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ESMARTCITY

Enabling Smarter City in the MED Area through Networking

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

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

WP3 – Testing

Activity 3.4 – Assessment of Pilot Project Results

Deliverable 3.4.2 – Testing and Evaluartion of Pilot Activity Reports

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Responsible Author: **Isabel Rodríguez / Orlando Paraíba (PP4 - ENA)**

Project Coordinator: **Iris Flacco (LP – ABREG)**

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

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1 Contents

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1 – INTRODUCTION

Deliverable 3.4.2 is aimed to provide an evaluation report on the pilot test developed by partners in different types of sites in each territory, including smaller and larger cities, academic and public buildings, public city lighting, intelligent districts and living labs, offering through their diversification a heterogeneity that is assessed in this document in order to facilitate the replication of the project results as well as to support a Green Paper on Innovation Policy Change based on lessons learnt.

This report has the goal to evaluate the pilot activities deployed by the partners and to describe achieved results, critical issues faced and impact generated on the involved sites.

Considering the heterogeneity of the pilot deployments carried out, this report try to compile information for each one of them following the indicators agreed on the Methodology for Testing Deliverable (D.3.2.2) in order to provide a whole vision on the results and to extract conclusions that serve for future replications.

To achieve the pretended goal, this assessment report makes a double evaluation. On the one hand, there is a quantitative evaluation based on numerical indicators that allows to establish a comparison between different pilot activities; and in the other hand there is a qualitative evaluation based on the perception of the results obtained.

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2 - TYPES OF PILOT ACTIVITIES

All the pilot activities carried out aimed to testing Smart City concept in partner´s areas increasing the level of innovation by enriching city infrastructures via smart devices, embedded systems and sensor/actuators and enhancing innovation potential of SMEs allowing them to utilize Smart City infrastructure as test bed for innovative applications/services.

The projects developed intended to decrease the overall energy consumption while maintaining and optimizing the user-required level of comfort. The achievement of this goal has been carried out from different approaches, taking into account the specificity and needs of each territory, the great heterogeneity of the pilots and the existence or not of previous experiences in smart city solutions (from small towns incorporating smart city practices for first time into their public management, to cities with a consolidated penetration of the smart city concept even recognized by the European Parliament).

The pilot activities also seek to contribute to the improvement of the innovation capacity of cities, through the creation of an innovation ecosystem involving companies, research centers, academia and public authorities, creating in these territories the necessary conditions for the implementation of the Smart City concept. In this ecosystem, technology is placed at the service of citizens.

The implementation of this innovation ecosystem is based on sharing information and knowledge about intelligent systems and aims to enable new products/applications, increase energy management capacity, open opportunities for research, make cities more efficient, communicate energy efficiency values and establish more informed policies.

All these pilot activities can be grouped into two main themes: “Building Energy Efficiency” - through two variables: control and monitoring of systems- and “Smart Pubic Lighting”. They are distributed by partner as follows:

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Partner	Country	Municipalities	Theme	
			Building Energy Eficiency	Smart Public Lighting
LP Abruzzo Region	Italy	Pescara		✓
Industrial Systems Institute ISI (PP1)	Greece	Patras	✓	
Energy Agency of Granada APEGR (PP2)	Spain	Huetor Tájar + Agron		✓
City Development Agency East Sarajevo RAIS (PP3)	Bosnia Herzegovina	East Ilitza		✓
Energy & Environment Agency of Arrábida ENA (PP4)	Portugal	Setúbal + Palmela + Sesimbra	✓	
RGW Region of Western Greece (PP5)	Greece	Patras	✓	
Metropolitan City of Milan MCM (PP6)	Italy	Milan	✓	
Politecnico di Milano POLIMI (PP7)	Italy	Milan	✓	
National Institute of Applied Science INSA Lyon (PP9)	France	Lyon	This pilot is focused in gathering data about the use of streets through motion and environment sensors for a better comprenhension of how smart lighting can reduced with the most effectiviness the energy consumption of public strets lamps.	

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3 - SUMMARY OF PILOT ACTIVITIES

3.1 – IDENTIFICATION

LP. REGION OF ABRUZZO

THE PILOT	Integrated system of Smart lighting along one of the main roads of Pescara, replacing the old lighting system with a new one intelligent, effective and efficient, in order to evaluate the actual saving of electricity through a combination of the brightness adjustment of the lamps to the conditions of environmental visibility and lighting management. Inovative application case that add to new redevoleped public lighting system (with new LED devices) a series of smart devices (remote control of the lamp, environmental sensors, video surveillance, data collection unit and a control centre).
THE TECHNOLOGICAL SOLUTION	Use of powerline technology (conveyed waves) for information transfer on the existing electricity network, that allows complete and timely management of the plant and, potentially, allows to manage up to 1.022 peripheral devices with each individual concentrator.
COMMUNICATION NETWORK	**Telephone communication network:** based on SIM cards on a 2G network (GPRS) to transfer data from the control panel concentrator to the cloud supervision system in relation to lighting, the Weather station and vehicle counting system. The Meteorological Station is equipped with a battery with a solar panel for charging and transfers the data to the panel concentrator via 868MHz wireless communication.

	Powerline communication network: uses two distinct technologies even with the same physical transport support and the same power supply line as the lamps: - 111KHz "narrowband" Powerline communication according to CENELEC standards in Band B with ASK type modulation to transfer lamp data to the control panel concentrator. - "Broadband" Powerline communication with frequencies from 2 to 28 MHz, according to IEE 802.3u, Home Plug AV, OFDM modulation to transfer the camera data to the electrical panel. It allos to pass on the video surveillance cameras also on the existing power line installed.
TECHNOLOGY USED TO CONTROL LIGHTING SYSTEM	Everything is controlled and managed through the integration of a Web Platform that allows to view all the data monitored by the hardware performed previously in the local LAN or in Cloud mode. The communication of the software with the control panel takes place via GSM, GPRS, 3G, LTE or TCP / IP communication for point-to-point remote control of the single lighting apparatus. The innovative system of point-point remote control allows from any PC connected to the Lan (or to the Internet) and equipped with Web browsers to command and interrogate every single cabinet of the plant and every single luminous point located on the communal territory. It represents the platform that through the conveyed wave technology enables the existing power line of public lighting installations to transmit high-speed data. Installing electronic devices in Series after the lamp protection fuse, it’s possible to detect malfunction of the lamp; in this manner the lamp communicate with the Control/Command Centre, receive instructions for this for turning the lamp on or off, reducing or adjusting the luminous flux of the Lamp itself in function of real environmental scenario.
VARIABLES MEASURED	- Variables about lighting system: energy parameters (active, reactive energy and Frequency), voltage and current parameters on 3 phases, power comsuption parameters

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	- Variables about smart system: traffic analysis parameters (vehicle speed, counting and type), environmental parameters (temperature internal and external, humidity internal and external, wind speed, wind direction, atmospheric pressure, rain parameters as rain height and other parameters, UV index and solar radiation, evapotranspiration).
CONTROL ACTIONS THAT COULD BE TAKEN	Monitoring of alarms and data as: -Alarm about low battery, extra-use of power (linked with some energy theft probably), Alarm about not-working lighting devices (at least 3), Alarm about lighting devices which don't receive correct comands (alarm works at least for 5 devices) -Environmental Alarm (high/low humidity, high/low temperature, rain alarm when a fixed value of high rain is superated, very strong wind)
OTHER SERVICES PROVIDED	Electrical parameters, panel-mounted remote control devices at the lighting framework level 1 weather station, i.e. Wireless Plus station for the measurement of the meteorological parameters, solar and ultraviolet radiation, Including software module Traffic analysis (enabled for TAI adaptive lighting) 2 video cameras and broadband conveyed wave system

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PP1. ISI

THE PILOT	The pilot deployment in the premises of the Industrial Systems Institute offices utilizes smart equipment and IoT infrastructure to address the Smart City paradigm following two concepts, Energy Efficiency in buildings and the concept of the building as a Living Lab.
THE TECHNOLOGICAL SOLUTION	A number of IoT devices is used in the form of energy meters, sensors and actuators that gather information on the building operation and act upon results from the analysis of the gathered data. The analysis is based on big data analytics performed using open source tools and IoT data acquisition platforms. The installed equipment includes various sensors that measure temperature, relative humidity, light levels and motion/human presence. Moreover, numerous energy metering devices have been deployed to measure energy consumption of devices and control their performance remotely and automatically based on a set of rules. Other components of the system include gateways and mini computers acting as intermediates between the sensors and the servers gathering and analysing the collected data.
COMMUNICATION NETWORK	Based on open source solutions and well known communication protocols to achieve the neccesary communication between all system components. A group of sensors and energy metering devices use Zigbee protocol to communicate with an intermediate gateway that sends gathered data to an MQTT broker. Other devices use WiFi to communicate directly with the MQTT broker, which is responsible for data flow between edge points and the data collection servers. Where neccesary, messages from devices are transformed to an appropriate format before being sent to the message broker, to facilitate data storage.

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PP2. APEGR

THE PILOT	Agron Municipality: Change of part of the existing public lighting, in the church area and on the main streets, with energy efficiency and night sky protection criteria, managed through a remote management software. Monitoring of environmental variables. Huetor-Tájar Municipality: Change of municipal sports ground lighting with energy efficiency and managed through a remote management software. Monitoring of environmental variables and the municipal sport ground capacity. This information is displayed on a LED screen.
THE TECHNOLOGICAL SOLUTION	Agron Municipality: The 8 high-power metal-halide public lighting points (400 W) at the church area of the municipality have been changed to LED technology of 150 W and 3,000 K with downward lighting, regulation at 80%, and off at 1:00 a.m. 25 lamps of low-energy consumption but also of low-luminous efficacy, and classified in the municipal energy audit as light-deficient, have been changed to new LED luminaires of 35 W and 3,000 K and Upward Light Ratio (ULR) <1% regulated at 50% at lighting-on time, and at 30% from 2:00 to 5:30 a.m. Air quality (PM2,5, PM10) and Temperature and Relative humidity sensors have also been installed. All components are remotely managed through a management software web-hosted and working as SaaS. Huetor-Tájar Municipality: The 24 floodlights at the municipal sports ground of MH technology and 2000W, already changed to LED technology and 900W each, have been integrated into a remote management software to monitor and analyse their energy consumption. Air quality, PM, and Temperature and Relative humidity sensors have also been installed. An IP camera with video analytics has been installed too in order to count the users of the sports facilities. A LED screen has been implemented as well at the sports ground to provide citizens with this information. All these components are managed through the remote management software aforementioned, which is web-hosted.

COMMUNICATION NETWORK	Agron Municipality: Communications between the gateway and the light points is performed via radiofrequency (433 Mhz/ multi-band). Communications between the gateway and the management software is performed through the internet (Ethernet, WiFi). Huetor-Tájar Municipality: Communications between the gateway and the 4 lighting control modules installed, one in each switchboard of the 4 existing floodlights poles, and the environmental station as well, is performed via radiofrequency (868 MHz) using LoRa (Low Range), a wireless LPWAN (Low-Power Wide Area Network) technology. The gateway communicates through a 3G router with the company's cloud server where the management platform is hosted. Communications between the IP camera and this server is done through the 3G router too. Finally, the miniPC that receives and sends information from/to the 2 power grid analysers installed and the information screen communicates with the management platform through the 3G router too. Access to the management platform is done through the Internet.
TECHNOLOGY USED TO CONTROL LIGHTING SYSTEM	Agron Municipality: Each light point is equipped with an intelligent control module, which is capable of controlling: switching on and off, dimming (0-10 V) and consumption measurement. Huetor-Tájar Municipality: The current drivers of the floodlights are not dimmable, and it has not been possible for the City Council to replace them for dimmable ones during this project due to budget limitations. However, it is intended to be done in the future, so a control module has been installed in each of the 4 floodlight poles' switchboards, which will be connected to the future drivers through a DALI control bus to allow the remote dimming and switching on and off of the floodlights.
VARIABLES MEASURED	Intensity, Voltage, Power

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CONTROL ACTIONS THAT COULD BE TAKEN	Agron Municipality: Dimming. Switching on and off. Huetor-Tájar Municipality: Manually: Switching on and off. In the future, the floodlights will be equipped with intelligent adaptive lighting devices to allow their remote dimming and on and off turning (not implemented in this project due to the City Council budget limitations).
OTHER SERVICES PROVIDED	Agron Municipality: Measurement of PM2,5, PM10, Temperature and Relative Humidity. Huetor-Tájar Municipality: Measurement of PM, Temperature and Relative Humidity. Air quality qualitative index. Count of the number of people going into and out of the sports facilities, and occupancy. Availability of this information for citizens.

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PP3. RAIS

THE PILOT	The pilot has been deployed in the Municipality of East Ilidza, in a town square called Veljine. The pilot lighting system consists of 32 lamps mounted on 16 streetlight poles. The existing system is enhanced with intelligent light controllers that enable intelligent control of the lamps, remote monitoring and control. The system also monitors air quality parameters using a separate air quality sensor.
THE TECHNOLOGICAL SOLUTION	The existing lighting system control was based on conventional approach that switches all lamps on/off according to the environment light level measured by photocell. The existing system was enhanced with intelligent light controllers that enable intelligent control of the lamps, as well as remote monitoring and control using a web platform. Switching the lamps on/off is done based on astroclock time. While switched on, a lamp luminosity level is controlled based on additional parameters related to the time period and detected motion close to a streetlight pole. In a time period when lower frequency of traffic is expected, the lamps are automatically dimmed to lower light levels and only switched to higher level for a short time when motion is detected. In this way, significant energy consumption savings are realized. The lighting controllers are connected to the gateway device which sends all the data to the web plaftorm.
COMMUNICATION NETWORK	Communication network for connecting the light controllers and the IoT gateway device is based on self-forming and self-healing low-power short-range wireless network. All light controllers are connected to the gateway directly or over a neighbour. The IoT gateway is connected to the control center by using mobile data network. Air quality sensor uses Wi-Fi connection to communicate with the control center.

TECHNOLOGY USED TO CONTROL LIGHTING SYSTEM	The lighting system is based on High-pressure Sodium (HPS) lamps and consists of 32 lamps. Each lamp has a power of 70 W. Two lamps are mounted on a single streetlight pole. Since the existing lamps are not dimmable, a special driver for voltage regulation was applied to control each lamp (PHILIPS HID-DynaVision). A single intelligent light controller (Tvilight SkyLite or CitySensePlus) is used at each pole to control a pair of lamps based on astroclock time, predefined light levels, and movement of pedestrians and vehicles. Controllers are connected to local neighbours and to the gateway device (Tvilight IoT Gateway) via short-range low-power wirelless network. The gateway is connected to the monitoring and management software (Tvilight CityManager) by using mobile data network.
VARIABLES MEASURED	The system measures energy consumption and estimates energy savings. It also calculates the estimation of number of kilograms of CO_2 saved as an equivalent of the saved energy. It is possible to measure energy grid parameters such as input current, voltage, power, and power factor.
CONTROL ACTIONS THAT COULD BE TAKEN	Automatic control provides control actions based on astroclock time so that each lamp can be switched on/off according to sunset/sunrise time. Dynamic dimming working mode enables automatic setting of appropriate luminosity level based on the predefined time schedule and motion sensing. Motion sensing is enabled on 4 controllers. Other 12 controllers receive control signals from the motion sensing controllers. Manual control provides means to switch individual lamps on/off remotely using monitoring and management software.
OTHER SERVICES PROVIDED	The system provides measurement of air quality by air quality sensor, based on $PM_{2.5}$ particles level. The air quality sensor also provides measurements of temperature, humidity and pressure.

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PP4. ENA

THE PILOT	Equipment to measure energy consumption and software for centralized monitoring of 29 public buildings in Setúbal, Palmela and Sesimbra Municipalities. All the data gathered is analysed on a IT Platform to enhance the use of energy and awareness on the buildings monitored.
THE TECHNOLOGICAL SOLUTION	The system is comprised of energy analysers installed on each service building and one gateway that sends the information to the cloud, where all information is processed in an energy management application. In some buildings, information related to energy consumption and energy performance indicators is displayed. The management system is capable to generate and analyse energy performance indicators, generating alarms when deviant situations are identified. Reports are configurated to be automatically generated and support the action of technicians and policy makers.
COMMUNICATION NETWORK	Locally are used an Ethernet network infrastructure. The hub allows simultaneous use of various communication protocols such as KNX, MODBUS, DMX512, X10, ZiGBEE to communicate with various types of measuring devices. The hub can communicate with the online management platform using the Ethernet interface with TCP / IP protocol support, ensuring real-time two-way communication via GSM, GPRS and Wi-Fi.

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PP5. RWG

THE PILOT	The pilot includes the installation of 28 smart meters in 11 buildings of RWG authority and in 3 schools, for the purpose of monitoring the energy consumed by these buildings. Also 15 gateways were implentented for communication with smart meters for internet accessibility.
THE TECHNOLOGICAL SOLUTION	Installation of 28 smart meters in buildings, along with the corresponding gateways that collect the data. All information gathered by the gateways is sent to RWG's server, while the data monitoring and management are performed through an open-source platform, also installed in RWG's server. The platform enables remote monitoring of each device in real time or historically. Energy efficiency scenarios are created after preprocessing and analyzing each building's data , extracting meaningful information about the energy consumed during the time that meters have been installed. Additional information such as indoor temperature/humidity is exploited to create useful widgets in the platform and augment its usability.
COMMUNICATION NETWORK	The communication network used by the installed devices is ZigBee. It is based on 802.15.4 IEEE protocol, and is widely used in IoT related applications. Among its advantages lie the low battery consumption, low cost, small package usage compared to WiFi and Bluetooth, larger range than Bluetooth (1-75 meters). ZigBee can operate at different frequency bands, namely 2.4GHz, 868MHz, 915MHz, and it can support up to 65000 nodes per network.

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PP6. MCM

THE PILOT	Development of efficient and scalable building advanced control strategies.
THE TECHNOLOGICAL SOLUTION	Innovative solution that allows dynamic structural control of buildings, consumption monitoring and air purification. The operation of the solution is based on the fiber optic infrastructure of the Metropolitan City of Milano (MCM) network. The collected data has been used initially to assess the control performance of the current building management strategy. Then, dynamic mathematical models have been developed which are able to capture the building behaviour for both the room temperature and the CO_2 level. Exploiting such models, a set of advanced control strategies has been developed. These control strategies exploit a new measurement of the IoT multi-sensor network - that is the people occupancy profile - so to reduce the building energy consumption while increasing the user comfort.
COMMUNICATION NETWORK	The network is composed by different systems in heterogeneous contexts: - Fiber Optic to obtain environmental measures combined with measures relating to the stability of buildings. - Energy monitoring system to analyse the consumption of the individual elements connected to the network. - Air purification system. The central core of the solution consists of the software platform modules dedicated to data acquisition from the 4 subsystems (included in the supply and described below), normalization, integration with third parties, processing, presentation and distribution. The integration platform offered therefore has the purpose of normalizing and integrating heterogeneous data sources in a single repository and developing a presentation layer of field data, both punctual and aggregated in summary dashboards. This platform will present aggregate data to third parties against a precise definition of interchange formats and protocols.

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PP7. POLIMI

THE PILOT	Development of efficient and scalable building advanced control strategies
THE TECHNOLOGICAL SOLUTION	An IoT multi-sensor network has been installed over an academic building of Politecnico di Milano. The collected data has been used initially to assess the control performance of the current building management strategy. Then, dynamic mathematical models have been developed which are able to capture the building behaviour for both the room temperature and the CO_2 level. Exploiting such models, a set of advanced control strategies has been developed. These control strategies exploit a new measurement of the IoT multi-sensor network - that is the people occupancy profile - so to reduce the building energy consumption while increasing the user comfort.
COMMUNICATION NETWORK	The network is composed of 12 multi-sensors installed over 8 rooms of the pilot building. Such multi-sensors are able to measure temperature, relative humidity, luminosity, human presence, air quality (CO_2 and VOC) and perform a people counting function. The devices are connected through a mesh network with Thread network protocol. The measurements collected by such sensors are routed to a central data storage, where the data is formatted and stored in a database. An initial graphical interface has been deployed which is able to monitor the profile of the measured variables.

PP9. INSA LYON

THE PILOT 	A deployment of 15 nodes on public lighting poles, for collecting traffic characteristics and environmental data.
THE TECHNOLOGICAL SOLUTION 	Deployment of 15 nodes that detect people motion with PIR sensors and a sound sensor. Collect the data and send it through LoRaWAN network before being stored in a local database.
COMMUNICATION NETWORK 	Needs an existing LoRaWAN network for real time functioning but can be used as a diagnosis tool without connectivity, relying on local data storage.

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TECHNOLOGY USED TO CONTROL LIGHTING SYSTEM	No actual control of the lighting system. These devices can only monitor the environment to help and decide the relevance of installing a smart lighting system.
VARIABLES MEASURED	Presence, luminosity, sound level, temperature, humidity, air pressure
CONTROL ACTIONS THAT COULD BE TAKEN	If connected to a real time control platform, could be used to control light levels at individual scale. However, this is an academic prototype preferably focused on offline diagnosis that actual control for reliability issues.
OTHER SERVICES PROVIDED	The system monitors some environmnetal variables (temperature, humidity, sound level) of interest per se. The objective is however to correlate them to the street usage.

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3.2 –PROCUREMENT PROCESS AND COSTS

We can organize the pilots developed into the aforementioned two categories "Smart Pubic Lighting" and "Building Energy Efficiency". Considering its specificities the costs are considerably different, so they will be analyzed separately.

Smart Pubic Lighting

There are 3 pilot projects related with Smart Pubic Lighting, with an average life time expectation of 15 years for the equipment installed.

The costs of the pilot lighting projects developed can be classified according to two dimensions, a technological dimension related to equipment installation and a second one related to the development of new management methodologies.

The total cost of the equipment installed is 43.570,94 € with a cost per streetlight point of 537,91 €, but the cost of developing new methodologies has a total cost of 24.650,97 €, it means a cost per streetlight point of 304,33 €, in total each streetlight point has a cost of 842,25 €.

The maintenance costs for all the projects are 514,80 €/year, this means 9,90 €/year for each streetlight point.

The total economic benefits of implementing smart street lighting pilots are 3.855,06 €, despite the high development costs of the pilot projects due to its small scale and the methodological approaches developed, the global payback (15 years) amortizes the investment made.

Half of the procurement processes developed where normal public procurement procedure (50%) and the other half where green procurement.

Building Energy Efficiency

There are 6 pilot projects related with Building Energy Efficiency. For this analysis, the project from INSA Lyon, is included in this category due to its specificity already explained.

These pilots have an average life time expectation of 11,7 years for the equipment installed.

The costs of the pilots projects developed can be classified according to two dimensions, a technological dimension related to equipment installation and a second one related to the development of new management methodologies and technologies.

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In this group is included the pilot project developed by the Metropolitan City of Milan (MCM), which has different characteristics from the rest. This project aims to develop and test a new measurement and control technology based on fiber optic sensors, so the cost of implementing this pilot is significantly different from the others and should be analyzed separately in order to not distort the other values.

Thus, considering the pilot project of MCM, the total cost of implementing the pilot projects is 157.991,10 euros. Without this consideration, the total cost of the equipment installed is 72.916,10 € with an average cost per building monitored of 1.620,36 €, but the cost of developing has a total cost of 64.899,08 €. This high cost of development is mainly related with the development of the nodes for collecting traffic characteristics and environmental data. Not considering the development of nodes, the total cost per building monitored is 1.729,23 €.

Having in mind that some of the buildings has several variables monitored, the cost per variable monitored is 312,94 €.

The maintenance costs for the projects are 3.729,20 €/year, this means 82,87 €/year for each building .

The total economic benefits of implementing monitoring systems are 20.724,00 €, what means that the average payback time for buildings monitored is 3,75 years.

All the procurement processes developed to purchase monitoring systems for buildings were normal public procurement procedure.

3.3 – TECHNICAL APPROACH

All the pilots developed are based on scalable systems, 50% of then are easily replicable, another 40% replicable with minor adaptations and only 10% needs relevant adaptations to be replicable.

The process of installation requires high skills but are quick to install in 70% of the monitoring systems and 10% needs an high qualified team, whereas 20% of the systems are easy to install.

The installed systems tend to be autonomous: 50% don’t need any interaction and the other 50% need some (few) information for its right use.

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Maintenance is undemanding, 60% requires only simple periodic (low frequency) actions and 10% requires periodic actions to be taken by specialized team. 30% of the systems doesn't require any kind of maintenance.

The systems installed:

- Are able to support relevant variations in data flow in 70% of the cases;
- Allow new devices or its reallocation;
- Are based on open communication protocols;
- 100% of them deliver all the information needed for new devices implementation;
- Only 20% depend 100% on the communication network for its proper functioning.

The communication network deployed is mainly stable (90% with minor failures and 10% with no failures).

Data is stored in locals servers for 60% of the pilots and 40% on the web. Despite this, 90% allows the full control of the system from the web.

To upgrade the systems installed, more than half of the cases (60%) are possible only by the developer of the solution and 40% by other ICT developers.

For 80% of the cases, everybody can use the data if have the right permission.

3.4 – INDICATORS AND CONTROL PERFORMANCE

Considering the two themes "Smart Pubic Lighting" and "Building Energy Efficiency", different kinds of indicators where analyzed.

<u>Smart Pubic Lighting</u>

These pilots cover an illumination area of 16.000 m^2, and 81 streetlight points. The implementation of these pilot projects reveal that is possible to ensure the good quality of the public lighting reducing the average amount of light (average reduction of 5,18 lux), controlling the amount of light available accordingly to the real needs.

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The reduction of power installed due the conversion to LED bulbs is 10,1 kW. Adding the light control, we obtained savings of 60% of energy consumed.

Two control strategy where used in street lighting systems. On the one hand, the reduction steps in the light flux according to operating hours, for instance:

- From 23:00 to 1:00, reduction of 20%
- From 1:00 to 2:30, reduction of 50%
- From 2:30 to 5:00, reduction of 30%

On the other hand, the control of the lighting level according to presence sensors.

<u>Building Energy Efficiency</u>

The total amount of monitored buildings is 47, categorized as follows:

- 14 Schools;
- 14 Offices;
- 2 Libraries;
- 4 Sport facilities;
- 3 Swimming pools;
- 10 Other buildings;

These 47 buildings have 3.093 permanent users and are monthly visited by 132.385 persons.

With these pilots, 271 physical variables are monitored. Only 3% of the sensors installed have redundancy. The sampling time varies from 1 second to 3 hours. The installations allow the continuous data acquisition. In average 90 days of information were already collected with a success acquisition rate over 96,7%.

From the information collected, 42 different indicators were established with sampling periods from 1 minute to one month, with a computation success over than 96,5%.

One of the buildings also has the capability to control the power supply by an ON/OFF control on the main circuit breaker.

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4 - IMPACTS OF PILOT ACTIVITIES ON THE INVOLVED SITES

Following the "Methodology for Testing" document (Deliverable 3.2.2), it was agreed the need to analyze the impact of the pilot solutions on the users' community in order to evaluate how the solution is perceived by final users and to guarantee a wide application and spread of the proposed solution itself.

For that purpose, questionnaires were drawn up to quantify the pilot solution impact as a source of benefits and innovation as well as the user satisfaction.

Due to the heterogeneity of the pilot deployment cases, two types of questionnaires were designed, one for the pilots related to Energy Efficiency Buildings, and the second one for Smart Lighting pilots, whereas in the specific case of INSA Lyon an exception was made because the building questionnaire was better adapted to its specificities. All of them contained numerical indicators measuring the social impact of each proposed solution.

A total of 319 questionnaires were conducted by the ESMARTCITY partners distributed as following:

PARTNER	Nº OF QUESTIONNAIRES
LP Abruzzo Region	66
Industrial Systems Institute ISI (PP1)	11
Energy Agency of Granada APEGR (PP2)	68
City Development Agency East Sarajevo RAIS (PP3)	50
Energy & Environment Agency of Arrábida ENA (PP4)	58
RGW Region of Western Greece (PP5)	29
Metropolitan City of Milan MCM (PP6)	30
Politecnico di Milano POLIMI (PP7)	63
National Institute of Applied Science INSA Lyon (PP9)	20
TOTAL	**395**

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By averaging and analyzing the numerical answers provided by the users, the main conclusions obtained are the followings:

Regarding the Energy Efficiency Building Pilots:

Information prior to the installation
54% of survey respondents admitted to have some information prior to the pilot installation (upgrade, operation, scope) compared to 23% who considered to have a lot of information. Other 23% specified that they had no previous information.

Information after the installation
52% of surveyed stated to have some information after the pilot installation (upgrade, operation, scope) whereas 36% considered to have a lot of information. Only 11% claimed that they had no previous information.

Impact on everyday activities
48% of building users didn't change anything on their daily activities after the implementation of the pilot, 47% had minor changes and only 5% felt significant changes.

Impact on privacy
The privacy of user was not compromised in 78% of the cases, whereas 21% has some concerns and 1% feel that don't have privacy.

Perception on environment benefits
Most of the people recognize the benefits of installation on the environment (74% referees a positive impact), 25% believes don't change anything and only 1% refers and negative impact.

Perception on economic benefits
73% of the users believe in a positive impact of the pilot installation on economy, whereas 19% believes that doesn't change anything and 3% refers a negative impact.

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Perception on smart building solutions

77% believes that the ESMARTCITY pilot can become a starting point for the adaptation of smart building solutions for buildings´ owners in the future, 19% believes that nothing has changed and 4% refers that pilot cannot be a changing point for the future.

Impact on educational purposes

The great majority of the users (95%) recognize that smart building pilot installation can be used for educational and training purposes in order to increase people's awareness about the benefits of smart building (60% surely and 35% maybe). Just 5% does not recognize benefits for for educational and training purposes.

Perception on best practices

62% of the surveyed should suggest as a best practice the smart building installation to another organization, 31% could consider as a best practice to recommend and 7% don't consider this as a possibility.

<u>Regarding the Smart Lighting Pilots:</u>

Perception on the pilot installed

The perception of the changes in the street lightning introduced by a smart service is very diverse:

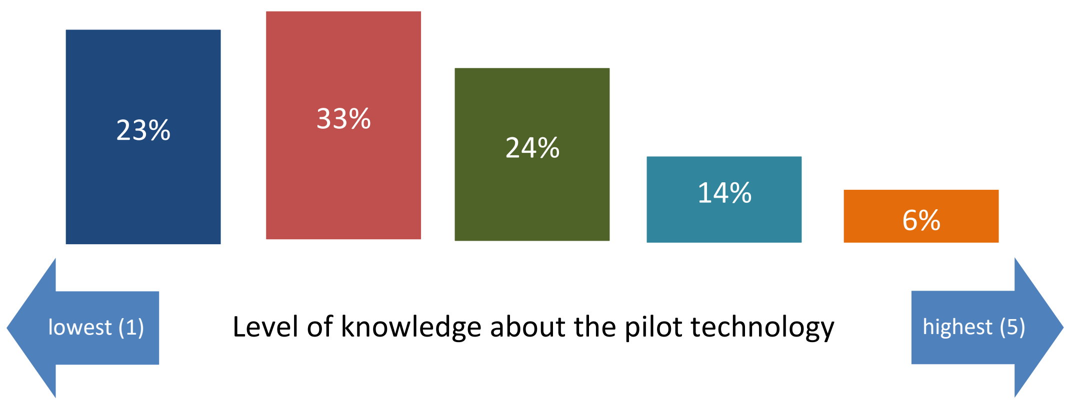
- 43% noticed in the same day;
- 22% didn't know it was part of a smart service and thought there was a problem with public lighting;
- 17% paid attention to it in the moment of the survey;
- 16% noticed in 7 days;
- 3% called the representatives of the local government to report a problem with public lighting and they didn't realize that it was an energy saving project.

Information about the implementation

When questioned about the information related to the first full operative Smart City service – smart street lighting implemented in the frame of ESMARTCITY project, 39% of the population recognize to have some information and aware on saving electricity savings achievements, 26% didn't get information, but suppose it is something useful and 35% of the population surveyed refers to have been informed about all the facts and benefits of system and fully support the Agency in this project and its continuation.

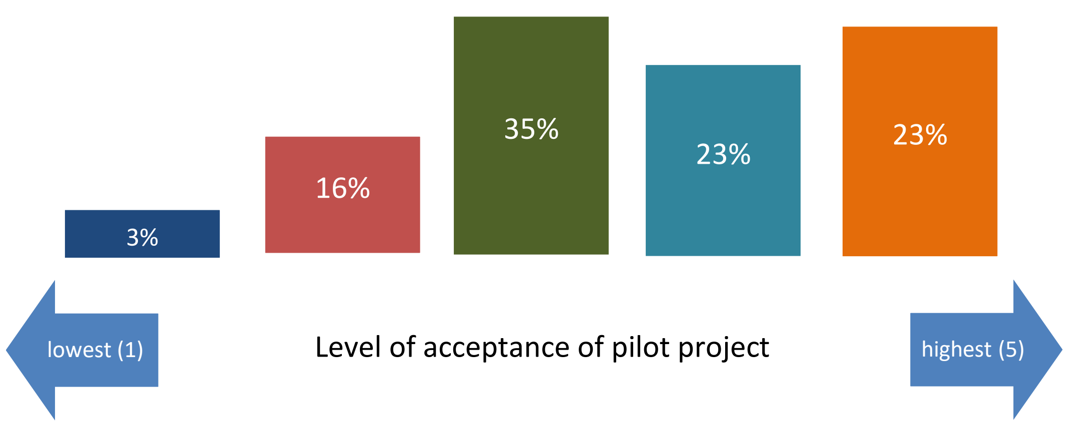
Level of knowledge

Evaluating from 1 to 5 (where 1 is the lowest level and 5 the highest) the knowledge about the pilot technology, the perception of the population is the following:



Level of acceptance

Evaluating from 1 to 5 (where 1 is the lowest level and 5 the highest) the level of acceptance of the pilot project, the perception of the population is the following:



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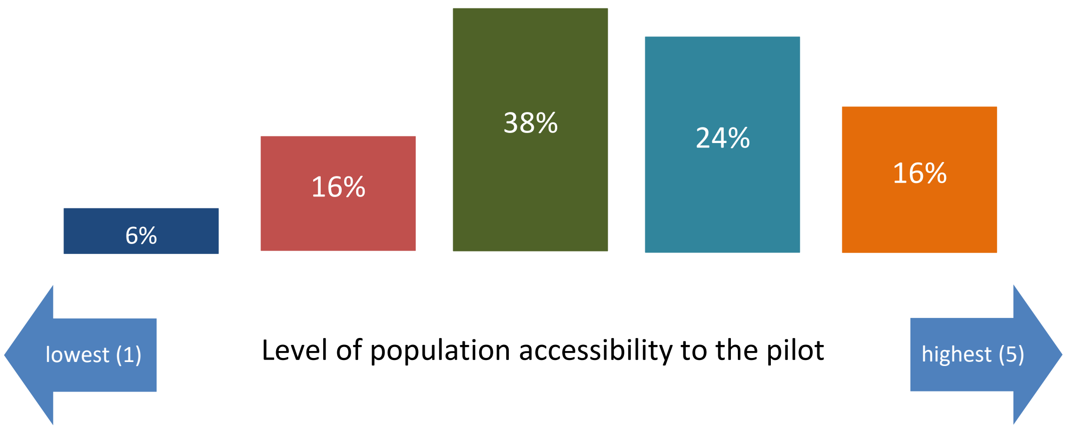
Level of population accessibility

Evaluating from 1 to 5 (where 1 is the lowest level and 5 the highest) the level of accessibility of the population to the pilot project, the perception of the population is the following:



Perception on the light pollution and sleep quality

45% of population surveyed considers significant and visible from first day the improvements related to light pollution control and sleep quality. 23% considers the light pollution reduction visible but not enough, 13% expect better effects whereas 15% didn't notice any change spontaneously and 4% refers that the situation is the same as before.

Perception on the level of illumination

54% of the people consider that safety of the citizens has been preserved, through a sufficient level of illumination to allow pedestrians to pass throughout the night without worry, even the level of illumination could be further reduced, 23 % considers that illumination is enough when the sensor detects a passage and when the lights come on to the maximum level, but before that felt was restrained to walk down that street. 14 % consider the illumination is enough but still don't have full confidence in the system. 9% don't consider the illumination enough but still walk on the street.

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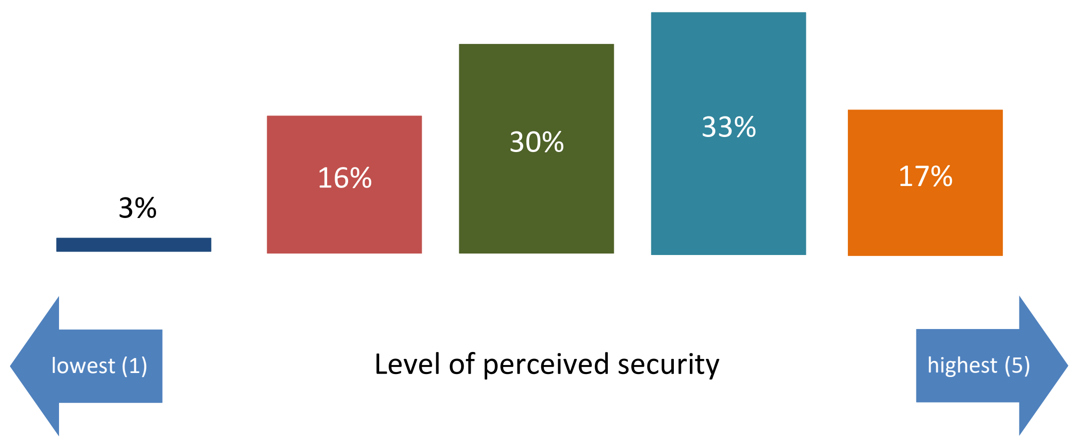
Perception on the security

Evaluating from 1 to 5 (where 1 is the lowest level and 5 the highest) the level of perceived security, the perception of the population is the following:



Investments in Smart Lighting projects

35% of the people consider that one of the top priorities of the city should be to continue the investing and seeking external EU funds to expand the existing Smart Public Lighting project. 38% think this investing is important but when the ongoing problems in essential utilities are resolved. 20% considers this investment good but not crucial to quality of life. Only 7% of the people see it as completely unnecessary waste of energy, money and time.

Solutions applied to other fields

For 48% of the people surveyed, the implementation of other smart solutions in fields like public transport or waste management is an opportunity for local companies and university to create economic growth and jobs. 18% agrees with this strategy but not as a priority, whereas other 18% agrees with the strategy but think that the quality of the existing service needs to be addressed first. 10% have some doubts due the benefits are long-term and not immediately. 5% disagrees, they feel more comfortable with less technology in daily activities.

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5 - CRITICAL ISSUES FACED

During the development of the pilot deployments, partners faced several problems and challenges. In this section, we make a global description of these difficulties found.

Technical challenges

- Difficulties in the communication network due to technical lack of local sites for transferring data in real time.
- Difficulties in the design/optimization of prototypes.
- Difficulties to find the smart solution that fits the specific needs of each community due to the huge variety existing on the market today
- Inexistence of global solutions valid for every installation. Each street, each building, each neighbourhood, each system needs its own solution adapted to its specific needs.
- Weakness on communications infrastructure and 4G network and fibre.

Involvement challenges

- Lack of engagement of public administrations, what is essential in the management and regulation of smart technologies.
- Hitches to include all the stakeholders of a community, including governments, academia, industry and civil society (Quadruple Helix). Without cohesion, the smart city concept is not exploited to the full. A smart city has to be based on a holistic vision that provides a common understanding among smart cities stakeholders.
- Lack of communication with citizens results in top-down approaches. Projects have to be developed with input from civil society, taking into account its culture and customs.

Smart-city-culture challenges

- Limits in the introduction of ICT practices in some areas mainly agricultural and depopulated due to lack of knowledge and preparation, especially of the elderly.

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- Lack of knowledge in small and medium-sized municipalities about what can be done in the field of smart cities and how it can be applied at their scale. This problem could be an opportunity for development of new smart services/applications related to public lighting, energy efficiency building management or water supply. It´s needed more capacity building and dissemination about ICT technologies among the municipal staff, in order to familiarize them with it.
- Inexistence of a clear view related to crucial aspects on smart city about the property and management of the collected data (who is the owner of data? how can we provide the access to it? where should we put the limits on the data access? should be the business based on the collected data service-oriented or applications license-based?). It´s extremely relevant to promote a deep reflection about data property with all stakeholders.

Budget challenges

- The limited municipal budget represents a barrier to the implementation of measures involving ICT. It´s needed the adoption of innovative financing mechanisms to support smart solutions.

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6 – CONCLUSIONS

Deliverable D3.4.2 presents a detailed evaluation of the testing phase of the project through the analysis of the pilot deployments (technical characteristics, achieved results, critical issues faced and impact generated on the involved sites). This report try to be an assessment of all the partner´s pilot activities as a whole in order to provide a useful, comprehensive and deep analysis of the results obtained through this project.

In this framework, the main conclusions obtained from the assessment of the ESMARTCITY Pilot developed by partners are catalogued and described as follows:

- **Smart City concept** transforms digital technologies into better public services for citizens, better use of resources and less environmental impact by managing more efficient systems integrated in a smart mode (that includes smart metering and additional services).

- If smart cities want to solve city challenges, their best first step is to involve all **stakeholders** in the community (including government, industry-business, academy and citizens; Quadruple Helix) to explore the complexity of the issues they face and involve them in collaborative decision making and future planning of their city.

Procurement process and costs:

- The scale of Smart Lighting projects is important for its cost-benefit relation, although the implementation of small scale projects -as the developed in this case- has economic benefits despite the high development costs.

- Despite the small scale of the pilots, to invest in monitoring systems for buildings has a very interesting payback period.

- Green Procurement processes are still poorly used. They should be promoted nearby Public Administrations.

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Technical approach:

- The technology used in the pilot deployments is scalable and easily replicable. It could be a good approach for future smart cities start with small areas and then growth the system into a bigger dimension.

- High qualification is needed to install and operate smart systems. Challenges ahead are related to education and training.

- Maintenance of smart cities systems is undemanding: most of the cases require only simple periodic actions. Keeping maintenance costs of smart systems under control is revealed as a factor of great importance not always taken into account in the design of smart cities services. A benefit of transforming buildings/lighting systems into smart ones is the capability for predictive maintenance. A smart system can monitor the entire performance and trigger alerts for maintenance before anything malfunctions. Therefore, it is easier and less costly to maintain the system in operational conditions.

Indicators and control performance:

- It is possible to ensure the good quality of the public lighting reducing the average amount of light, controlling the amount of light available according to the real needs.

- The installed systems reveal to be very resilient to the communication failures having high rates for computing indicators/variables.

Impacts of Pilot Activities on the involved sites:

- The communication about the smart systems installed still present failures, once there is people revealing lack of information about these systems and its benefits. This lack of information affects to the citizen perception about their privacy guarantees, as well as the environmental and economic benefits of smart city technologies.

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- The smart city installations have an enormous potential to be used for educational and training proposals.

- There is a considerable lack of knowledge about the technologies used in smart city applications despite the level of acceptance and accessibility of the population to the pilot are pretty high.

- Parameters related to smart light solutions such as light pollution control, sleep quality or level of illumination are well-considered by citizens even recognizing that these effects still have potential for improvement.

- The security aspects related to smart lighting should be addressed to ensure the security perception of citizens who remain in doubt with it.

- Citizens have a good perception related to the investment on smart city solutions and they are conscious about the social benefits related.

- Despite the small scale of the pilots developed, there is a huge potential of communication and awareness related to energy efficiency use due to the relevant number of people (132.400 persons) that visit the 47 buildings involved in the projects.

Other conclusions:

- Both for municipalities incorporating smart city practices for first time into their public management, and for cities with a consolidated penetration of the smart city concept, these pilots solutions adopted could be a **reference** for other municipalities in the area interested in this type of smart solutions or the trigger for a more ambitious strategy with more systems installed and in bigger areas.

- With an appropriate transferring strategy, the smart solutions installed could become the proof-of-concept and the showroom for **future projects** of smart city services in the different territories. Clear business models should motivate local government and potential investors to inject additional money in the process of conversion of many conventional city services into modern smart ones. It is expected that the future

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investments to enhance and to cover new city areas with smart systems could be ensured by the saving s from these pilot projects.

- Most smart city applications, saves cities' money from day one. Besides a low energy bill and reduced operational expenses, they offer revenue generating opportunities, as a direct financial benefits, but also many **secondary benefits** related to the improvement of environment parameters (air quality, measured in CO_2 reduction correlated with energy saving, light pollution decreasing affecting the biodiversity, etc.), health (i.e. improving status of the natural sleeping cycle, comfort, decrease of traffic accidents) and social (public security and safety, revitalization of abandoned areas, monitoring of habits and traffic flows in crucial points, better and more customized working and living conditions essential for raising productivity, etc.).

- The pilot solutions installed contribute to improve the city management providing policy makers, Public Authorities and energy managers with **decision support tools** to optimize strategic/economical/ environmental impacts of their decisions and operations. Smart systems offer their administrators large volumes of real data which, when analyzed correctly, provide useful insights that should be taken into account when planning having in mind the more efficient use of resources. The data collected provides tools and information that allow municipalities automating and acting on their consumption profiles, optimizing their performance in order to reduce the final energy consumption and contributing to a smarter city where technology is at the service of citizens.

- **Open Data**. All the data available in the smart city systems could be available as open data to provide new services to the authorities and citizens. This should be catalyst for many incoming start-ups and services providers with innovative ideas to generate added value for citizenship. The management of the collected data should be more discussed with all stakeholders because it should be considered as a public property of all citizens and the usage should be defined only for interest of the community. The business based on data collected should be service-oriented, not applications license-based. This strategic approach is the most valuable for the development of new concepts based on additional analytics of the collected data, fostering entrepreneurship and providing new services to the community.

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- The public usage and share of the data collected could contribute to build an **innovation ecosystem** that involves companies, research centres, academia and public authorities, providing the necessary conditions to develop the Smart City concept.

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Tag cloud resulting from all ESMARTCITY partner´s reports.

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