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ESMARTCITY

Enabling Smarter City in the MED Area through Networking

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

WP3 – Testing

Activity 3.3 – Pilot Testing

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CO	Confidential, only for members of the partnership and MED Programme	

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1 Vision of Smart City in Granada Province

1.1 Introduction

The purpose of this document is to describe the components, deployment process and subsequent monitoring of the pilot project consisting in the improvement of the lighting installations of the public sports facilities in the municipality of Huétor Tájar (Granada), implemented within the 'ESMARTCITY: Enabling Smarter City in the MED Area through Networking ' project, under the initiative of the Provincial Energy Agency of Granada.

This is the first 'smart' lighting system installed in the municipal sports facilities, so it is a reference for other small and medium-sized municipalities in the province interested in this type of 'smart' solutions.

1.2 General Concept of Smart Cities

Among the technical and philosophical definitions of the concept of Smart City at an international level, whose selection is set out below, the citizen always constitutes the central point. Indeed, the Smart City is created by everyone and adapts to everyone's needs:

"*A sustainable smart city is an innovative city that uses ICT and other means to improve the quality of life, the efficiency of urban operation and services, and competitiveness, ensuring that it meets the needs of current and future generations with regarding economic, social, environmental and cultural aspects*". United for Sustainable Smart Cities (U4SSC).

"A city can be defined as 'smart' when it invests in human and social and traditional (transport) and modern capital. The ICT infrastructure feeds sustainable economic development and a high quality of life, with wise management of natural resources, through participatory governance". European Telecommunications Standards Institute *(*ETSI, 2015).

"A smart city means different things to different cities and is a constantly evolving topic. An Intelligent City is able to provide all the services that its citizens need in the most efficient way, while creating jobs, fostering new ideas, being respectful of the environment and taking into account the opinions of citizens. In addition, an intelligent city is a city that manages its mobility, energy, buildings, space and digital information in an efficient way in energy consumption, efficient in the use of resources, sustainable and scalable in favor of people's well-being, citizens, workers and travelers". (Agoria, 2018).

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1.3 The State of Village of Huétor Tájar: Challenges and Opportunities

The municipalities of the province of Granada are part of the 95% of the Spanish municipalities that have less than 20,000 inhabitants, hence the importance and challenge of incorporating Smart City practices into their public management, adapting them. These initiatives are generally scalable, however, they imply certain prerequisites and enabling forces for the implementation of ICT, digitalization, Big Data and Open Data practices, among others, mainly of a technological, cultural, infrastructure and financial nature, which not all small and medium-sized municipalities meet.

Nevertheless, Huétor Tájar, a medium-sized municipality with a population of 10,286 inhabitants, can be considered a pioneer one in the implementation of energy efficiency and Smart City services in comparison with the rest of similar municipalities in Granada province. Before the beginning of this project, Huétor Tájar already had a remote management system implemented in its conventional street lighting facilities, as well as LED technology in a considerable part of these facilities. In addition, there is a municipal small olive-stone-based district heating facility, which distributes heating to 5 public buildings and is also remotely operated. And so they are the water supply service and a photovoltaic plant installed on the roof of the public indoor heated pool located at the municipal sports facilities. So there is a clear interest of the City Council in this kind of smart city solutions.

Additionally, the following complementary mechanisms should be developed:

- Development of the communications infrastructure and strengthening of the 4G network and fibre.
- Capacity building and dissemination about information and communication technologies among the municipal staff, in order to familiarize them with it and improve their usage and maintenance.
- Adoption of smart solutions that incorporates innovative financing mechanisms.
- Creation of entities for sensor management.

However, Huétor Tájar faces a common challenge for the small and medium-sized municipalities: a limited municipal budget, which represents a barrier to the implementation of measures involving ICT.

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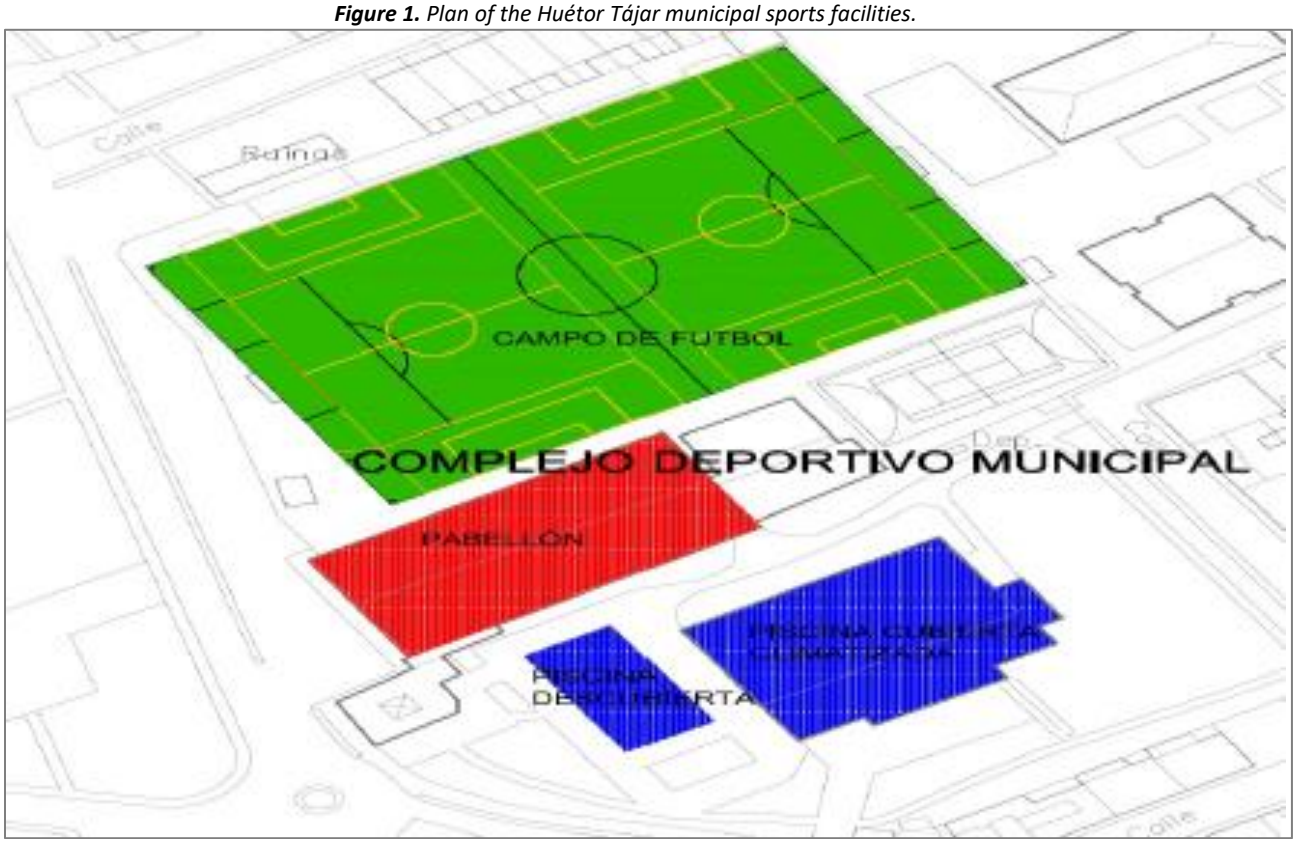
2 Summary of the Pilot Deployment

The pilot project implemented in Huétor Tájar is located at the main municipal sports facilities, and within them, at the football pitch, which must be illuminated for the different activities taking place in it. This lighting system was already equipped with LED technology, and has been integrated into an intelligent management software to monitor and analyse their energy consumption and electrical variables. In the future they will be equipped with intelligent adaptive lighting devices (they could not be installed under this project because of City Council's internal issues). Additionally, environment sensors to measure air quality and meteorological variables have been implemented, as well as an IP camera to measure the occupancy of the facilities and an information screen for citizens. All these components are managed through the aforementioned management software.

Figure 1. *Plan of the Huétor Tájar municipal sports facilities.*



The football pitch`s lighting system consists of 24 floodlights, which had already been changed from metal halide (MH) technology and 2,000 W to LED technology and 900 W each. They are installed on 4 poles, so each one of them supports 6 flloodlights.

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Figure 2. *Floodlights at the Huétor Tájar municipal football pitch.*

System network communications is done using LoRa (Long Range) radio communications technology between the lighting control modules and the environmental station and the gateway. Interconnection between this and the company's cloud server where the management software is hosted is performed through a 3G router. Access to the management platform is done through the Internet. Details of the communication system are given in following chapters.

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***Figure 3**. Gateway for communications between the lighting system and the management software.*

All these components are managed through a management software, which is web-hosted and works as Software as a Service (SaaS), so it is adaptable for all types of formats (smartphones, tablets). It allows the real-time monitoring of environmental and electrical variables and energy consumption, as well as of the number of users of the sports facilities and the control of the information provided to them on the LED screen. Moreover, when the intelligent adaptive lighting devices are installed, it will allow the remote switching-on and off, dimming, creation of maintenance alarms and generation of reports.

The management software will be further described in following sections.

2.1 Motivation

Saving and energy efficiency is a basic pillar of the new energy model that is being developed for the Andalusia region, where Huétor Tájar is located, as it is reflected in the Andalusia Energy Strategy 2020. This model is based on a new culture based on the principles of energy efficiency that tries to involve the entire population: industries, infrastructure, public administrations and citizens, promoting a responsible use of a basic and scarce asset such as energy.

Saving and energy efficiency actions find in the Public Administration an ideal environment for their development, based on its double facet of energy consumer and of entity with an exemplary and sensitizing role to encourage them among the citizenship.

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Saving energy in the Administration means rationalizing public spending, which in a weakened economic-financial context such as the current one constitutes a strategic priority. In addition, saving energy allows reducing the negative impact on the environment, contributing to the fight against climate change and atmospheric pollution.

As regards the energy sources, it is noteworthy the great dependence of the municipalities on electricity as an energy vector, with about 90% of total primary energy consumption and a very low share of renewable energy.

By uses, public lighting is the installation that represents the highest incidence in the energy consumption of a municipality, reaching 52% of the total energy consumption of municipal facilities and 59% of municipal electricity consumption. The importance of public lighting installations is such that in some municipalities it accounts for up to 80% of the electricity consumed and up to 60% of their energy bill.

2.2 Pilot Definition and Goals

The purpose of the pilot project carried out in Huétor Tájar was to convert the lighting installations of sports facilities into installations with adaptive lighting and criteria for protection of the night sky as far as possible, making them more innovative and sustainable.

To carry out the above, a series of objectives were established that are listed below:

- Improve conventional sports facilities with innovative and more sustainable management services.
- Seek greater compliance with the night sky protection criteria in these facilities.
- Facilitate management to improve service to citizens, giving them environmental information, as well as helping municipal technicians to provide an adequate service and with the lowest cost of maintenance and resources.
- Develop a new product for multi-sports lighting installations / services that can be easily replicated in small and medium-sized municipalities.
- Study the possibility of integrating the different vertical solutions on the same horizontal platform that equips the municipality with smart city technology.
- Test in real context and under real operating conditions, concepts and possible replication of experience in other small and medium-sized municipalities (in addition to larger municipalities).
- Provide information of interest to provide policy-makers, energy managers, and public administrations in general, decision support instruments to optimize the environmental impacts of their decisions.
- Improve cutting-edge knowledge and enhance technology transfer activities.
- The solution should tend to be open, replicable and scalable.

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3 Pilot Implementation

3.1 System Architecture

The Huétor Tájar pilot project consists of the implementation of a management system that allows real-time monitoring of the electrical variables and energy consumption of the municipal sports ground lighting facilities, in order to increase the level of information of the City Council about the infrastructure and improve its policy of use.

To that aim, two power grid analysers have been installed in two switchboards, one of them giving service to the football pitch lighting and watering, among other elements, and the other one located at the porter's office controlling the sports hall lighting and other services. These analysers are connected to a mini PC installed next to the first of the aforementioned switchboards, inside another one developed for this project, through a RS485 cable.

In addition, when the intelligent adaptive lighting devices are implemented, it will allow the remote ON/OFF, dimming and configuration of adaptive lighting scenes to reduce energy consumption, based on the use of the sports facilities. In order to achieve that, four lighting control modules have been implemented, one in each outdoor switchboard of the four existing floodlights poles, which are connected in turn with the main switchboard of the football pitch mentioned above. The modules have been installed so that the DALI control bus for the future dimmable drivers can be connected.

An environment station with air quality, particulate matter and temperature and relative humidity sensors has also been implemented at the football ground, next to one of the lighting poles.

Communications between the gateway and the lighting control modules 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.

An IP camera with video analytics has been installed too, near the entrance, in order to count the users of the sports facilities. It is connected to a 3G router installed next to the mini PC aforementioned through a UTP cable. The PoE (Power over Ethernet) injector has been located inside the switchboard of the nearer lighting pole, and takes the power supply from it.

A LED screen has been implemented as well at the sports ground to provide citizens with the information gathered by all these devices. Similarly to the camera, it takes the power supply from the same outdoor switchboard. It is connected to the mini PC at the main switchboard of the football pitch through a RS485 cable.

The gateway, the IP camera and the mini PC communicate through a 3G router with the company's cloud server where the management platform is hosted.

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Access to the management platform is done through the Internet.

***Figure 4**. System architecture of the Huétor Tájar pilot project.*

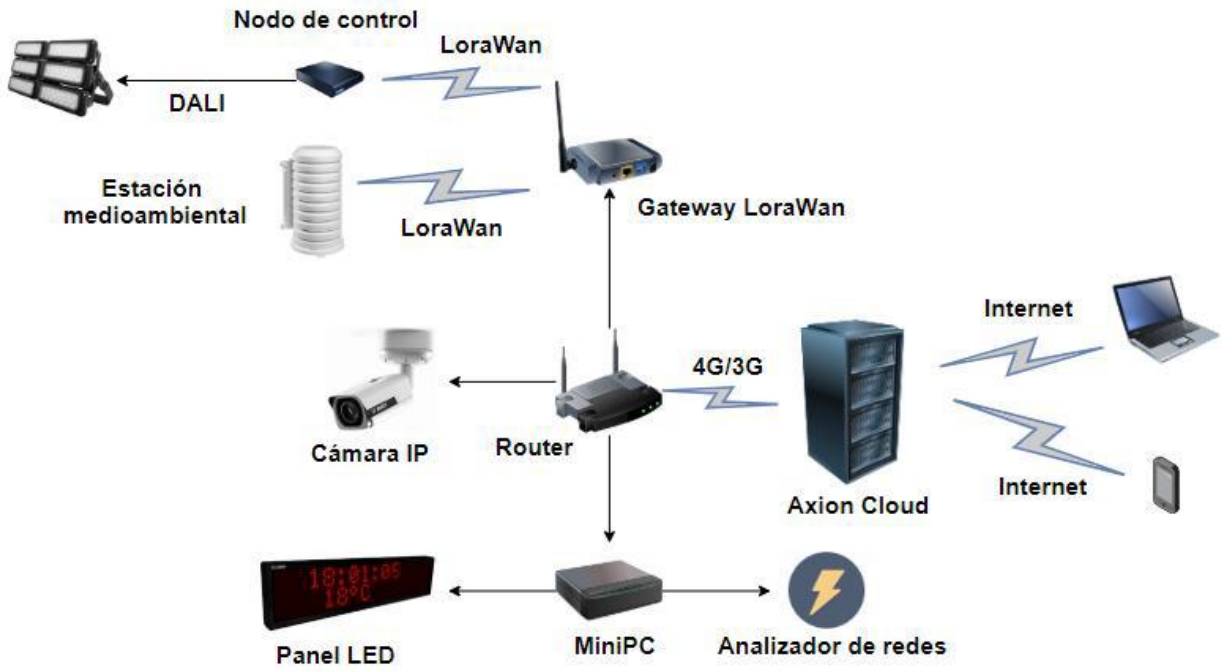

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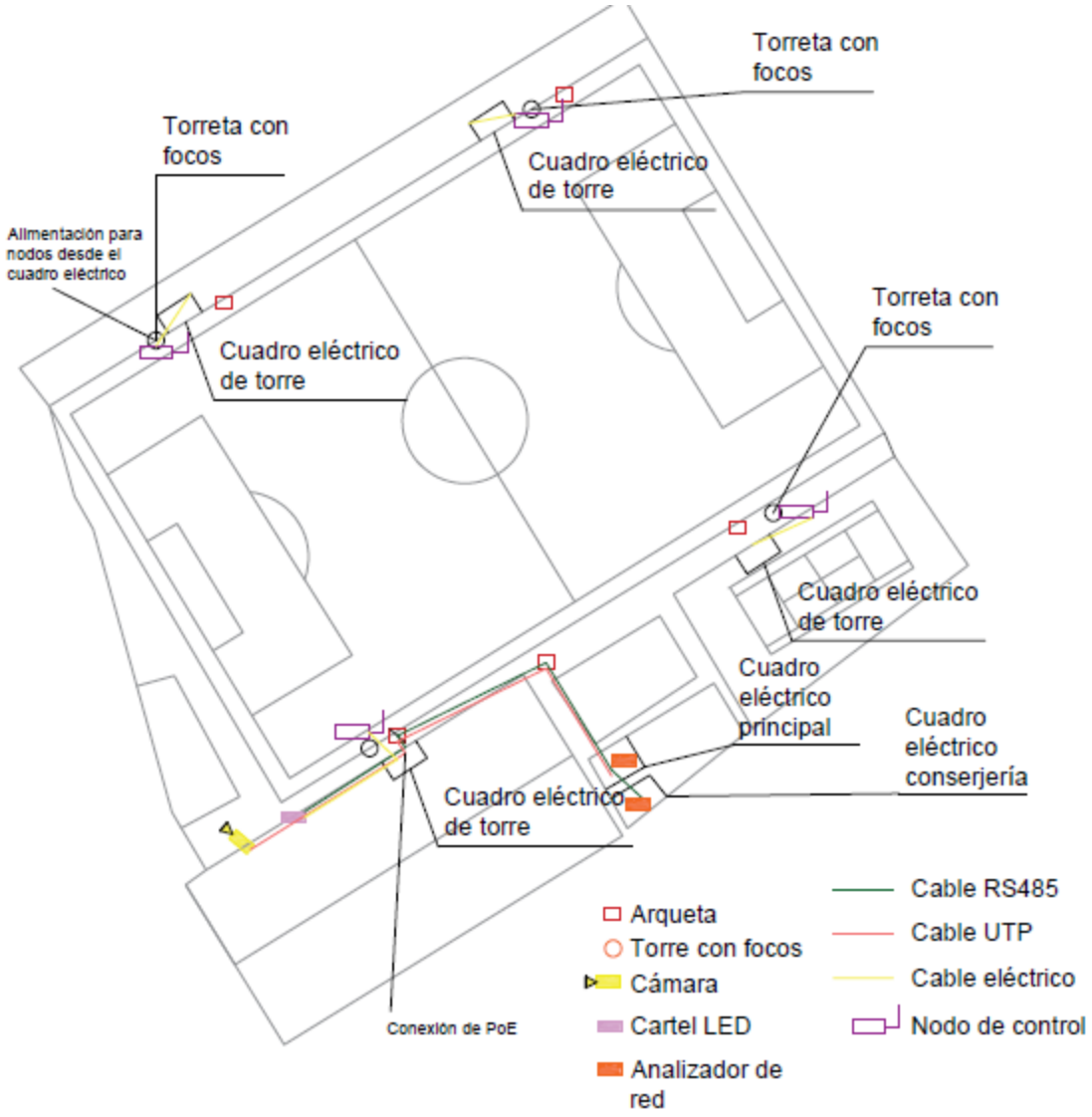
***Figure 5**. As-built plan of the Huétor Tájar pilot project.*



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3.2 User Requirements

The user requirements for the Huétor Tájar pilot project are summarized as follows:

- The system must perform intelligent lighting management.
- The system should act actively on total energy consumption.
- Information on energy savings and other possible measurements should be provided to municipal technicians and citizens.
- The system must be modular and expandable, both in hardware and software.

3.3 Functionalities

The functionalities proposed for the new lighting system implemented in Huétor Tájar are listed below:

- ***CITIZEN INFORMATION***: To offer real-time information regarding energy consumption and efficiency and / or environmental benefits of the system through the City Council website (for which this information must be open and easily integrated into) and / or an information screen to be placed at the municipal facilities.
- ***ADAPTIVE LIGHTING***: Use of intelligent lighting regulation systems, based on real-time detection and analysis of human movement and / or other activation events.
- ***QUALITY OF LIGHTING***: To achieve levels of uniformity and lighting established in current regulations.
- ***PROTECTION OF NIGHT SKY***: Specifically, the ULR Index or Upward Light Ratio will be valued, although preference will be given to compliance with the criterion "Functionality: QUALITY OF LIGHTING".
- ***SCALABILITY, INTEROPERABILITY AND SOLUTION FOR DATA HOSTING***: The system must be scalable and interoperable with other possible vertical solutions that the municipality could implement in the future, being also relevant the ease of use of the management platform. As for the data hosting solution, its maintenance cost during the first two years (cost of communications, subscription / license cost if any, cost of energy consumption of transmitting equipment) must be included in the budget offered by the winning company of the tender process, and must be as low as possible in the following years.
- ***ENERGY / ECONOMIC SAVINGS***: Depending on the percentage of reduction in regulation, provided they are duly justified and the criterion 'Functionality: QUALITY OF LIGHTING' is met.
- ***MAINTENANCE***: Described in the Interoperability and Solution for Data Hosting part.

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3.4 Communications System Architecture

Communications between the gateway and the lighting control modules 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. LoRa is a type of radiofrequency modulation that offers physical layer functionality and whose main characteristics are:

- Long range: around 5 - 10 km in urban areas and 15 - 20 km in rural areas.
- High sensitivity to receive data.
- Very robust against interference, thanks to the modulation on which it is based, "chirp": Chirp Spread Spectrum or CSS. This feature has great advantages over other wireless technologies in not licensed spectrum such as WiFi.
- Low consumption, allowing the devices to operate with batteries for a long period of time.
- Data transfer: up to 50 kbps.
- The network offers the possibility of being shared by other city services, which presents cost advantages over a solution with technology based on networks of mobile phone operators.
- Low transmission powers: maximum power of 25 mW (14 dBm).
- Point to point connection.
- Integrated end-to-end AES-128 data encryption, making it very robust against possible attempts to intercept the information it transmits.
- Highly scalable.
- Working frequencies: 868 MHz in Europe. This frequency band has the property of achieving a long range of propagation and good penetration and requiring very little energy consumption.
- Standard technology, there is a wide range of sensors and manufacturers that use LoRa / LoRaWan technology as the basis for their communications.
- The communication offered by this technology is bidirectional, allowing both the sending of data from the luminaire as well as the remote action on it, therefore allowing changes in its programming.

The gateway, the IP camera and the mini PC that receives and sends information from/to the two power grid analysers installed and the information screen communicate through a 3G router with the company's cloud server where the management platform is hosted.

Access to the management platform is done through the Internet.

The technical details of these devices are shown below.

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Mini PC

- SOC: Intel Atom x5-Z8350 Processor (2M Cache, up to 1.92 GHZ) CPU with 64 bit architecture; Quad Core
- Memory: 1GB / 2GB / 4GB DDR3L-1600 Storage Capacity 16GB eMMC / 32 GB / 64 GB eMMC
- Ethernet: 1x Gb Ethernet (full speed) RJ-45
- USB 3.0: 1x UB3.0 OTG
- USB 2.0: 4x UB2.0
- 2x USB 2.0 pin header (10 pins in total)
- Expansion: 40 pin General Purpose bus

Gateway LoRa

- Full inux operating system: Kernel v4.x running on Atmel-A5 Core @ 536 MHz
- LoraWAN: 863 MHz to 870 MHz (EU), 902 MHz to 928 MHz (USA)
- WiFi: 802.11a/b/g/n, 2.4 GHz and 5 GHz
- Bluetooth v4.0
- Ethernet
- 8-Channel LoRaWAN suppor with up to +27dBM max transmit power
- Comprehensive Certifications for FCC/IC (RG11) and CE (RG186)
- Industrial temeperature range: -30ºC to 70ºC
- Intuitive web-based configuration
- Integrated LoRa packet forwarded
- Default settings for multiple LoRaWAN Network Server vendors
- Enterprise-grade security

3.5 Operational Plan

The work plan has been structured in the following phases:

1. Initial work meeting and delivery of the main information for the development of the works.
2. Visit to the municipality together with the Provincial Energy Agency of Granada, and first contact with the municipal staff in charge and the facilities to be improved.
3. Delivery of signed and sealed documentation of final work planning by the winning company, in accordance with the provisions of the tender.

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4. Implementation of the project, including supply of materials and final installation according to the work plan, and acting to correct any deviation. The Provincial Energy Agency of Granada has been periodically informed about the status of the work.
5. Functional tests of the installation together with the municipality.
6. Reception and transfer of facilities. Signing of guarantee contracts with the municipality.

3.6 On-Site Implementation

The total duration of the implementation works was 8 weeks as of the signing of the contract. The works included the supply, installation, testing and reception of the facilities functioning correctly following the steps outlined in the previous section.

The personnel in charge of leading the tasks of development, deployment and commissioning of the hardware, as well as the coordination and installation tasks of the pilot, included an engineer and specialist in the design of communications protocols and systems integration, responsible for the management and internal planning of the project, as well as for the installation and commissioning of the system.

The on-site installation was made by two workers of a local company specialized in electrical installations.

***Figure 6**. Installation works in one of the outdoor switchboards of the floodlights poles.*

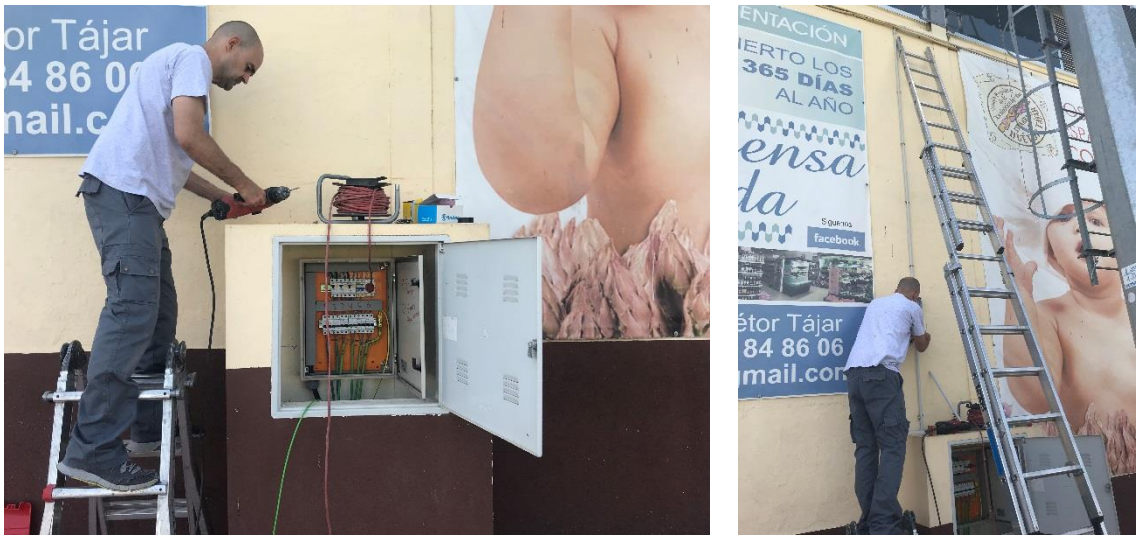

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***Figure 7**. Lighting control module inside an outdoor switchboard, including the terminal prepared for the future connection of the DALI control bus.*

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***Figure 8**. Power grid analysers and current transformer for the measurement of electrical variables.*

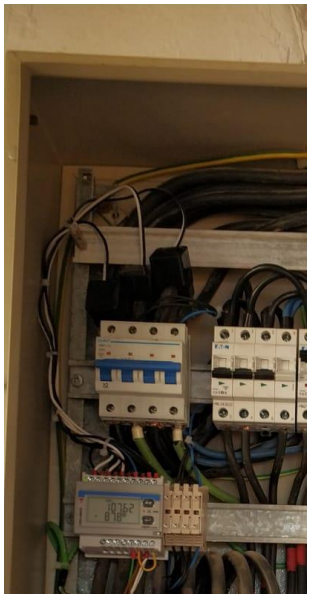

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***Figure 9**. Switchboard installed to host the gateway, the mini PC and the 3G router, next to the main switchboard of the football pitch.*

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***Figure 10**. Environment station and its configuration and final location.*

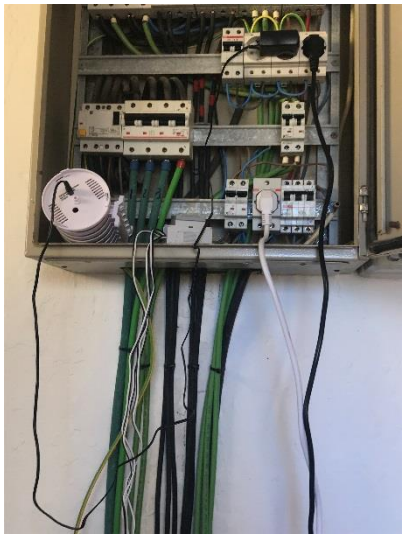

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***Figure 11**. IP camera for people counting and its PoE injector inside one of the outdoor switchboards of the floodlights poles.*

***Figure 12**. LED information screen.*

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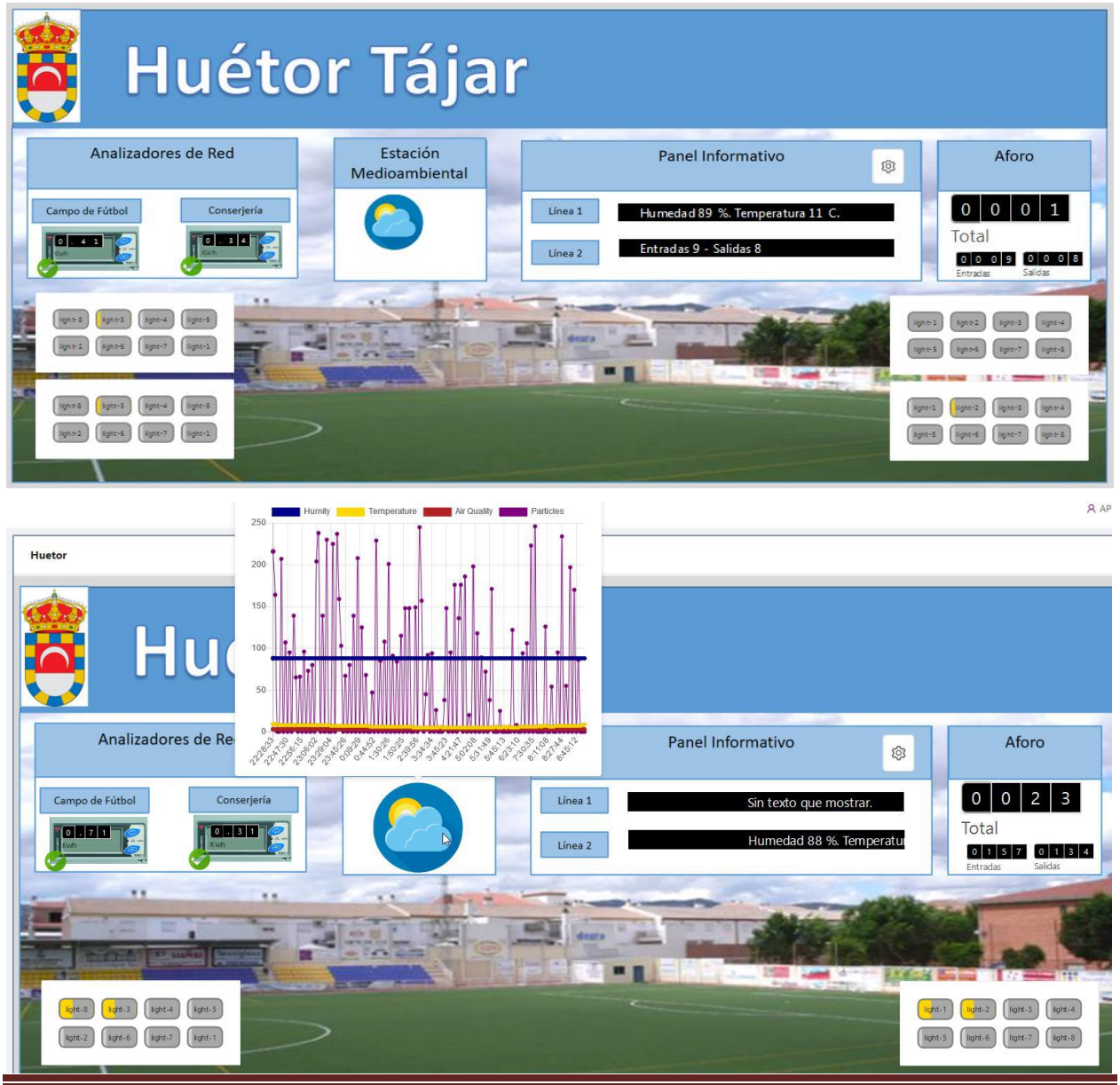
3.7 Management Software

The management of all lighting related services, as well as of the environment station, the IP camera and the information screen, is integrated into a software platform, for which a unified access interface has been provided to all the entities involved in the project through the following url:

https://nagan-telegestion.axion.es/login

***Figure 13**. Main interface of the Huétor Tájar management software.*



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This management platform is web-hosted and works in SaaS mode (Software as a Service). This makes it adaptable to all types of formats (Smartphones, Tablets).

Its main characteristics are:

- Control of the operating characteristics of the luminaires depending on the contour conditions at any time, achieving savings in electricity consumption as well as significant improvements in the quality of lighting and environmental impact.
- It allows remote and real-time monitoring of each of the elements involved in the provision of the service, the consistency of the managed data and the remote operation of certain elements involved in the early detection and management of failures.
- Autonomous operation (in house) or in the cloud.
- Data capture system (Broker) based on Free Software.
- Flexibility to adapt to customer needs.
- The platform's broker is multiprotocol, and the integration plugins of the main communication protocols are currently developed, including DALI or 0- 10V regulation for luminaires control, and SNMP and MODBUS for switchboards control.
- It allows the integration of luminaires based on the following architectures:
    - Point to Point: Control of luminaires individually, or by logical groups.
    - Gateway: Use of an intermediate element for the protocol conversion.
- Standard platform, not dependent on any specific equipment on the market. Compatible with multiple technologies and manufacturers, such as LEDS or conventional lamps.
- Designed to be permanently monitored, assisted and attended by a Network Operations Center. Customer service, including real-time management and post-sale monitoring of the service and the first level of operation, is performed through this operational center. The entire Network Operations Center, with all its functionalities, works in shifts to cover a 24h x 7d schedule.
- Free code, customizable to the client.

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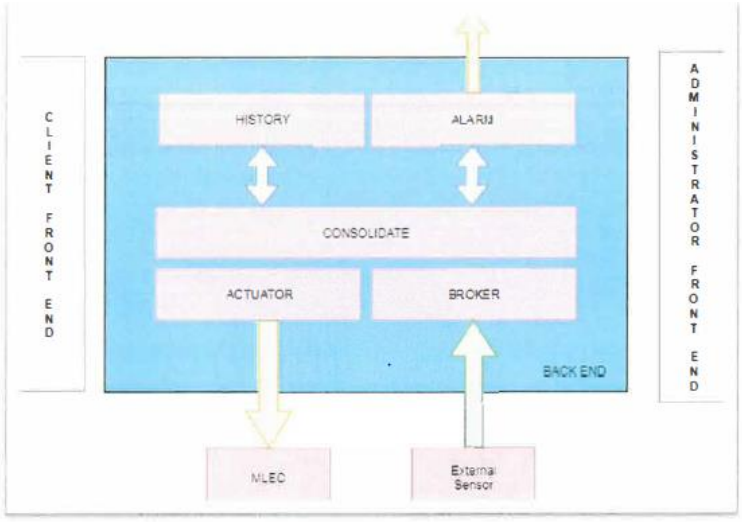
Figure 14. Data broker system of the Huétor Tájar pilot management platform.



3.8 System Management, Data Collection and Analytics

The management software monitors in real time the main electrical variables (tension, intensity and power) measured by the two power grid analysers installed, for each phase, as well as the energy consumption per moment of measurement and per day:

Figure 15. *Platform's information screen with the measurements made by the analyser installed in the main switchboard of the football pitch.*

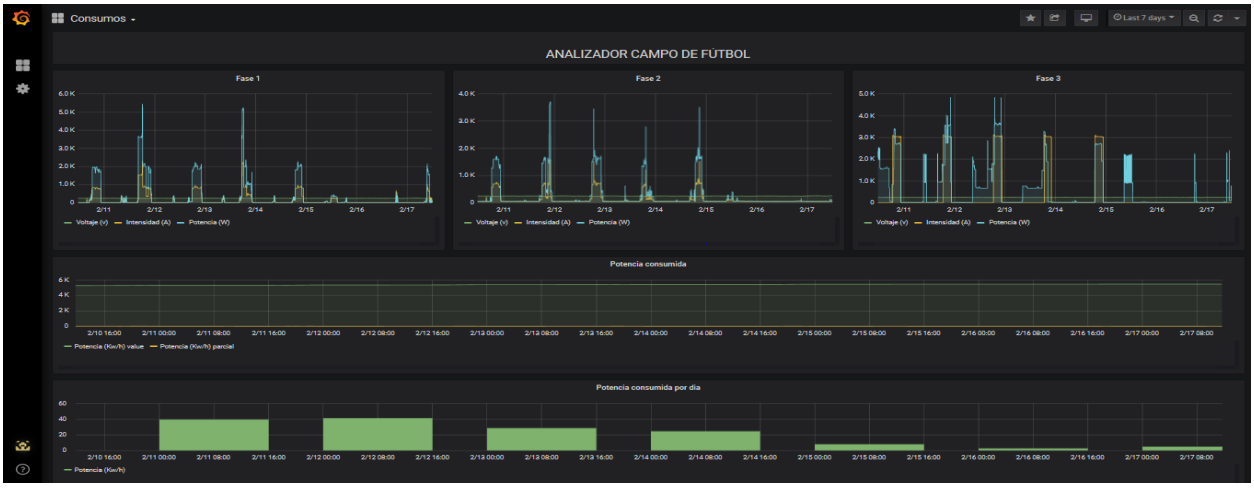


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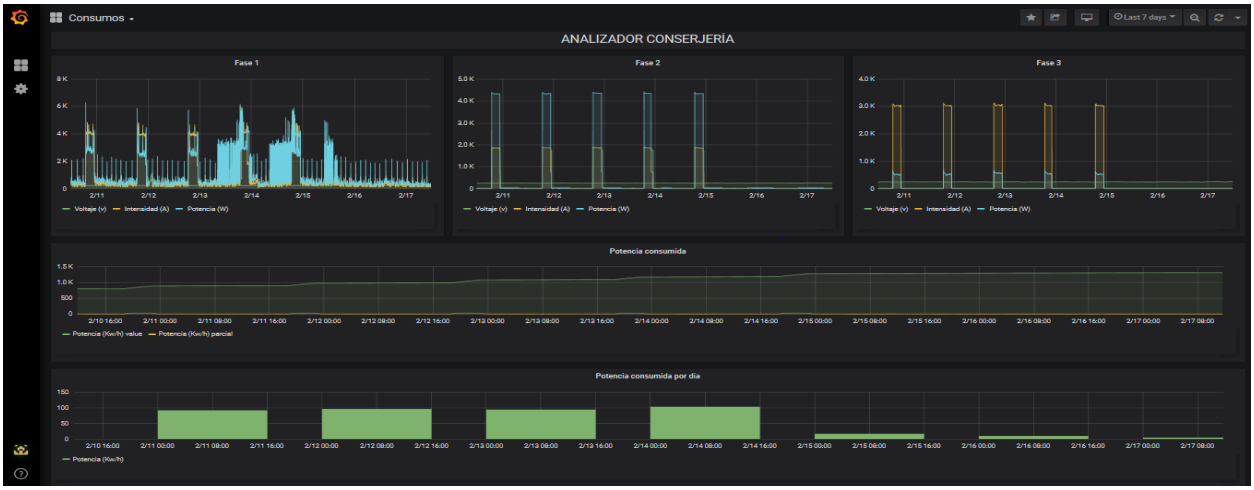
Figure 16. *Platform's information screen with the measurements made by the analyser installed in the porter's office switchboard.*



As for the measurements of the number of people going in and out of the sports facilities and its occupancy, as well as of the air quality (particles and air quality index) and meteorological variables (temperature, relative humidity), they are displayed on a different screen:

Figure 17*. Platform's information screen with the measurements of the people counter and the air quality and meteorological variables.*

The environment sensors had to be recalibrated, since they did not perform the measurements properly, being the problem solved. An automatic restart system had to be installed too in order to prevent the station from been blocked.

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The system for people counting, performed by the IP camera with video analytics, had to be reviewed as well, since some measurements were not coherent (for example, it showed negative values of the occupancy of the facilities).

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4 Conclusion

The new intelligent public lighting system implemented in the municipality of Huétor Tájar has benefits not only as regards the management of the lighting system of the municipal sports facilities, but also in the environmental, social and innovation aspects of municipal public services. Furthermore, when the intelligent adaptive lighting devices are installed, it will allow the reduction in energy consumption too, with the consequent economic savings and reduction of air pollution that this implies.

Climate, Environment, Air Quality Effects

Real-time assessment and monitoring of the air quality through the aforementioned qualitative index and particulate matter concentration, allows the detection of episodes of high air pollution by the municipal personnel in charge, providing them with information to support the decision making process regarding the actions to take to reduce it.

The same applies to the meteorological variables, temperature and relative humidity, which are indicators of climate change.

City Management Optimization

Despite the fact that the immediate notification of failures could not be implemented within this project, real-time monitoring of the electrical variables and energy consumption allows the municipal technicians and maintenance operators to detect possible anomalies in the system when they check the management platform.

This aspect will be improved in the future, when the new drivers are installed and this functionality is activated.

Civil Society Involvement

In order to evaluate the acceptance level of the new intelligent installations at the sports facilities by the citizens of Huétor Tájar, as well as their perception of accessibility and improvement of the quality of life related to them, a social questionnaire was distributed among nearly 50 people.

Results show, in general, a positive perception. Citizens consider that the implementation of measures to reduce the energy consumption of the municipal sports facilities is beneficial because of the economic savings and reduction of air pollution that this implies, and that they contribute to improve the quality of life in the municipality and to promote and enhance the practice of sports, with the consequent benefits on health.

This survey has also been useful to better inform the population about the pilot, which is the first smart lighting service implemented at the municipal sports facilities of their village. They

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generally think it will be beneficial for the city. However, most of them do not consider it as a priority.

Innovative Solutions

The main aspects that make the pilot experience implemented in Huétor Tájar an innovative project are the following:

- The remote management system is a universal product, adaptable to any technology.
- Adaptable to any type of lamp.
- Compatible with all luminaire manufacturers.
- Scalable LoraWan network providing standard protocol.
- Citizen information: Open Data integration information LED panel.
- Video analytics: People counter: through the video analytics, the people who make use of the municipal sports facilities can be counted, as well as the occupancy level in real time. This functionality can provide valuable information regarding the success of different measures to promote sport locally.
- Open Source horizontal platform.

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