
	Distribution of electricity	Transmission of electricity	Network usage	
	0,024	0,008	0,032	0,064

Now, many of residents have no access to off-street parking and the vast majority of those live in our towns and cities. One of the options is to charge electric car at home, but this relies on having access to off-street parking.

Lamp post charging is also more cost-effective and much less obtrusive as the charging points require no additional street furniture. Adapting a lamp post into a charging point for electric vehicles can cost as little as 800 – 1000 €. This is roughly half the cost of a conventional home charging point, depending on technology, and it's potentially one of the more cost-effective charging solutions today.

Streetlamps with charging technology allows drivers to conveniently charge their vehicles closer to home, while helping to tackle air pollution15. BEV cars in Europe emit, on average, more than 3 times less CO2 than equivalent ICE cars. In the worst-case scenario, an electric car with a battery produced in China and driven in Poland still emits 37% less CO2 than petrol. And in the best-case scenario, a BEV car with a battery produced in Sweden and driven in Sweden can emit 83% less than an ICE car. Electric cars bought in 2030 will reduce CO2 emissions four-fold thanks to an EU grid relying more and more on renewables[17].

Cities will need significantly more public, quickly scalable and easily accessible charging stations in the near future. The so-called AC charging of EVs offers many advantages in this context. Charging with alternating current (AC charging), often referred to as low-power charging, includes charging capacities between 3,7 kW to 22 kW. Public AC charging offers enormous advantages, as:

- EVs have long parking times, especially overnight,
- On average 40 to 60 percent of city residents do not have a private parking space,
- the AC charging stations can be installed cost-efficiently and quickly[16].

The increase in the number of charging stations for EVs can be a reason for someone to buy an electric vehicle. The reason is that the lack of charging stations can negatively affect the decision to buy an EV. With the increase of filling stations, this can change and lead to an increase in the purchase of EVs, a reduction in the number of conventional vehicles and better air quality.

Smart Lighting

Technology overview

Public lighting system is recognized as smart public lighting system in traditional sense, when it is capable of providing:

- the sufficient amount of illumination at the correct time (adapting to the period of night, week, month and year)
- the correct amount of light in the needed space (adapting to the current traffic density of pedestrians, cyclists or users of small electric vehicles or motor vehicles in the illuminated area).

Smart lighting in a more modern sense can adapt the spectrum of light (colour temperature) to the period of night or year or to the illuminated space.

Public lighting recognized as smart in contemporary sense is additionally capable of:

1. Interactively reacting to other parameters of the current city status:
    - traffic status
    - security status
    - state of the environment
    - state of social activities
    - by receiving and intelligently responding to data from other smart city systems.
2. Collecting data on different parameters of the situation in the city (traffic, safety, environment and others) through detectors and sensors installed on smart public lighting luminaires and transmitting the corresponding data to other smart city systems.

Smart public lighting in today's sense also provides precise measuring of engaged electrical power in the luminaires and sensors and memorizes the state of quality of the electrical network and the operational states of the luminaires.

Also, in today's sense, smart public lighting incorporates control programs that allow remote reprogramming of intelligent controllers in luminaires and analytics of collected data on the electrical energy consumed, the quality of the electrical network and the operational status of luminaires.

Despite the fact that smart public lighting is only one of the Smart City, it has extremely great importance in terms of the Smart City infrastructure backbone thanks to the following facts:

- high density (capillarity) of public lighting infrastructure within the area of a city;
- legal simplicity in the sense that the entire system is owned by one or a small number of legal entities;

- suitability of mechanical public lighting infrastructure for the mounting of sensors, actuators and communication devices of the public lighting system. The physical layout and shape of the public lighting infrastructure is extremely suitable for most sensors (and cameras), actuators (and digital displays, loudspeakers) and wireless communication elements (short-range radio communication devices, Wi-Fi access points, 5G small base stations);
- the presence of electricity infrastructure in all positions with the simple provision of 24/7 presence of electricity supply.

Implementation of best practices

With regard to communication technology, smart lighting systems are divided into:

1. Wired control systems
    - Over power cables:
        - Power Line Carrier technology
        - Basic technologies (mains voltage modulation, mains voltage phase cutting, basic power cable signalling)
    - Over additional communication cables:
        - Serial communication by pairs (RS-485, current loop and the like)
        - Pilot wire control
2. Wireless controlled systems
    - Long-range private radio networks (LoRaWAN, SigFox, UNB, etc.)
    - Short-range private radio networks (ZigBee mesh, Bluetooth mesh and the like)
3. Cellular telecom providers machine to machine networks
    - NBIoT, LTE-M

In the initial stages of the development of wirelessly controlled individually controlled smart lighting systems, it seemed that private radio network systems (long and short range) would become the dominant solution given the lower operating costs (70% share of networked public lighting systems in 2017 (Northeast group LLC: "Global LED and Smart Street Lighting: Market Forecast (2017-2027)"). However, with the increase in availability and declining prices of devices and services of telecom-based machine to machine communication systems, by the end of the last decade, a trend of a strong increase in smart lighting systems based on telecom communication emerged thanks to better coverage and greater long-term network safety and reliability.

The largest telecom networked smart lighting systems were realized in the following EU cities:

1. Paris (FR) 280.000 light points

2. Madrid (ES) 225.000 light points
3. Birmingham (UK) 130.000 light points
4. Milano (IT) 101.000 light points

Technology trends

The global share of smart networked systems within the total of new or renewed public lighting installations in the period up to 2027 is estimated to grow to more than 29% (Northeast group LLC: "Global LED and Smart Street Lighting: Market Forecast (2017-2027)").

The dominant market trends affecting the increase in interest in smart lighting are:

1. New legislation at the level of the European Union and individual countries aimed at the necessity of introducing intelligent lighting management systems in order to save energy and protect the environment ("GPP Revision of the EU Green Public Procurement Criteria for Road Lighting and traffic signals");
2. Increase in contracting of public lighting systems according to different business models based on the “Light as a service” principle that requires the possibility of accurate direct measurement of energy consumption on the public system independent of other electrical appliances often connected to the same meters (tram and bus stops, outdoor advertising and other electrical equipment on public lighting poles).

All examples of smart lighting projects described in more detail in case studies provide intelligent lighting control in the time domain, remote parameterization of the luminaires, and precise remote measurement of consumption per individual luminaire.

The basic trends that we can notice in smart public lighting systems are:

1. Trend of switching to cellular wireless communication through LTE-M and NB-IoT;
2. The trend of switching from on premise server monitoring and management solutions to centralized cloud monitoring and management solutions;
3. Trend of expanding the scope of sensor and actuator functions that use communication channels of smart lighting and use luminaires as a physical and electrical platform (Zhaga standardization of the electrical interface of sensors and communicators with luminaires, software standardization of communication of the extended set of smart city parameters;
4. Trend of Smart Lighting System Integration with integrated Smart City monitoring and control platform (Smart City Dashboard) and other parallel Smart city cloud management platforms (TalQ and FiWARE standardization of communication;
5. Trend of integration with autonomous or hybrid solar power supply systems on the luminaires or public lighting poles.

SWOT Analysis - Smart Lighting

Strengths	Weaknesses
• existing availability of mechanical and electrical infrastructure in the system • high density and very good positioning of the infrastructure of existing public lighting • high achieved level of electrical, communication and software standardization • significant reserves in available electrical power due to the high increase in energy efficiency of luminaires achieved by LEDification • increasing availability and decreased cost of smart public lighting systems • high technological similarity and compatibility with solar power systems • minimum production of hazardous waste during the life cycle of public lighting	• susceptibility to disturbances of electronic components (drivers and LEDboards) and mechanical (aluminium) raw materials markets • insufficient standardization on the interfaces between the basic components inside the LED luminaires (driver and LEDboards) • insufficient adaptation to the relatively low level of cleanliness of electricity networks for the power supply of public lighting systems (especially air suspended networks). • short life cycles of communication solutions in relation to the expected life cycle of public lighting systems (minimum 15 years)

Opportunities	Threats
• energy saving trend related to the global energy crisis • trend of automation of public system maintenance jobs • environmental trend related to the global environmental crisis (protection against light pollution, hazardous waste generation) • trend of switching to “Light as a service” business models • trend of integration of the smart city systems and citizens via smartphones • trend of switching to autonomous power sources (solar systems) • trend of digitalization advertising • trend of increasing need for video security systems	• lack of expertise in the public and legislative system and instability of legislation • lack of experience in the public lighting sector with communication systems • insufficient levels of expertise on new technologies among traditional investors and public lighting installers • public sector budget constraints due to the global financial crisis • slow process of creating the market needs of citizens to use smart city data via mobile apps • weak resilience of legislation to the transfer of political conflicts to the field of contracting of infrastructure systems • increased complexity in planning the maintenance of public lighting systems

Following key are activities needed for accelerated advancement of smart lighting systems:

- accelerated development of a wide range of sensors and actuators suitable for installation in luminaires (Zhaga D4I multisensors);
- standardization of the interface among the basic components of the luminaire (driver - LEDboard);
- development of mobile applications for automatic cloud registration components of public lighting;
- accelerated development of software interfaces for integration with parallel and superior smart city software platforms;
- rapid adaptation of the public lighting system to the transition to a 24/7 electrical power supply system;
- accelerated cooperation with mobile app developers;
- accelerated integration with autonomous solar power supply systems.

Key activities needed to eliminate distractions for the development of smart lighting systems:

- development of models for the alignment of contracting of public lighting systems with the “Light as a service” principles;
- professional and permanent adjustments of legislation for the design of smart public lighting systems;
- accelerated education on the IT aspects of public lighting in the public sector and electrical engineering community;
- enhanced cooperation with the mobile app industry on the creation of new solutions integrating smart city data;
- refinement of the legislation of public tenders in terms of protection against the transfer of political conflicts to public infrastructure sector.

Economic viability

Before the recent energy crisis, the share of annual electricity consumed by modern LED luminaires in the investment value of the luminaires was 1:12. After the crisis it grew to 1:4 this year with the trend of further increase resulting in a much quicker payback period for every smart lighting component.

The introduction of time intelligence in the management of public lighting further contributes to the savings of electricity by approx. 30%. The introduction of spatial intelligence contributes more than an additional 30%. In this regard, only the introduction of basic time and space intelligence in modern luminaires allows the return of additional investment within 7 years, which is financially acceptable. Benefits from the possible use of EU funds aimed at environmental protection and the realization of energy savings from recovery and resilience programs are not included in these calculations.

Savings on the maintenance of smart public lighting systems compared to classical systems are at least 40% and also have acceptable periods of return on investment.

The integration and interoperability of smart lighting with other smart city systems brings additional revenues that the SmartEPC project seeks to evaluate and will provide additional strong improvement of financing opportunities.

Other Smart City Services

Technology overview

Cities are growing at a staggering rate. As per the United Nations, currently, over half the total world's population lives in urban areas. This number is expected to jump to 68% by 2050. With the growing population, however, new challenges are also emerging for the city administration relating to public services. To overcome these challenges, cities are considering digital transformation. In other words, they are looking to become "Smart Cities." In a nutshell, a Smart City is a city that can collect and analyse all sorts of data from a variety of sectors, ranging from urban planning to waste management. In order to become a Smart City, a city needs to build and maintain a streamlined network of interconnected sensors, systems, and feature-rich software. Today, most public lighting is still reliant on outdated technology based on traditional light sources. One of the main goals is to save energy by replacing the current public lighting infrastructure with innovative LED solutions and cutting-edge technologies that save money, make public spaces safer, and improve quality of life for residents.

Implementation best practices

Air pollution, often referred to as the "invisible killer", is one of the biggest public health risks worldwide. According to Harvard University, the presence of harmful gases and particles in the atmosphere results in 8.7 million premature deaths per year, roughly 20% of all deaths.

Tourism and travelling have become an important part of modern-day life, but they, among many positive, have a number of negative consequences. Environmental impact is probably the most obvious one. It consists of many different aspects, such as depletion of natural resources like water and land, discharging waste, pressure on endangered species, noise pollution, carbon footprint and many others. One of the aspects which is hard to notice at first is the impact on the air quality.

When monitoring environment parameters in urban areas, the following questions arise:

- How to deploy sensors fast and with simplicity?

- How to secure power infrastructure?
- How to deploy non-intrusive sensors?
- How to best utilize existing infrastructure?

Importance of clean air is obvious when it comes to health and life quality, but research also show its influence on tourist demand. High levels of $SO2$, PM2.5, PM10 and $NO2$ have strong negative impact on the number of tourists in that area.

Technology trends

With IoT devices designed to observe and measure specific environmental conditions, businesses and government entities can implement environmental monitoring at a variety of locations. Whether measuring water, soil or air quality, these IoT sensors can provide visibility into site conditions and deliver data-driven insights, allowing site managers to address problems more proactively and effectively.

Instead of waiting for a negative environmental survey report to come back or for long-term consequences to arise, industrial and commercial businesses can responsively clean up contaminants, repair malfunctioning equipment or adjust operations to reduce risk and prevent financial losses.

As more companies and government bodies focus on developing and deploying intelligent operations to support sustainability efforts, environmental monitoring technology becomes increasingly relevant to their goals. With IoT-based environmental monitoring, organizations in agriculture, manufacturing, waste management, public utilities and other critical industries can:

- Reduce the risk of equipment failure by halting operations in poor conditions;
- Prevent the build-up of harmful pollution in groundwater, soil and indoor and outdoor air;
- Make workplace accidents less likely by implementing leak detection and pollution monitoring systems in risk-prone environments like oil and natural gas fields;
- Protect the local plant and animal life, as well as agricultural production and public health, by improving groundwater and aquifer protection.

Pollution monitoring has become an incredibly valuable tool in manufacturing, civil planning and agriculture. These systems can allow organizations to observe, measure and even mitigate pollution and contamination that affect both natural and manmade water stores, air quality and soil quality. Monitoring the acidity and overall chemical composition of these environmental elements can provide both private and public organizations with valuable information – but they also need the ability to process and react to that information quickly.

SWOT Analysis – other Smart City Services

Strengths	Weaknesses
1. Easy installation 2. Affordable 3. Long product life 4. Low power consumption 5. Connectivity agnostic 6. Valuable data insight	1. Large number required to see the bigger picture 2. Skilled workforce 3. Regulatory requirements for public disclosure
Opportunities	**Threats**
1. Improving citizen wellbeing 2. Sustainable urban planning 3. Actionable insights 4. Consolidated information repository 5. Crowdsourcing 6. Stakeholder engagement	1. Political uncertainty 2. Internal workforce to deliver expected project results 3. Project dissemination

Economic viability

Air pollution is currently mostly monitored using government sponsored monitoring stations, while these instruments can collect a lot of good quality data, they are expensive to build and maintain (a recent installation in Irvine, California cost more than $1 million) and have a poor spatial coverage (London has a monitoring station density of 0.09 sites/ km2). Several programs around the world are monitoring air quality on a much more local scale, resulting in actionable insights for residents, city planners and environmental groups.

The Array of Things project in Chicago began in 2014 and is currently installing more than 500 sensor nodes across the city. Each node contains a range of screen-printed electrochemical gas sensors, as well as instrumentation to monitor traffic, light and noise pollution. The nodes are designed and manufactured by Waggle, a spin out from the Argonne national laboratory in Illinois, USA. Each node, costing approximately $2000, transmits data to a central server where all data is freely available to residents, businesses, and academics, with the aim of improving air quality across the city. Waggle have received unprecedented interest from other cities to replicate the project, with Seattle expected to be the next metropolis to get the array of things treatment.

In Oslo, Norway, the EU funded city-sense project has utilized public transport to produce a pollution map of the city to inform government and residents alike of potential pollution hotspots. Sensors fitted to city buses and hire bicycles monitor pollutants across the city. Buses have the advantage of following the same route several times a day, so temporal coverage of an area is possible, while bicycles can visit areas that automobiles and large monitoring stations cannot. By travelling through parks, down alleys and side streets, such sensors can detect pollution on a hyper local level.

Finally, as part of a partnership between Uber and Drayson Technologies, drivers have been provided with a CleanSpace tag, an RF powered device that contains a printed carbon monoxide sensor. Data on air pollution will be provided in the form of a graph on the driver's phone and will also be uploaded to the cloud to create a broader map of pollution in the city. Such a network presents a huge opportunity to allow individuals to see the air they're breathing and contribute to such data to give insights on improving the air quality.

Advancements in the way we monitor gases in urban areas will enable everyone to accurately monitor air quality and provide actionable insights to improve the environment around them.

Implementation Opportunities and Challenges

Guidelines for maximizing common implementation

Given the assumption that the full stack service offered is available at a particular location, here is a list of key benefits per service offered on top of the connected lighting

For street side 5G solutions the key benefits are listed below:

- Deliver street side solutions and leverage smart lighting capacity and infrastructure to ensure 5G experience;
- Integrating into any streetscape with minimum visual impact;
- 5G user experience;
- Increased broadband connection points;
- Detect failed light posts;
- Low power consumption for sustainability goals.

Overall, the case is that the owner of the smart lighting infrastructure can benefit even more (financially) by giving into concession the infrastructure (light posts) which for sure is appealing to CSP's as they are mitigating the challenges faced when trying to deploy 5G base stations in a traditional way (own infrastructure).

For environment monitoring the key benefits are listed below:
Installing various environment sensors (heat or air quality) on existing or connected light pole solutions creates new service opportunities and allows for city officials to create an ecosystem that will allow to make informed decisions on improving the quality of life.

The results of such an integrated solution are:

- Integrating into any streetscape with minimum visual impact
- Improving city life
- Generate pollution heat maps
- Low power consumption for sustainability goals.

For EV charging it is vital to mention that pole-mounted charging offers a cost-effective and creative approach for sitting and installing public charging stations. In addition, they present an important tool that can help expand access to charging. The key benefit of implementing the EV charging into lamp posts besides driving sustainable mobility (the key thing to achieve climate goals is to turn electric but also it needs to be complemented by appropriate infrastructure) is also an open position for a new revenue stream. CSP's offering such services would probably be delighted to be able to place EV chargers by paying the concession to the existing infrastructure (light posts).

Smart lighting plays a very important role in all of the above challenges. Besides direct impact on all the above factors, public lighting also plays a pivotal role in development of most of the smart city systems by providing physical and electrical infrastructure suitable for most of the smart sensing, communication and smart engagement devices, sensors, cameras, detectors, communication base stations, signalling devices, loudspeakers, displays… In recent years a lot of development was invested in public lighting systems in order to enable maximum energy efficiency, minimum environmental load, high level of connectivity and embedded intelligence as well as to enable it function as energy and communications backbone to Smart City devices to be installed on its infrastructure. There is a variety of integrated smart city pilots and projects worldwide tailored around public lighting systems in modern cities. This development goes further learning and adapting to experiences gained from these projects.

Recommendations – The Smart EPC upgrade action package

Energy efficiency services (e.g. Energy Performance Contracting or EPC) are available on the market already for quite some time. Throughout last years there has been a lot of debate on statistical treatment of this kind of projects and whether they could be treated as “off balance sheet” for public sector entities. This debate was somewhat settled by EIB and EUROSTAT issuing a guideline “A Guide to Statistical Treatment of EPCs1” in May of 2018. This guideline helped not just in matters of statistical treatment of EPCs, but they helped in laying out minimum standards this kind of contracts need to achieve in order for them to be treated on balance sheet of ESCO companies.

Even though the rules for EPC contracts are now practically the same in whole EU there are still several different types of contracts throughout different sectors (building, public lightning, industrial etc.) and different countries. There are valid reasons for this when difference in technical solutions or difference in national legislative is brought up. But, when analysing the sector of street lightning sector, more similarities than differences can be found. State of the street lightning, potential of reconstruction, legal and financial risks and problems seem to be quite similar across the EU countries. This gives an opportunity to develop a uniform EU market for reconstruction of street lightning via EPC type of contracting. Numerous new technologies that can be incorporated in street lighting systems such as smart sensors, smart metering, etc. create an environment where smart solutions and application can thrive and boost cities and counties in a new digital/smart era where these technologies enhance safety and quality of people’s lives (Smart City aspects). Street lighting systems make an ideal infrastructure for this to happen. In order to do so, on EU level, standardised EPC documentation that promotes and requires this kind of ICT solutions needs to be developed and accepted. This would open the EU market and break down national boundaries for ESCO companies since all documentation would be practically the same. To this date most ESCO companies are focused locally or at national level at the most. There are still small number of companies working on EU level. If there was a standardised contract and tender documentation for this kind of projects, all ESCO companies interested in specific tender could analyse specific tenders and prepare their bids in much shorter time. This would lower preparatory costs not just for public sector and ESCO companies but also for financial institutions financing this kind of projects making them more financeable. Making EPC methodology and documentation standardised would create an “off the shell” solutions for public sector and “off the shell” products for ESCOs and financiers which should lead to more vivid market. Also, standardisation of contracts and methodology would create a pool of projects that have quite similar risk profiles (same legal clauses, same technical requirements etc.) which helps create a sound market conditions for lowering the cost of capital as well as opening room for development of secondary markets (buying and selling of ongoing EPC projects on secondary markets). Also, technical requirements for ICT solutions brings IT and telecom industries in story making them essential part of developing new solutions and services baking up or leaning on energy efficiency as a core problem. This helps in bringing together different market/industry players much faster than they are doing now and helps EU in transformation to smart digital society based on energy efficient measures.

However, there is a big untapped potential in sectors and with actors not yet engaged in services triggering energy, CO2 and cost savings. At the same time, new technologies have emerged opening the door for new types of services which use ICT to better control and steer energy consumption and to integrate energy services with non-energy benefits. By bundling various services and benefits, additional target groups, sectors and financial resources can be accessed. Finally, ICT-tools and big data generated by smart meters, smart devices and sensors will help monitor and verify energy savings and flexibility and thus provide for appropriate remuneration of optimised consumption in public lighting systems. A particular challenge for energy services of this kind is that while they aim to involve different services (e.g., system services) and benefits (e.g., comfort) towards increasing their viability, they should nevertheless result in real, measurable energy savings and performance improvements of the overall energy system. Project partners (cities) will use and apply more accurate and dynamic measurement and verification of energy savings and flexible consumption based on latest NB IoT technology (or similar), also in order to ex-ante identify and develop business opportunities; in this use 'big data' generated by smart meters, equipment, sensors and tools for standardised processes; address potential legal and contractual aspects (e.g. in relation to existing contracts or warranty, safety and data security issues linked to existing and newly deployed equipment).

Energy performance contract is not considered as public debt if arranged properly, respectively if arranged in accordance with EUROSTAT rules defined in Guidance on statistical treatment of Energy Performance Contracts (EPCs) (May 2018). One of the EUROSTAT rules is that energy cost savings delivered from the implemented reconstruction should cover all energy performance contract expenditures. Not only that overall budget costs regarding public lighting will be reduced, but also most of the financial and technical risks will be transferred to a private company (ESCO). Contracted services (i.e., energy savings, lighting standard) are guaranteed for all the contract duration and there is an exactly specified payment deduction mechanism in case when contracted/guaranteed services are not delivered. Payment for measured and proved results and not for the effort is the general idea behind any performance-based contracts in delivering value for the money to end users. Since ESCOs take on majority of risks, they are often highly specialized in financing and technical knowledge, so traditional tender and contract execution risks are significantly reduced. In the EU 2021-2028 financial scheme, innovative financing models will be highly encouraged, so there is possibility for EU funding those types of contracts.

An Action Plan for the public lighting system reconstruction should be the key strategic document used to analyse the current state of infrastructure and reconstruction potential, as well as the optimal coverage and models of public lighting financing. 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 reconstruction of the public lighting system and represents a strategic document of the city in terms of developing the public lighting system in the period of next fifteen years' time. As a part of the Action Plan, the analysis of the existing situation of the public lighting system will be done for the purpose of defining the overall construction and upgrade needs, reconstruction potential and method for infrastructure operation and management. An analysis of the existing situation will be made based on the collected and processed data from public lighting energy audits, which cover the entire system infrastructure. In addition to the technical aspects, the analysis of the maintenance and construction of the public lighting system, as well as the energy balance of the electricity consumption will be carried out. The Action Plan presents potentials of reconstruction in terms of energy and cost savings. It should be emphasized that, apart from the reconstruction of existing luminaires, the technical solutions proposed by the Action Plan also include additional reconstruction with the aim of achieving the current lighting standards (minimum light technical parameters in accordance with norm HRN EN 13201:2016) as well as reconstruction for the purpose of the alignment with the legislative framework of light pollution limitations. During the analysis of financial models, a so-called analysis of a combined funding will be carried out, respectively a utilization of the Structural Funds for co-financing of public light system's build, upgrade and reconstruction.

Resume and Conclusion

Financial efficiency has become a critical factor in determining projects success, especially since relatively recent higher capital adequacy requirements for banks herald a new era of banking with tighter lending conditions. Investing in energy efficiency really does make sense in the high-energy-consumption world of city management, often bringing productivity and capacity benefits as additional benefits from equipment upgrades and technology investments that come as part of the energy performance contracting solution.

The implementation of energy performance contracting in EU is still at its early stages. However, its attractions are so compelling, with project risk transfer to the solutions provider, that it is difficult to believe these arrangements will not become mainstream by the end of the decade.

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