REPLICATE	Project no. 691735 REPLICATE PROJECT Renaissance of Places with Innovative Citizenship And Technology	This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

REPLICATE PROJECT

REnaissance of PLaces with Innovative Citizenship And Technology

Project no. 691735

H2020-SCC-2015 Smart Cities and Communities

Innovation Action (IA)

D6.8 Standardization and synergies between intelligent lighting systems and ICT Smart City platform

Due date of deliverable: 31/01/2019

Actual submission date: 28/11/2018

Start date of project: 01/02/2016 Duration: 60 months

Organisation name of lead contractor for this deliverable: Tecnalia

Status (*Draft/Proposal/Accepted/Submitted*): Submitted

Project co-funded by the European Commission within the 7th Framework Programme		
Dissemination Level		
PU	Public	X
CO	Confidential, only for members of the consortium (including the Commission Services)	

Editor/Lead beneficiary:	Tecnalia
Internally reviewed by:	Eurohelp

Index of contents

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

1 Executive summary

LEDs and smart controls have advanced greatly in recent years and provide many features and advantages that improve amenity, environmental, safety and financial outcomes in towns and cities.

However, while the energy and cost saving benefits are driving adoption, cities are increasingly seeing the lampposts as smart city infrastructure. With an even and widespread distribution across urban areas, readily available power and integrated connectivity, smart street lighting is being used to form the technology foundation of a city, a network infrastructure for sensors and smart devices to improve community liveability and resilience.

Through the addition of data collection devices such as sensors and cameras, street lighting infrastructure can be used as a platform to host a variety of applications in the areas of environmental monitoring, traffic optimization, smart parking and public safety. Furthermore, street lighting infrastructure is being used to host charging points for electric vehicles, and as a base for public Wi-Fi and communication networks.

This document analyses the challenges and barriers faced by the use of the lampposts as Smart city infrastructure, along with the current standards and initiatives in the field of Smart Lighting dealing with non-light uses cases.

Furthermore, the document identifies synergies between different and vertical lightning systems being developed in the three lighthouse cities and the ICT Smart City platform concept developed in WP6, with a focus of interoperability (technical and semantic).

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

2 REPLICATE

The main objective of REPLICATE project is the development and validation in three lighthouse cities (**San Sebastián** – Spain, **Florence** – Italy and **Bristol** – UK) of a comprehensive and sustainable City Business Model to enhance the transition process to a smart city in the areas of the energy efficiency, sustainable mobility and ICT/Infrastructure. This will accelerate the deployment of innovative technologies, organizational and economic solutions to significantly increase resource and energy efficiency improve the sustainability of urban transport and drastically reduce greenhouse gas emissions in urban areas.

REPLICATE project aims to increase the quality of life for citizens across Europe by demonstrating the impact of innovative technologies used to co-create smart city services with citizens and prove the optimal process for replicating successes within cities and across cities.

The Business Models that are being tested through large scale demonstrators at the three cities are approached with an integrated planning through a co-productive vision, involving citizens and cities' stakeholders, providing integrated viable solutions to existing challenges in urban areas and to procure sustainable services. Sustainability of the solutions is fostered in three areas: economic and environmental and finally, fostering transparency in the public management.

In addition, the Model features the replicability of the solutions and their scale up in the entire city and in follower cities, particularly in three follower cities (**Essen** - Germany, **Laussane** – Switzerland and **Nilüfer**–Turkey) that are involved in the project and therefore, have access to know-how and results achieved on the project so they can apply the developed model. At the moment, there are 2 observer cities, Guanzhou (China) and Bogota (Colombia).

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

3 INTRODUCTION

3.1 Relation to Other Project Documents

This document analyses the current standards and initiatives in the field of Smart Lighting and identifies synergies between different and vertical lightning systems being developed in the three lighthouse cities and the ICT Smart City concept developed in WP6, with a focus of interoperability (technical and semantic).

The work has been focused on finding a subset of open standards that guaranty a good communication for the ICT Smart City Platform and intelligent lightning services.

The information included in the following reports has been useful for the development of this deliverable as they include information related to the pilots' smart lighting deployments and future plans along with questionnaires filled by the involved partners in the case of BRISTOL pilot.

- D3.11 Report on Public Lighting System, a specific deliverable dealing with the smart lighting implementation in San Sebastian.
- D4.3 Florence Pilot action progress report year 2 which includes a section covering the Smart Lighting deployment in Florence.
- D6.2 Roadmap of Digital services catalogue from the 3 cities. It includes a summary of services data flow, interoperability and governance issues gathered from the point of view from each of the stakeholders involved in the services implementation and deployment, including the municipality data hub. Sections 6 to 9 of this document gathers detailed design information about the Smart city services to be deployed in the three pilots.
- The different monitoring programmes of the pilots (D10.4, D10.5 and D10.6) which define the KPIs gathered by the Monitoring Platform from the three pilot interventions.

Since the document includes information regarding data gathering, storing and sharing tasks it has a direct relationship with the data management principles stated in the Data Management Plan (DaMP). In fact, some of the information included in this document about the data sets needed for the different smart services and the way in which those data sets are going to be processed complements the general rules about research data management included in the DaMP.

3.2 Reference documents

This document is based in the following projects level documents:

Ref.	Title	Description
REPLICATE Grant Agreement signed 240713.pdf	Grant Agreement	Grant Agreement no. 691735
DoA REPLICATE (691735)	REPLICATE Annex 1 – DoA to the GA	Description of the Action
REPLICATE Project Management Plan	D1.1 Project Management Plan (v.1) (29/04/2016)	REPLICATE Project Management Plan
REPLICATE Data management plan	D1.5 Data Management Plan (v.1) (31/07/2016)	REPLICATE Data Management Plan
D3.11 Report on Public Lighting System	Report on Public Lighting System (31/01/2018)	Concept and systems behind the implementation proposed for the innovation on the public lighting system in San Sebastian
D4.3 FLORENCE Pilot action progress report year 2	FLORENCE Pilot action progress report year 2 (02/02/2018)	The pilot action progress report (year 2) includes a section covering the Smart Lighting deployment in FLORENCE
REPLICATE Deliverable D6.1.	Integrated ICT architectures and services requirement specification (10/02/2017)	Integrated ICT architectures and services requirement specification
REPLICATE Deliverable D6.2	Roadmap of Digital services catalogue from the 3 cities (31/01/2018)	Includes detailed information about the services design with special emphasis on the collaboration among the different stakeholders. Data flows and data governance issues among the different stakeholders are analysed in detail.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

3.3 Abbreviations list

GA	Grant Agreement
CA	Consortium Agreement
DoA	Annex I–Description of the Action
DaMP	Data Management Plan
Km4City	Knowledge model 4 the City
LOD	Linked Open Data
EIP	European Innovation Partnership
EIP -SCC	European Innovation Partnership – Smart Cities and Communities
DIN	Deutsches Institut für Normung (German Institute for Normalization)
IoT	Internet of Things
GDPR	General Data Protection Regulation

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

4 DELIVERABLE DESCRIPTION

This deliverable gathers the results of Task 6.7. Standardization and synergies between intelligent lightning systems and smart city platform.

Task 6.7 is oriented to the standardization and search of synergies between different and vertical lightning systems and the ICT Smart City concept developed in WP6, with a focus of interoperability (technical and semantic).

This task has been focused on finding a subset of open standards that guaranty a good communication for the ICT Smart City Platform and intelligent lightning services. This situation will not impose a specific platform to any City. But the portability of the applications and services running on top of Smart City platforms will substantially improve if a set of essential open standards is recognised as common requirements for all platforms.

It has been analysed synergies of every intelligent lightning system (developed and deployed in every lighthouse cities) in order to:

- Set a Service of Common Enablers, which enable the composition of existing services into value added composite services, which can be monetized in a Business Framework.
- Favour a cost-effective deployment of intelligent systems for Smart Cities.

The information described above is described under the present document which covers:

Section 5 defines the Smart lighting concept based on the EIP-SCC Humble Lamppost initiative.

Section 6 presents a number of international smart lighting related initiatives, which are trying to boost the smart lighting deployment by removing barriers as well as providing interoperable technical solutions based on open standards. It includes industrial based consortiums, standardization bodies and government initiatives.

Section 7 presents the current state of the Smart Lighting deployments in three pilots. The information gathered in this section is still evolving since some of the services are being implemented and deployed. The final information will be included in D6.5 Integrated architecture and services catalogue for the Community Ecosystem v2. Specifically, the section provides information about use cases being implemented and the technical information about their deployment, the high-level architecture of the solution, protocols/standards used and connectivity solution. Also, it includes what data is being used in the control room and what data is being transferred to the data aggregation platform.

Section 8 includes information about the innovations, impacts and scalability of the Smart Lighting interventions regarding its integration with the Smart city platform and the so called non-lighting use cases. Finally, **Section 9** contains the conclusions of the analysis.

5 Smart lighting concept

This section defines the Smart lighting concept based mainly on the EIP-SCC (European Innovation Partnership on Smart Cities and Communities) Humble Lamppost initiative [7] and IoTUK [8]. It also gathers the information about current standards and other initiatives regarding smart lighting.

LEDs and smart controls have advanced greatly in recent years and provide many features and advantages that improve amenity, environmental, safety and financial outcomes in towns and cities.

Streetlights are strategic assets for cities and road authorities. The way outdoor lighting systems are operated and managed has changed greatly over time. Previously light levels could not be changed; the lighting remained at full power throughout the whole night. The energy consumption of the lighting installation could only be estimated.

The large number of streetlights and their wide geographic distribution in the cities made them difficult and expensive to operate. More recently concerns about global warming and rising cost of energy have incentivized cities to deploy new solutions addressing these issues.

Intelligent outdoor lighting helps to reduce energy consumption and at the same time to increase safety and reduce maintenance costs for cities and road authorities. Outdoor Lighting Networks (OLN), together with the deployment of more efficient luminaires, are proven solutions that support municipalities and utilities to increase the performance of their lighting management and to decrease cost.

By using Luminaire Controllers, Sensors, Streetlight Cabinet Controllers and a Central Management Software, cities turn their systems into a Smart Outdoor Lighting System, that allows dimming schedules, automatic identification and report of lamp failures, real time control, automatic measurement of energy consumption, and much more.

Thus, smart controls provide cities, suburbs and rural communities with many important benefits including those summarised below:

1. Efficiently maintain important safety infrastructure (public lighting) through computerised asset management techniques;
2. Tailor lighting levels to the precise requirements so that excess lighting is reduced and any harmful or unwelcome effects are minimised;
3. Reduce electrical energy usage at times when less lighting is required;
4. Precisely measure the electrical energy consumed (in contrast to the current practice which is not metered) to capture the benefits of tailored lighting levels and off-peak dimming and switching;

However, while the energy and cost saving benefits are driving adoption, cities are increasingly thinking of the smart lighting deployment as IoT infrastructure With an even and widespread distribution across urban areas, readily available power and integrated connectivity, smart street lighting is being used to form the technology foundation of a city, a network infrastructure for sensors and smart devices to improve community liveability and resilience.

Through the addition of data collection devices such as sensors and cameras, street lighting infrastructure can be used as a platform to host a variety of applications in the areas of environmental monitoring, traffic optimization, smart parking and public safety. Furthermore, street lighting infrastructure is being used to host charging points for electric vehicles, and as a base for public Wi-Fi and communication networks.

Brian Buntz of the Internet of Things Institute provides a useful metaphor: 'Lamp posts may well follow a trajectory similar to that of mobile phones. It wasn't so long ago that mobile phones were suited for one purpose only - making calls. Now, making a phone call has become almost secondary to all of a smart phone's other capabilities. Similarly, while the lamp posts of yesterday provided only illumination, modern-day lamp post can serve as multi-functional smart-city nodes, capable of monitoring everything from crime to parking to weather.'[9]

According to the IoTUK report "The future of street lighting: The potential for new service development" [10], the progression of smart lighting infrastructure involves three stages:

1. Switching to led bulbs: LED lights provide a number of benefits including increased life expectancy, health and safety benefits and cost savings.
2. Connected street lighting: LEDs are essentially electronic devices that can be connected to central control systems in order to give operators the ability to monitor and regulate light levels depending on weather conditions affecting the visibility, traffic (both vehicles and pedestrians) conditions, or safety and emergency situations. Besides, the control system can be used to conduct remote monitoring and to meter electricity usage more accurately.
3. New service development. Both traditional lamp posts and more advanced smart lighting installations have the potential to act as a smart city platform, enabling a range of other smart city applications through the integration of data collection devices such as sensors and cameras. Lighting infrastructure is being used as a basis for solutions in many areas, like for example:
    a. Environment monitoring
    b. Transport optimisation (traffic management and parking)
    c. Public safety
    d. Electric vehicle charging

e. Wi-Fi and internet provision

f. Digital signage and public communication

Even though this document includes some information about the three stages, its main focus is the third one: **New service development.**

According to the EIP guide for city leaders ("Exploiting the 'humble lamp post' a kick start to smart city A guide for city leaders), "*a city that only looks to cost savings is losing out on the real potential. One of the clever bits about smart cities is the ability to interconnect infrastructures so that they can serve multiple purposes. And the neat thing about most cities is that their lamp posts offer just that opportunity. Cities can benefit from a wealth of other features and services alongside more reliable and adaptable lighting that bring very tangible new forms of value*".

Smart lamppost systems are those that:

- Retain, serve and indeed enhance the principal compliant obligations of street lighting (way-finding, public safety)
- Use low-emission luminaires
- Are connected as a network, enabling system-wide controllability (e.g. central mgmt. system), and integration of smart services
- Include within the network a number of additional smart services (sensors and the like) that extend services beyond just the provision of light
- Arguably, have 24x7 power to enable continuous smart services

Thus, a "smart lamppost", with its various services, will most likely be mixed within a larger portfolio of existing 'traditional' lampposts (that have been upgraded to low emission (LED) lighting.

Next figure illustrates the possible uses cases of the so called "humble lamppost":

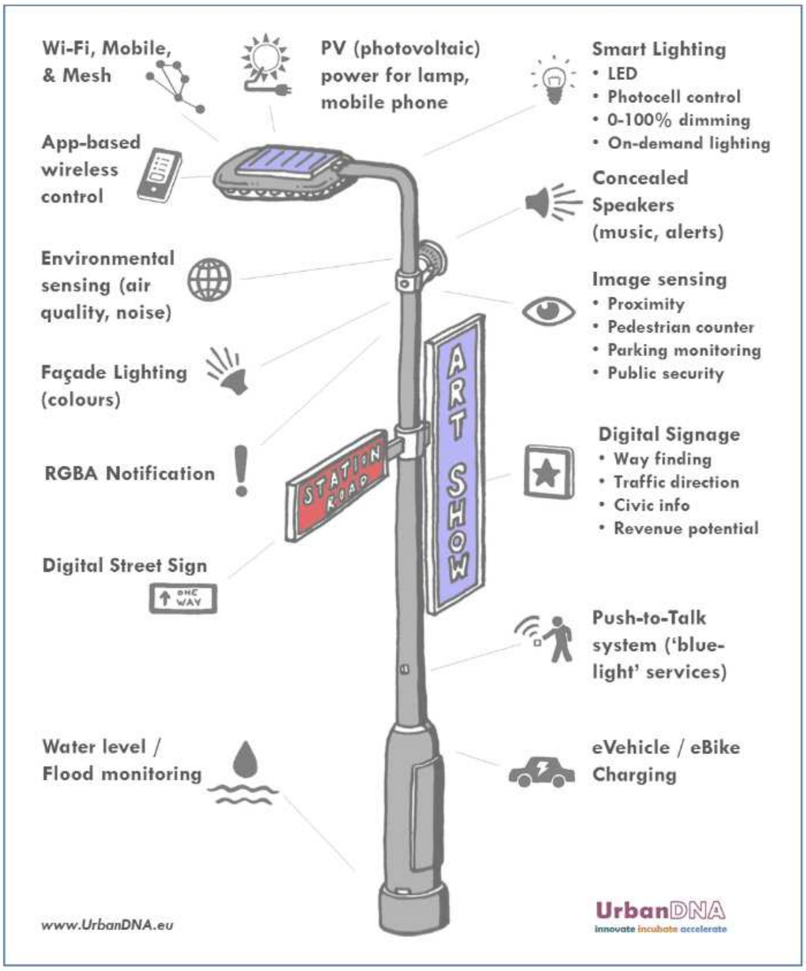

Figure 1 Imagine… A dozen things to do with a lamppost that does not involve light

5.1 Smart Lighting uses cases

Use cases related to the Smart Lighting concept applied to the urban areas are often classified in two categories:

- Lighting related
- Non-light related

Next table shows a list of the most representative Humble lamppost uses cases gathered from two sources: Sharing Cities European project and DIN SPEC 91347 [11]. This list is also used by EIP and other initiatives for use cases comparison.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

Humble Lamppost Use Cases		DIN	ShC
LIGHTING Related			
L1	Basic LED Energy, GHG, and Maintenance Improvement		Y
L2	Additional Energy Savings / Optimisation (CMS "Trim & Dim")		Y
L3	Safety, Attractiveness & Façade / Mood Lighting (incl Improve the Quality of service and people safety –fault reporting)		Y
L4	Alternative Clean Energy – PV cells to power some lights		Y
NON-LIGHT Related			
NL1	Event-controlled adaptive street lighting system	Y	
NL2	Traffic monitoring (Driver Information; Traffic Monitoring; Parking)	Y	Y
NL3	Intelligent communication between vehicles and the imHLa	Y	
NL4	Public Wi-Fi	Y	Y
NL5	Wireless network support with a picocell or microcell	Y	
NL6	Environmental data acquisition (air quality, noise, water levels, etc)	Y	Y
NL7	Charging station for electric vehicles (vans, cars, bikes)	Y	Y
NL8	Drone charging infrastructure	Y	
NL9	Energy storage	Y	
NL10	Remote maintenance	Y	
NL11	Public security	Y	Y
NL12	Private security and surveillance / geofencing –pedestrian monitoring	Y	Y
NL13	Signage and advertising	Y	
	Public Engagement (safety of place, information speakers, information signage, tourist info)		Y
Other (Please specify)			

Table 1 DIN and Sharing Cities Use case table

This set of use cases will be used to map the current REPLICATE smart lighting deployments in the three pilots, identifying synergies and improvement areas.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

5.2 Adoption barriers

Over summer 2017 the European Innovation Partnership for Smart Cities & Communities (EIP-SCC) launched a demand side survey to understand what European Cities were thinking and doing in terms of upgrading their public street lighting assets.

This survey included the following questions: How did cities see the opportunity? What were they planning to do about it? Who was going to pay for accessing this opportunity? How much? And what business models were preferred? Exactly what types of additional services did cities have in mind? What was blocking progress? Were cities up for collaboration to develop real scale in the market and accelerate adoption?

Ten big messages emerge:

1. *A solid return on investment:* there is a significant opportunity to exploit the 'humble' lamppost to save energy and, *at the same time*, implement additional 'smart' services
2. *'Smart' is certainly the ambition:* 60% of EU cities want to implement wide array of additional Smart services on their lampposts, most notably around connectivity and IoT-enabled features
3. *The time to act is now:* we squander €120 million each week at an EU-level through inaction, and too many of those that are implementing are accessing *only* the LED energy gains. Delay to act on the relatively-simple smart lamppost risks delay in acting on other smart solutions – a potentially nasty 'knock on' effect
4. *Boutique volumes; supermarket prices*: economies of scale require significantly greater volumes to be brought to the market, within a city, or by collaborating to aggregate demand between cities
5. *Access to finance is the big blocker for scale adoption*: yet there is no shortage of money in the market
6. *Leadership and business justification are the critical challenges*: leadership is both 'of issue' and 'not of issue' – i.e. it is city specific. So, working with those leaders that that want to act will pave the path to success. (There are, however, still some technical matters that present persistent irksome challenges)
7. *Solutions must be city-needs-led*: cities must drive the agenda, they define the need and desired outcomes
8. *Overcoming individualism*: the diversity of EU cities and their contexts, needs and wants always warrants tailoring of solutions; however, that should not be used as an excuse to avoid collaborating around common approaches and solutions, and actively sharing experience

9. *Exploit the conditioned avenue to scale adoption:* the grant-financed EU smart cities 'Lighthouse' programmes, and European Innovation Partnership Marketplace provide an important route to early action
10. *Getting this smart city 'quick win' behind us is important as it builds market confidence* – of cities, of investors in cities, of Governments, and Industry – to free up space to tackle the much bigger and more challenging opportunities to transform services and outcomes in our cities.

Regarding the barriers to scale & accelerate the adoption of large volumes (above 10,000) the response was interesting, and clear: Access to Money. After that, was a structural constraint which came from several (smaller) cities that just couldn't produce the volumes. And the third niggle was about justifying the return on investment – though that was a much smaller concern.

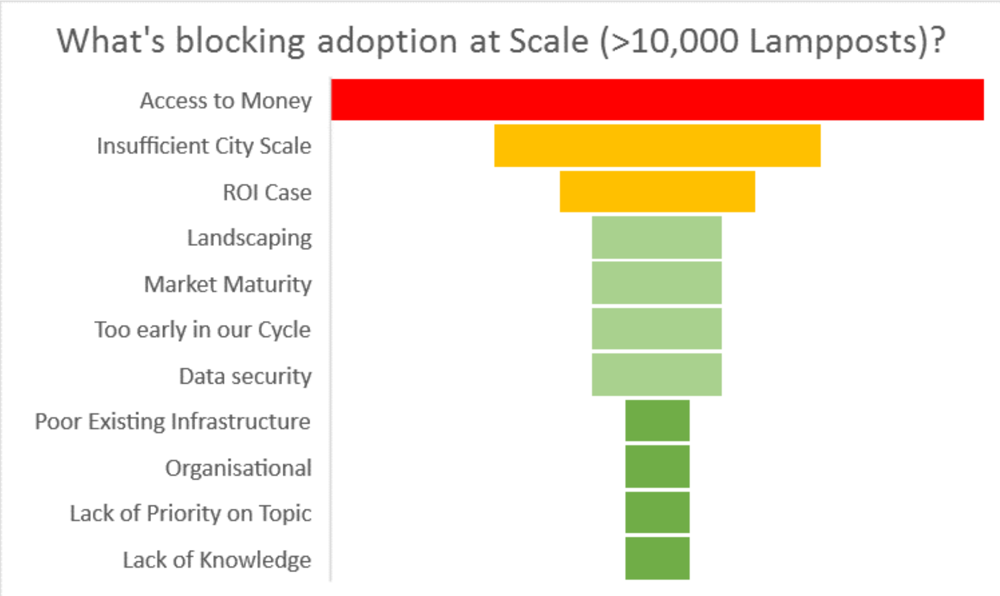

Figure 2 Smart Lighting adoption barriers

EIP-SCC initiative seeks to **capture common designs, and work with standardisation bodies to develop common guidance and specifications** that cities can use with confidence, industry can design to with confidence, and financiers can invest in with confidence.

5.3 Technological challenges

For the development of intelligent lighting systems, the convergence and integration of different technological areas is necessary:

- **The area of lighting**, since the development of LED technology is a determining factor in the evolution of solutions for lighting. With respect to previous lighting technologies, LED technology provides greater light efficiency, quality lighting and a longer life of the luminaire, in addition to its exceptional regulation capacity. The development of LED technology has also led to an important evolution in the power devices of the luminaires, with innovative solutions for monitoring and controlling them.

- **The area of communications**, with the possibility of designing and implementing devices of small size that, together with new protocols and architectures, enable wireless connectivity point to point with low cost and low consumption.
- **The area of the digital systems**, with reference to the storage, treatment, combination and processing of data, and with the development of management applications and visualization of the information obtained on different platforms and devices.
- Finally, **the area of sensorization**, with the possibility of integration of data acquisition devices for different applications on the same intelligent lighting management platform.

The development of a management system with these characteristics poses a series of challenges. It requires careful and adequate analysis and selection of technology, in an environment of dynamic standardization, with new solutions, alliances and proposals emerging and disappearing at great speed and competing with each other. It requires the integration and compatibility of criteria, regulations and specifications of the lighting industry with those of the communication systems industry and the Internet of Things. Requires acceptance by the end user, taking into account considerations and guarantees of security and privacy. And it requires a model based on the highest standards of reliability and quality.

The first level of intelligent lighting corresponds to the luminaire and its control. At this level, intelligent lighting is the ability to make light dynamic (in colour, in intensity), interactive (with the bidirectional exchange of information) and adaptive (according to demand), all in real time. It includes monitoring capabilities which allow the acquisition of very valuable data for efficient urban lighting management and maintenance. Furthermore, it can be used to generate programmable lighting profiles in real time, according to the location of the luminaire, adapted to the environment and its characteristics, optimizing energy consumption and cost. In addition, it provides information for the preventive maintenance of the facilities, by measuring parameters related to the driver itself, the LED module or the electrical network, enabling diagnostic and test procedures and the effective management of alarms and incidents.

To complete this first level of intelligent lighting, and to enable the second level, that of data management, it is necessary to have a bidirectional communication system with the luminaires

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

and a storage and data processing platform, with the corresponding business intelligence capacity and with tools for presenting and displaying results.

The second level of intelligent lighting includes the possibility of acquiring data from public lighting installations and the ability to act on them from the smart lighting solution allows going beyond the mere management of a basic urban service. Once the capacity of transport and treatment is available, robust, safe and efficient, of the active lighting data, it is possible to combine them with other urban data sources and create analysis and intelligence tools to propose better urban policies and solutions of added value for citizens and municipal managers.

There is, finally, a **third level of intelligent illumination.** Each luminaire for outdoor lighting can be converted into a data server (data-enabled lighting). The lighting infrastructure thus becomes a service: in addition to being points of light, the luminaires are nodes of the Internet of Things infrastructure. The communication devices and the network architecture are prepared to facilitate the incorporation of additional sensors (environmental, noise, movement, vibration and a long list of possibilities),

Regarding the communication and security requirements, the picture becomes really complex once support for non-lighting applications is considered. These applications can be loosely grouped into three categories in terms of their network requirements and criticality of the systems they support:

- **Monitoring applications**: Applications such as air quality, noise monitoring, traffic, or pedestrian activity monitoring place relatively light demands on the network. The attraction of a smart city platform is to be able to deploy a wider range of sensors across more parts of the city to provide new data on the city environment. Ease of deployment, low operating costs, and breadth of coverage will be important considerations.

- **Operational systems**: Applications such as smart parking, gunshot detection, or smart waste collection require reliable secure networks that can ensure accurate and timely information. Response times are important as part of overall message systems but medium or possibly medium-high in terms of network latency.

- **Critical systems**: Controlling traffic lights, public safety cameras, and other critical operational equipment requires highly secure, reliable networks, often with significant bandwidth and low latency requirements. Such applications are typically supported by dedicated broadband networks.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Public messaging and digital signage cover a wide variety of potential applications. In some cases, the performance and security requirements will be relatively low (advertising, non-critical public information). Yet, these systems can also include traffic and public safety messaging, which have greater reliability and security requirements. As public information systems become more integrated in to other real-time city systems—including vehicle information systems—reliability and security aspects will become more significant.

6 Smart lighting initiatives and standards

This section presents a number of international smart lighting related initiatives, which are trying to boost the smart lighting deployment by removing barriers as well as providing interoperable technical solutions based on open standards. It includes industrial based consortiums, standardization bodies and government initiatives.

The selected initiatives are the following:

- EIP humble lamp post initiative (Lighting and non-light use cases)
- Digital Illumination Interface Alliance (DiiA) (Lighting use cases)
- Zhaga (lighting and non-light use cases)
- TALQ Consortium (lighting and non-light use cases)
- German Institute for Standardization: DIN (lighting and non-light use cases)
- IPWEA – SLSC (Lighting use cases)
- US-DOE MSSLC (Lighting use cases)
- FIWARE Street Lighting models

The focus has been organizations providing specifications, standards or guidelines useful for IoT use cases.

Furthermore, a specific Smart Lighting data model developed by FIWARE is presented.

6.1 EIP-SCC humble lamp post initiative

https://eu-smartcities.eu/initiatives/78/description

The European Innovation Partnership on Smart Cities and Communities (EIP-SCC) is a major market-changing undertaking supported by the European Commission bringing together cities, industries, SMEs, investors, researchers and other smart city actors.

EIP-SCC is organised in Action Clusters. An Action Cluster is an assembly of partners committing to work on specific issues related to smart cities, by sharing the knowledge and expertise with their peers, giving added-value to their national and local experience and identifying gaps that need to be fulfilled at European level. The work of each Action Cluster is collected under thematic Initiatives.

An Initiative pools the work of the various partners around a particular objective, promoting learning beyond project and geographic borders, and opening the results to the world at large. Links with EU-funded projects allow results to be consumed by the thousands of people active on the Marketplace. One of the initiatives launched by the Integrated Infrastructures and

Processes action cluster is the "Humble Lamppost" which main goal is: 10 Million Smart Lampposts across EU Cities.

Over summer 2017 the European Innovation Partnership for Smart Cities & Communities (EIP-SCC) launched a demand side survey to understand what European Cities were thinking and doing in terms of upgrading their public street lighting assets.

Some "products" have been delivered to inform the market. They are available on the EIP-SCC website, specifically:

- **Insight paper** resulting from a 2017 demand-side survey of 100+ EU cities, that captures extensive market messages
- **Demand side readiness documents**: a 'Leadership Guide' to inform politicians, and a 'Management Framework' to align across functions and disciplines. Both seek to accelerate and strengthen confidence in decision making in cities, and align the demand side of the market to aid demand aggregation. These have been branded under the BSI standards logo to lend greater trust and help sustain the documents. This has been co-developed with the Sharing Cities SCC01.

According to the humble lamp post initiative there are many lamppost-based possibilities that include optimising the core role the lamppost plays - that of offering light and safety - and a host of other services. The "dozen things you can do with a 'humble lamppost' that has nothing to do with light" (see Figure 1 Imagine... A dozen things to do with a lamppost that does not involve light).

Such additional services include: offering a (potentially free) public Wi-Fi network; providing the powered foundations for a mesh network of (IoT) sensors across the city; helping drivers find a parking place; improving public safety; supporting environmental monitoring (air quality, waste, flooding). They can be a place for electronic street signage, public information and advertising (revenue); be the home of sensors that help direct visually impaired people; a powered web of electric vehicle (car, bike) charging points; or even pedestrian-flow monitors that can help keep the high street a vibrant place. Or looking more to the future, how connected and automated vehicles could move in a streamlined and safe fashion around your city.

Indeed, a city's lamppost estate should be considered more as a regularly-spaced network of elevated posts with power throughout the city that can help transform the efficiency and effectiveness of a range of city services, rather than just poles to hang lightbulbs on.

6.2 Digital Illumination Interface Alliance (DiiA)

https://www.digitalilluminationinterface.org/

The Digital Illumination Interface Alliance (DiiA) is an open, global consortium of lighting companies that aims to grow the market for lighting-control solutions based on Digital Addressable Lighting Interface (DALI) technology.

DiiA has established the DALI-2 certification program that covers the functionality specified in the latest version of IEC 62386, the international DALI standard.

DALI (Digital Addressable Lighting Interface) is a protocol (language) for bi-directional communication between lighting control products. A 2-wire bus is used for communication (commands/data) as well as for power to some devices.

Commands allow control, configuration and querying of the products.

- Examples of **control** commands include those that start a fade to a defined light output level, recall scenes or turn the lights off.
- Examples of **configuration** commands include those that change the fade time or change the light level stored in a scene.
- Examples of **query** commands include those that ask what the current light output level is, or whether there is a lamp failure.

Commands can be addressed to individual devices, to a group of devices, or broadcast to all devices.

DALI-2 has added control devices which include application controllers and input devices. These have two different purposes, but are sometimes combined into the same product.

- **Application controllers** are the "brains" of a system. They use information from any source, make decisions and send commands to control, configure or query the lights (control gear) or other devices on the bus.
- **Input devices** provide information for use by application controllers. The information could be from push-buttons, occupancy sensors, light sensors, rotary controls, slider controls or other devices.

6.3 Zhaga consortium

https://www.zhagastandard.org/

Zhaga is an industry-wide consortium aiming to standardize specifications for interfaces between LED luminaires and light engines. The aim is to permit interchangeability between products made by different manufacturers. Zhaga defines test procedures for luminaires and LED light engines so that the luminaire will accept the LED engine.

The Zhaga specifications, known as Books, describe the interfaces between LED luminaires and LED light engines. By describing a connectivity fit system for smart outdoor luminaires, Book 18 marks Zhaga's first contribution to the emerging world of smart lighting.

Book 18 defines a standardized interface between an outdoor LED luminaire and a sensing/communication module that sits on the outside of the luminaire. The module connects to the LED driver and control system, and typically can provide sensory inputs while also communicating with other luminaires in a network.

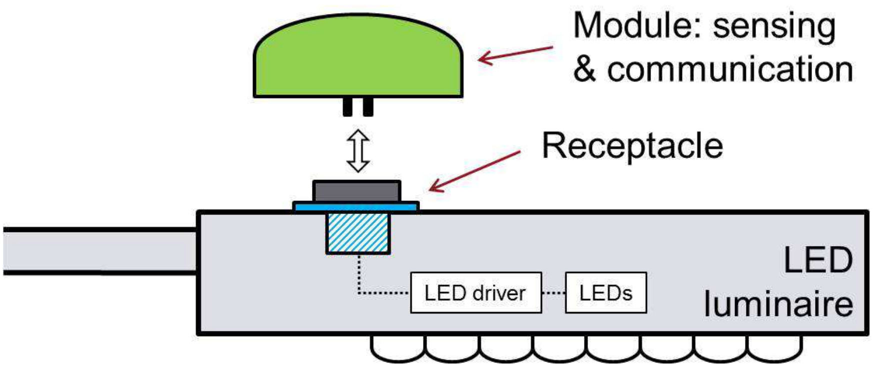

Figure 3 Zhaga book 18 scope

The Zhaga specification includes a socketed receptacle that allows a compatible sensing/communication module to be easily removed and replaced. This will allow the luminaire to be upgraded easily via the addition of new smart capabilities to the module. Book 18 defines the luminaire-module interface, but will not define the capabilities of the module.

6.4 TALQ Consortium

https://www.talq-consortium.org/

The TALQ Consortium aims to define a globally accepted smart city protocol for central management software to configure, control, command and monitor heterogeneous smart city device networks.

TALQ provides answers to the main challenges of building really smart cities including increasing safety and comfort for inhabitants, reducing energy consumption and CO2 emissions worldwide, raising cost efficiency for operators managing a smart city.

Founded originally by lighting industry leaders, TALQ is open to new industry members from the entire smart city environment. Stakeholder partners, such as cities, municipalities, utilities, consultants, and others can also join its Partner program.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

The TALQ Specification initially defined the application protocol between a Central Management System (CMS) and Outdoor Lighting Networks (OLNs) to enable configuration management, lighting control and monitoring of outdoor lighting systems. Nowadays, TALQ consortium provides a smart city protocol that uses a common language for smart city applications, such as outdoor lighting control, waste management and parking. The new TALQ interface is a specification for information exchange, suitable for implementation in various products and systems.

This way, interoperability between Central Management Systems (CMS) and Outdoor Device Networks from different vendors will be enabled, such that a single or many CMSs can control different networks and smart city applications in different parts of a city or region. Next figure shows the TALQ architecture.

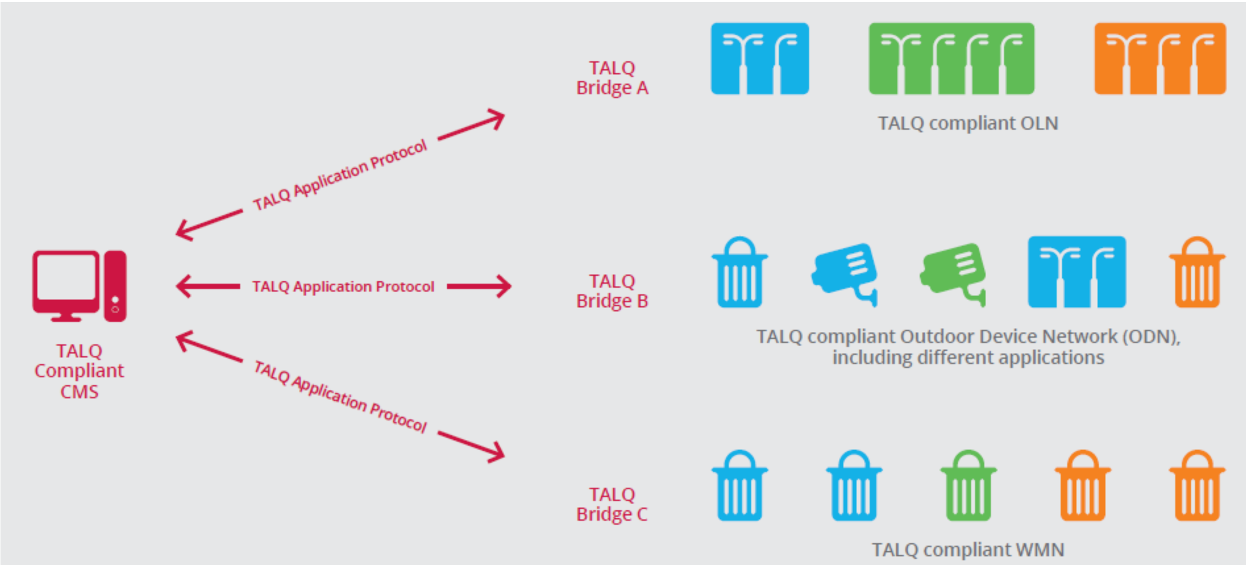

Figure 4 TALQ architecture

6.5 German Institute for Standardization: DIN

https://www.din.de/

The German Institute for Standardization, is the independent platform for standardization in Germany and worldwide. As a partner for industry, research and society as a whole, DIN plays a major role in paving the way for innovations to reach the market and advancing progress in innovative areas such as Industry 4.0 and Smart Cities. More than 32,000 experts from industry, research, consumer protection and the public sector bring their expertise to work on standardization projects managed by DIN. The results of these efforts are market-oriented standards and specifications that promote global trade, encouraging rationalization, quality assurance and environmental protection as well as improving security and communication

On March 22, 2017, DIN, the urban institute and their consortium partners present the worldwide first technical standard (DIN SPEC 91347) and classification for "integrated multifunctional street lamps" at CeBIT, Hannover. This way the integrated multifunctional street lamp can become a key component of smart cities and communities.

Sensors can detect parking spots and traffic, collect environmental data and enable event based light control. With the acquired data, new services for citizens and municipalities as well as new business models for start-ups and companies can be created.

6.5.1 DIN SPEC 91347: ImHLa Technical specification

DIN defines the "integrated multi-functional Humble Lamppost" (imHLa) as a lighting system consisting of at least one lamppost and a luminaire, which as well as providing illumination includes other functional components; the prerequisite is a constant electric power supply and a connection to the telecommunications network.

The DIN SPEC 91347 describes integrated multi-functional Humble Lampposts (imHLa) as integrated, networked systems. They are of modular design and can house components with connectivity, sensory, actuator and energy system technology. The DIN SPEC 91347 defines four fundamental aspects for the standardization of imHLas:

- physical integration of hardware within the mast and, where economically feasible, of individual components with each other
- logical integration of individual components, for example for data exchange and communication
- economic integration of individual components for operational and business models
- macro-integration of imHLa into Open Urban Platforms in Smart Cities

Street lights have been part of every urban landscape for many years, and with the introduction of mobile, wireless internet and powerful microcomputer systems known as sensor nodes, the "Internet of Things" has also become ubiquitous.

Since sensor nodes need to be set up in cities, and because lamp posts are connected to the electricity supply, two essential prerequisites for the integrated multi-functional digitalization infrastructure are already present: namely blanket coverage and a power supply. This means cities can add digital components to become the "smart(er) cities" of the future. Street lighting therefore paves the way for setting up an integrated digital urban infrastructure that links various components and services, and provides access to information.

The DIN SPEC 91347 focuses on 14 use cases and a classification system for different modular configurations of imHLa. The use cases delineate the circumstances and contexts in which imHLa can be implemented to the advantage of local communities and act as case studies to demonstrate possible advantages. The selected use cases give specific examples of the wide range of potential applications for the lamppost, but it is not an exhaustive list and many other uses are possible.

DIN SPEC is initially intended for public street lighting managed by municipal authorities but does not preclude application to other fields.

The DIN SPEC 91347 has been open for free download

6.6 IPWEA - SLSC

http://www.slsc.org.au/home

The Institute of Public Works Engineering Australasia (IPWEA) is the peak association for the professionals who deliver public works and engineering services to communities in Australia and New Zealand.

IPWEA has been closely monitoring developments with street lighting since 2012 and, in 2014, published its Practice Note 11: Towards More Sustainable Street Lighting. By early 2016, IPWEA concluded that there is an overwhelming commercial, safety and environmental case for the wholesale renewal of street lighting infrastructure. While there is a growing push in both Australia and New Zealand to see this happen, there were a range of significant knowledge gaps, misaligned interests and out-of-date guidance for those who manage such deployments.

At the same time as LED street lighting and control systems have matured, so too has a range of other digital outdoor infrastructure assets falling under the umbrella of the Smart City. Street lighting is providing the backbone for the Smart City and hence the interrelationship between these two aspects of public infrastructure must be considered together.

Recognising the fundamental digital transformation now underway in street lighting and other outdoor infrastructure, IPWEA established the **Street Lighting and Smart Controls (SLSC)** Programme.

IPWEA has created an advisory SLSC Council to help guide the work of the Programme and a Technical Advisory Group (TAG) to provide industry review and feedback on key Programme outputs.

The SLSC Council has adopted the following Mission for the SLSC Programme: To accelerate the efficient adoption of modern street lighting and smart controls technologies and best practices

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

throughout Australia and New Zealand, in support of the government's Energy Productivity and Smart Cities agenda.

IPWEA is collaborating with many industry players that are involved in TALQ and also with EIP. Its work complements the results from EIP Humble Lampost and address core streetlighting in more detail and control management systems (CMS). This helps inform cities to advance to procurement activities.

In July 2017, the SLSC Programme released two model specifications to help councils, main road agencies and utilities buy both LEDs and smart controls with confidence. These robust model specifications build on both Australian and international standards and have been developed with broad stakeholder input. These specifications are free to download at www.slsc.org.au or www.slsc.org.nz.

6.7 Municipal Solid-State Street Lighting Consortium

https://www.energy.gov/eere/ssl/doe-municipal-solid-state-street-lighting-consortium

The DOE Municipal Solid-State Street Lighting Consortium shares technical information and experiences related to LED street and area lighting demonstrations and serves as an objective resource for evaluating new products on the market intended for those applications. Cities, power providers, and others who invest in street and area lighting are invited to join the Consortium and share their experiences. The goal is to build a repository of valuable field experience and data that will significantly accelerate the learning curve for buying and implementing high-quality, energy-efficient LED lighting.

DOE offers a variety of resources to guide municipalities, utilities, and others in their evaluation of LED street lighting products.

- Specifications help determine appropriate performance characteristics for a lighting application.
- Financing guidance and tools provide information and evaluation assistance for LED lighting investments.
- Frequently asked questions address issues surrounding street lighting.
- Demonstrations evaluate LED products in real applications.

The DOE Municipal Solid-State Street Lighting Consortium's Model Specification for Networked Outdoor Lighting Control Systems helps cities, utilities, and other local agencies accelerate their adoption of systems that can further reduce the energy and maintenance costs of operating their streetlights

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

6.8 FIWARE Street Lighting models

FIWARE have defined a set of harmonized data models to enable data portability for different applications including, but not limited, to Smart Cities. They are intended to be used together with FIWARE NGSI version 2.

FIWARE data models include **Street Lighting models**: These data models are intended to model streetlights and all their controlling equipment towards energy-efficient and effective urban illuminance. It encompasses the following entity types:

- **Streetlight.** It represents a particular instance of a streetlight. A streetlight is composed by a lantern and a lamp. Such elements are mounted on a column (pole), wall or other structure.
- **StreetlightGroup**: It represents a group of streetlights being part of the same circuit and controlled together by an automated system.
- **StreetlightModel.** It represents a model of streetlight composed by a specific supporting structure model, a lantern model and a lamp model. A streetlight instance will be based on a certain streetlight model.
- **StreetlightControlCabinet.** It represents automated equipment, usually on street, typically used to control a group(s) of streetlights, i.e. one or more circuits.

7 Pilots Smart lighting services

This section presents the current state of the Smart Lighting deployments in the three pilots. The information gathered in this section is still evolving since some of the services are being implemented and deployed. Specifically, the section provides information about use cases being implemented and the technical information about their deployment, the high-level architecture of the solution, protocols/standards used and connectivity solution.

Also, it includes what data is being used in the control room and what data is being transferred to the data aggregation platform.

Next table provides a summary of the pilots' strategy regarding the Smart lighting deployment.

For each of the use cases defined by Sharing cities project and DIN (See 0) the pilots current approach is depicted:

- √ → Implemented or under deployment
- X → Analysed but discarded
- ¿? → Under analysis
- ○ → Not considered

Humble Lamppost Use Cases		DIN	ShC	San Sebastian	Florence	Bristol
LIGHTING Related						
L1	Basic LED Energy, GHG, and Maintenance Improvement		Y	√	√	√
L2	Additional Energy Savings / Optimisation (CMS "Trim & Dim")		Y	√	√	
L3	Safety, Attractiveness & Façade / Mood Lighting (incl Improve the Quality of service and people safety –fault reporting)		Y	√	√	
L4	Alternative Clean Energy – PV cells to power some lights		Y			
NON-LIGHT Related						
NL1	Event-controlled adaptive street lighting system	Y			¿?	
NL2	Traffic monitoring (Driver Information; Traffic Monitoring; Parking)	Y	Y		√	
NL3	Intelligent communication between vehicles and the imHLa	Y				
NL4	Public Wi-Fi	Y	Y	X	√	
NL5	Wireless network support with a picocell or microcell	Y				

NL6	Environmental data acquisition (air quality, noise, water levels, etc)	Y	Y		√	√
NL7	Charging station for electric vehicles (vans, cars, bikes)	Y	Y			X
NL8	Drone charging infrastructure	Y				
NL9	Energy storage	Y				
NL10	Remote maintenance	Y				
NL11	Public security	Y	Y			
NL12	Private security and surveillance / geofencing – pedestrian monitoring	Y	Y			
NL13	Signage and advertising	Y				
	Public Engagement (safety of place, information speakers, information signage, tourist info)		Y			
Other (Please specify)	Access Limited Traffic Zone				√	

Next sections provide detailed information on the pilots current Smart lighting deployment and future plans.

7.1 San Sebastian smart lightning services

In the latest years, the city of San Sebastian has started the substitution of conventional lamps with LED lamps, in the Replicate project framework the replacement of traditional luminaries to new LED technology and the development of the intelligent systems and IP services has been done. The smart lighting deployment includes the installation of an intelligent and remote-control system of the street lights, controlling point to point, with the target of having the capability of controlling every single light point, monitor the energy consumption, manage calendars, regulation (DIM) of the lights according to the real needs of the environment, and the presence of cars and persons.

The smart lighting system installed is a vertical service in the smart city concept. The system has the power to **regulate the street lamps** based on different factors and conditions. A calendar can be established to regulate the lamps, and additional detectors (of rain, of presence, of movement...) have been installed to dim/regulate the lamps if there is somebody there (Presence), or if it is raining, etc. Everything is oriented to save energy consumption.

The **communication** to each lamp is done using Broad-Band PLC (Powerline communication) through the existing electric wires, so it is not necessary to implement additional infrastructures (More wires, road works, and so on) to manage the installation and control each lamp.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

The electric network is transformed in a TCP/IP LAN, adding the possibility to install **sensors, cameras, and any other IP device of interest**, using the lamp control box and the PLC network. The communication is up to 200MB/s, which allows large amounts of data to be sent through the electric wire. The system can work not only at night, but also during the day (24H operation is possible) as the system has a software with astronomic clock allowing that the lamps can be turned off during the day using a relay on the control box.

The main actors of the platform are:

- **Leycolan**: Provider of the installation, street lamps, control system, IP services... Leycolan has installed all the lighting system and is responsible of the maintenance during the duration of the project.
- **Municipality, Fomento de San Sebastian**: Owner of the infrastructure

7.1.1 Scope and Architecture

The proposal consists on implementing just one "control Node" in every lamppost or point/service to be controlled, and just 1 head end or concentrator at every control cabinet of each circuit. The communication for these services is carried through the existing Power line for the supply of energy to the lampposts. Therefore, it is not needed to incur in additional and expensive road works, or deployment of new wiring for implementing these services of light management and/or new services.

The system includes an internet connection, to be managed and administrated remotely. Also, it has to have a connection to exchange data with the platform, but this is not necessarily to be done through the internet, it can be done through a wireless or WIFI network, or the municipality internal network. All the devices installed in the installation could be controlled through the internet, or remotely.

With this thinking the proposal consists on implementing a remote-control system for the 90 Lampposts, having 2 central cabinets: 1 providing the power and control to 52 lamps, and the second one providing the power and control to 38 lampposts.

7.1.2 Intelligent lighting system

To have the control of every lamppost, 1 control Node will be installed in each lamp, for the intelligent lighting system (It is incorporated into the pole). In order to make it more intelligent, it is proposed to implement specific detection systems, in some of the posts, making a maximum coverage of the detection areas in order to provide maximum security and effectivity when providing light in all cases that there is presence in the area. The proposal includes the installation of 4 detection Radars. (Wide angle detection radars that will manage the light regulation according to the presence of persons or vehicles), and 12 vision detection cameras. The aim of these presence detectors is to provide the adequate lighting to the passing by

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

people or cars. Every street is classified according the Spanish street light regulation RD 1890/2008, and could be adapted also to EN13201.

Additionally, the control system will contribute to reduce the street light maintenance costs. The system can have the knowledge and information of every lamppost, the working regime that has implemented, and can report alerts to the maintenance department, reducing considerably the maintenance costs compared to older conventional systems, where the maintenance was carried out only through the need of physical visit to every lamppost, except for scheduled, mandatory mechanical inspections.

7.1.3 Innovative services possible to implement using the existing infrastructure of the public lighting

While it is stablished a system for the street light management, and due to the system characteristics, it is possible to implement new services for the citizenships using the infrastructure available.

As the lighting is regulated/dimmed/managed taking in account different parameters, the lighting energy savings can be contrasted with different days, traffic flow, weather, pedestrian presence, etc. to get statistics and understand better the behaviour of the inhabitants. That could be very interesting while taking decisions for the future management of the area infrastructures or manage them by the municipality.

In addition to the intelligent lighting control system, different IP services have been implemented, taking advantage that with the installation of the head ends and the control nodes; it is created a LAN over the power grid covering the street light installation grid. The implementation includes: 6x2 IP audio services, 4 IP vision cameras (2 for the Municipality police, and 2 for Streaming viewing cameras), 2 rain sensors, 1 vehicle counter, and 2 energy meters.

With the implementation of the new technology LED lights and all these new generation devices for the remote-control management and additional IP services, the street light system has been converted into a LAN, where every single lamppost is and intelligent point and where it is possible to connect an IP device that can work over internet and promote the IoT activities in the area.

7.1.3.1 IP Services implemented

In addition to the replacement of the Conventional Lights with LED Technology there have been implemented the following IP services:

1. Presence detection:
    a. with Radar Technology (4 Units)

   b. with vision Technology (2 Single and 12 double vision –detection cameras)

2. Rain sensors: 2 units
3. Audio over IP (Sound system): 6 units of 2 loudspeakers.
4. Video Surveillance for Municipality Police use: 2 devices (Domo type).
5. Video surveillance, for municipality use: 2 devices
6. Vehicle counting device: 1 unit.

With all these devices, it is possible to control, or get knowledge and information about the street lighting service status, about its performance, on real time, at every moment. It is possible to regulate the lights or modify the regulations.

It is possible to act on the sound system and give notices/advertisings, or evacuation notices, for example. Data can be stored, from the vehicle count that are coming into this area or leaving the area of the project.

The modified infrastructure with this technology, can perform these services, but additionally as it has been created a LAN network over the Power line, is also possible to incorporate other IP services that could come later, just with the connection of any device to the created LAN network. Therefore, it is possible to say, that it has been created a smart street lighting system. For more detailed information about the achievements see D3.11 Report on Public Lighting System.

7.1.4 Data management and interoperability

Interoperability

REST API is provided for its integration, based on REST standard and uses JSON formatted data exchange. The requests to the API are based on POST commands through HTTP or HTTPS (it is configurable) protocol to a web server placed on the central computer of the lighting system.

The REST API is composed of four services: lighting control, file control, energy meters control service and scenario control. The lighting control category includes functionalities to get data from environmental sensors and cameras installed in the luminaries along with the luminaries' configuration, monitoring and control functionalities.

The Lighting system collects information on real time, so it is possible to know the real status of the lamps in each moment. The energy consumption data/measurements per lamp are provided every minute from the control box to the central computer, by the system.

The system records internally in an 8GB memory all the data collected from the lamps. It also records detection information, traffic flow information provided by the traffic flow camera, etc. Normally it is set to record the last 6 months period information, but it can record more historic

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

data if needed. As the lighting system head end computer has a quite complex OS the data is stored in files, not in any special database, to enable easier access from outside.

Data governance

The municipality or the customer owner of the installation is going to be the data owner.

The municipality will have access to all data measured by the lighting system: energy consumption of street lights, energy savings, detections, traffic flow information, etc. These data will be analysed to be published as linked open data. The municipality would be able to decide which of these data parameters are useful or open to the inhabitants.

7.1.5 ICT Smart City Platform alignment

The ICT Smart City Platform collects data using the API provided. All this information is provided from the Smart lighting system as open-data. Some of the provided data may need some analysis in the platform, but most of data is going to be provided after processing it. The FIWARE smart lighting Model will be used to export the data to the municipality data centre.

The system enables to transmit energy consumption data to the ICT Smart City Platform, elaborate graphs with the energy consumption data, and analyse the effects of presence detection, and rain sensor.

Currently, once a day, the inventory of devices associated with each cabinet is collected and every 5 minutes the information given by each node/device. The Smart City ICT platform uses the API getAllNodeInfo method every 5 minutes to collect the information of the two cabinets.

The following data is gathered:

By cabinet/hub:

Inventory
reception_timestamp
hub_id
hub_name
group_id
device_id
device_name
device_type
geometry_type
geometry_coordinates

By device:

Status
reception_timestamp
hub_id
device_id
device_type
ecurrent
dim_level
voltage
energy
power
power_factor
detection_counter
event_timestamp
r
lux_level
active

The smart lighting information is stored in the municipal data lake some graphs are visualised using a BI tool. Next figure shows a visualization example:

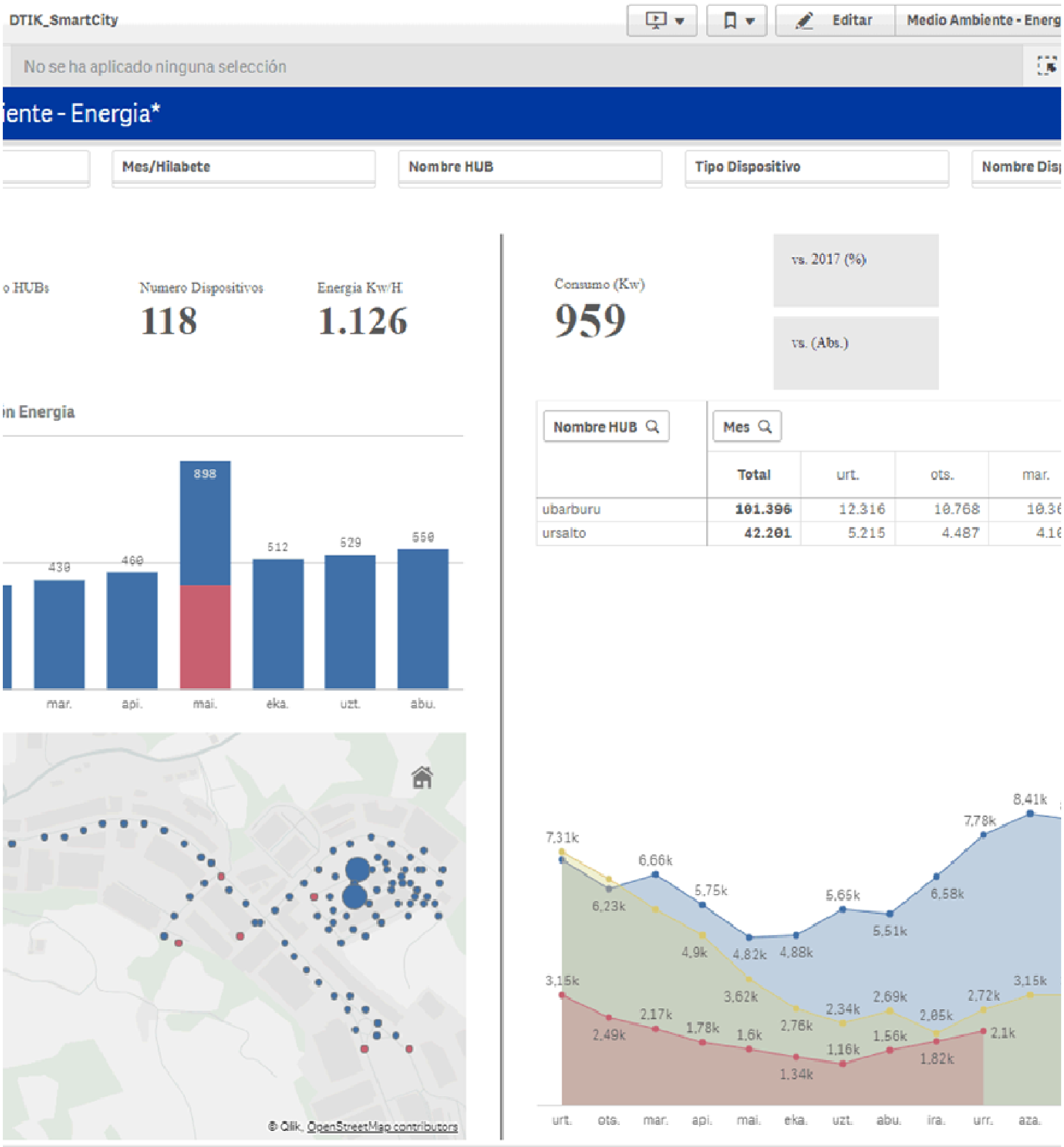

Figure 5 Smart Lighting information visualization

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

7.2 Florence smart lighting services

According to the DoA, Florence plans to develop **"a new lighting system integrated with technological equipment for value-added services".**

For the purpose of the definition of the measures on public lighting systems, the action must be related to what is specified in the Municipal Public Lighting Plan adopted (DG 00517/2009), which shows the lighting classification of the place; the intervention area is characterized as the functional structure of public green area with historical and architectural value, mainly pedestrian and cycling with the resulting minimum and average values of illuminance to be respected.

The standard UNI11248 indicates the classification Fbis for pedestrian routes, which is associated with the lighting category S2 input for the analysis of risks where the reference values are indicated by the UNI EN 13201-2 for the facility in operation under flow control. Classification of lighting project:

- Average illuminance (minimum maintained): 7.5 lux
- Minimum illuminance (minimum maintained): 1.5 lux

The Smart Lighting Manager module of the ICT platform will provide the possibility, as a result of specific events, to command a specific brightness level regardless of the value set up through a static and determined configuration. **The remote adjustment control can be managed on the base of different events**:

- Road car traffic detection based on sensor output;
- People motion detection based on video analytics;
- Illumination level based on digital sensors output;
- Security alarms provided by urban security systems.

The data regarding energy consumption, the actions/decisions taken, the collective user behaviour will be accessible for the ICT integrated infrastructure.

The smart light system will deploy energy efficiency (LED bulbs) together with **other advanced services** like,

- Wi-Fi spots,
- light surveillance (to watch on sensible targets like IoT installations),
- traffic access control.

Moreover where possible, the light will be activated by alarms of specific smart actuators (PLCs) that, interacting with the system of video cameras, will allow the introduction of adaptive lighting, characterized by high environmental sustainability criteria according to which light activates with different luminous intensities in real time following the actual use of the paths: in pedestrian areas (parks) the adaptive lighting will be adopted in 70 lighting spots and 25 cameras will be placed.

The data regarding energy consumption, the actions/decisions taken and the collective user behaviour will be accessible for the ICT integrated infrastructure.

The main actors of the platform are:

- **Municipality if Florence and citizenship**: Users of the area.
- **SILFI**: Implementation and maintenance
- **UNIFI**: Data harvesting
- **Thales**: Lamppost design and video surveillance systems
- **SPES**: Analysis of the possible services
- **Telecom**: IoT and capillary network possible match

7.2.1 Scope and technology

Context:

Florence there are 40.500 lampposts and 3.500 traffic lights; in the district there are about 7.500 lampposts which are not networked or efficient.

Only in the Cascine park during the 1st (first) two years a pilot action has been implemented to test an adaptive light system in a special environment as an urban park.

Main issues to be targeted:

The public lighting service has to be efficient to reach the savings targets set in the SEAP (2020) and in the Smart City Plan (2030-2050). The design must be compliant with the special boundary conditions of an UNESCO historical city. Above the energy efficiency issue, the infrastructure, which is one of the most capillary in a city, can be optimised carrying other services on board (video surveillance, environmental sensors, Wi-Fi, IoT capillary network, traffic sensors/cameras, data collection...) to minimize the impact and to reach a wider coverage with a low-cost implementation.

Implementation size: about 6.000 lampposts, the 80% of the total in the district. Refurbishment of 1,000 public lighting lamps done: scale up at city level already started.

General description: The municipality is going to develop a tailored refurbishment plan of the public lighting infrastructure in the district trying to match for each area the best lighting conditions and the needed additional services (video surveillance, traffic control, WIFI, weather pluvial sensors....).

A new lamppost design is under analysis which could be able to host additional services, save energy and stand in harmony with the historic urban landscape. The new technology will ensure better perception of colours and visibility at night thanks to the switch from the yellow / orange light of the old sodium and mercury lamps to the white light of the high colour rendering LED, with positive impacts on road safety, increasing the possibility, for those driving and moving at night, to better distinguish obstacles and road signs.

Lights will be kept on for the whole night, with a lower power, and will not be switched off 11.15pm.

Implementation of "smart" solutions and technologies: new tools for environmental or acoustic monitoring of the city and new possible services to citizens (WIFI, security, etc.) thanks to the "sockets" (connection points) present on each lamppost.

Innovation level: high (data from the lamppost will be collected according to their features and capabilities: wifi, light level, passages of people, environmental parameters, etc. Data will be aggregated and unified with the rest of the smart city data in the unified model and tools).

Benefits: the action will reduce the energy consumption of the public lighting network (and the GHG emissions), increase safeness in the district, optimize the impact of the services infrastructures.

The efficiency plan has been started by SILFI spa, in-house firm of the Florence Municipality, and it had presented the technical-economic project for the Energy redevelopment of public lighting systems approved by the Municipal Council.

The technical analysis covered the following issues:

1) The objectives
2) The technology to be used
3) The intervention criteria

The main objectives have been:

1. Observance of the applicable laws in Italy regarding outdoor lighting.
2. Environmental related savings
    - Energy savings obtained thanks to the high efficiency of the lighting fixtures and to the reduction in light intensity during the night;
    - Reduction in the CO_2 emissions levels resulting from the energy savings obtained;
3. Public lighting cost reduction
    - Increased safety and improved visibility of the outdoor spaces, in accordance with the contents of the Public Lighting Municipal Plan;
    - Reduction of the operating and maintenance costs;
    - Improvement of the public service;

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

4. Public service improvement
5. Non-light services development
    - Configuration of socket devices, useful to develop services that are typical of Smart Cities.

In order to optimize and improve the intervention impact on the quality of the public service, construction works have been launched to provide new support and new electrical infrastructures for the efficient use of LED luminaries.

7.2.2 Intelligent lighting system

Regarding in particular the Cascine Park, with a view to effective prevention of nocturnal road accidents, which, despite significantly lower traffic volumes, can lead to very negative consequences, it is necessary to emphasise the importance of street lighting (although greater weight have non-visual factors that alter the threshold of attention and of vehicles conductors' reaction, as well as the conditions of the road surface). Inadequate lighting has, in fact, the effect of reducing the efficiency of the many visual functions that are involved in the various situations that arise driving a motor vehicle.

With the replacement of traditional lamps with LED, visibility and visual comfort will be improved by the average luminance contrast of the roadway and by luminance uniformity able to ensure that the perception of the road is provided in a clear way and without uncertainty.

The new LED fixtures installed will also be equipped with systems able to regulate the luminous flux emitted from the sources which correspond to energy savings and reduction of greenhouse gas emissions. The flow regulators installed on the individual LED devices will be interconnected with each other through a local network of Wi-Fi communications to ensure the point-to-point remote control of individual luminaires and the possibility to adjust the light output in real time.

In terms of the environmental values of the park, it should be highlighted that the installation of LEDs with higher colour rendering allows a more natural night vision of the park, while minimizing the direct scattering of light by lamps set outside the areas to be illuminated will reduce the disturbance to the animals living in the park and which must be protected through a light pollution abatement.

7.2.3 Innovative services possible to implement using the existing infrastructure of the public lighting

Leveraging the smart lighting infrastructure

- Video cameras installation and connection (wifi, fiber network)
- LTZ devices
- Anemometer

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

- WIFI
- Other sensors (temperature, humidity, ...)

7.2.3.1 Access Limited Traffic Zone (LTZ) pilot

In the last years the Cascine park area has been subjected to changes due mainly to the creation of the new tramline, the Opera theatre, the information centre "Centro visite" and to the new management of the existing structures.

To manage all those changing processes and to enhance a further evolution aimed at increasingly optimising the liveability and the use of the biggest urban park, the municipal administration has adopted the Cascine 2020 Masterplan, developed with a participative process involving stakeholders and citizens in the decision making. In particular the Masterplan states that, with the new tramline reaching directly the park, the area should be reserved to pedestrians and bikers and limited to traffic heading to the city centre.

To do so, the Masterplan foresees the integration of the tramline with a set of other measures facilitating the parking and the transit only in the tangential areas together with the establishment of a **limited traffic zone** (LTZ). The realisation of the LTZ will increase the road safety internal to the park especially during the night; the "weak" road users (pedestrians and bikers) will benefit from this restriction, closing the by-pass to the ordinary municipal road system, valid also for two wheels vehicles which are causing a lot of accidents during the nights.

Together with the traffic restriction, the maximum speed will be limited to 30 km/h to increase safety, and four telematic access points will be built.

The picture below shows a common realisation scheme with all the components needed: an integrated camera with infrared device for night reading of the license plates, a laser grader and a transponder for the detection of installed on-board devices on authorised vehicles.

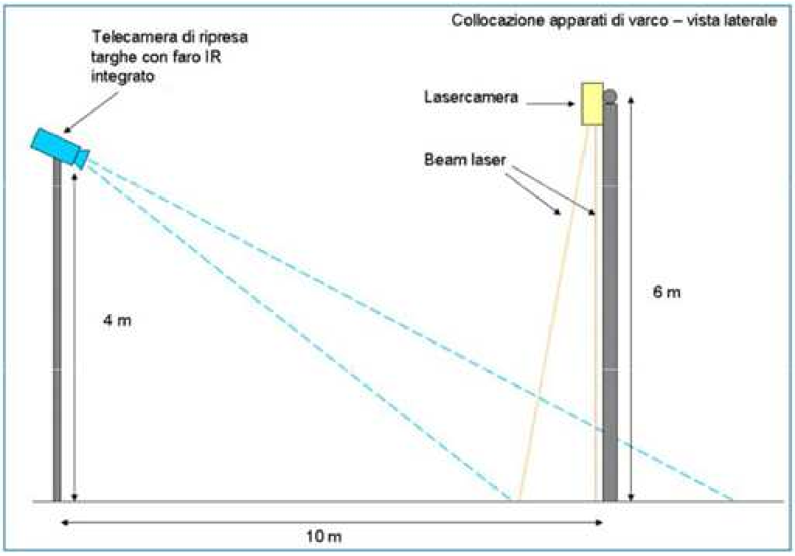

Figure 6 Common realisation scheme of a traffic access control point

All those devices will be integrated with the public lighting infrastructure which will be retrofitted installing LED lights to optimise the performances and the safeness.

The telematics control devices of the LTZ Cascine and the new LED lighting systems will be coupled in correspondence of the access to the Park gates, where the presence of the passage will be highlighted through a particular lighting solution, with the aim of creating "bright doors" that mark the access to the protected area.

In the year 2016 the activities of the REPLICATE project focused on the completion of the design, which covered both the LTZ Cascine, whose final draft was approved by the Council Resolution 2016/G/00680, as well as the retrofitting of the city's public lighting, whose project was approved by the Council Resolution 2016/G/00646.

In 2017, the pilot test ZTL Cascine has been deployed and the refurbishment of 1,000 public lighting lamps has been done. The scale up at city level has already started.

7.2.4 Data management and Smart platform alignment

Smart Light Manager: (Florence Municipality-Silfi, UNIFI, Thales) a smart light manager will be implemented extending the test in the Cascine park and integrating the data. The data integrated into the smart lights manager will include the smart lighting location, status and Consumption, Video cameras status (and data flow if possible), sensors data flow, LTZ data and status. The sensors will include anemometer, temperature and humidity, among others.

The Smart Light manager will be in charge of monitoring the results, analysing consumptions and interfacing with the Smart City Control Room and the Smart City platform.

VideoCameraManager (Florence municipality, Thales): new surveillance and monitoring digital cameras will be positioned on the public lighting network. A video managing system will be provided to collect data from those new installations as well as from the 221 existing cameras in the district, currently managed by the Municipality of Florence for security and traffic monitoring issues.

This module is also in charge to provide video flows and data to the Florence ICT Smart City platform. The new system will be able to manage also events and alarms arriving from other different subsystems (i.e. intrusion detection) and correlate them with the video cameras in order to redirect automatically to the video dashboard the relevant video flows.

7.3 Bristol smart lightning services

Initially, there were three aspects to the smart lighting aspect to be explored. A summary is provided below:

1. Exploring a link (or simulating a link) to the **energy demand** management system. The agents involved in this case are NEC with BCC with Route Monkey supporting.
2. Exploring if **EV charging** can be integrated into smart lighting. The agent involved in this case is BCC under the Go Ultra Low project.
3. Deploying **sensors** (the Array of Things sensor platform) on lampposts in the area and working with citizens to explore the business case / added value. The agents involved in this case are UoB and KWMC with BCC supporting.

7.3.1 Smart lighting Energy linked to the energy demand management system

Bristol's energy service along with the highways team shall work together on a lamp replacement programme over 3 years, starting in 2018/19. The objective is to replace low and high-pressure sodium lamps with LED lamps. This will save an estimated £190,000 of electricity per year.

However, there is no proposal for demand-side management interventions as part of the lamp replacement.

7.3.2 EV charging integrated into smart lighting

Bristol municipality have been in discussion with several companies offering a lamppost charging solution. There are some interesting products, and there are trials already taking place in London and Oxford. The highways team are involved in other charge point installations and they have already expressed an interest in exploring lamppost charging.

However, several key barriers remain before Bristol will be able to take this further:

1. **Funding**: The Go Ultra Low programme includes a capital grant from UK government with targets around the number and type of charge points. These are specifically for Fast and Rapid charging only. Therefore, the Council does not have a budget identified for slow lamppost chargers.
2. **Position of lampposts**: Many streetlighting columns are located at the back of the pavement, and those at the kerb side may also be moved (in the long-term), in order to avoid the cost of vehicle collisions. Therefore, there is increasing problems with how to deal with the trailing cable across the pavement.
3. **Citizenship preference**: It's also worth noting that the feedback from Bristol's recent market research report indicates that the preference for public charging is leaning more towards Rapid (1/2 hour) charging.

Another of the key issues in the UK is that streetlights are typically unmetered. There is a national agreement on charges for unmetered supplies and typically they need to draw less than 500W. There are different theoretical solutions to this such as agreeing a larger energy draw on an unmetered supply or having a separate metered supply. All of these would need special permissions/ dispensations.

An alternative that has been looked at is for example the Ovo Kensington & Chelsea example is for the meter to be integrated within the charge cable and charges to be based on the mobile phone enabled smart meter in the cable (https://www.financialexpress.com/auto/car-news/how-street-lamps-could-charge-electric-vehicles-siemens-invests-in-this-start-up-for-evs/1163978/). In all cases there would need to be agreements between the highway authority, local distribution organisation and electricity seller.

Recently some news appear about new proposals, announced by Transport Secretary Chris Grayling, designed to make it easier to recharge an electric car rather than refuel petrol or diesel vehicles in UK.

Under the plans, if there is a parking space adjacent to the street light, if should have an in-built electric vehicle charging point. The proposed measures would mean the UK having 'one of the most comprehensive support packages for zero-emission vehicles in the world'.

Many local authorities in the UK already have initiatives with combining the street lighting network and charging points.

In London, Wandsworth, Richmond, Hounslow, Westminster and Kensington & Chelsea have all had trials, some with new street lights and others with existing luminaires. However, the trials have revealed a series of technical, practical and interoperability issues with using street lights to charge electric vehicles. While the conversion of existing street lights to LED does free-up current-carrying capacity which can be used to charge vehicle batteries, it's become clear the

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

dedicated high-current circuits are required to deliver the fast charge times demanded by drivers.

A national policy could also harmonise the diverse platforms that are already starting to appear on the streets. Some local authorities are providing free systems while others have partnered up with private sector suppliers. For instance, Kensington and Chelsea Council signed an agreement with energy company, Ovo, and German tech firm ubitricity, to install 50 charging points in street lights. These use ubitricity's proprietary SimpleSockets technology, so drivers will have have to use their own ubitricity cable connector.

7.3.3 Deploying sensors (the Array of Things sensor platform) on lampposts

7.3.3.1 Initial plans

KWMC will work to identify and inform procurement of IoT solutions that bring tangible benefit to communities. This could include air quality sensors and sensors for monitoring traffic.

The Array of Things is being introduced to the Bristol Demonstration based on the original work undertaken by the Urban Center for Computation and Data of the Computation Institute, a joint initiative of Argonne National Laboratory and the University of Chicago. The Array of Things is a network of interactive, modular sensor boxes collecting real-time data on the urban environment, infrastructure, and activity for research and public use. A range of different sensors can be deployed measuring atmospheric, air quality, and environmental factors and even sound, movement or infrared images.

Bristol City Council will deploy the sensor platforms on existing intelligent lighting posts within the demonstrator area.

A Makerlab run by KWMC based in Filwood Green Business Park (South Bristol) will be engaged in training residents to make sensor boxes with strong community identity branding. KWMC will work with UOB on the sensor technology in conjunction with Argonne Labs and the Array of Things. Prior to this project KWMC will be producing a Deployment strategy for the Citizen Sensing Programme learning from other citizen sensing projects and building a network of expertise.

The Citizen Sensing Programme will be supported by a Steering Group that includes representatives from BIO, UOB and BRISTOL, with potential for international representatives from Argonne Labs, Barcelona Smart Citizen Team and Amsterdam's WAAG Society. We will also consult with UK Future Cities Catapult who are engaged in Citizen Sensing projects across the UK.

BRISTOL will deploy the sensor platforms on existing intelligent lighting posts within the demonstrator area. The deployment will also be part of the 'Citizen sensing' pilot being run by KWMC.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

7.3.3.2 Current status

Bristol is progressing with the deployment of sensors on lampposts, however due to external dependencies these will be predominantly third-party platforms and not the Array of Things (See 11). Bristol will still trial AoT, but too much limited scope and numbers, as the collaborators from Argonne are only able to provide 3 nodes per city installation. This is due to manufacturing and other unforeseen constraints.

Instead, a mixture of limited high-accuracy environmental sensors, combined with larger volumes of devices of higher resolution in terms of data points (but potentially of lower quality measurements) will be deployed. The whole intervention will have an emphasis on air quality monitoring and to that effect we are combining deployments of devices from this local provider http://atmotech.co.uk with the citizen sensing kit that was designed in Barcelona https://smartcitizen.me/#sck, as well as KWMC's 'ladybird' mobile air quality sensors.

Preliminarily at around a dozen proprietary sensors will be deployed in lampposts around the city and about 120 smart citizen devices to be used by citizens at selected households/facilities. A number of the portable monitors will be also deployed at selected routes across the city. The use case is simple and focusses around air quality measurements of mobile groups (e.g. taxi drivers), selected points of interest (e.g. schools) and selected areas in the city.

However, this "simple" use case is a good example of using the smart lighting deployment as infrastructure for other non-lightning use cases. It would be far more about citizen sensing and developing the case for citizen involvement in the deployment of sensors on lampposts, than developing the case for smart lighting. Here we are talking more about smartening up existing infrastructure with community contribution.

At the moment it is not possible to supply more specific details on the data architecture, as the majority of the kit is on order and pending delivery, so there is an element of integration study that is required prior determining it.

There will be definitely things to extract with respect to standardisation of interfaces (mobile/domestic/city sensing systems) and flows of (environmental/air quality) data towards the city platform.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

8 Innovations, Impacts and Scalability

According to the IoTUK report "The future of street lighting: The potential for new service development" [10], the progression of smart lighting infrastructure involves three stages:

1. **Switching to led bulbs**: LED lights provide a number of benefits including increased life expectancy, health and safety benefits and cost savings.
2. **Connected street lighting**: LEDs are essentially electronic devices that can be connected to central control systems in order to give operators the ability to monitor and regulate light levels, conduct remote monitoring and to meter electricity usage more accurately.
3. **New service development.** Both traditional lamp posts and more advanced smart lighting installations have the potential to act as a smart city platform, enabling a range of other smart city applications through the integration of data collection devices such as sensors and cameras.

Even though this document includes some information about the three stages, its main focus is the third one: **New service development,** so that the focus of this section is to analyse the innovations, impacts and scalability of the Smart Lighting interventions regarding its integration with the Smart city platform and the so called non-lighting use cases. Some information about the second stage is included but the details about the first and second stages can be found in the pilot specific reports.

The scalability and economic feasibility of using the Smart lighting infrastructure to provide IoT services and to share data with the ICT city platform is still an open issue. The economic, environmental and social benefits of improving the quality and the control of luminaries is recognised.

However, this is still not the case with the non-lighting uses cases and services. The environmental and social impacts of this new services largely depend on each specific service and the economic feasibility from a business point of view is one of the main adoption barriers (See section 5.2).

8.1 San Sebastian

Innovation: The smart lighting deployment in San Sebastian the street light system has been converted into a LAN, where every single lamppost is and intelligent point and where it is possible to connect an IP device that can work over internet and promote the IoT activities in the area.

Regarding interoperability, a REST API is provided for its integration, based on REST standard and uses JSON formatted data exchange. The API include functionalities to get data from environmental sensors and cameras installed in the luminaries along with the luminaries

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

configuration, monitoring and control functionalities. The data model used not based in any standard but is open so interoperability is also provided.

Therefore, the smart lighting infrastructure is ready to act as a smart city platform and its already collecting data.

However, the sensors deployed in the luminaries are being used to control and adapt the light levels but not for providing new services and the integration of the data with the Smart City platform is only used for monitoring.

Impact: The action will increase safeness in the district, optimize the impact of the services infrastructures. From the SMEs impact point of view Leycolan will increase its portfolio of services not only providing a better lighting solution but also IoT related services.

From the point of view of the municipality and the citizenship, a huge amount of data could be made available to the municipal control room and the smart city platform, that can be used to provide new services or to improve the current ones.

Replicability: The system deployed to connect the smart lighting system to the smart city platform is replicable from the technical point of view, since the protocols, APIs and data models are open.

8.2 Florence

Innovation: Data from the lamppost will be collected according to their features and capabilities: wifi, light level, passages of people, environmental parameters, etc. Data will be aggregated and unified with the rest of the smart city data in the unified model and tools.

Regarding interoperability, the smart city API defined by KM4CITY API is provided for its integration. The API include functionalities to get data from environmental sensors and cameras installed in the luminaries. The data model used not based in any standard but is open so interoperability is also provided. Therefore, the smart lighting infrastructure is ready to act as a smart city platform and its already collecting data.

Florence pilot has implemented two non-light use cases using the lamppost: The Limited Traffic Zone (LTZ) and WIFI access point. These are very innovative examples of using the lampposts. However, the deployment is still limited to the pilot test Cascine.

Impact: The action will increase safeness in the district, optimize the impact of the services infrastructures. SILFI, the third-party municipal company acting as an ESCO, will increase its skills and market chances. A huge amount of data could be made available to the municipal control room. The impact of other infrastructures (wifi network, video surveillance, traffic & access control...) minimised while their coverage will be widened.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

Replicability: The system deployed to connect the smart lighting system to the smart city platform is replicable from the technical point of view, since the protocols, APIs and data models are open.

8.3 Bristol

Innovation: Bristol intervention will combine devices installed in the lampposts with other devices like the citizen sensing kit that was designed in Barcelona https://smartcitizen.me/#sck , as well as KWMC's 'ladybird' mobile air quality sensors. This is the only example of combining the smart lighting infrastructure with other data sources in the city to provide a new service.

Impact: The whole intervention will have an emphasis on air quality monitoring and awareness by the citizenship, so the social and environmental impact is very high.

Adverse health effects caused by air pollution are increasingly being recognised and debated at national and international level. Knowle West Media Centre is currently working with communities in East Bristol to gather air quality data using sensor technology to see what can be done to tackle the problem of poor air quality at a local level.

9 CONCLUSIONS

While the energy and cost saving benefits are driving Smart Lighting adoption, cities are increasingly seeing the lampposts as smart city infrastructure. Smart street lighting is being used to form the technology foundation of a city, a network infrastructure for sensors and smart devices to improve community liveability and resilience.

Through the addition of data collection devices such as sensors and cameras, street lighting infrastructure can be used as a platform to host a variety of applications in the areas of environmental monitoring, traffic optimization, smart parking and public safety. Furthermore, street lighting infrastructure is being used to host charging points for electric vehicles, and as a base for public Wi-Fi and communication networks.

This vision is shared by the three lighthouses cities and they are working to add to the lampposts the connectivity and sensors needed to implement non-light use cases and to connect the Smart City platform with the Smart lighting system.

The implementations developed in the cities have demonstrated the feasibility of the implementation's potential providing a baseline for next steps.

Regarding standardization, most standards are applicable to the installation and deployment of LED lighting and their control and configuration capabilities. Only a few initiatives cover the provision of other services. Among the more interesting ones are:

- TALQ, which have evolved from a smart lighting specific protocol to a more generic IoT protocol.
- Zhaga: Book 18 defines a standardized interface between an outdoor LED luminaire and a sensing/communication module that sits on the outside of the luminaire.
- DIN SPEC 91347 defines four fundamental aspects for the standardization of the "integrated multi-functional Humble Lamppost" (imHLa):
    - physical integration of hardware within the mast and, where economically feasible, of individual components with each other
    - logical integration of individual components, for example for data exchange and communication
    - economic integration of individual components for operational and business models
    - macro-integration of imHLa into Open Urban Platforms in Smart Cities

However, even without standards, interoperability in the pilots is ensured by the use of open APIs and data models.

10 References (Bibliography)

[1] DECISION (EU) 2015/2240 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL: https://ec.europa.eu/isa2/sites/isa/files/celex_en.pdf

[2] Km4City Smart City Ontology and services http://www.disit.org/5606

[3] The Smart Appliances REFerence (SAREF) ontology: http://ontology.tno.nl/saref/

[4] Wikipedia, The Free Encyclopedia, Data governance," (accessed January 19, 2018), https://en.wikipedia.org/wiki/Data_governance

[5] http://searchdatamanagement.techtarget.com/definition/data-governance (accessed January 19, 2018)

[6] http://www.datagovernance.com/adg_data_governance_definition/ (accessed January 19, 2018)

[7] EIP-SCC Humble Lamppost initiative https://eu-smartcities.eu/initiatives/78/description

[8] IoTUK https://iotuk.org.uk

[9] Buntz, Brian. Why the IoT Is Coming to Street Lights. Internet of Things Institute. [Online] 22 April 2016. http://www.ioti.com/smart-cities/why-iotcoming-street-lights.

[10] https://iotuk.org.uk/future-street-lighting-report/

[11] DIN SPEC 91347 (2018-03) Integrated multi-functional Humble Lamppost (imHLa)

[12] Digital Illumination Interface Alliance. https://www.digitalilluminationinterface.org/

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

11 Annex I: Array of things initiative

https://arrayofthings.github.io/

The Array of Things is a collaborative effort among leading scientists, universities, local government, and communities to collect real-time data on urban environment, infrastructure, and activity for research and public use.

From the technical point of view, the Array of Things (AoT) is an urban sensing network of programmable, modular nodes that will be installed around cities to collect real-time data on the city's environment, infrastructure, and activity for research and public use. AoT will essentially serve as a "fitness tracker" for the city, measuring factors that impact liveability in cities such as climate, air quality and noise.

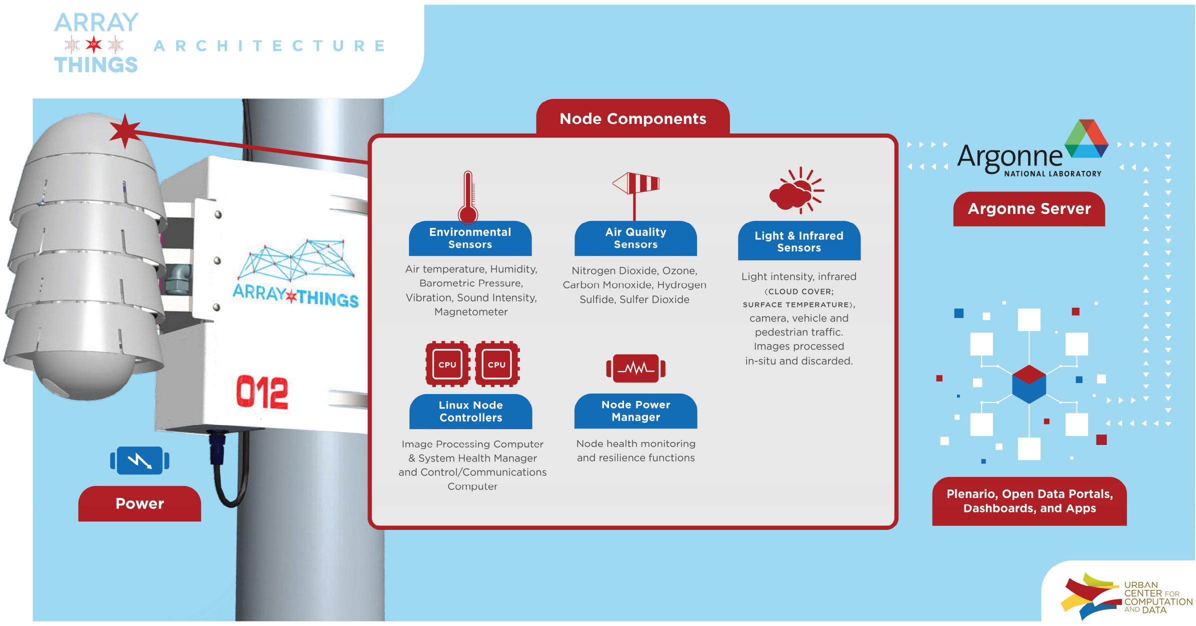

Figure 7 Array of things architecture (Source: http://arrayofthings.github.io/)

AoT will provide real-time, location-based data about urban environment, infrastructure and activity to researchers and the public. This initiative has the potential to allow researchers, policymakers, developers and residents to work together and take specific actions that will make cities healthier, more efficient and more liveable. The data will help cities operate more efficiently and realize cost savings by anticipating and proactively addressing challenges such as urban flooding and traffic safety.

Because the data will be published openly and without charge, it will also support the development of innovative applications, such as a mobile application that allows a resident to track their exposure to certain air contaminants, or to navigate through the city based on avoiding urban heat islands, poor air quality, or excessive noise and congestion.

The nodes will initially measure temperature, barometric pressure, light, vibration, carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, ambient sound intensity, pedestrian and vehicle traffic, and surface temperature. Continued research and development will help create sensors to monitor other urban factors of interest such as flooding and standing water, precipitation, wind, and pollutants.

Array of Things is interested in monitoring urban environment and activity, not individuals. In fact, the technology and policy have been designed to specifically minimize any potential collection of data about individuals, so privacy protection is built into the design of the sensors and into the operating policies.

Measurement	Purpose/Application	Sensor(s) Used
Carbon Monoxide	Air Quality/Health	SPEC Sensors 3SP-CO-1000
Hydrogen Sulphide	Air Quality/Health	SPEC Sensors IAQ-100
Nitrogen Dioxide	Air Quality/Health	SPEC Sensors 3SP-NO2-20
Ozone	Air Quality/Health	SPEC Sensors 3SP-O3-20
Sulfur Dioxide	Air Quality/Health	SPEC Sensors 3SP-H2S-50
Air Particles	Air Quality/Health (PM 2.5 to ~40)	Alphasense OPC-N2 (included in ~20% of nodes)
Barometric Pressure	Weather Conditions	Bosch BMP180
Humidity	Weather Conditions	Honeywell HIH4030, Honeywell HIH6130, Measurement Specialties HTU21D, Sensirion SHT25
Temperature	Weather Conditions	Honeywell HIH6130, Measurement Specialties HTU21D, STMicroelectronics LPS25H, U.S. Sensor PR103J2, Sensirion SHT25, Bosch Sensortec BMP180, Measurement Specialties TSYS01, Texas Instruments TMP112 & TMP421
Physical Shock/Vibration	Detect heavy vehicles, shock to street pole (e.g. accident)	Freescale Semiconductor MMA8452Q
Acceleration and Orientaion		Bosch BMI160
Magnetic Field	Detect heavy vehicle flow	Honeywell HMC5883L
Infrared Light	Cloud cover, sunlight intensity	AMS-TAOS USA TSL206RD

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

Light	Cloud cover, sunlight intensity	LAPIS Semiconductor ML8511, Melexis MLX75305
Ultraviolet Intensity	Cloud cover, sunlight intensity	Silicon Labs Si1145
Visible Light	Cloud cover, sunlight intensity	AMS-TAOS USA TSL250RD, Avago Technologies APDS-9006-020
RMS Sound Level	Sound intensity (loudness)	Knowles SPV1840LR5H-B
Camera	Street conditions, traffic flow, events	ELP-USB500W02M-L 170, ELP-USB500W02M-L 140