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ESMARTCITY

Enabling Smarter City in the MED Area through Networking

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Priority Axis 1. Promoting Mediterranean innovation capacities to develop smart and sustainable growth

Specific Objective 1.1 To increase transnational activity of innovative clusters and networks of key sectors of the MED area

WP3 – Testing

Activity 3.3 – Pilot Testing

Deliverable 3.3.1 – Pilot deployment – Partner PP3

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PP	Restricted to Programme Partners and MED Programme	
RE	Restricted to a Group defined by the Partnership and MED Programme	
CO	Confidential, only for members of the partnership and MED Programme	

Content

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1 Vision of Smart East Sarajevo

1.1 Abstract and Keywords

The Vision of Smart East Sarajevo is a general strategic decision of the City of East Sarajevo and its Development Agency (RAIS) as the partner in the EU Intereg MED Esmartcity project. All municipalities of the East Sarajevo confirmed their participation in this vision. The Municipality of East Ilidza signed the Memorandum of Understanding with the City Development Agency East Sarajevo for the participation in the EU Interreg MED Esmartcity project and the pilot project for Smart Street Lightingis successfully implemented in the area of the Municipality of East Ilidza.

The pilot Smart Street Lighting in East Ilidza is the first fully-implemented smart city service in the Western Balkans region, in Bosnia and Herzegovina and the Republic of Srpska, and this solutions is the proof-of-concept and the showroom for future project of smart lights and smart city services in general in this part of Europe.

The Feasibility study, Methodology for Testing and Pilot Deployment Operational Plan Framework defined the most important goals for the implementation phase and the verification process. The projectis aligned with the most important global strategic documents as theEU Digital Agenda 2020 and the UN Sustainable Development Goals Agenda 2030, as the Goal 11: "Sustainable Cities and Communities".

1.2 General Concept of Smart Cities

Today's cities are centers of innovation and creativity, but they often face great challenges such as climate change, infrastructural concerns, increased pressure on city services like transport and healthcare, etc.

To address these challenges and capitalize on the opportunities, cities are encouraged to become "*Smart Cities*".

First, we need to look at some definitions of the term Smart city: *"A smart city is an urban area that uses different types of electronic Internet of Things (IoT) sensors to collect data and then use these data to manage assets and resources efficiently. This includes data collected from citizens, devices, and assets that is processed and analyzed to monitor and manage traffic and transportation systems, power plants, water supply networks, waste management, crime detection information systems, schools, libraries, hospitals, and other community services*. [1]*Another definition would be that, smart city collects and analyzes data from IoT sensors and video cameras. In essence, it "senses" the environment so that the city operator can decide how and when to take action*. [2]

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What most definitions have in common is that they consider the use of smart technologies and data as the means to solve cities' sustainability challenges – economic, social and environmental issues.

Smart technologies are often classified as ICT solutions. They range from expensive hardware solutions such as city control centers, smart grids and autonomous vehicles, through to much lower cost solutions such as smartphone apps, online platforms etc.

If smart cities want to solve city challenges, their best first step is to bring together city stakeholders (government, business, universities, community, organizations, public services and citizens) to explore the complexity of the issues they face and involve them in collaborative decision making and future planning of their city.

1.3 The State of City of East Sarajevo: Challenges and Opportunities

The City of East Sarajevo is independent administrative area from the existing City of Sarajevo.

This pilot area is related to one of the parts of East Sarajevo, named East Ilidza.From the official source, Municipality of East Ilidza has 14.763 permanent residents and a population density of 530 inhabitants/km^2 in the total area of 27.9 km^2 which is mostly suburban and rural area.

In last couple of years, East Ilidza area has gone through dynamic and turbulent changes, which had huge impact on processes like urbanization and immigration from rural to urban areas.

New urban areas were built, with lack or without direct access to different public services.The existing public lighting system is implemented in the urban part of the municipality and the part of main roads.

A small part of the East Ilidza has a description of the urban area, which needs specific public services as a public lighting system.

City Development Agency East Sarajevo noticed this opportunity and decided to create an experimental area in the town square in theMunicipality of East Ilidza, where deployment and testing smart digital solutionswere possible. With this pilot project, East Ilidza can contribute to reducing the energy consumption of the city due to smart public lighting.

2 Summary of the Pilot Deployment

The pilot has been deployed in the Municipality of East Ilidza, in a town square called Veljine. The existing lighting system in the area consists of 36 streetlamps that cover a length of 272m. The deployed pilot system will include 20 Energy Meters installed on streetlight poles, coupled with Energy Metering Controllers and Sensors that will monitor air quality, motion and ambient light conditions. The system will also monitor several public lighting parameters and statistics that will be used for future profiling.

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System network communication will be done using LoRaWAN radio communications technology in combination with Wi-Fi depending on device type and current conditions in the installation area. Interconnection between the sensor network and the Data Center will be performed over the mobile network. Details of the communication system are given in following chapters.

For the needs of the pilot deployment a standalone server will be deployed by the City, rather than a Data Center. All aspects of the system will be expandable and scalable both in software and hardware, so that in the future it can be converted into an integrated control system for Smart City of East Sarajevo and all other services within the jurisdiction of the City.

2.1 Motivation

A city doesn't turn itself into a smart city after installing smart streetlights. A smart city gets its name for letting smart streetlights function in many other ways.

Smart street lighting can be complemented with the addition of security cameras, environmental sensors, traffic monitors, as well as an embedded electric vehicle (EV) charger installed on a lamppost. Each embedded sensor or gadget adds another benefit for cities installing smart street lighting.

Public lighting represents one of the finest powered grids spread across towns and cities throughout the globe. It is a nerve system of a city that connects over 260 million streetlights worldwide with access to 24/7 power. Street poles are therefore an ideal spot for mounting smart city systems, because of their geographical distribution which usually covers all city areas and roads where people live.

First example for future extensions of this project is the City Security and Safety Surveillance system with installed security cameras, which can be embedded into a smart streetlight, to monitor public areas as well as providing footage of incidents. Security cameras and various sensors are able to utilize the infrastructure, such as power and networks, from smart street lightings.

Second example is the Environmental sensors network, which can collect data such as humidity, temperature and air quality for citizens in wider area of the City.

Third example is the Road and Traffic sensors, which can also be installed and provide real-time information on road and traffic conditions.

Future advanced functions could be designed, e.g.streetlights could even possibly project a colored light on the path of an emergency vehicle, so that traffic ahead could start moving aside even before hearing the siren.

Through Open API approach, multiple devices, systems and assets can be interconnected to help cities become future-ready and leverage such interoperability.

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Further good news is that unlike most smart city applications, intelligent lighting saves cities' money from day one. Besides a low energy bill and reduced operational expenses, they offer exciting revenue generating opportunities e.g. leasing space for smart advertisement billboards, as a direct financial benefits, but also many secondary benefits as anenvironmental parameters improvement (e.g. air quality, measured in CO_2reductioncorrelated with energy saving),light pollution decreasing affecting the biodiversity and health improving status of the natural sleeping cycle, etc.

For network options, cell towers today are based on 3GPP network and are being rapidly updated to offer NB-IoT communication through a simple software update. Such M2M-based low-cost communication offers deep coverage to connect smart streetlights and other smart city devices such as parking nodes, traffic counters and air pollution sensors.

Regarding these facts, the usage of streetlights poles becomes the heart of this project and future projects.

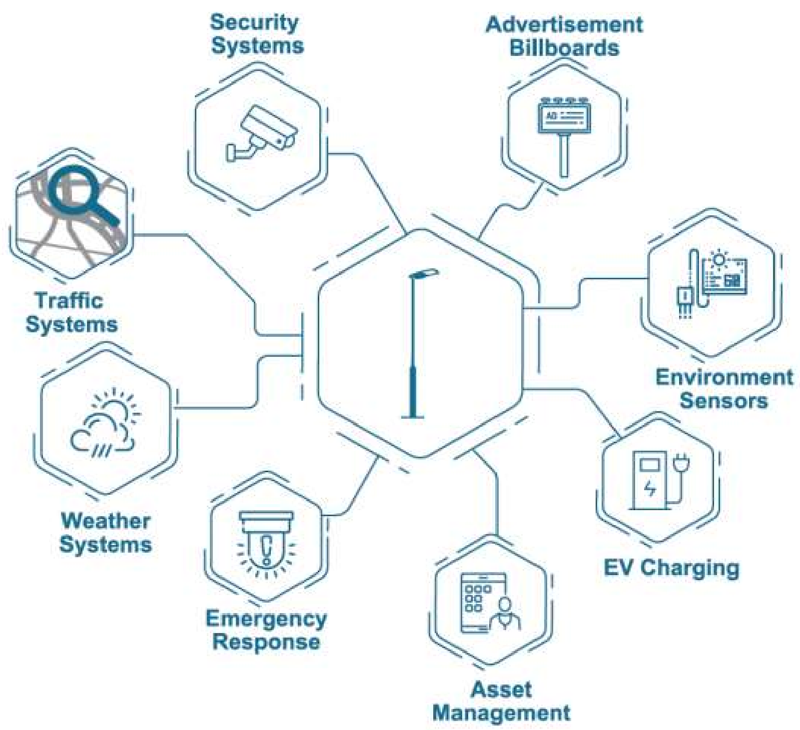

Figure 2.1: Smart City Lights – Smart City Backbone

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2.2 Pilot Definition and Goals

Collecting the data from the Intelligent and Smart Public Lighting system in the East Sarajevo City aim to optimize working regime of the system aligned with real needs and habits of the citizens. The system is getting able to react in the real-time to external event triggers. In parallel, many system parameters are collected in the form of measurements and triggered events, then these parameters are sent to the data center(s) to be stored, classified and analyzed. This enables that many Artificial Intelligence and Machine Learning algorithms could be applied on the data to define optimal and suboptimal working regime of the system aligned with the mathematical goal function considering trade-off between opposed subgoals (Energy Saving vs. Enough Light for Safety and subjective sense of the Quality of Life, etc.).

The City of East Sarajevo, urban and suburban area, is characterized by good development potential of Green Growth sector. Focused interventions on highly innovative Smart City sub theme can enhanceinnovation level in the area lagging behind EU average, implementing UN Sustainable Development 2030 Agenda and EU Digital Agenda 2020 strategies challenges.

Technology-driven Smart City concept is a response to challenges that many cities face, such as lower ICT use level, unemployment, weak infrastructure, socio-economics inclusion, increasing competition and many others.

A city becomes “smart” when investments in human and social capital and traditional transport and ICT-driven communications infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, trough participatory governance. Smart City system strikes a balance between economic, social and environmental demands, focused on Smart Sustainable Green Growth recognizing economic growth and sustainability as welfare prerequisites.

In East Sarajevo, a lot of city’s energy expenditure go to street lighting. When times are lean, energy efficiency is becoming increasingly important. The aim is also to keep maintenance costs under control. Investing in energy-saving measures with intelligent street lighting therefore seems a logical step, but the current situation is often forgotten in this respect. Even the transition to LED lighting is still not an obvious development, but it could be assumed as a first step forward.

Additional saving and improvement are defined in the pilot project. This approach understands that the Public Lightning System is not fixed anymore on 100% power all the time and the system should be connected with some other parameters. The system is working in time cycles setting the power level on more than one e.g. 100-70-40-20% of maximum power or any other regime. Transitions could be defined by timer e.g. every 3 minutes, until pedestrian or car appear what triggers the System to go back to the maximum level 100% power. Power levels and length of time cycle is the subject of the optimization process during the project late phases.

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3 Pilot Implementation

3.1 System Architecture

The Smart Public Lighting system is designed to meet the User Requirements from the EU Interreg MED Esmartcity Pilot Deployment Operational Plan Framework for East Ilidza [3]and all main goals are met. In this chapter, it will be described the implementation process, hardware and software components, sensors and measurement methodology, wireless communications backbone system, data centers and other system components.

The system is defined by its User Requirements, which contains main goals to achieve, and Functionalities, as the technical parameters.

Basic schematics of the system elements are presented in the Figure 3.1 and Figure 3.2

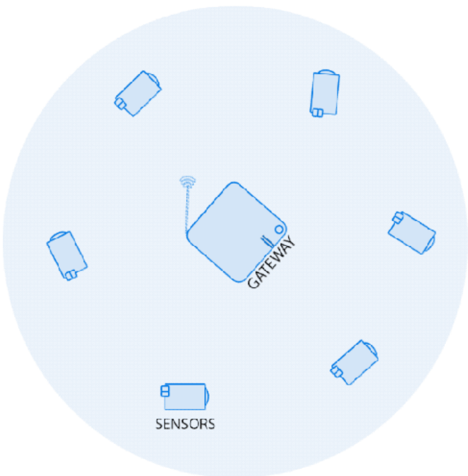

Figure 3.1: Basic Smart Lights cell, The Gateway node with Controllers system

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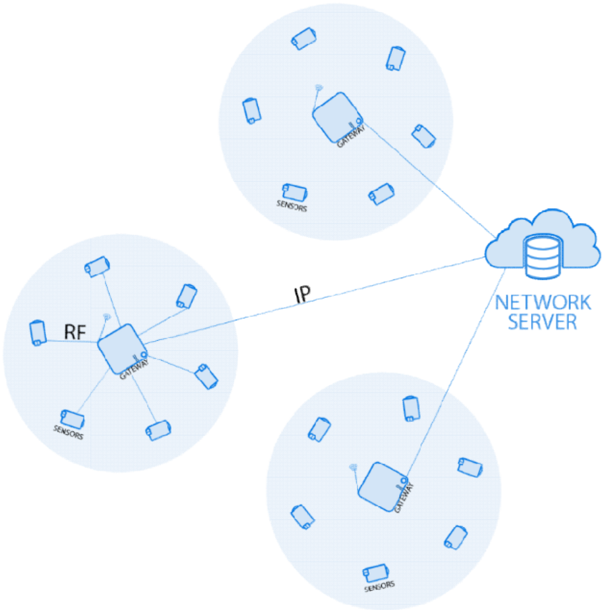

Figure 3.2: Physical Topology of the Smart Lights system in the City of East Sarajevo

3.2 User Requirements

The main goal in this pilot was to establish an experimental framework which will allow users to use smart city applications in real-time and under different settings and parameters. This pilot solution is the proof-of-concept for future projects and investments in the Smart City vision in East Sarajevo. The results are presented to local governments (City, all municipalities), industry sector, academic community, but also to citizens collecting their feedbacks on experience and future development ideas and their needs.

To create this experimental framework, the pilot project meets following requirements:

- Sensors (sensors network): The primary goal is to deploy sensor network that can support primary monitoring and management of the public lightning system and to provide additional information on Air Quality.
- Data Center: The City of East Sarajevo and the Municipality of East Ilidza established data centers where all collected data is stored, clustered and analyzed. The central Data Center is located in the RAIS in the City of East Sarajevo, and secondary one (acting as the backup location, too) in the Municipality of East Ilidza. The management of the system is available from both locations equally. Data centers are enhanced by Machine Learning, Artificial Intelligence and Data mining algorithms and technologies that can

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provide deeper knowledge about collected data, what helps decision makers to find the optimal solutions and planning for the public streetlight service in the City.

- Open Data Policy: Open data can contribute to improve efficiency of public services. Better efficiency in these processes and delivery of public services can be achieved with data sharing between different sectors of community. The Open Data launches the entrepreneurship actions across the City but even wider, creating the ecosystem for innovations and creativity work, especially focusing younger population.
- Wireless networking will be deployed for interconnecting the different components of the system as described in the previous and following sections.

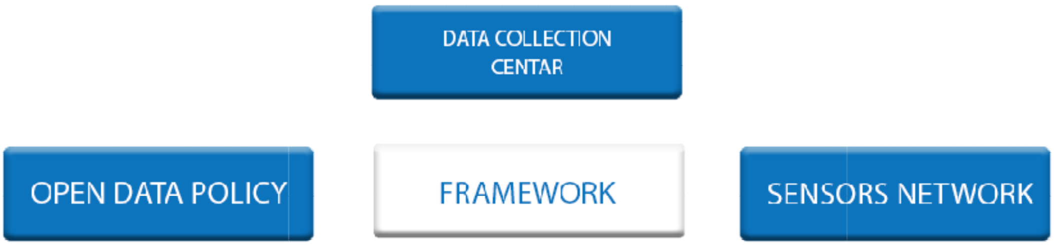

Figure 3.3: Experimental Framework

3.3 Functionalities

The system has the following functionalities:

- Possibility of intelligent street lighting management, as soon as significant energy savings are achieved
- Remote control of each individual streetlamp, which can work in multiple modes: ON, OFF, Dimmed (adaptable, 10% -100%)
- Working according to predefined rules, so that certain parts of the day apply a different predefined mode of operation (all bulbs are turned on at 19:00 and turn off at 7:00, e.g.)
- The ability to manage street lighting based on sensor signals installed on the pillar of street lighting and whose role is the detection of the level of illumination and motion detection. The possible scenario is as follows: All the bulbs go off when no motion is detected. Movement sensors are placed on each pillar of street lighting and detect movements on the surface beneath the pillar. After the movement is detected, only certain bulbs are turned on, while the others work in a different mode of operation (either is turned off or dimmed at 10-30%).

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- Gateway collects data from the end devices (sensors, controllers) via the LoRaWAN network and forwards them further via Ethernet, mobile GPRS or any other telecommunication (wire or wireless) connection to the network server.
- The network server processes all incoming data eliminates duplicate packets, adjusts data transfer rates and sends certain data packets to the application server.
- Based on the received data, the real-time image of the complete system is generated through the software application and based on these data can perform certain actions through the user interface of the application installed on the application server.
- The system also supports the mode of operation in fully automatic mode.

The smart system creates many direct and indirect benefits for the City of East Sarajevo and helps the City government to optimize the resource allocation. The benefits of the system are as follows:

- Provides full control over the street lighting system
- Enables significant energy savings
- Fully scalable
- Supports the use of equipment of different manufacturers that are compatible with the data transfer standard used
- Enables full control of each individual module of the system
- Extensible with additional sensors and management network
- Most software solutions are not limited to the number of sensors
- Data uses standard protocol but also can be connected to any telecommunication network
- The LoRaWAN network has a very large bandwidth and availability, low power consumption, good indoor coverage and a good data protection mechanism.

3.4 Communications System Architecture

The Smart Public Lighting system is a complex system, where the communications system acts as a backbone. The communications system is designed to serve the Smart Public Lighting system now, but it is also geographically expandable and scalable for any future needs. The basic concept of the communications for enabling smart city services is to combine LPWAN technologies (e.g. LoRaWAN) and widely deployed WiFi with the mobile systems (e.g. 4G-LTE now, and 5G in the future).

The implemented topology is mesh with preference to deploy one additional gateway in the future for the purpose of redundancy and load balancing what increases the availability and performances of the system.

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LoRaWAN network architecture is deployed in a star-of-stars topology in which gateways relay messages between end-devices and a central network server. The gateways are connected to the network server via standard IP connections and act as a transparent bridge, simply converting RF packets to IP packets and vice versa.

The system consists of end device (sensors, controllers), network (LoRaWAN connection for communication between sensors/controllers and gateway and IP connections for communication between the gateway and network server), gateway and a network server.

The main advantage of the LoRa network is that it allows the connection of an unlimited number of end devices, has a wide range of coverage with minimal power consumption.

In addition to covering large surfaces and having low power consumption, LoRa has deep coverage within buildings and a good data protection mechanism.

Some of the other advantages of LoRaWAN[1]:

- It uses 868 MHz/ 915 MHz ISM bands which is available worldwide,
- It has very wide coverage range about 5 km in urban areas and 15 km in suburban areas,
- Single LoRa Gateway device is designed to take care of 1000s of end devices or nodes,
- It is widely used for M2M/IoT applications,
- LoRaWAN supports three different types of devices viz. class-A, class-B and class-C.

Basic features of LoRa are displayed in theTable 3.1:

Table 3.1: LoRaWAN, Basic Features

Feature	LoRaWAN	Narrow-Band	LTE Cat-1	LTE Cat-M	NB-LTE
Modulation	SS Chirp	UNB/GSK/BPSK	OFDMA	OFDMA	OFDMA
Rx Bandwidth	500-125 KHz	100 Hz	20 MHz	20-1.4 MHz	200 KHz
Data Rate	290 bps-50 Kbps	100 bit/s 12/8 bytes max	10 Mbps	200 Kbps-1 Mbps	20 Kbps
Max Output power	20 dBm	20 dBm	23-46 dBm	23/30 dBm	20 dBm
Battery life time	105 months (≈ 9 yrs)	90 months (7.5 yrs)		18 months (1.5 yrs)	
Link budget	154 dB	151 dB	130 dB+	146 dB	150 dB
Security	Yes	No	Yes	Yes	Yes

[1] LoRaWAN standard

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One of the disadvantages is that the LoRaWAN network size is limited by a parameter called a work cycle. It is defined as the percentage of time the channel can occupy. This parameter derives from regulation as a key limiting factor for traffic that serves the LoRaWAN network.

For some applications e.g. Air Quality sensor, WiFi is chosen because of practical reason in the implementation area.

All applied solutions are transparent for the end user and they are not aware of the communications systems at all or any parts of it.

3.5 Operational Plan

The Operational Plan described the implementation path, pilot goals and predict the types and quantities for each component for the future implementation phase. With reference to the Operational Plan, initial system is designed to contain following components and quantities:

Table 3.2: Operational Plan, Bill of Material

No.	System Node	Number of Nodes
1	Gateway	1
2	Controllers	10
2.1	▪ Including	
2.2	○ Photocells (light intensity) sensor (optional) ○ Motion Detection sensor (optional) ○ Air quality sensor (with sensing ability for CO, CO2, Particles, etc.)	
3	Poles (existing)	10
4	Bulbs (existing)	20

The general technical requirements for each component are planned to ensure future extensions, scalability, interoperability and maximizing the performance and effects for smart city services, not only for the Smart Public Lights, but also for any future projects. Most of the components, including the communications system, could be used for additional services without any additional costs in the same area of the pilot implementation. The system is, for this purpose and higher reliability, oversized approximately 20%.

The Operational Plan for the smart public light system implementation should define a few phases:

1) **Phase 1.** Define general-purpose components of the system, as the telecommunications infrastructure and city data center, in general but also the minimum operating level for this smart service; the minimum operating data center, for the storing and analyzing collected data, and the minimum throughput for the telecommunications system for transfer collected data from smart public light nodes to city data center from the smart public light system, have to be

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upgradeable in the future for new smart services and bigger amount and different format of collected data;

2) **Phase 2.** Define service-specific components, what means sensors and the data types which are recognized as useful for the city monitoring and decision-making.

Both phases could be implemented at the same time, but it has to be ensured that the subsystems don't lose interoperability.

Table 3.3: The Pilot Implementation Timeline

	Technology and Market Analysis	Public Call for the Equipment	HW Installation	SW Installation
Phase 1	15 days	30 days	7 days	7 days
Phase 2	15 days	30 days	7 days	7 days

One side of the general approach for the smart cities' implementation is to create the City Energy Plan what is related with energy efficient cities governing, including public light service as one of many of them.

In the period of the pilot implementation, the City of East Sarajevo doesn't have the City Energy Plan nor the Smart City strategy, so the pilot is designed independently with the perspective for an alignment when these official documentsare adopted.

As a general direction for the City Energy Plandeveloping, ithas to contain and describe directions and goals for the future and actual communal projects in the city focused on energy saving project and urban sustainability for longer period, as it follows:

1. Reduce total energy consumption: strategic directions and prioritization for public projects and call for private-public partnerships
2. Encourage energy conservation in residential, commercial, industrial, public and transportation sector
3. Increase opportunities to make energy choices at the local level; assure diversity in the mix of energy sources to minimize the impacts of supply restrictions in any part of the city and to decrease the reliance on non-local energy sources through conservation and development and use of local renewable energy sources

Related to the goal noted in (2), it is critical that the city government ensures optimal management of the public light service.

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The building of a smart city needs a clear and planned strategic approach with defined priorities. The project of a smart city is a long-term project and it should be implemented in a few phases. The implementation and the strategy have to define two types of actions:

- **general infrastructure**, which is common for all or at least for the most of public services and which has to be interoperable, scalable, technologically neutral and compatible backwards and forwards in technology timeline evolution;
- **service-specific infrastructure**, which is related to one or just a few of public services and which could be planned locally in a geographical mean or in the short-time time frame.

From the perspective of this project related with the smart public light system, there are examples for general and service-specific infrastructure/subsystems which have to be implemented, especially in the case that the smart public light system is first smart service in the city. There are 3 subsystems which have to fully operate to ensure the function service of smart public lights:

- **Sensors System**, to gathering data about consumption, local light node parameters, environmental conditions (including natural light level, optionally air quality sensors co-located with smart public light nodes or at least some of them). For the pilot implementation, the sensor network is developed for the area of the Dabrobosanska Street in the Municipality of East Ilidza and the collected data can be used for any purposes and future smart services.
- **Telecommunications Infrastructure**, to transport the collected data from the collecting location to central data center of the city (or at least in one of them – at least two of them for redundancy, in case of distributed analytics system); telecommunication system is a general purpose infrastructure which should be planned to service smart public light system but also new smart services in the future; it could be designed as a combination of proprietary infrastructure of the city (higher investment in the starting phase for later less monthly costs) and public commercial telecommunication infrastructure (mobile networks of telecoms, fiber-optic infrastructure etc.) in wired and wireless medias if it is necessary. For the pilot implementation, the telecommunications network is established as a backbone for any future smart service or even free public Internet access and many other public services. The current usage of the system is less than 10% of the total system capacity for the required QoS.
- **City Data Center**, to store collected data, to select, separate and classify them, to analyze and to support optimal decision making or automatic decision making by machines. For the pilot implementation phase, the Data Center is developed by very limited budget and aligned with the real needs for the single running smart service for the moment.For the future applications and new smart services, it is necessary to expand and enhance the capacity system with the plan for creating the multi-server clusters or blade systems for loading the virtualization and other advanced techniques. The current state of the Data Center in the City of East Sarajevo nor the Data Center in the Municipality of East Ilidza cannot provide a proper CPU, storage or communications capacities for the full running Smart City system with tens different smart services in the area of the City.

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The implementation has planned to finish within 4 months and the process was done within 3 months in the beginning of 2019.

Figure 3.4: The Pilot Implementation Steps

When the system is deployed in the production, the system worked in the testing phase for 15 days, to resolve all bugs and misfunctions in HW and SW components.

After the implementation of the pilot project, it was necessary to validate and verify reaching predefined goals, to clarify all benefits and revenues.

3.6 On-Site Implementation

Regarding the fact that current location and urban plan for this area is under the control of local authorities, the pilot description didn't allow to change the existing conventional luminaires with very specific and unique design and enhanced them with modern LED luminaires.That is the reason for some an extra effort and equipment for the realization of this pilot.

For the reason of existing non-dimmable bulbs, during the installation process, it was necessary to use additional devices called Driver for voltage regulation.

The Smart Public Lighting system is enhanced with the Air Quality sensor for the demonstration purpose of the co-existing smart services with service-specific resource but also which share the general-purpose infrastructure as the telecommunications backbone subsystem in the same area of implementation. This additional and optional service is very interesting from the perspective of the citizens because of usual weather conditions in East Sarajevo, especially in the winter period, what is important additional benefit for the pilot.

After the analysis of the real condition in the area, with all limitations and obstacles, with the goal of maximizing the effect and visibility of the pilot from the perspective of benefits for citizens, local government but also industry and academy, it planned to deploy the equipment with quantities, as it follows in the Table 3.4:

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Table 3.4: Implementation Report, Bill of Material

No.	System Node	Number of Nodes
1	Gateway	1
2	Controllers	16
2.1	▪ Controllers with Motion Detection (command node)	4
2.2	▪ Controllers without Motion Detection (follower mode)	12
3	Poles (existing)	16
4	Bulbs (existing)	32

With this approach, the whole area of walking zone in the Street Dabrobosanska is covered by the Smart Public Lights system what creates the unique and whole subsystem which can correspond with any future smart subsystems from this service or any new smart service in the City of East Sarajevo.

As it is noticed in the Table 3.4, the short description with technical details and function for each device types is given as it follows.

The Gateway is a central node to which all other nodes (end-devices) are connected and gateways serve as the transparent bridge relaying messages between end-devices and a central network server in the backend. Gateways are usually connected to the network server via standard IP connections while end-devices use single-hop wireless communication (creating communications "chain" path) to one or many gateways. All end-point communications are bi-directional, and support multicast and software upgrades "over-the-air".

Gateway	Quantity
▪ Wireless Network: 2.4 GHz ▪ Communication protocols: min. WiFi, Ethernet, 2G, 3G ▪ Expandable with: LoRaWAN ▪ Input Voltage: 85-264 VAC, 50 Hz ▪ Power consumption: < 8 W ▪ CPU: min. 1.0 GHz ▪ Operating temperature: -20°C - +60°C ▪ Data storage: min. 4 GB ▪ Housing: min. IP65, Waterproof, outdoor installation ▪ Compliance: RoHS, CE, EN 301489, EN 61547, EN 55015, EN 60950	1

The Controller on each streetlight lamp (up to 400W) to allow for individual remote control. The controller's role is to carry out turn on, turn off and operations for dimming light. These controllers have autonomy in operation, working through pre-defined rules (timing of ignition and extinguishing), or based on signals received through a digital input from, for example motion sensor. For data transfer use minimal bandwidth and support advanced data synchronization and notification mechanism.

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It the implementation and related to the existing distribution of streetlight poles, it is preferred to create the chain with one-hop distance communication to save the energy and in that circumstances, it finds the best solution to combine two types of controllers: the leading ones, with motion sensors, and followers, without motions sensors,which wait and follow the trigger information from the leading one which is associate with the group of followers. In the pilot, it used one leading controller associated to 3 additional following controllers, what operationally means that the motion trigger on the motion sensor in the leading one, creating the reaction of that leading controller and 3 additional following controllers in the row. From the perspective of the quality of service this could be even benefit because the trigger wakes up the part of street illumination what creates perception of better illumination increasing the light level and positively affects the citizens perception of security and safety compared to waking up only one streetlight pole with 2 bulbs.

Controller, with Motion Detection sensor (“leader”)	Quantity
▪ Power consumption: < 3 W ▪ Motion Detection: pedestrians, cyclists, cars ▪ Detection Range: 15 m on each side, 9 m front ▪ Detection Angle: < 270° ▪ Able to trigger 1-10 neighboring lamps upon motion detection ▪ Input voltage: 230 V, 50 Hz ▪ DALI[2] Loads: min. 1 ▪ Dimming Control: 0-10 V or DALI ▪ Surge Protection: 6 kA ▪ Operating Temperature: -20°C - +60°C ▪ Housing: IP65 ▪ Astro Clock: battery backed real-time clock ▪ Wireless communication: 2.4 GHz, IEEE 802.15.4. self-forming self-healing wireless network ▪ Safety mode: YES (Auto safe)	4

Controller, without Motion Detection sensor (“follower”)	Quantity
▪ Power consumption: < 3 W ▪ Input voltage: 230 V, 50 Hz ▪ DALI Loads: min. 1 ▪ Dimming Control: 0-10 V or DALI ▪ Surge Protection: 6 kA ▪ Operating Temperature: -20°C - +60°C	12

[2] DALI (Digital Addressable Lighting Interface), EN 60929 (until 2009), IEC 62386 (2009 - now)

▪ Housing: IP65 ▪ Astro Clock: battery backed real-time clock ▪ Wireless communication: 2.4 GHz, IEEE 802.15.4. self-forming self-healing wireless network ▪ Safety mode: YES (Auto safe)	

Sensors will be installed on each pillar of street lighting. The main role of the motion sensor is to detect movement and send a signal that it is necessary to turn ON/OFF the bulb. The idea is that the bulb under which the detected object is operating in 100% mode, while the other bulbs work in the mode of 10 or 30%. It can also be set to ensure that all streetlamps are bright in automatic mode of 10% at a certain time of night, when the assumption is that there will be neither passers nor vehicles to fall after the motion sensor notices movement.

Air Quality sensor is additional enhancement for the Smart Public Lighting system which is not in the focus of this system and acting as an additional benefit and the proof-of-concept for future smart services co-existing in the same area.

Air Quality sensor	Quantity
▪ Built-in WiFi ▪ Communications Protocols: WiFi 2.4 GHz (IEEE 802.11 b/g/n) ▪ Dual-laser Counter ▪ Weather Measurement: Temperature, Humidity and Pressure ▪ Particles Measurement: PM1, PM2.5, PM10 ▪ Operating temperature: -20°C - +60°C	1

Existing *High-pressure Sodium* (HPS) bulbs[3] are not dimmable, so they had to find and adjust them with special drivers. Formal limitations of the project did not allow to change existing bulbs with dimmable ones or new models based on LED technology. Firststep of the implementation was to find corresponding driver which will allow the system to dim HPS bulbs in luminaires. This adjustment enabled option to control the dimmability of existing bulbs in the project proposal conditions. The solution was found in the commercial PHILIPS HID-DynaVision Programmable driver, it was possible to proceed with the project.

Driver	Quantity
▪ Input Voltage: 208-277 V ▪ Power Factor: min. 0,95 ▪ Rated Power: 70 W ▪ Power Loss: max. 8 W	32

[3]HPS 70W, UnknownVendor

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▪ Operating Temperature (min): -30°C - +50°C ▪ Regulating Range: 30% - 100%	

Figure 3.5: Phillips HID-DV Driver

On the image down below, it finds the technical schematic for the Philips HID-DV wiring diagram.

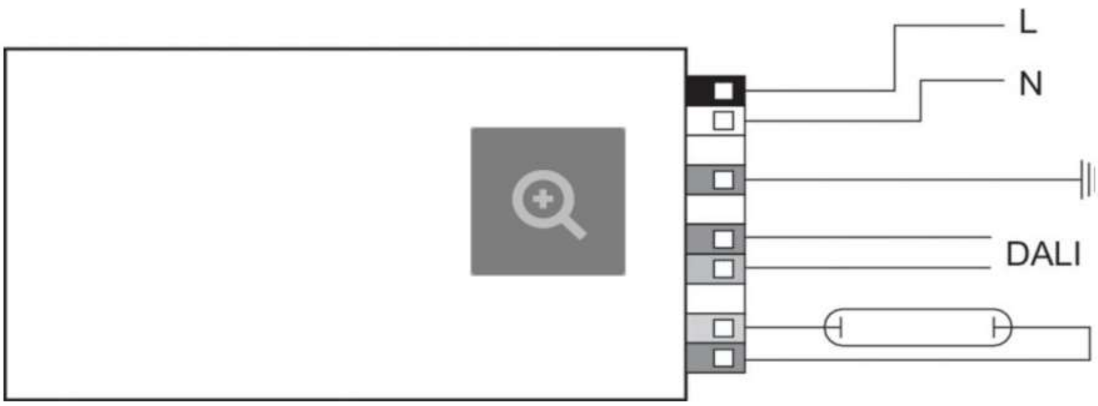

Figure 3.6: Phillips HID-DV Wiring Diagram

After adjusting conventional luminaires with HPS bulb with special drivers, the system was ready to start implementing smart functions of the Smart City project.

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Figure 3.7: On-Site Implementation on Conventional luminaries with HPS bulbs

3.7 Data Centers

The existing public lights system in the City of East Sarajevo is a conventional old-fashion system with very low or not-at-all modern ICT-driven solution present. It means that there is no any bidirectional transfer of information on current state of the system to any of potential stakeholders in the process of the City public services management. Some and very limited overview of the state of the system exists in the power company which monitors its system from the aspect of power flow and state estimation perspective.

The existing system is currently designed to work with predefined schedule in manual or semi-automatic mode with limited installations of photocells in some location which can regulate timing of the system turning on and off. In some plans for the future implementations and in very limited current implementations, there is an option for remote control of the system. Both solutions are very limited on

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conventional framework of the public lightswithout any autonomous self-regulations, collecting data and sending feedback to the operating centers.

The new system, which is implemented in this project, is enhanced by intelligent data-driven self-regulating mechanism and with smart response to citizens habits and profile of their needs should deliver the optimal quality of service increasing the total efficiency of the system driven on automatized decision making based on data-driven decision from the data center. The system is connected in bidirectional communications mode with the data center(s) where the collected data is stored for the analysis and calculating optimal decision as a response on real needs in the real-time. That means that the data driven decision making can deliver the maximal the Quality of Service and the Quality of Life for the citizens against the power consumption and environment degradation. This trade-off is possible by collecting the relevant group of parameters for deterministic mathematical-based computations.

The key data to be collected are: current state of the weather, daylight period depending mostly on the period of year but in some also on current weather state, intensity of presence of pedestrians and traffic in the location, profiling citizens habits by hours (intensity is lower during the night hours, e.g.), days (citizens are more active during weekends, e.g.), months (citizens are more active during the summer period, e.g.) where some presumptions could be proven on collection of exact data.

In the case of a local community in East Ilidza, there is the official data[4] about existing public light nodes for the whole municipality:

- number of public light nodes: 1550
- energy consumption per year: 1.163.398 kWh
- energy costs per year: 188.948,00 BAM (approx. 96.550,00 €)

For the pilot project chosen a location, the square Veljine – walkzone in the Street Dabrobosanska, there is a specific data:

- technical data for the energy company: measurement place Dobrinja 1 (energy meter located in the building Megaprojekt)
    - number of streetlight poles with 2 light sources (bulbs): 16
    - total number of light sources: 32 (16x2)
    - energy cables length for the public light nodes: 272 m
    - each node is metal pole, height 7 m
    - the public light system in the location Veljine works in the automatic working regime

[4]Source: webpage of the municipality East Ilidza, www.istocnailidza.net

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- in case if we consider the average number of working hours per day during the year is 12 hours per day, the total number of working hours per year per light source is 4380 hours; following the official data, in the location Veljine, there are 32 light sources with nominated consumption 70 W per light source (Na-type, old technology)

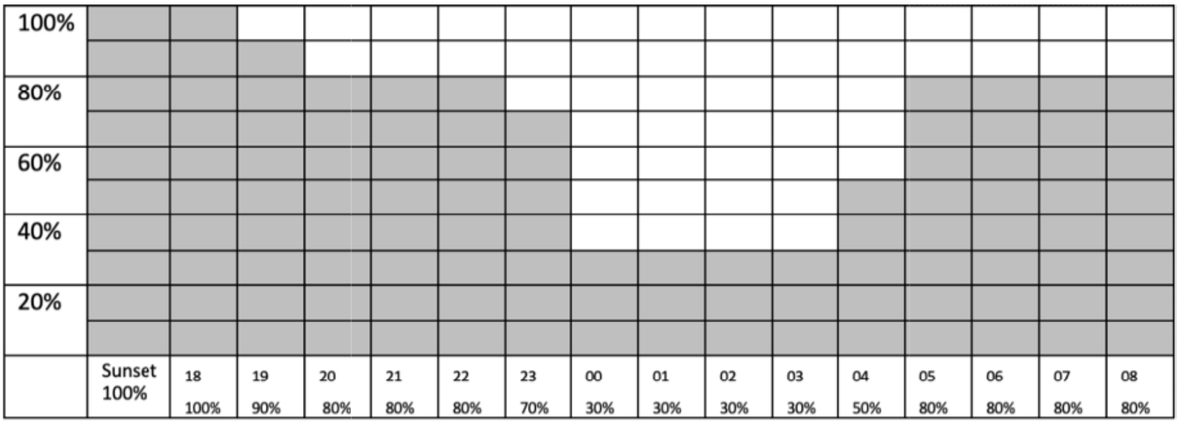

Figure 3.8: Winter Schedule for Smart Lights Dimming mode – initial state

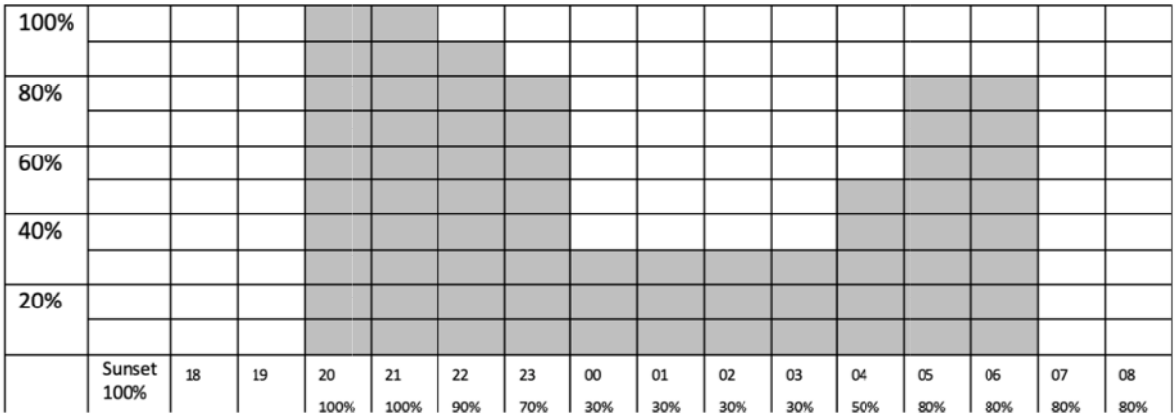

Figure 3.9: Summer Schedule for Smart Lights Dimming mode – initial state

From figures above, Figure 3.8 and Figure 3.9, it is possible for create the business model which proves the financial effects for energy savings, as it follows:

Table 3.5: Basic Business Model for the Pilot based on the Initial State

	Number of Light Sources	Light Source Type	Power (Consumption)	Cost/kWh	Consumption/year	Costs/year [€]
Existing State (Non-Smart)						

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1.	16	Na	0,07 kW	0,08 €	5,034 kW	402,72 €
Savings using Smart Monitoring						
2	16	Na	0,07 kW	0,08 €	3,095 kW	247,60 €
Total Savings						**155,12 € (38,51%)**

Winter Dimming Schedule (16-hours working model) presents a default level of light in case that there is no vehicles or walkers around the light source. This "smart" approach ensures that the consumption is decreased from 5,034 kW to 3,095 kW, what means 38,53%. For the local system in the location Veljine, it means that the smart control of the system can save 155,12 €. There are a lot of secondary benefits for the environment. The implementation of "smart" features in the location Veljine, it is saved the ecological equivalent of 36 planted trees and 2 tons of CO_2.

Summer Dimming Schedule (11-hours working model) presents a default level of light in case that there is no vehicles or walkers around the light source. This "smart" approach ensures that the consumption is decreased from 5,034 kW to 2,709 kW, what means 46,18%. For the local system in the location Veljine, it means that the smart control of the system can save 186,00 €.

The total effect prediction of implementation of the ICT-driven Smart Public Lights are planned to have achievement no worse than decreasing the power consumption up to 38%, decreasing air pollution up to 150%, decreasing the light pollution up to 300%, all depending on very local current state and the level of implementation of all intelligent functions.

The initial results of the project started with the energy saving 41% and continually **increasing on monthly basis by 1%**, reaching **current level of 46%** using advanced algorithms for self-regulating.

The software for analyzing the collected data updating financial and environmental benefits for the current state of energy saving and the total saving for the period from the beginning of installation until now. It is possible to count and predict the time for the return investment which can vary depending on the current state of energy savings.

Beside primary benefits, there are many secondary and tertiary benefits of the Smart Public Lighting System implementation. The collected data is going to be defined as an Open Data under Creative Commons license, what means that the data or at least some part of them could be publish and made available to analyze from the third-party subject including many upcoming start-ups related with new and smart ICT-based solution in hardware and software topics what directly effects the entrepreneurship ecosystem and effects the economic growth in the City. With approach, the City canbenefit in many directions with the model based on the Open Innovations 2.0 (Quadruple Helix model)which is defined model for the EU HORIZON 2020 projects.

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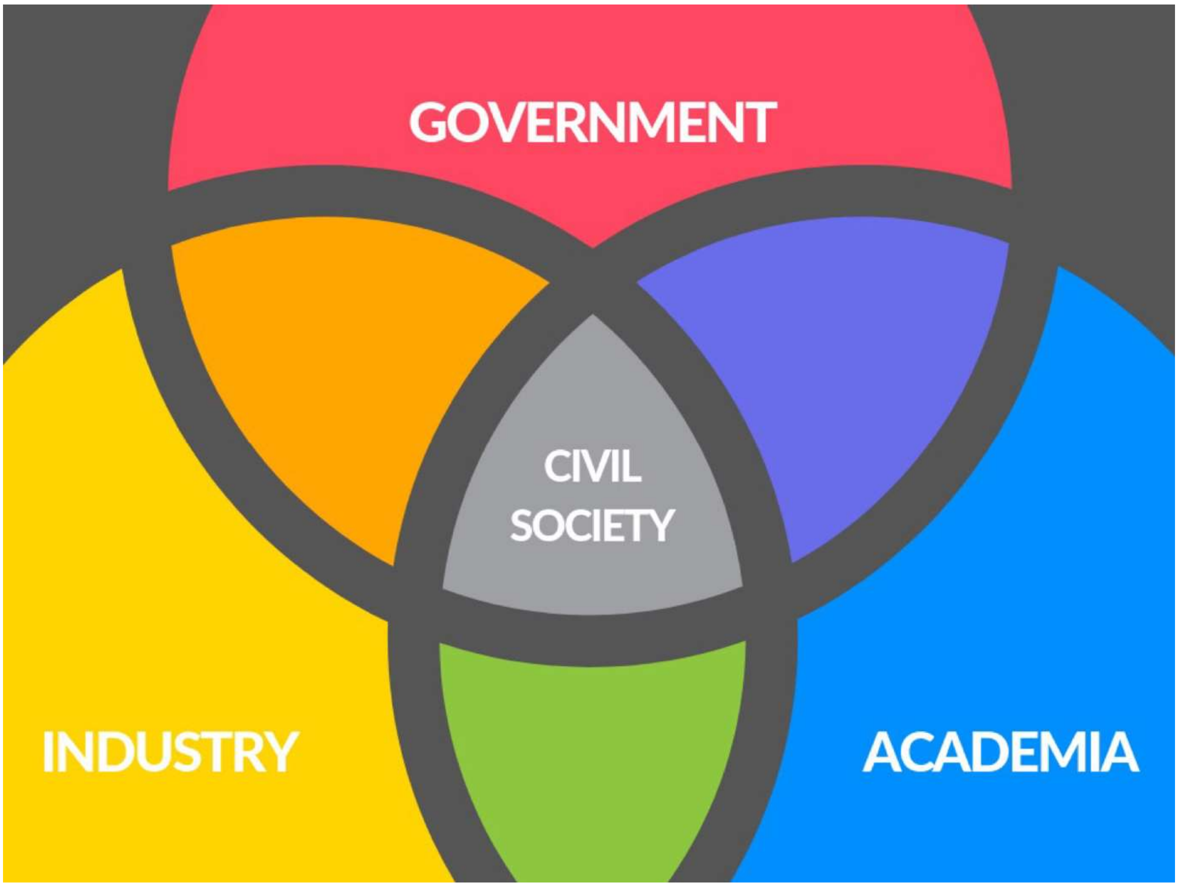

Figure 3.10: Open Innovations 2.0 model - Quadruple Helix, in the EU HORIZON 2020

3.8 System Management, Data Collection and Analytics

The system of Smart Public Lights in the City of East Sarajevo has 2 data centers: the main one located in the official building of the Government of the City of East Sarajevo, where is located the Development Agency East Sarajevo, and redundant one located in the official building of the Government of the Municipality of East Ilidza. Both data centers are identical with the same function, management control and collected data in the real time.

The data center is designed to provide the full overview of the Smart Light system, statistics, trends and to analyze the collected dataset for current and future optimization in manual and automatic decision making and resources management. Some of functionalities of the Data Center and its software solutions are presented in the following figure taken from the operating system after the implementation.

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In figures Figure 3.11 - Figure 3.20, it is presented the Data Center functionalities related to the primary pilot service the Smart Public Lighting, and in figures Figure 3.21 - Figure 3.23it is presented the functionalities of the additional smart services the Air Quality Monitoring which is co-located with the primary one in the same area of the installation.

The main screen is the dashboard with the most important general system information. On the Dashboard, it is possible to verify the current level of energy savings in kWh together with the current level of energy consumptions, equivalent CO2 decreasing, the number of installed gateways and controllers in the system and their operating status and eventual misfunctions.

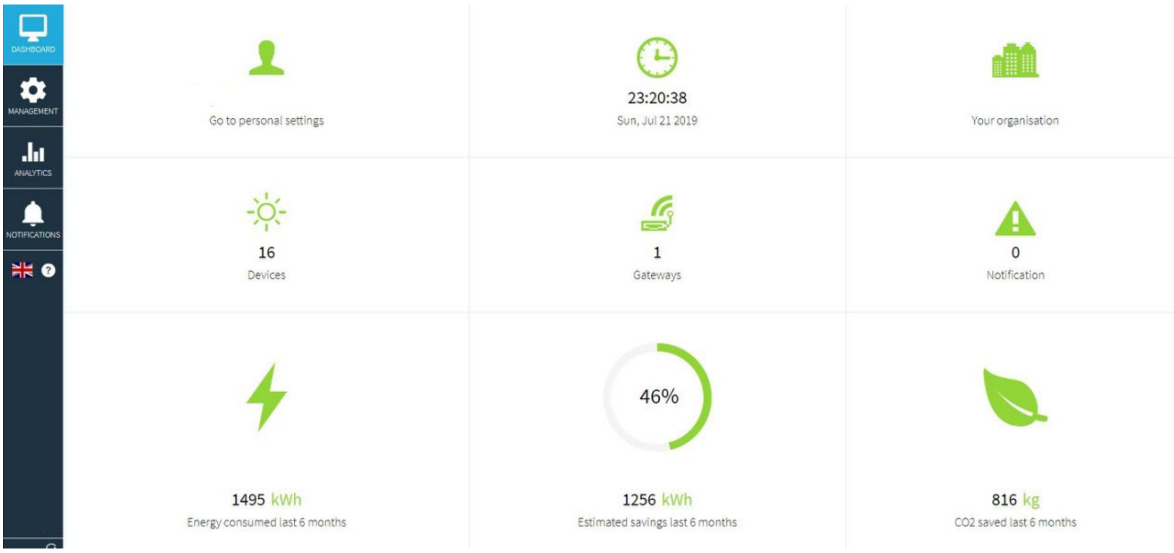

Figure 3.11: Data Center, Dashboard screen of the management software

Some of additional options in the Data Center is geographical overview of all installations with precise GPS locations and visual status report in the real time, as it follows in the next 2 figures: Figure 3.12 and Figure 3.13.

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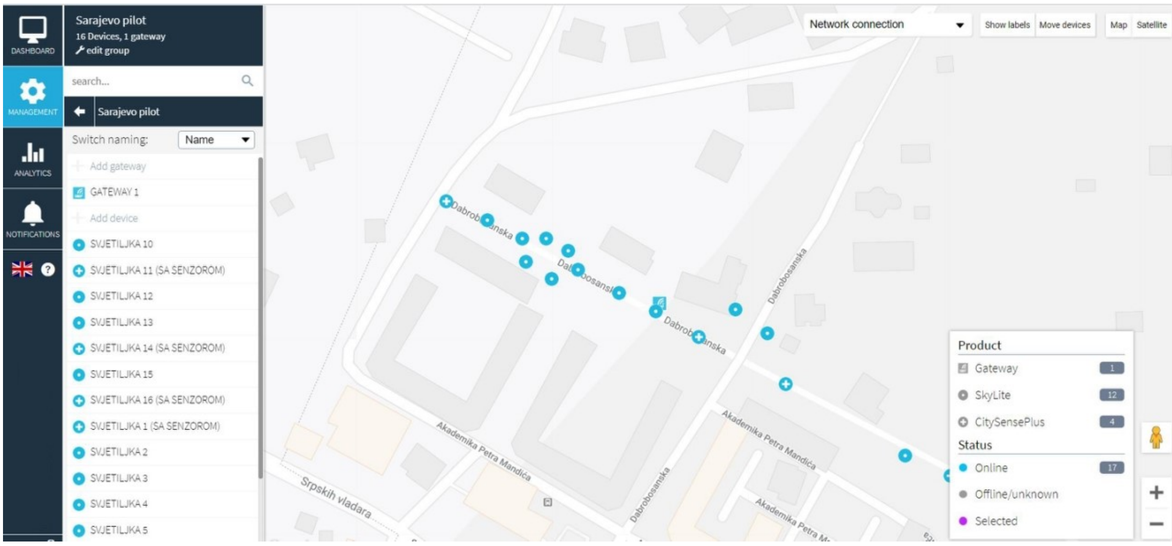

Figure 3.12: Data Center, GPS locations of each single controller (poles, bulbs)

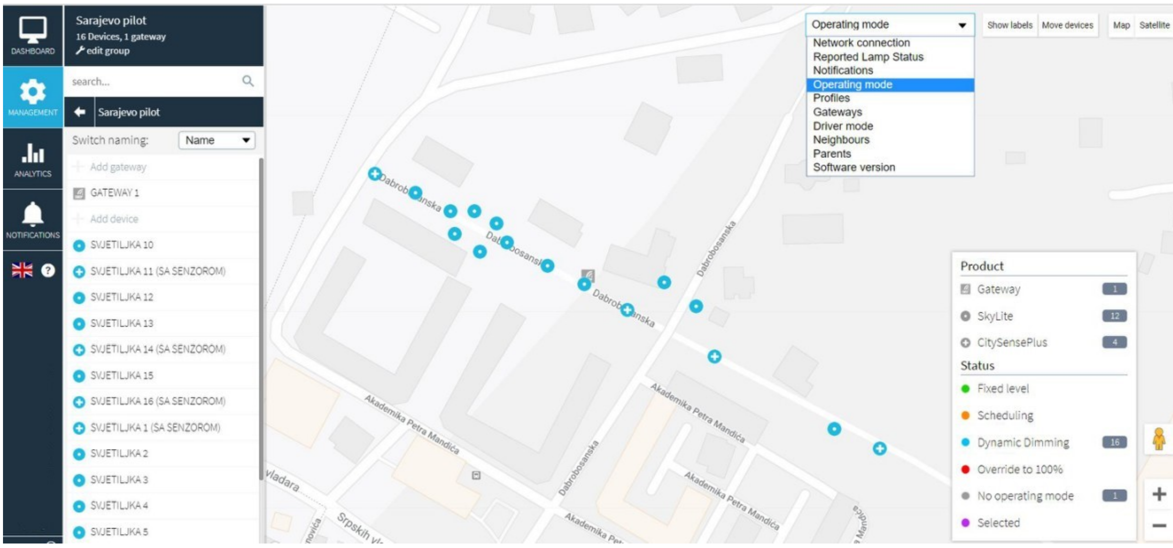

Figure 3.13: Data Center, Monitoring functions

The Data Center presents the result of the data analysis in the form of data-driven self-regulation and optimization, what causes the action which changes the original dimming schedule. This current schedule is result of the analysis of the citizens habits, including pedestrians and cars moving for days in a week, week in a month or some specific part of a year. The simple model explanation is finding optimal working regime for the maximum energy saving against less dimming actions as possible

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(toavoid bulb damaging and decreasing bulbs lifetime). Some other parameters are also in the calculations, but the figure describes only the basic level.

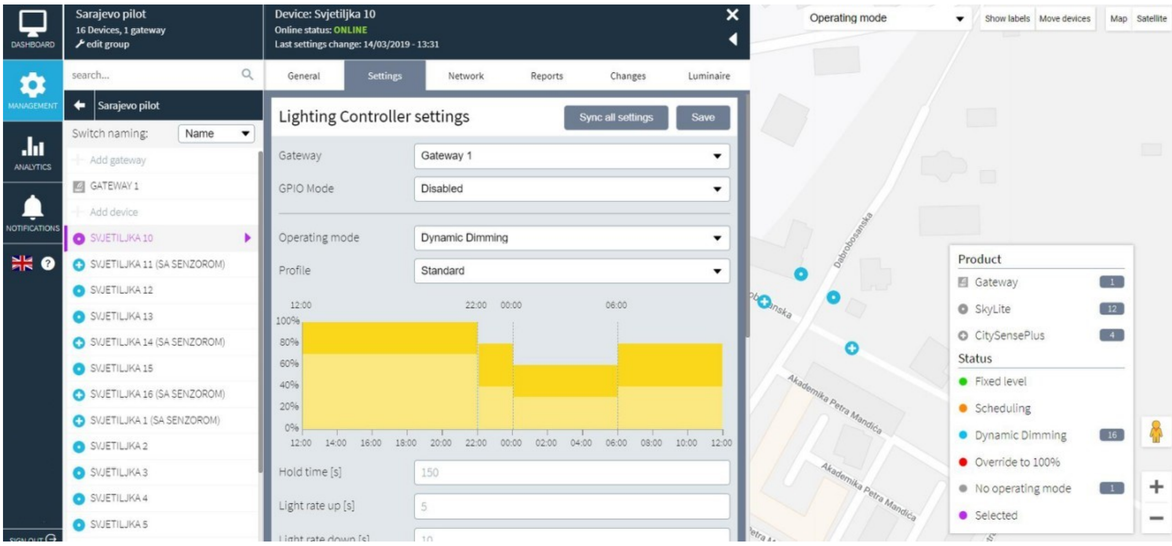

Figure 3.14: Data Center, Current Dimming Schedule after data-driven Self-Regulation

Data Center also provide detailed statistic about each single bulb, including their working hours, dimming actions, exact date and time for each action and the log information based on external triggers, automatic commands from the Data Center and errors.

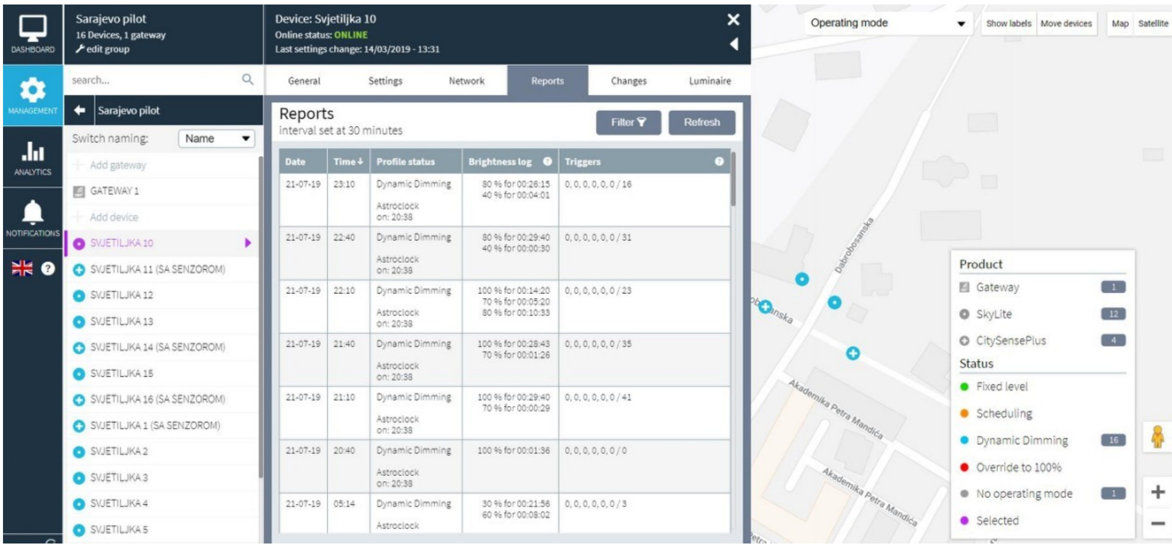

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Figure 3.15: Data Center, Statistics for each single bulb

Data Center provides details general statistics of the system efficiency, presenting the information on energy saving, energy consumptions on daily or monthly basis, with trendline and prediction for coming days or months. The following figures are clear proof for the self-sustainability for the smart lights system and around these data is possible to calculate the business model for any future projects.

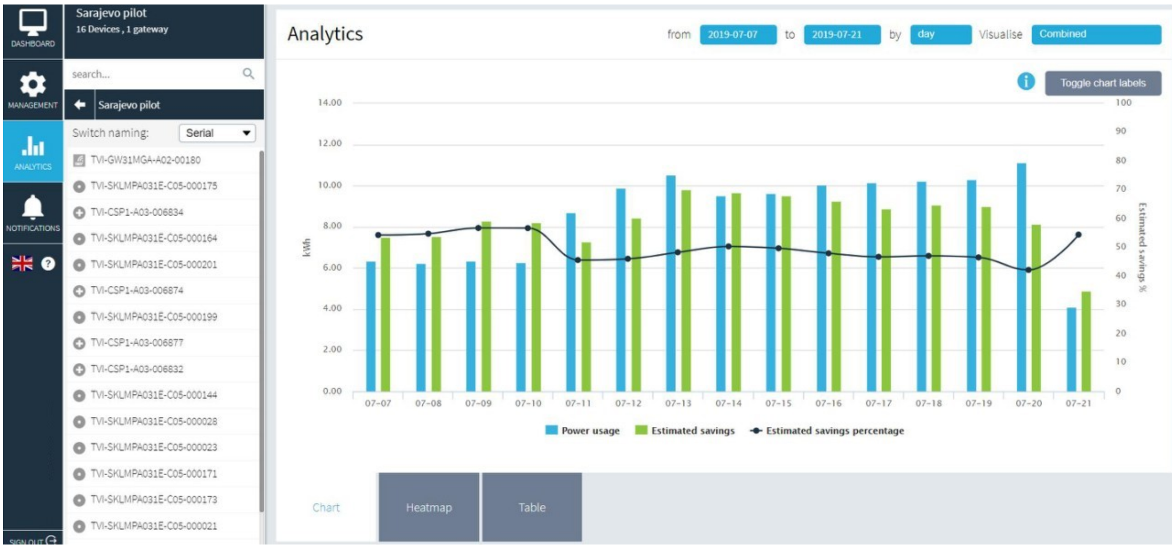

Figure 3.16: Data Center, Statistic on Daily Base with trendline and predictions

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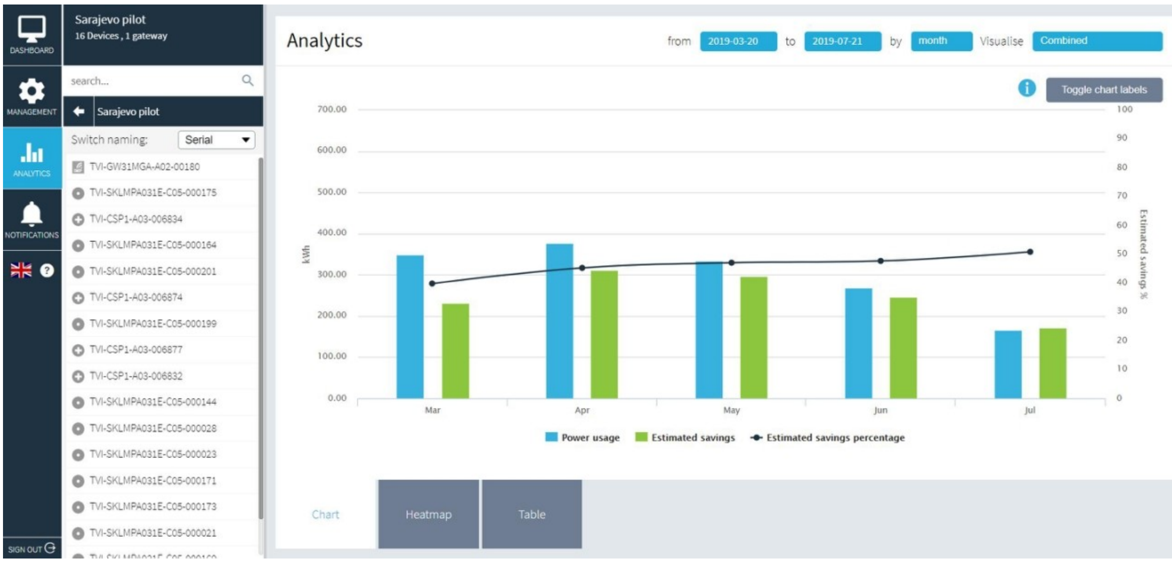

Figure 3.17: Data Center, Statistic on Monthly Base with trendline and predictions

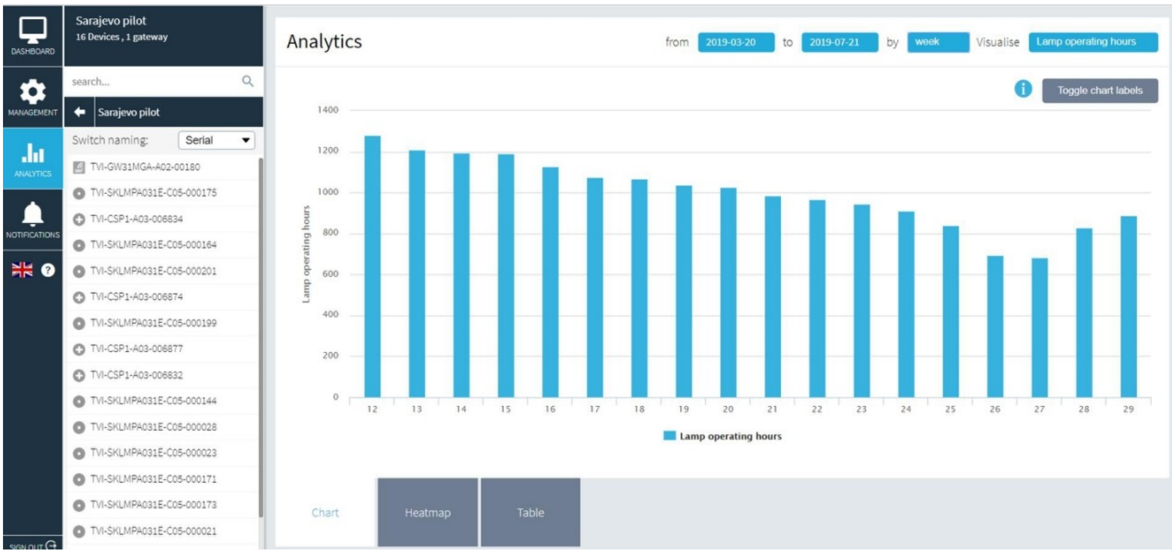

Figure 3.18: Data Center, Statistic on Bulb Operating hours

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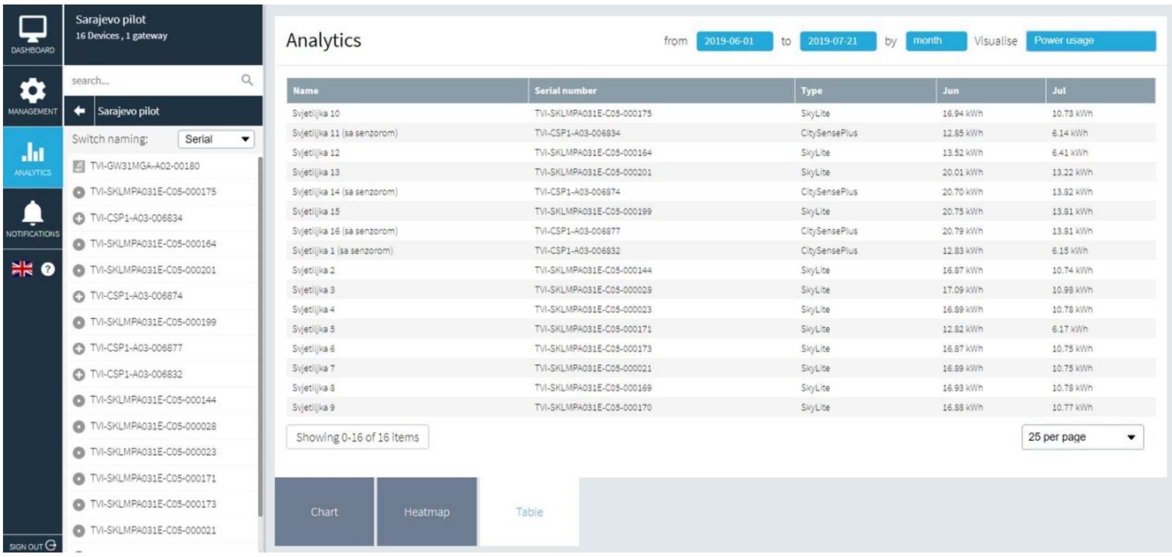

Figure 3.19: Data Center, Status for each single bulb

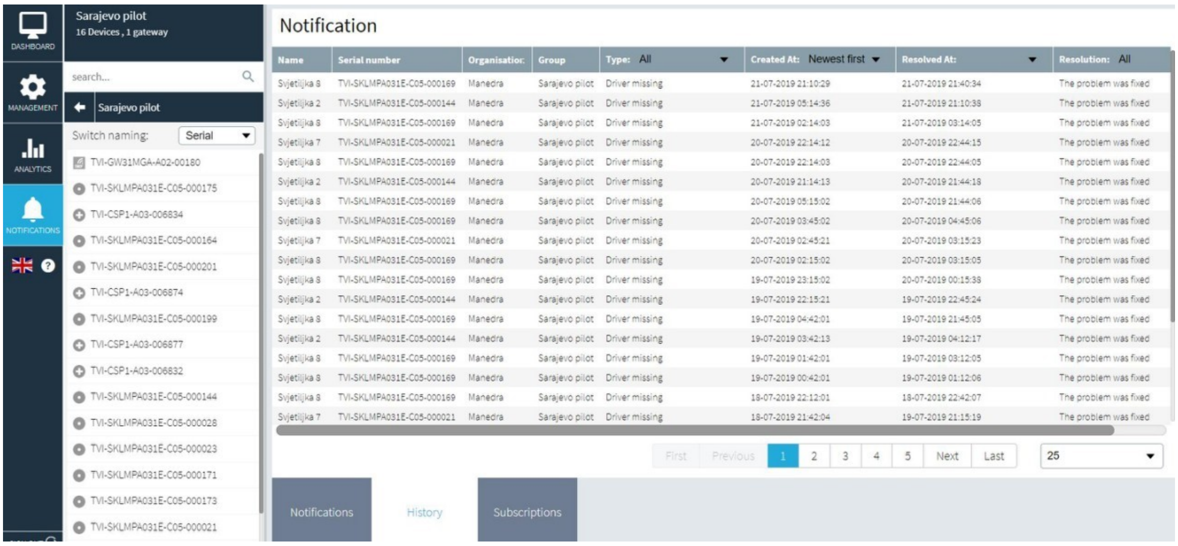

Figure 3.20: Data Center, Notifications and Error information for each single bulb

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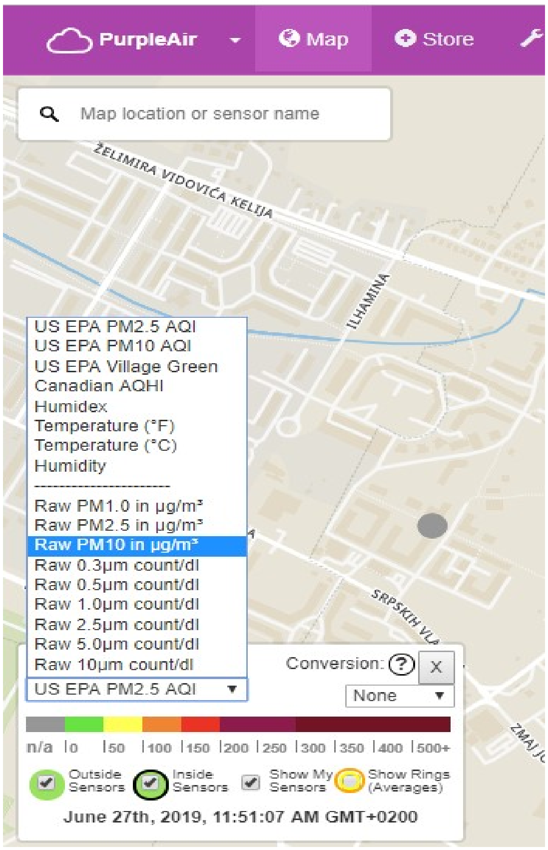

Figure 3.21: Air Quality Monitoring Sensors, Menu and Options

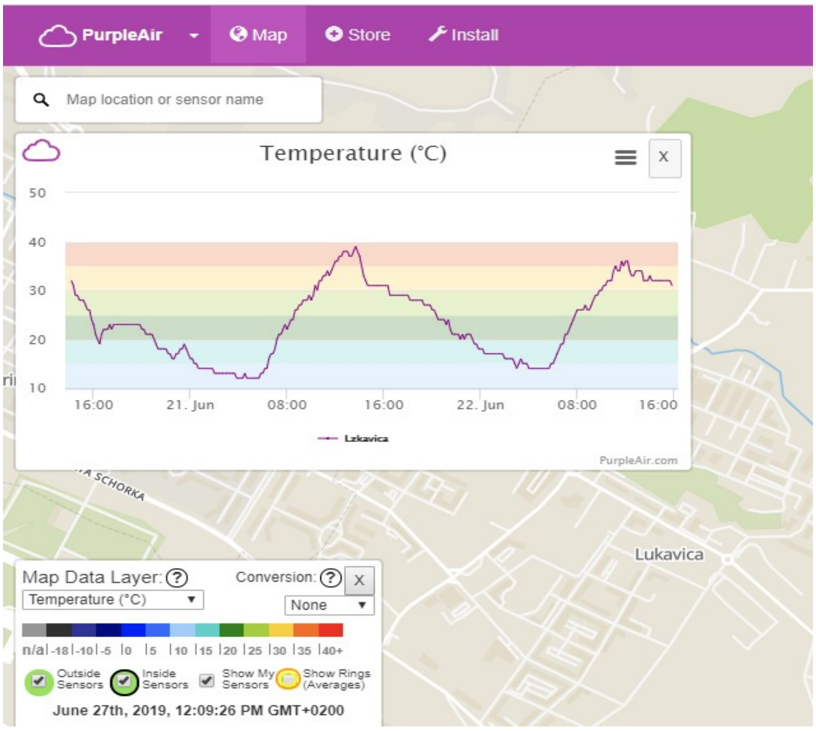

Figure 3.22: Air Quality, TemperatureMonitoring (real-time with history)

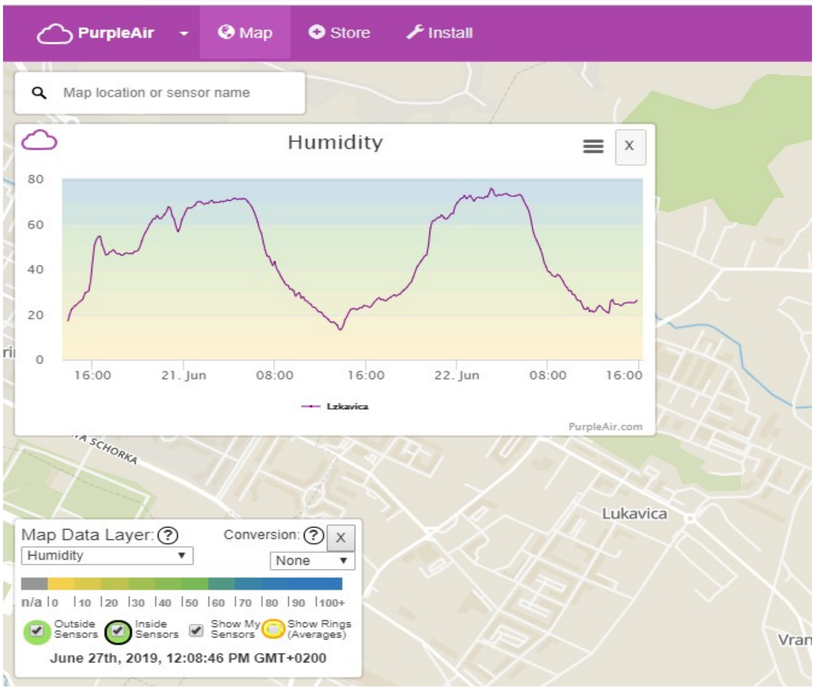

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Figure 3.23: Air Quality, Humidity Monitoring (real-time with history)

4 Conclusion

The project is designed to be sustainable bringing significant savings on so many ways described in the project proposal. After the funding period is over, the implementation, or better say the costs, will be the responsibility of the local authorities since they are responsible by the law and regulations for these issues. It is expected that the future investments to enhance and to cover new city areas with the system could be ensured by the saving s from this pilot projects.

The project is the proof-of-concept for the future smart services projects. The total energy savings, as the primary goals defined by the EU MED Esmartcity Feasibility Study for the Municipality of East Ilidza is reached by **the current level 46%**, what is above compared with the predicted 38%.

The project is implemented involving allstakeholders in the community, including government, industry, academy and civil society following the Open Innovation 2.0 model, in each single stage of the project implementation.

The risk assessment for the project gives the almost no risk. The predicted saving and revenues, including the hypothesis of the project sustainability is proofed. The business model for this project and any future investment in the smart lights project is clear

The Urban Growth poses many challenges to plan infrastructure which are able to serve all needs of citizens. Some of these challenges are caused by the intensive increasing the number of city inhabitants and some others are related with physical expansion of cities. These challenges could be explained by the prediction of the UN, which said that today, around 55% of the global population live in the urban areas and it is expected that this percentage is going to increase to the level between 68-75% by 2050. It is clear that it could be concluded that the cities are expected to become bigger and more numerous worldwide, with a few exceptions.

As the process of urbanization accelerates, challenges confronting the future of cities are constantly growing. This project is directly focusing on two of many challenges in these trend, first one is optimizing energy consumption and air pollution issues in the urban areas, as a primary effects, but on a wider picture, the project is affecting many other challenges too, as safety and security, biodiversity, transportation, and the Quality-of-Life as a whole.

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4.1 Climate, Environment, Air Quality Effects

Cities, and urban areas in general, causes a climate change dominantly. In many aspects, the effects could be decreased very fast in case that the city government has enough data and proper picture of all processes and services in cities to be able to share, reallocate and optimize resources usage. The official statistic from the UN says that cities generate around 70% of global Greenhouse Gas Emission. It is very clear that future megacities will face many challenges to ensure the regular services for the citizens including critical ones as Energy, Water distribution but also Transportation and Waste management and many others.

4.2 City Management Optimization

This project should increase total efficiency in the energy management in the City and to be used as a proof-of concept with clear undoubtful business model which will motivate local government and potential investor to inject additional money in the process of conversion many conventional city services into modern smart ones.

Direct effect of the project success from the energy savings is financial one what ensure additional money for other projects. Saved money can be used to be reinvested to enhancing and to maintain the System itself making it sustainable but it is expected that the saving will ensure additional money saving which could be diverted on other project in the communities and which are important for the City as a new sport capabilities, schools, green areas and many other project which improve the Quality of Life parameters.

4.3 New Business Opportunities

This concept of the project allows that the local government can create many sideline projects in the Public-Private Partnership involving the (local) industry and the business sector into the process of the City development. This step can catalyze many new domestic, primary local based, products and solutions.

The collected data should be presented under the license of the Open Data, making them public for the citizens. This strategic approach is the most valuable for potential entrepreneurs who can create many start-ups based on additional analytics of the collected data. This affects mostly younger generation who present entrepreneurial affinities and who have a proper ICT knowledge to use these opportunities.

Combination of the PPP approach with the Open Data strategy, this project could be used a model for the launching new ecosystem what is going to create many new jobs in the City.

The project understands that the collected data is under the Open Data license which means that the collected data is available for public usage. This should be catalyst for many incoming start-ups and

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innovative ideas and the license requires two-direction openness what means that Open Data could be used only for the Open Source projects. The management of the collected data should be more discussed with all stakeholders because it should be considered as a public property of all citizens and the usage should be defined only for interest of the community. The business based on the collected data should be service-oriented, not applications license-based.

4.4 Civil Society Involvement

The project is primary focused to engage residents and affects residents in many aspects. The most obvious aspect in which the project is related with residents, is decreasing the light pollution. These goals have to be confronted with the residents' expectations to keep resident areas under the light for pedestrians what understands to ensure proper light because safety and security. In parallel, residents prefer darker in the night for better sleeping quality in areas closer to buildings. This trade-off has to be led by two lines, first one is objective measurement and tracking needs but also it is very necessary and strongly recommended to measure subjective opinions of residents about the system efficiency that meats their expectations. The questionnaires are very useful method to verify objective measurement and confront them to each other for optimal decision and maximizing the Quality of Life.

It is expected that citizens can change the regular behavior, especially in first phases of the project implementation. Public Light dimming could seem to them as not enough bright for walking, but it could be proved that it is mostly subjective observation based on existing experience. After some period, citizens will accept the new working regime for the System, and it is expected that the System will ensure proper service for them.

This hypothesis should be proven during the phase of Testing and Verification so the System could be set to the proper working point.

4.5 Innovative Solutions

The project is innovative in many ways, not only because of the implementation of sensors networks and automatization but because the System has to become independent and self-regulated using the Artificial Intelligence and Machine Learning algorithms for calculation what is current optimal working regime. The presence of AI and ML as parts of the solution makes this approach innovative, high-tech trend aligned and really "smart" because it ensures that the human interaction and presence in the service monitoring and governance is not necessary anymore.

The project is designed to be sustainable bringing significant savings on so many ways described in the project proposal. After the funding period is over, the implementation, or better say the costs, will be the responsibility of the local authorities since they are responsible by the law and regulations for these

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issues. It is expected that the future investments to enhance and to cover new City areas with the System could be ensured by the saving s from this pilot projects.

5 Future Work

The project is designed to effect practice operational benefits and to act as an emancipation trigger for the future actions improving the urban life in the 21st century in the City of East Sarajevo. All general goals in the strategy for Smart East Sarajevo development, based on Smart Lights as a backbone, are organized in 7 goals, as follows. All goals can be applied on all future smart services including Smart Waste management, Smart Public Transportation etc.

5.1 Increasing Awareness of the Possibilities for ICT-driven Smart Concepts

This project introduces the one of many possible smart services for enhancing the Quality of Life for the citizens of the City of East Sarajevo in the 21st century. Activities related with the project should affect wider population increasing the understanding and awareness of possibilities what results with better understanding all benefits and to increase total expectations about the urban living style in the City. The project should be built around the strategy with clear short-term and long-term plans for the City development. The project planning, implementation and testing phases should be transparent driven with engagement of public sector and citizens as much as it possible, including seminars, training, workshops, conferences, other education program involving academic sector, social media presentations and presence in electronic and printed medias. The scope of this action should be much wider than the geographic location of the System in the early-stage pilot project.

5.2 Existing Resources Usage Optimization

The conventional working regime for the Smart Lighting system is based on static schedule. The system has its operational parts with no remote control, with limited manual remote control and semi-automatic control for some areas where the City made some job in a last decade. In all these variances in the System, there is no communications between any central node (located in the City, Power companies or any other legal subject). The lack of information in the real-time and the lack of data collection for long-term observation and profiling, keeps decision makers and all stakeholders blinded on the status of the System and future planning for enhancements.

Installation of sensors and acquiring proper data about the system and citizens behavior and habits, the decision makers can predict and profile the real usage of the system and the needs in the real-time and for long-term. Application of modern mathematical models for optimization based on existing and new-designed algorithms of Artificial Intelligence and Machine and Deep Learning, it is possible to transform the system into fully automatic and self-optimizing and self-control system with human interaction at all.

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That means that the full-scaled deployed system should be able to collect data from remote location of street public light poles, to transfer them via the telecommunications channel (usually recommended using existing mobile network 4G-LTE and incoming 5G) to one or more data centers, where data will be stored, analyzed and where the data center can make decision about optimal action. In this System, the Data Center will send commands to the System to react on the current needs and triggers.

This perspective enables a few important components of the general term "Sustainable Cities, Urban Environments and Communities" involving the technologies for attribute "Smart" and real-time management for the attribute "Responsive".

The implementation of the system should improve energy efficiency, decrease energy consumption and decrease spending money in this purpose, but also it could be expected that these activities improves the environmental parameters (e.g. air pollution) and decreasing light pollution in the very urban areas.

5.3 Green ICT-Driven Solutions and Sustainable City of East Sarajevo

The fight against climate change will be won or lost in the urban areas: the vast majority of the European population lives and works in cities and uses an estimated 80% of all energy consumed in the EU. The municipalities and cities want to play their part. They created the Covenant of Mayors, in which they commit to a reduction in carbon-dioxide emissions by at least 40% by 2030.

First step towards the Green and Environmental-friendly City is changing the existing Natrium-based (and other if exists) with energy-saving LED light sources. This step is not part of vision for "intelligent and smart" system but it is necessary step to maximize effects of the system.

Besides that, the City local government can use the collected data for optimization decision making, it is really important for all city's residents to have up-to-date public information about the air, light and noise pollution, as well as the temperature and humidity on their locations. At this moment that kind of information are available only for the few places where the fixed measurement stations are. The Public Lighting system with its intelligent and smart function can co-locate many other functions as environmental monitoring because of its geographical diversity across the City. It enables that the system can collect data about Air Quality (Temperature, Humidity, CO2, CO, NO2, SO2 etc.), Noise Pollution, Light Pollution and many others using the same infrastructure including the physical location, power system, telecommunications channels, etc.The steps of transfer to the LED light sources and installation of intelligent mechanisms should be combined and done at once.

5.4 Reduction of Light Pollution and Preservation of Biodiversity

The advance of street lighting means that there is less darkness in increasingly larger areas. This has a negative effect on humans and the environment. Most bodily functions follow a 24-hour rhythm. Disturbing this natural Day-and-Night rhythm by too much intense artificial light will have long-term

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physical and psychological effects expressed through decreasing the Quality of Life. The environment also benefits from a good balance between light and darkness. Certain plant and animal species will even disappear due to too much light pollution.

5.5 Safety and Security

The accelerated growth of the urban population is creating a greater need for safety (physical integrity) and a greater sense of security. White LED light increases people's sense of security, but it also improves general visibility and makes face recognition easier. Installation of LED light sources (optionally, with color control from white to warm yellow) combined with sensors network and controllers, the system is converted into the smart system. This enables some future project as creating Connected Smart Public Lighting which goes even beyond this: it is an essential part of a future-oriented safety policy, in which lighting is used for an interactive response to the environment and with option to communicate between each other for some applications e.g. light follows a pedestrian etc.

5.6 An Attractive City with Comfort and Quality of Life

Densification of urban areas, more complex mobility systems and climate change are all threats to the quality of life and comfort of the residents of cities and municipalities. Governments are facing the challenge of optimizing their policies, city processes and services with respect for the economic, social and sustainability aspects. This includes the right lighting as well. Lighting should not only be sustainable: suitable lighting and connected services in all the right places should also offer comfort and improve the quality of life in cities.

5.7 Maximum Experience and City Marketing

Many large cities have promoted themselves with city marketing for quite some time now. The competition between cities is becoming more and more intense. However, city marketing is also becoming increasingly important for smaller cities and municipalities. The right street lighting plays an important role in how residents and visitors experience cities.

5.8 The Potential for Future Co-Existing Smart Services based on The Pilot

Examples of possible co-located services with the public light system, which can share resources, infrastructure or data, if necessary, are:

- Smart Grid Street Light. Smart streetlight is a system (automatic photocell controlled, 0-100% dimming, On-Demand Light levels) which to communicate to individual luminaires, streetlights are able to save up to 70% in energy consumption and extend life to 10 years and beyond. The system provides unique flexibility in dimming and on-demand

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adjustability. It is possible to add facade light with color changing to improve ambient and esthetic light perception.

- Concealed Placement Speaker (CPS). A fully integrated speaker within each multimedia luminaire provides audio at the street level for ambient music, pre-recorded announcements, dial-up mass notification and advertising.
- Image Sensors. 180-degree image sensors are concealed and offer a unique method of gauging pedestrian traffic, providing accurate data by the minute, hour or day. This is a powerful tool for tenants, landlords and public safety officials.
- Digital Signage. The digital banner is a 2-sided LED display that provides street-level visual communication. Custom graphics can be used for advertising, community announcements and real-time alert notifications. Additionally, digital street-signs allow for better traffic management. E.g. a smaller one, with a horizontalorientation, could be used as a street sign (e.g. 5th Avenue) and a bigger one with vertical orientationcould be used for advertisements and announcements.
- Emergency Call Station. The emergency call station is a communication device designed for the public to easily call for help. It is also well-known as a „blue button" worldwide. It is available as a stand-alone unit or mounted to a pole.
- Environmental sensors. This subsystem includes air quality sensors (CO_2, NO_2, particles e.g. PM10, temperature, humidity…) and sound and light pollution level, seismic sensors and many similar sensors. At the bottom of the pole, it is possible to install the water sensor to detect flooding.
- RGBA Notification. It is an indicator light with high power and possible rotation (similar to a light on police vehicles) to announce a warning or any other message in a visual way e.g. supporting sound warnings and announcements.
- Electric vehicles charger station.

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6 Literature

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7 List of Figures

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