6 April 2016

Intelligent Lighting Control

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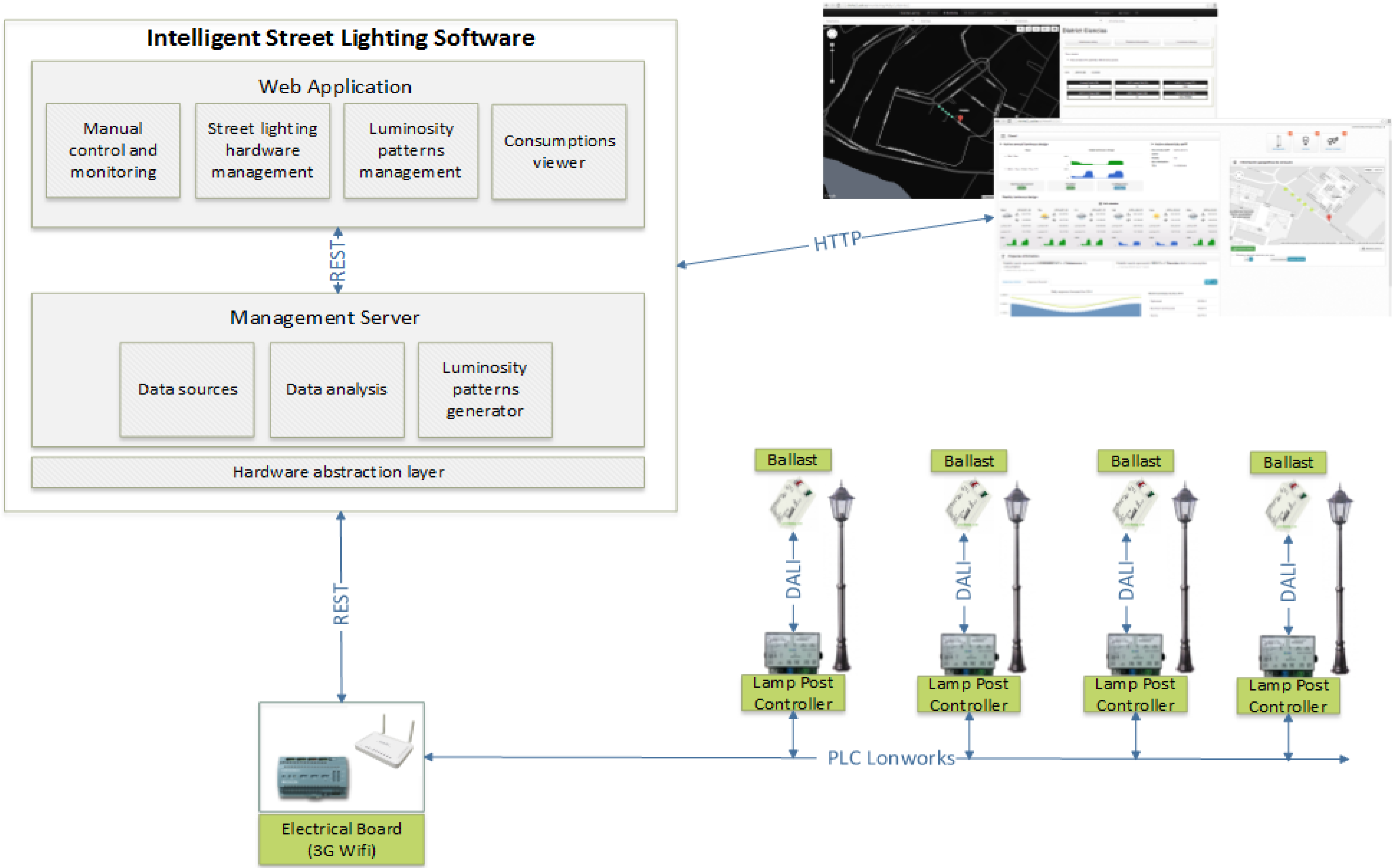
THE PROJECT

Street lights on Smart Cities: contribute to energy savings

- Monitoring and control of each lighting installation
- Alert Notification hardware lighting
- Establishment of adequate light intensity at each public road
- Control of consumption

Paseo Canalejas (Salamanca) Summer 2013

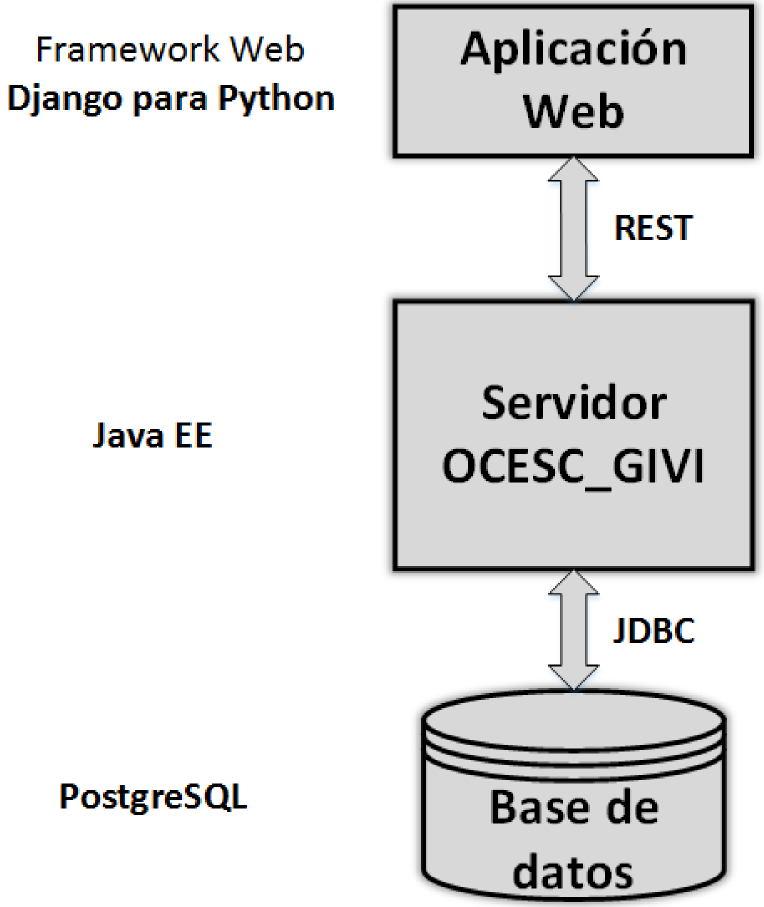
THE PROJECT II



Objetives

- Lighting management calendars.
- Adequacy luminosity based on traffic and pedestrian flow through proposed algorithms.
- Design method to limit consumption in lighting.
- Synchronizing lights on and off based on an astronomical clock, and weather prediction.
- Prediction and historical consumption.
- Web interface.

Architecture



- Union with OCESC_CAD interface
- GUI to manage the functionality provided by the server OCESC_GIVI
- Responsive interface, internationalized

- All business logic
- Daemon processes: meter reading, lighting weekly calendars
- Exposes functionality via REST Web Services

Lighting Calendars

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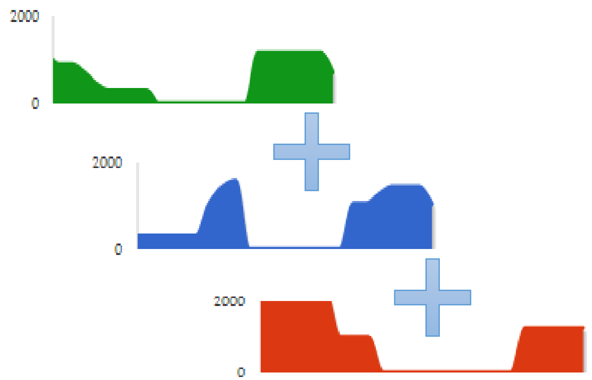
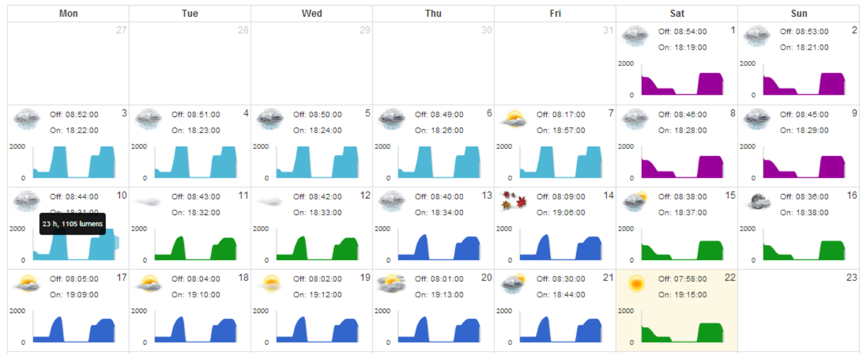


Lighting patterns



Lighting Calendar

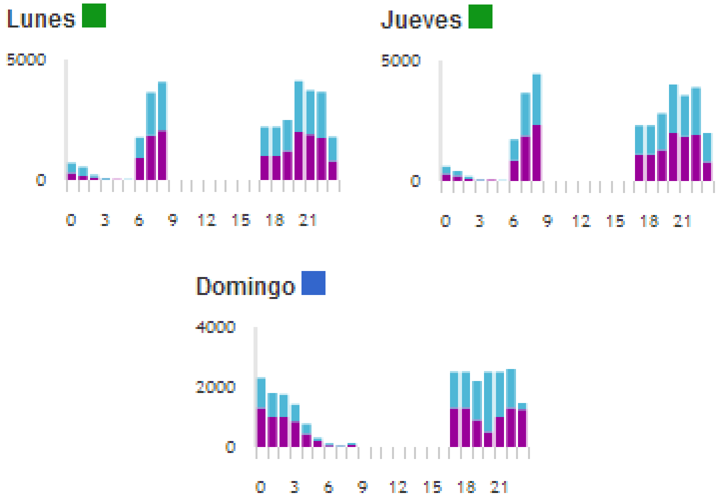
2 options

Manual setup: the user customizes the light patterns of each day

Smart Configuration: the system estimates the proper lighting schedule for each zone based on the use of public roads

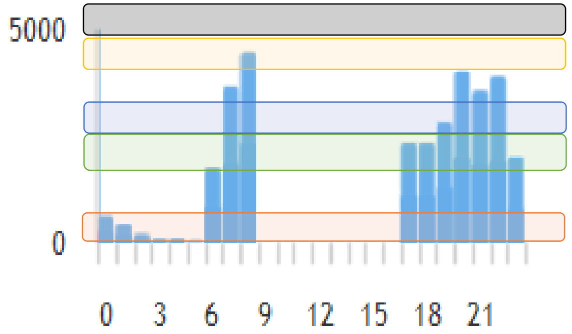
Smart Configuration

1. Classification of days based on historical data of traffic and pedestrian flow.



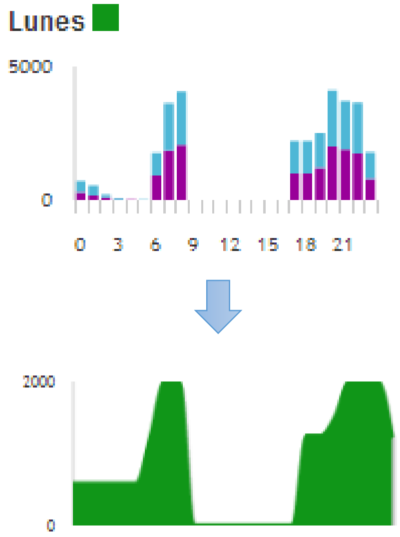
Analysis of variance **(ANOVA)**

2. For each group of days, hours classification depending on traffic and pedestrian flow.



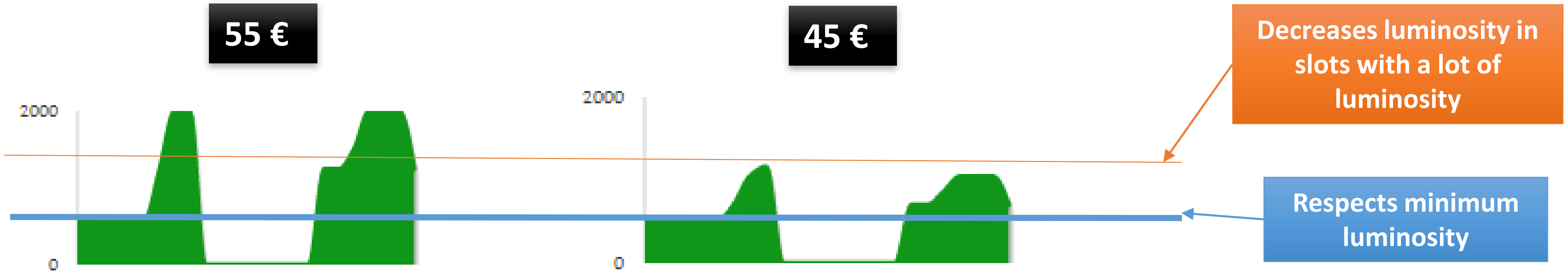
EM (Expectation-maximization) algorithm **(EM)**

3. Adjust light intensity (lumens) as a function of average pedestrian / traffic flow of each cluster



Smart configuration with estimated maximum expenditure

- Adequacy of lighting schedule based on the use of public roads, but ensuring maximum estimated annual expenditure.
- Respects minimum limits of brightness to suit the laws of each place.
- Try adjusting spending introduced optimum brightness level in each hour.



Smart configuration with estimated maximum expenditure

Distribution of expenditure

$$L_{min} \rightarrow RNA_{pow} \rightarrow Pow_{min}$$
$$E_{min} = Pow_{min}\, Nh$$
$$E = E_T - E_{min}$$

STEP 1 Extra expenditure = Total expenditure – minimum expenditure.

$$\overline{P_i} = \overline{Pd_i}\, D_i$$
$$\overline{Pd_i} = \frac{1}{J\,K}\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K} y_{ijk} \,/\, j \in g_i$$

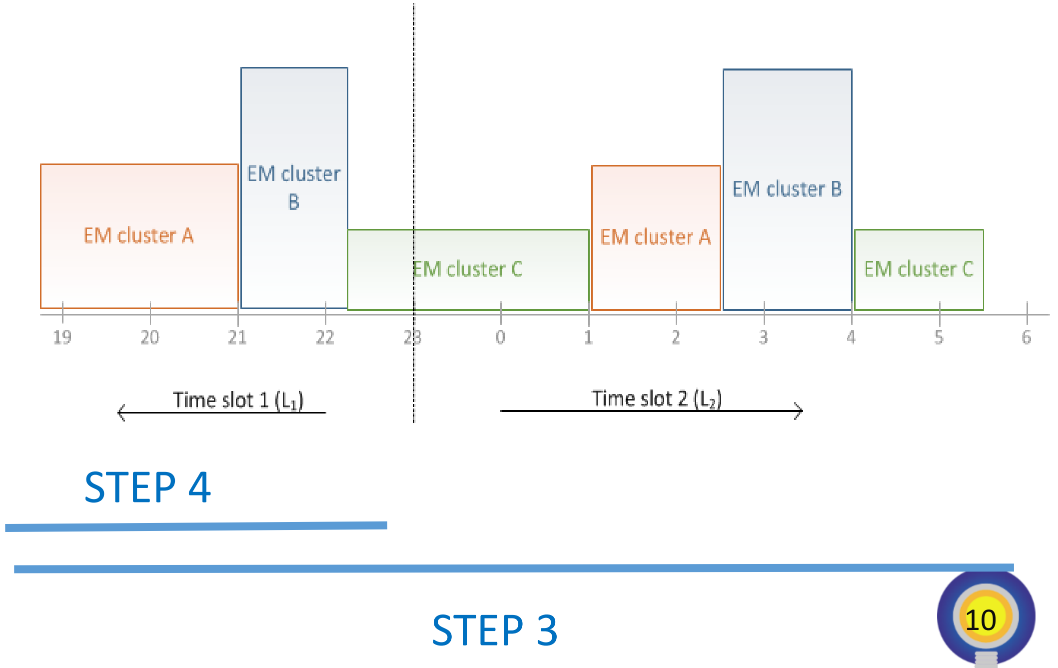
STEP 2 Extra expense distribution among groups of days.

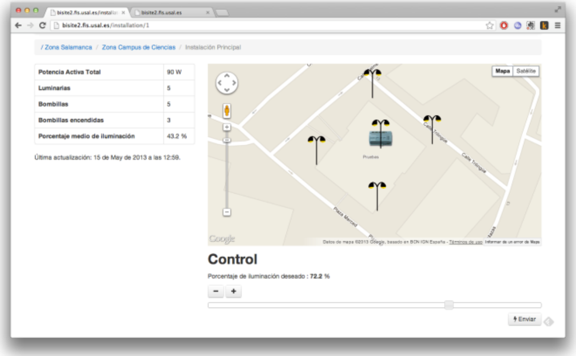
$$E_i = \frac{Nh_i}{Nh}\, E\, \rho_{Nh} + \frac{P_i}{P}\, E\, \rho_P$$

STEP 3 Distribution expenditure of each type of days between slots with the same electricity rates.

$$Nh = \sum_{i=1}^{I} Nh_i \;\; ; \;\; P = \sum_{i=1}^{I} P_i$$

STEP 4 Distribution of expenditure of each time slot for each hour of the night





Hours on and off

The hours of "switch on and off" are different every day, depending on the hours of dawn and sunset, and the predicted weather.

Every week, for each facility:

1. Check the weather forecast (Yahoo Weather)

YAHOO! DEVELOPER NETWORK

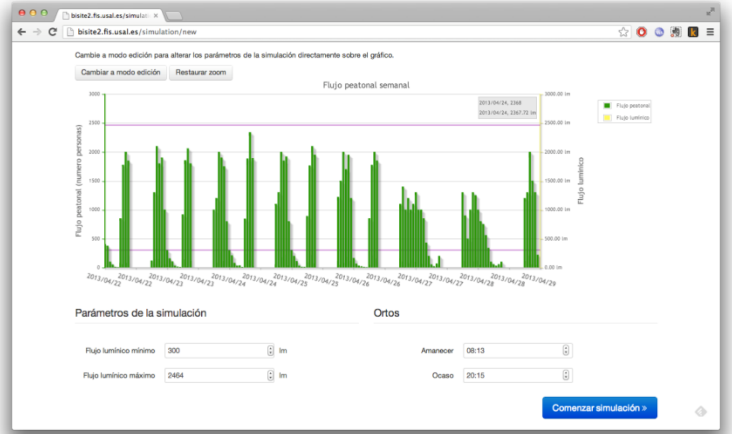
2. Setting times on and off depending on dawn and sunset hours and weather conditions

3. Sending lighting schedule for each facility (Web Service OCESC_CAD) and storing as historical data

Prediction and visualization of consumption

Consumption prediction

As we know the lighting calendars of each installation of street lighting, we will estimate the power consumed by luminaries.



Historical of consumption

Viewing historical data consumption.

Managing electricity rates

Term of active energy (kWh price)

With and without time restrictions

Predicting consumption: use of neural networks

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Necessary to know the power consumed by a lamp according to the light intensity projected. → Using neural networks: Multilayer Perceptron (MLP)

Historical consumption data luminaires (accessible through OCESC_CAD) → Training 2 neural networks → Storage networks trained in database (serialization)

Consumption prediction of a facility →

Historical of consumption

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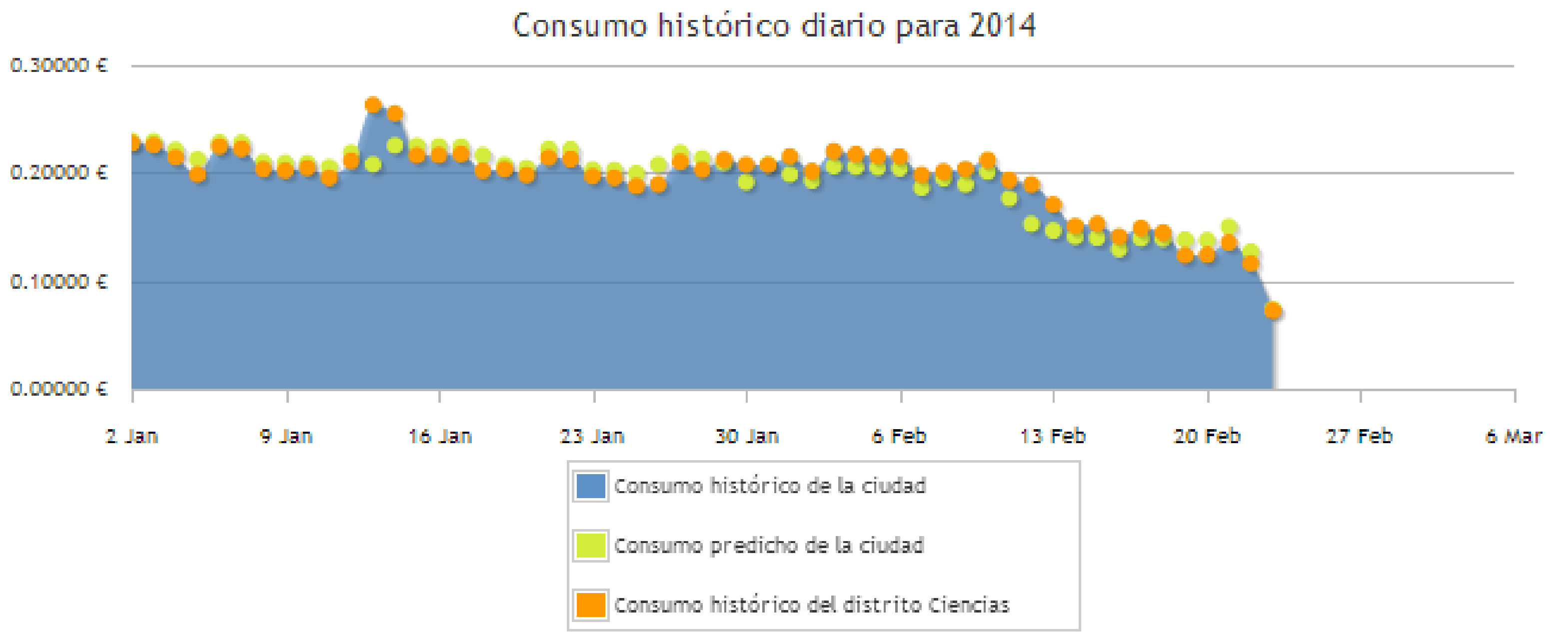
- Reading consumption of the facilities every hour for changes in the price of KWh (differents slots of the electricity tariff).
- Storage of historical data and forecast for each hour in the database.



Technologies

SERVER OCESC_GIVI

- Java EE 7
  - EJB Stateless
  - JPA, EclipseLink
- Servicios Web RESTful
  - JAX-RS, Jersey
- Servidor: Glassfish 4
- Base de datos: PostgreSQL
- Librerías:
  - OCESC_CAD
  - Weka
  - Yahoo Weather
  - Sunset Sunrise Lib, Mike Reedel

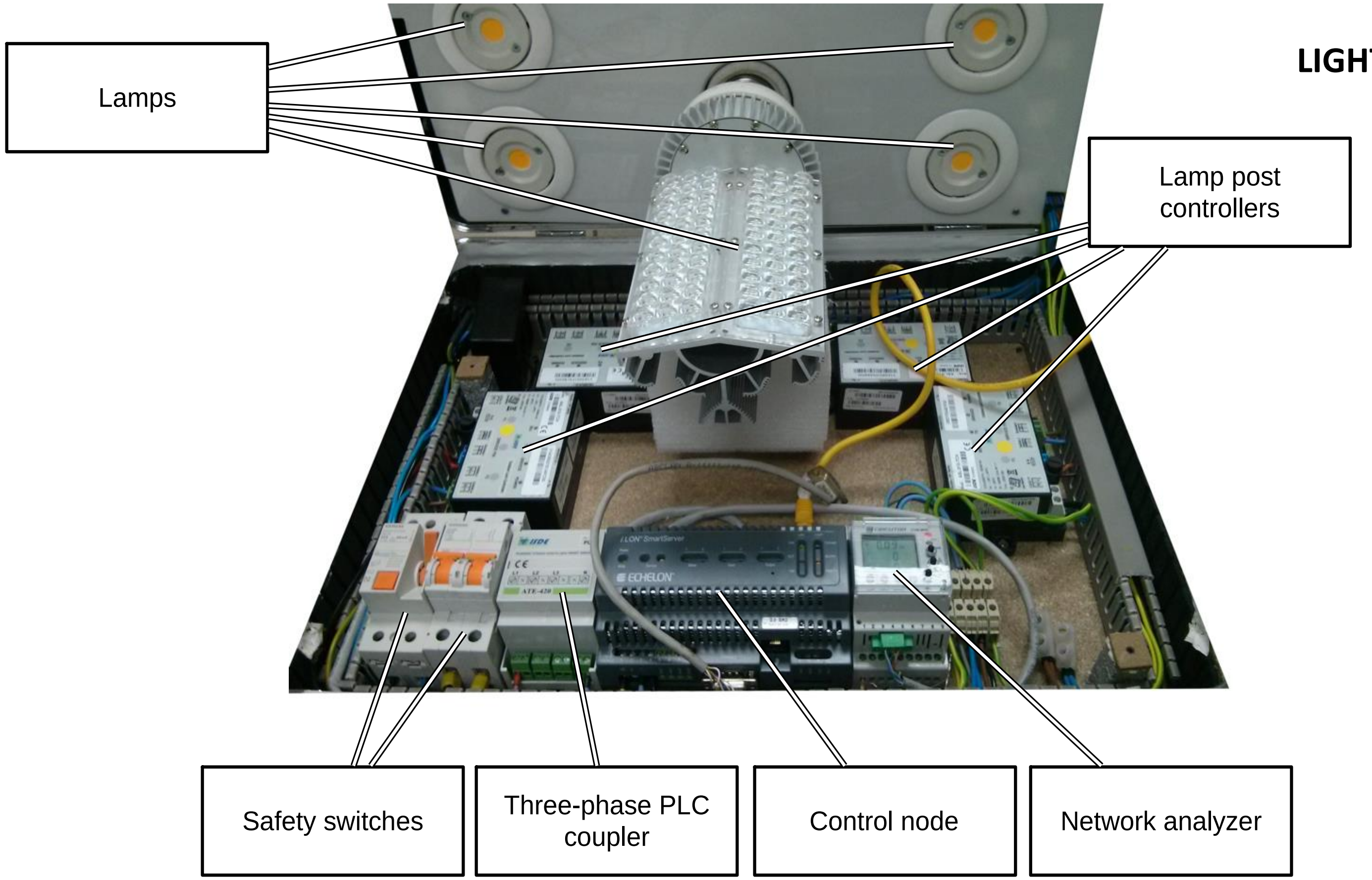
WEB APPLICATION

- Framework web Django para Python
- Bootstrap: HTML5, CSS3
- jQuery:
  - jqPlot
  - fullCalendar
- Librerías:
  - OCESC_CAD
  - OCESC_GIVI
  - Google Maps API

Tests

Throughout the development of the project, the functional components have been tested in prototype shown in the figure.

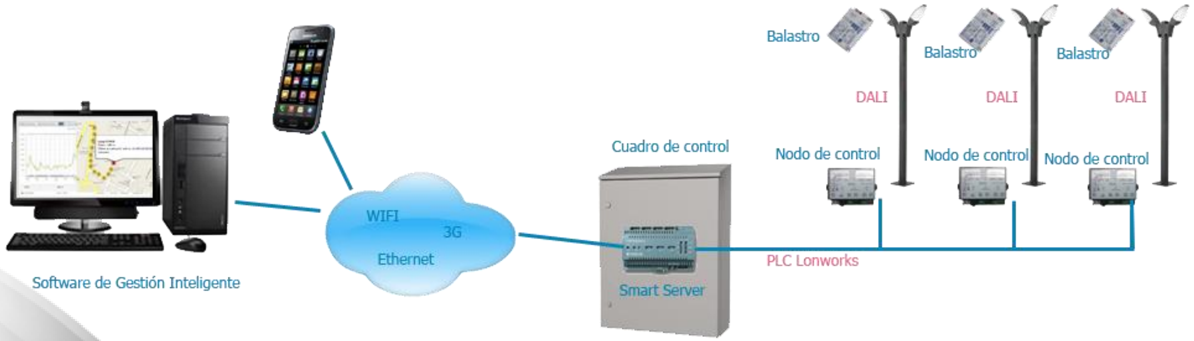
- Proper establishment of lighting calendars.
- Comparisons between expected and historical consumption.



Conclusions

- Management and development of lighting calendars:
  - Fusion of algorithms for finding light patterns depending on traffic and pedestrian flow.
  - Creating algorithm approximate maximum expenditure.
  - Real time control.

- Visualization and comparison of expected and historical consumption
- Flexibility in electricity tariffs.
- Integration of web interfaces.



Installation in La Fuente de San Esteban

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