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**Abstract:**

This document will contain the list of EMS to be adapted in each site, and the strategy to better adapt them to SmartKYE platform.

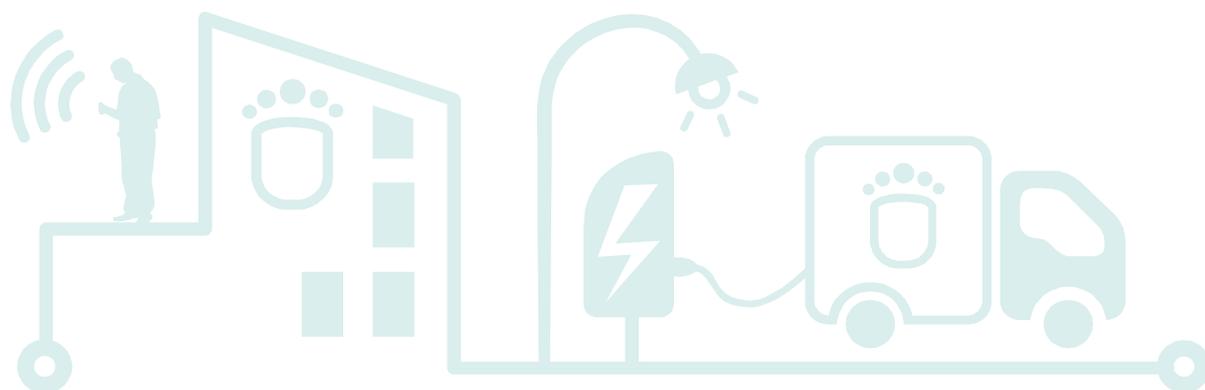
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## Table of Contents

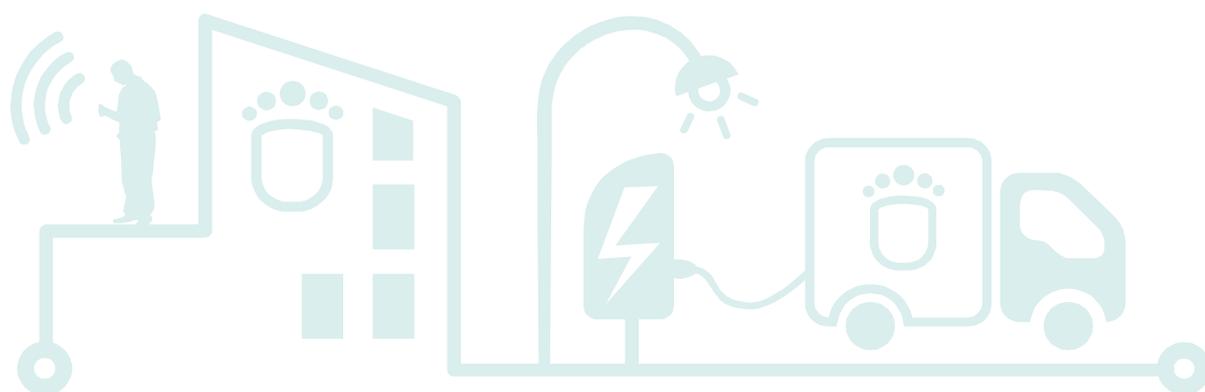
<b>1</b>	<b>Introduction .....</b>	<b>9</b>
1.1	Purpose of the Document .....	9
1.2	Scope of the Document .....	9
1.3	Structure of the Document .....	9
<b>2</b>	<b>EMS adaptation to SmartKYE platform.....</b>	<b>11</b>
2.1	EMS web services to adapt .....	11
2.1.1	EntityService.....	11
2.1.2	AttributeService .....	12
2.1.3	MetricService .....	13
2.1.4	MessageService .....	14
2.2	Publish–subscribe pattern.....	14
<b>3</b>	<b>Analysis of the existing EMS.....</b>	<b>16</b>
3.1	22@ district – Barcelona Pilot site .....	16
3.1.1	Barcelona Building EMS .....	16
3.1.1.1	Barcelona MediaTIC’s Building BMS .....	16
3.1.1.2	BDigital Office Energy Management Platform .....	19
3.1.2	Public lighting System.....	21
3.1.2.1	Introduction.....	21
3.1.2.2	System description .....	21
3.1.2.3	System architecture .....	23
3.1.2.4	Graphical User interface .....	25
3.1.2.5	Equipment .....	26
3.1.3	Electric vehicle infrastructure .....	30
3.1.3.1	Introduction.....	30
3.1.3.2	System description .....	30
3.1.3.3	System Architecture.....	33
3.1.3.4	Web application user interface.....	35
3.1.3.5	Map .....	35
3.1.4	Energy micro-generators .....	37
3.1.4.1	Introduction.....	37
3.1.4.2	System description .....	37
3.1.4.3	System architecture .....	38
3.1.4.4	Web application user interface.....	41
3.1.4.5	Equipment .....	43
3.2	Lasithi – Crete Pilot site .....	49



3.2.1	Generator Management System.....	49
3.2.1.1	Introduction.....	49
3.2.1.2	System description .....	49
3.2.1.3	System architecture .....	50
3.2.1.4	Web application – User interface .....	54
3.2.2	Building Management system.....	58
3.2.2.1	Introduction.....	58
3.2.2.2	System description .....	58
3.2.2.3	System architecture .....	58
3.2.2.4	Equipment .....	59
<b>4</b>	<b>Components adaptation definition.....</b>	<b>61</b>
4.1	Barcelona 22@ district – Pilot site .....	61
4.1.1	Barcelona Building EMS .....	61
4.1.1.1	Conceptual data model adaptation .....	61
4.1.1.2	Metrics & attributes provided .....	63
4.1.1.3	Design of the EMS adaption. ....	63
4.1.2	Public lighting System.....	67
4.1.2.1	Conceptual data model adaptation .....	67
4.1.2.2	Metrics & attributes provided .....	67
4.1.2.3	Design of the EMS adaption. ....	68
4.1.3	Electric vehicle infrastructure .....	71
4.1.3.1	Conceptual data model adaptation .....	71
4.1.3.2	Metrics & attributes provided .....	71
4.1.3.3	Design of the EMS adaption. ....	72
4.1.4	Energy micro-generators .....	76
4.1.4.1	Conceptual data model adaptation .....	76
4.1.4.2	Metrics & attributes provided .....	76
4.1.4.3	Design of the EMS adaption. ....	79
4.2	Lasithi – Crete Pilot site .....	83
4.2.1	Conceptual data model adaptation .....	83
4.2.1.1	Metrics & attributes provided .....	84
4.2.1.2	Design of the EMS adaption. ....	85
<b>5</b>	<b>Adaptation process planning .....</b>	<b>89</b>
5.1	22@ district – Barcelona Pilot site .....	89
5.1.1	Barcelona Building EMS .....	89
5.1.2	Barcelona Public Lighting EMS.....	90
5.1.3	Barcelona Electric Vehicle EMS.....	90



5.1.4	Barcelona Energy Micro Generators EMS .....	91
5.2	Lasithi – Crete Pilot site .....	91
5.3	Adaptation process Gantt .....	92
<b>6</b>	<b>Conclusions and next steps .....</b>	<b>94</b>
<b>7</b>	<b>Acronyms .....</b>	<b>95</b>
<b>8</b>	<b>Annex I .....</b>	<b>97</b>
8.1	MediaTIC building BMS systems .....	97
8.1.1	BDigital energy management platform – Devices installed.....	100
8.2	Technoflex energy generators – Equipment information .....	102
8.2.1	Mini-aerogenerator of 5kW of power generation. ....	102
8.3	Crete pilot site - More Care EMS Algorithms implemented .....	104
8.3.1	Load Forecast.....	104
8.3.2	Wind Forecast .....	105
8.3.3	PV forecasting model.....	105
8.3.4	Unit Commitment/Economic Dispatch.....	107
8.3.5	Economic Dispatch .....	107





## List of Figures

Figure 1 - Publish–subscribe model .....	15
Figure 2 - Barcelona pilot site – Systems architecture.....	16
Figure 3 - MediaTIC building space organization .....	17
Figure 4 - MediaTIC BMS system architecture.....	18
Figure 5 - BDigital energy management platform architecture.....	20
Figure 6 - Strategic action units .....	22
Figure 7 - Hierarchical units .....	22
Figure 8- Public lighting product scope .....	23
Figure 9 - System deployment architecture.....	25
Figure 10 - Public Lighting control system Web Interface.....	26
Figure 11 - Segments controller.....	27
Figure 12 - Solution architecture .....	31
Figure 13- Two charging stations at @22district .....	31
Figure 14 - System architecture .....	33
Figure 15 - User Interface .....	35
Figure 16 - Installation map.....	36
Figure 17 - Wind turbine at Sant Guim facilities .....	37
Figure 18 - Solar panel at Sant Guim facilities .....	38
Figure 19 - System architecture .....	39
Figure 20 - Web application log-in page.....	41
Figure 21 - Sample graph of combined data from the web application .....	42
Figure 22 - Historical data about wind direction (among others) shown graphic (radar) and text (table) forms .....	43
Figure 23- Vertical axis wind turbine1 kW .....	44
Figure 24 - Yield curve Eolic system 1 kW .....	44
Figure 25 - Average wind Eolic system 1 kW .....	45
Figure 26 - Installation 1Kw diagram yield curve .....	46
Figure 27 – Sola panel schema .....	47
Figure 28 – Weather station interface .....	48
Figure 29 – Weather station software analysis.....	48
Figure 30 - Overview of MORE CARE functionalities.....	49
Figure 31- Overview of new MORE CARE architecture .....	51
Figure 32 - Architecture of More Care application .....	52
Figure 33 - More Care Main Screen.....	54
Figure 34 - Thermal Units Current Production.....	55
Figure 35 - Wind Farms Current Production.....	55
Figure 36 - Island Day Demand Curve and Load Forecasting for the next 12 hours .....	56

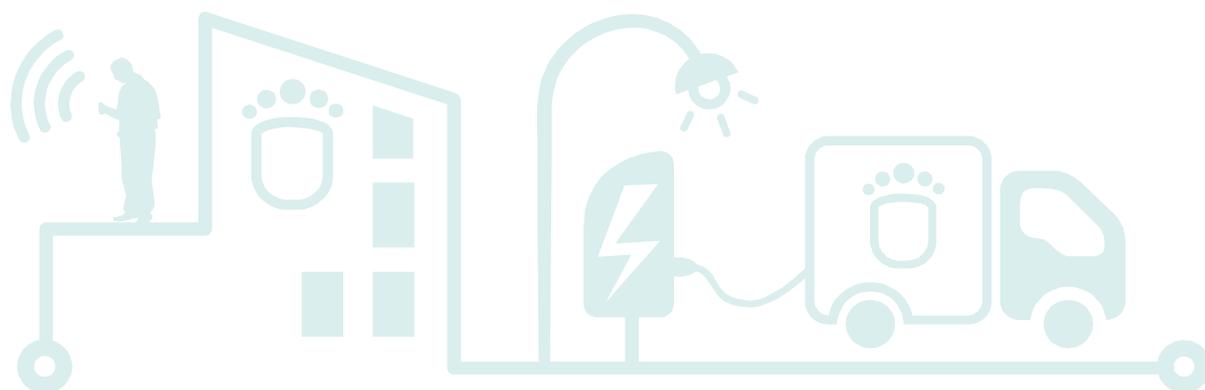


Figure 37 - Transmission Grid of Crete and optimal power flow visualization .....	56
Figure 38 - Technical Characteristics of the Units .....	56
Figure 39 - System Parameters .....	57
Figure 40 - Messages to the Operator .....	57
Figure 41 - The Unit Commitment Chart .....	57
Figure 42 - Architecture of the data acquisition from the public buildings .....	59
Figure 43 - BK3000TG Controller.....	59
Figure 44 - BK4000TG Controller.....	60
Figure 45 - Architecture – Barcelona Building EMS adaptation .....	64
Figure 46 - Barcelona Building EMS adapter structure.....	65
Figure 47 - Barcelona Building EMS adapter – Polling service algorithm .....	66
Figure 48 - System deployment architecture .....	68
Figure 49 - EMS adapter application implementation structure .....	69
Figure 50 – Algorithm implemented .....	70
Figure 51 - Architecture EMS adaptation .....	73
Figure 52 - EMS adapter application implementation structure .....	74
Figure 53 – Algorithm implemented .....	75
Figure 54 - Architecture EMS adaptation .....	79
Figure 55 - EMS adapter application implementation structure .....	80
Figure 56 – Algorithm implemented .....	82
Figure 57 - Architecture EMS adaptation .....	86
Figure 58 - EMS adapter application implementation structure .....	87
Figure 59 – Algorithm implemented .....	88
Figure 60 – SmartKYE EMSs adaptation planning.....	93
Figure 61 - MediaTIC building BMS architecture.....	98
Figure 62 - Barcelona pilot site – MediaTIC thermal floor control (for each fan coil).....	99
Figure 63 - 4Noks ModBus/TCP Ethernet Gateway .....	100
Figure 64 - Digi Temperature/Humidity/Brightness sensor .....	101
Figure 65 - Energy consumption sub-metering sensors .....	102
Figure 66 - Eolic system 5 kW .....	102
Figure 67 - Yield curve Eolic system 5 kW .....	103
Figure 68 - Yield curve Eolic system 5 kW .....	103
Figure 69 - Installation 5Kw diagram yield curve .....	104



## List of Tables

Table 1 - MediaTIC building .....	19
Table 2 - Some of the SCADA tags.....	53
Table 3 - Building characteristics .....	58
Table 4 - Barcelona Building EMS data model adaptation .....	61
Table 5 - Barcelona Building EMS metrics and attributes provided .....	63
Table 6 – Public lightning EMS data model adaptation .....	67
Table 7 – Public lightning EMS Metrics and attributes provided .....	67
Table 8 - EV EMS data model adaptation .....	71
Table 9 – EV EMS metrics and attributes provided .....	71
Table 10 – Micro generators EMS data model adaptation.....	76
Table 11 - Microgenerators EMS metrics and attributes.....	77
Table 12 – More Care data model adaptation .....	83
Table 13 – Crete energy generators metrics and attributes.....	84
Table 14 - Barcelona building EMS adaptation plan - Summary .....	89
Table 15 - Barcelona public lighting EMS adaptation plan - Summary .....	90
Table 16 - Barcelona electric vehicle EMS adaptation plan - Summary .....	90
Table 17 - Barcelona microgenerators EMS adaptation plan - Summary .....	91
Table 18 – Lasithi EMSs adaptation plan - Summary.....	91





## 1 Introduction

### 1.1 Purpose of the Document

The objective of WP4 is to tackle the integration with the different Energy Management Systems (EMS) deployed in a neighbourhood in order to be able to interact with them in a service oriented way. The last implies functionality wrapping where it is not there, and possibly install and host the services being delivered by the open service platform developed in WP3. Specifically this WP will:

- Integrate with existing EMSs and other information systems existing in the neighbourhood today that contain data used for the SmartKYE EMS and the SmartKYE business cockpit.
- Integrate with the EMS for energy generation purposes to be used in the pilot sites in SmartKYE.
- Integrate with the EMS for district public facilities (buildings) to be used in the pilot sites in SmartKYE.
- Integrate with the EMS for public lighting systems to be used in the pilot sites in SmartKYE.
- Integrate with the EMS systems for transport to be used in the pilot sites in SmartKYE.
- Create a blueprint containing general guidelines for the integration of EMS and lessons learnt during the process.

### 1.2 Scope of the Document

The deliverable D4.1 “EMS Adaptation plan”, that is part of the work done in the task T4.1 “Analysis of existing EMS and design of the specific strategies for migration”, contains the list of EMS to be adapted in each site, and the strategy to better adapt each system to the SmartKYE platform.

In the first part of the document, it is analysed in detail the specifications of the existing EMS deployed in each pilot sites. Secondly, it is defined, based on the architecture and use cases defined in previous WPs, the specific components in the selected EMS that needs to be affected and the required adaptation in order to be part of SmartKYE system.

Based on this deliverable, it will be generated the migration process to be undertaken in T4.2 “EMS adaptation”. Finally, after the proper adaptation of all the EMSs, the report D4.3 “Guidelines for transferability of EMS adaptation strategies”, containing the guidelines to adapt EMS at any potential new site, will be delivered at the end of WP4.

### 1.3 Structure of the Document

The remainder of this document is structured as follows. In Section 2, it is defined the process for the EMS adaptation to SmartKYE platform. This includes a brief generic description of the SmartKYE EMS web services to adapt and the SmartKYE EMSs publish-subscribe pattern that must be implemented.

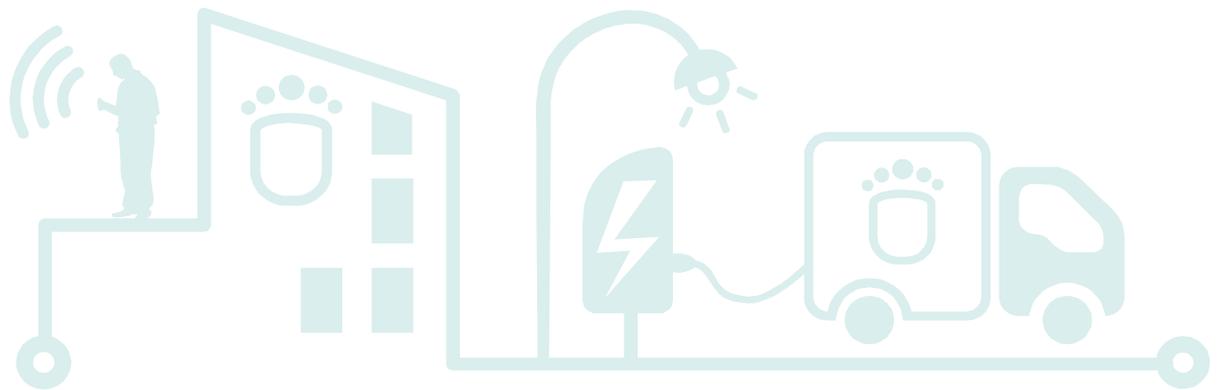
In Section 3 in described in detail the specifications of the different existing EMSs deployed in Barcelona and Lasithi and that will be part of the validation of SmartKYE project results.

In section 4, it is described the adaptation process that will be needed in each component of all the EMSs in order to adapt them properly to the SmartKYE system.

In section 5, it is shown the planning for the adaptation process in each EMS. The adaptation



will be tackled in two phases in order to provide feedback to the OESP developers. The first adaptation process will finalize in month 18 and the second phase in month 24.





## 2 EMS adaptation to SmartKYE platform

SmartKYE should integrate different EMS in a common single infrastructure that, at the end, will provide users a unified view of the energy-related elements of a given geographical area. These elements are handled by different and heterogeneous controls systems. For the project, we consider these:

- Public light control systems
- Electric vehicle management system
- Building management system
- Energy micro-generators

Other types of control systems could be added in the future; in fact the system has been designed to be as much extendable as possible.

Each control system will take control of different devices and will cope with the complexities of the physical connection, specific device drivers, security of the data, etc.

Each EMS must do the following in order to join the SmartKYE platform:

- Implement the service interfaces used for the platform to access the EMS (defined in SmartKYE deliverable document D2.1). The concepts handled by the EMS must be translated to those handled by the platform (devices, metrics, etc.)
- Provide the access point URL for the implemented services to the platform managers, and let request coming from the platform reach the services
- Implement the publish-subscribe mechanism for advertising the data changes to the platform. This implies managing the subscriptions, continuously monitoring the subscribed stuff and distributing the information to the right subscriber upon necessary.
- Make use of the security mechanism defined by the platform for attending the requests
- Synchronise the clock with the platform

### 2.1 EMS web services to adapt

For an Energy Management System (EMS) to interact with the Open Energy Service Platform (OESP), a series of web services must be implemented. These services are grouped together according to the entity of the system model they are more related to.

A brief generic description of the services is provided below. On subsequent sections, more specific information on the implementation for each kind of EMS can be found. For a detailed listing of the actual data model, refer to the document D2.1 of this same project.

#### 2.1.1 EntityService

An entity in the system can represent a huge variety of elements, from a whole EMS down to the smallest measurable device (e.g. a charging point in an electric vehicle system). Entities are related between them in a hierarchical mode, and all of them must be able to communicate with the OESP through the following web services:

##### 2.1.1.1 listTopLevelEntities

###### **List<Entity> listTopLevelEntities()**

It returns a list of the top level entities (i.e. the EMSs). Given that the amount of top level entities in the system is moderate, no filtering parameters are needed.



#### 2.1.1.2 findEntities

##### **List<Entity> findEntities(EntityFilter entityFilter)**

The service returns a list of entities which characteristics match the filter passed as a parameter.

#### 2.1.1.3 findEntityDescendants

##### **List<Entity> findEntityDescendants(EntityFilter entityFilter, int depth)**

Given a filter and a level of depth, the service returns every entity which is a descendant (up to many levels as indicated) of the entity or entities which properties match the filter.

#### 2.1.1.4 getEntityTimeseries

##### **List<EntityProvidedMetric> getEntityTimeseries(EntityFilter entityFilter)**

Once every entity that matches the filter is found, the service returns a list of entities identifiers and a list of the associated metrics for each one of them (metrics are explained in section 2.1.3 below).

### 2.1.2 AttributeService

An attribute represents a property describing some aspect of a particular entity. Every entity in the system has a set of attributes which values can change over time, and the system will keep track of these updates. Moreover, it will be possible to subscribe to these updates and get notified every time the value of an attribute changes.

#### 2.1.2.1 getAttributeValue

##### **List<AttributeValueResult> getAttributeValue(EntityFilter entityFilter, List<AttributeType> attributeTypes)**

This service receives an entity filter and a series of types of attributes, and returns a list of entities that match the filter with a set of attributes of the given types. As the same attribute can have different values over time, only the most recent value for each attribute found will be returned, along with its timestamp. Finally, if an entity does not respond to this petition or one of its attributes cannot be read, it will be added to a list of errors and returned as well.

#### 2.1.2.2 setAttributeValue

##### **void setAttributeValue(String entityID, Attribute attributeType, BaseAttributeValue value)**

The value of an attribute is updated through this service. The entity identifier, the type of the attribute and the new value are received in the request.

#### 2.1.2.3 getAttributeTimeseries

##### **List<AttributeTimeseriesResult> getAttributeTimeseries(EntityFilter entityFilter, List<AttributeType> attributeTypes, Date startTime, Date endTime, long connectionTimeoutInSeconds)**

The service input includes an entity filter, a list of attribute types, start and end timestamps, and



a timeout in seconds. Once the desired entities and attributes are found, a list of points in time between the two dates and the existent value at that moment is returned for each one of them.

Since the SmartKYE architecture is distributed, some methods require a timeout of the request. Once it is reached, the method will trigger the delivery of already obtained results. A list of unavailable or unreadable entities will also be returned.

#### 2.1.2.4 subscribeAttribute

**String subscribeAttribute(EntityFilter entityFilter, List<AttributeType> attributeTypes, String subscriber)**

It creates a subscription to the updates of the attribute or attributes that match the given types and entity properties. The service returns a string identifier to be used for terminating the subscription.

Once an attribute under subscription is updated, the system will send a request with the updated information to the service (i.e. URL) given in the input.

#### 2.1.2.5 deleteAttributeSubscription

**void deleteAttributeSubscription(String subscriptionHandle)**

The system stops sending updates about the attribute or attributes under the subscription identified with the string code received as input.

#### 2.1.2.6 reportAttributeUpdates

**void reportAttributeUpdates(List<AttributeValueResult> updates)**

The system notifies the list of updates passed as a parameter to every entity subscribed to one or more of the attributes involved.

### 2.1.3 MetricService

A metric in the system refers to everything that can be represented by a real number at a point of time. Metrics in this system are always associated to an entity, and their values are periodically read and updated. As with attributes, the system offers subscriptions to metrics updates too.

#### 2.1.3.1 getMetricValue

**List<MetricValueResult> getMetricValue(EntityFilter entityFilter, List<MetricType> metricTypes, long connectionTimeoutInSeconds)**

It returns a list of updated metric values, last reading timestamp and entities associated, according to the entities and metric types matching the filter given. Entities not responding or without available data are added to an error list and returned as well. If the timeout is reached, the service returns the results found up to that point.

#### 2.1.3.2 getMetricTimeseries

**List<MetricTimeseriesResult> getMetricTimeseries(EntityFilter entityFilter, List<MetricType> metricTypes, Interval interval, long numberOfIntervals, long connectionTimeoutInSeconds, boolean aggregated)**



The service receives an entity filter and a list of metric types, and returns a list of points in time and the value of the matching metrics at that timestamp. The collection of time series is enclosed by an interval –consisting of a timestamp and certain duration– and a number of interval repetitions, both passed as parameters. Whether more than one entity is found, metrics can be aggregated on an interval basis when the input flag is marked as such.

A list of unreachable entities or which metrics cannot be read is also returned in the response. Even if some entities do not deliver their individual metrics to the system, still the aggregation will be executed for available results.

### 2.1.3.3 subscribeMetric

**String subscribeMetric(String subscriber, EntityFilter entityFilter, MetricType metricType, Interval interval, boolean aggregated)**

As with attributes, it is possible to subscribe to metrics and receive a notification when their values are updated. Subscriptions are determined by an entity filter and a metric type. The frequency of notifications is defined by an interval, as well as if the values must be individual or aggregated. A call to this service returns a string that identifies the subscription.

### 2.1.3.4 deleteMetricSubscription

**boolean deleteMetricSubscription(String subscriptionHandle)**

This service receives a subscription identifier and returns a boolean indicating if the subscription was found and deactivated.

## 2.1.4 MessageService

Messages in the system are the mechanism to communicate and induce changes to the entities. Depending on the nature of each entity, it will or will not be required to implement these kind of services, i.e. an EMS which only supplies information but cannot be controlled by the system does not need to provide any message service.

### 2.1.4.1 sendMessage

**List<EntityWithMessage> sendMessage(EntityFilter entityFilter, Message message)**

This service gets an entity filter and a message (including its type) and forwards it to every entity that matches the parameters. The service returns a list of entity identifiers and the message each one of them returned in response.

## 2.2 Publish–subscribe pattern

SmartKYE EMSs must implement the publish-subscribe pattern for distributing data changes to subscribers in the moment that the change by the EMS.

Publish–subscribe pattern is a messaging pattern with two kinds of actors: publishers –senders of messages– and subscribers –receivers–. In this paradigm, the receiver(s) of a message is not explicitly stated; instead, the message is categorized into classes receivers may or may not be subscribed to. In the same way, subscribers have a set of categories they want to receive messages of, rather than specifying which publisher they want to receive information from.

An application publishes information, and an event notification is broadcasted to all authorized



subscribers. In general, the relationship between the publisher and subscriber is mediated by a service that receives publication requests, broadcasts event notifications to subscribers, and enables privileged entities to manage lists of people or applications that are authorized to publish or subscribe. The focal point for publication and subscription is a "node" to which publishers send data and from which subscribers receive event notifications. Nodes can also maintain a history of events and provide other services that supplement the pure publish–subscribe model.

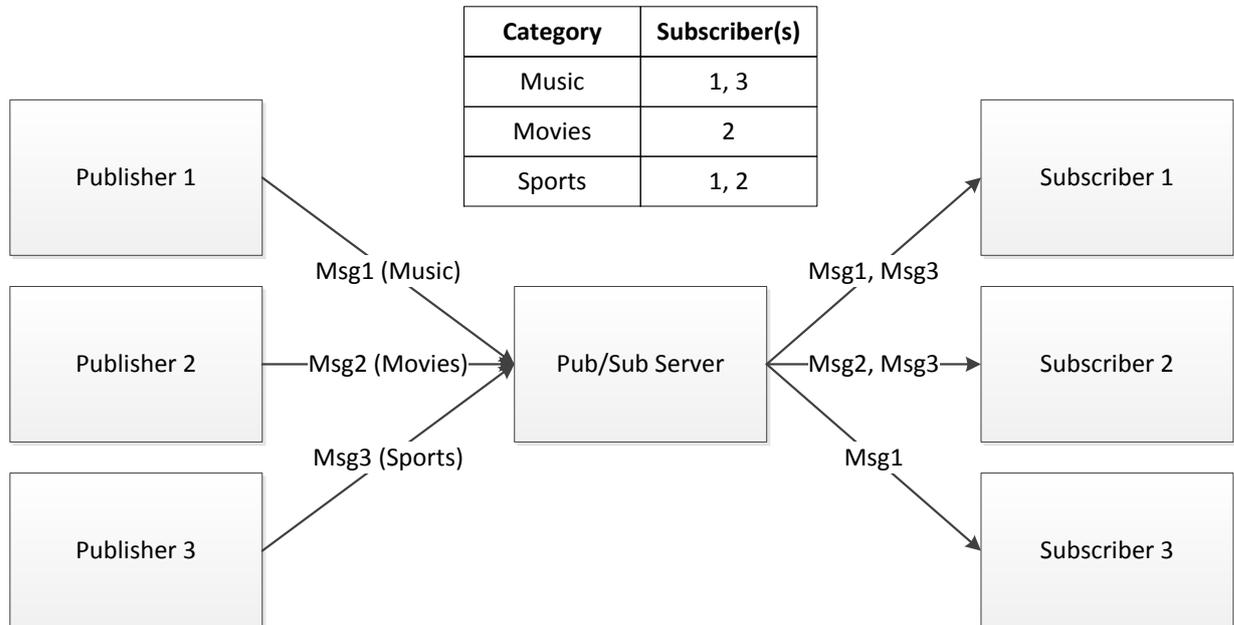


Figure 1 - Publish–subscribe model

Requirements for a publish–subscribe service can be driven by end-user needs as well as the needs of other components and services which can use the service. First, a publish–subscribe service must provide the basic features that implement a pure publish–subscribe pattern:

- An entity must be able to publish events to a service such that all subscribers to a node receive notification of the event.
- An entity must be able to subscribe to a node (or be informed that subscription is not allowed).
- An entity must be able to unsubscribe from a node (or be informed it is already not subscribed).
- An entity must be allowed to query the publish–subscribe service (or a specific node) to determine what optional features of this specification the service (or node) implements.

Some of the optional features a publish–subscribe service may implement include:

- A service may cache the last item published to a node.
- A node owner should be able to specify who may subscribe to a node.
- A node owner should be able to specify who may publish to a node.
- A node may be configured to persist published items to some persistent storage mechanism.
- A node may be configured to persist only a limited number of items.
- A service or node may notify their subscribers about any disturbance that may affect its performance.



### 3 Analysis of the existing EMS

The objective of this section is to provide detailed specifications of the different EMS available in each pilot site where SmartKYE platform will be deployed, demonstrated and evaluated. This will include, communications, HW platform, operation constrains, and any other relevant information related to each particular system.

#### 3.1 22@ district – Barcelona Pilot site

##### 3.1.1 Barcelona Building EMS

Barcelona pilot site “building EMS” will be composed by two main sub-systems, on the one hand the MediaTIC building BMS and on the other hand the BDigital’s office energy management platform.

All these systems will be integrated within SmartKYE platform, as illustrated in Figure 2, where besides systems already deployed in the building; a “Building EMS” building block will be added in order to implement the SmartKYE interface required.

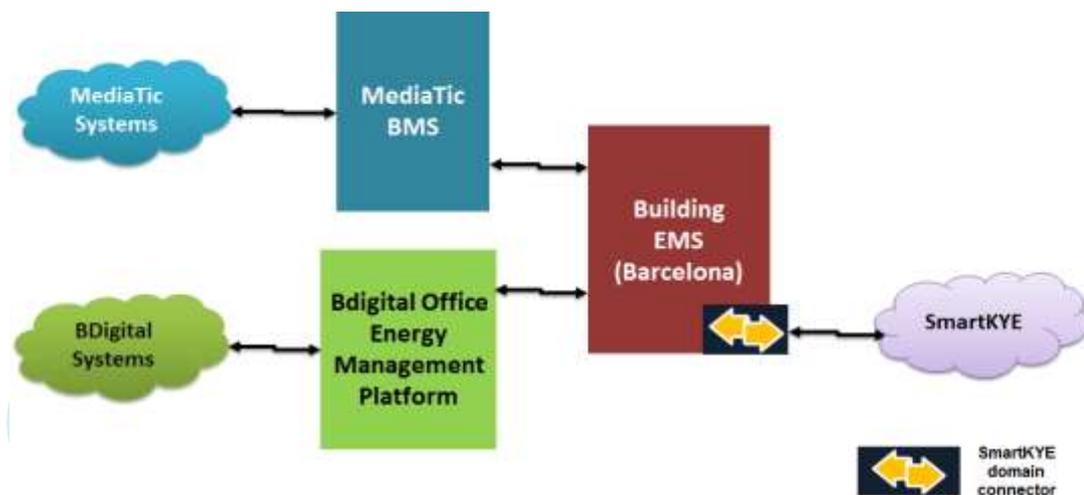


Figure 2 - Barcelona pilot site – Systems architecture

Following sections will present a detailed description of the current characteristics of the systems to be integrated, namely the MediaTIC BMS and BDigital energy management platform.

##### 3.1.1.1 Barcelona MediaTIC’s Building BMS

This section presents an overview of the main characteristics and components of the systems already integrated within the Barcelona pilot site MediaTIC building. Later sections of this document will focus on the required adaptations of such systems in order to integrate the data obtained for the MediaTIC building within the SmartKYE platform.

MediaTIC building is located in the 22@ district in Barcelona, at the Roc Boronat and Sancho de Ávila Streets. The building is designed to be a communications hub and meeting point for business and institutions in the world of information and communication technologies (ICTs), as well as for the media and audio-visual sectors.

Mainly, the MediaTIC building is used for business. To support the communication between institutions and to generate a business environment, the building includes different zones clearly



illustrated in Figure 3.

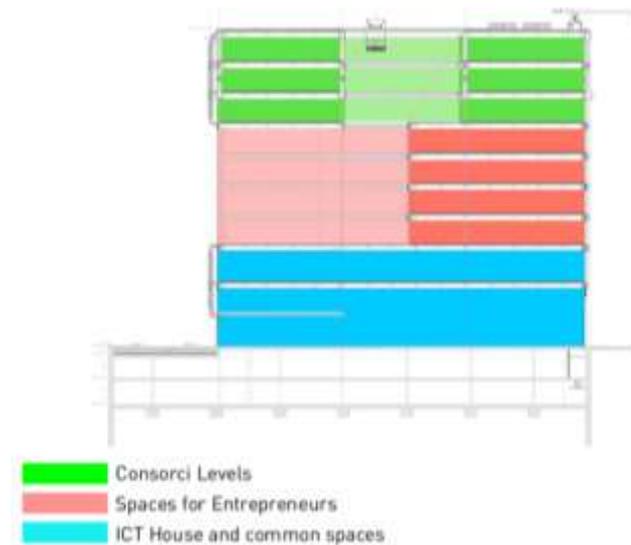


Figure 3 - MediaTIC building space organization

### Parking space

The parking zone is located in the basement of the building, in -1 and -2 floors. As the name represent, this zone is a private parking area. In this part of the building are located the main facilities sources that gives services to the building (water facility, district heating, main electricity facilities, etc.).

### ICT House and common spaces

This zone represents the first floor of the building (ground and attic). Ground floor space is dedicated to the general public and business. It is an open space available for all kind of events (public presentations, fairs, etc.).

### Spaces for Entrepreneurs

This building space will offer infrastructure, development and financial services for business in the media sector. In this zone is settled down several companies such as BDigital.

BDigital facilities are located in the 5<sup>th</sup> Floor, where more than 100 workers perform their activities in a daily basis.

### Consorti Levels

The upper part in the building (6th, 7th and 8th floors) is used by the Internet Interdisciplinary Institute (IN3\_UOC). The Internet Interdisciplinary Institute (IN3) is a research institute of the Universitat Oberta de Catalunya (UOC) specialized in the research of the network society and the knowledge economy, as well as in the study of network technologies and specific areas of software.

Referring MediaTIC building time table usage, most of the companies follows similar time table. Hence, the Media-TIC usage time table is between 7.30h to 21h. The maximum level of occupancy is reached at 10-13h when most of employers are in his workstation, and most of the unusual occupants visit different companies within the building. In the same line, the minimum level of occupancy is reached in the earlier hours in the morning (7.30h-10h), the lunch hour (13.30h-15h) and last hours in the afternoon (19.30h-21h). All systems operating within



MediaTIC building are monitored and in some cases controlled from a central location, a Building Management System (BMS) provided by Controlli<sup>1</sup>. Controlli BMS manages mainly all systems within public spaces of the building, leaving monitoring inside each company facilities to their responsibility.

### 3.1.1.1.1 MediaTIC BMS system description

As in any office building, there are several systems providing common services for the different areas of the building i.e., centralized heating and air condition system (HVAC), electricity facilities for offices and common spaces, among others. In general, all systems within MediaTIC building are constantly monitored by a building management system (BMS) supervised by the facility manager (and maintenance services of the building).

The functionalities of the MediaTIC BMS are:

- Monitor the actual status of the existing systems monitored, considering communications status and data obtained from each system (i.e., electrical parameters).
- The data collection and storage in a local database.
- Define timetables associated with the operation of certain systems, mainly operation of HVAC system.
- Assist building or facility manager in the maintenance of the building by generating alarms or messages in case of malfunctioning of any particular system monitored.

### 3.1.1.1.2 MediaTIC BMS system architecture

In the Annex section of this document is provided a detailed view of the different systems integrated and managed by MediaTIC BMS, clearly presenting main equipment or components involved as well as communication interfaces. From all these systems, only a sub-set of them will be integrated within SmartKYE platform, following MediaTIC facility manager requirements. A system view of the MediaTIC building EMS focused mainly in those systems to be integrated within SmartKYE platform is presented below:

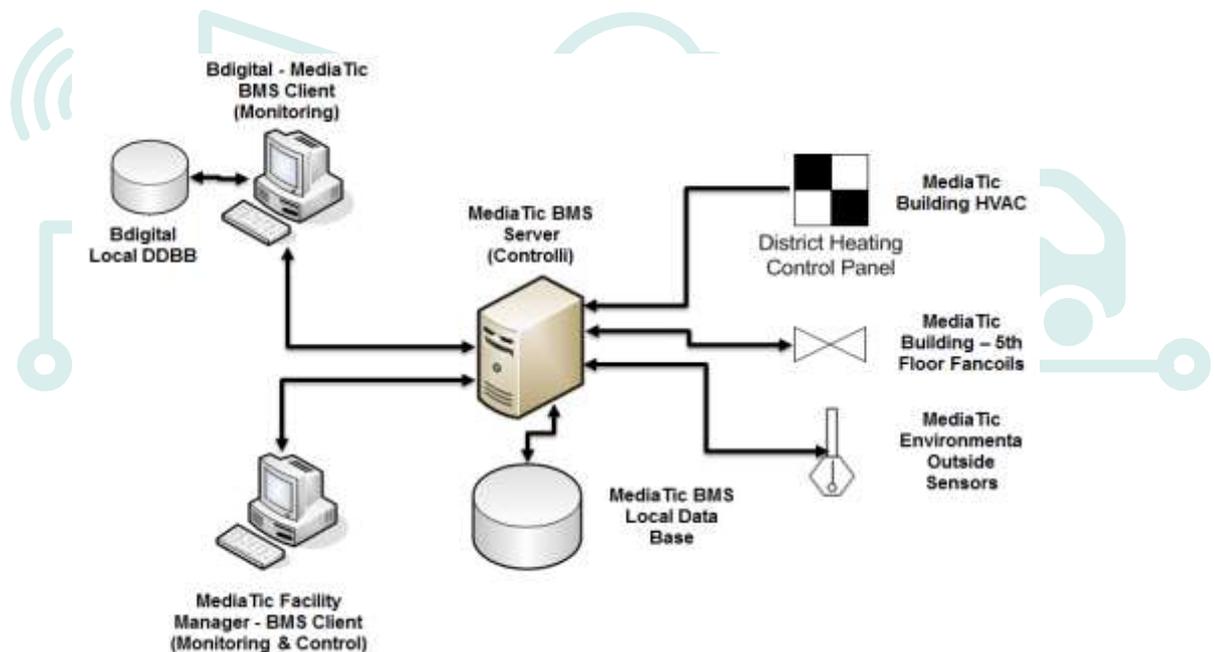


Figure 4 - MediaTIC BMS system architecture

<sup>1</sup> <http://www.controlli.eu/>



As mentioned before and illustrated in the previous Figure, only a sub-set of those systems monitored and controlled by MediaTIC building BMS will be integrated within SmartKYE platform. The following table provides a detailed list of the data to be obtained from the MediaTIC building BMS and integrated within SmartKYE platform:

**Table 1 - MediaTIC building**

Data	Detail Level	Sensor	Data Type	Granularity (min)
<b>Outside Temperature</b>	MediaTIC building	Temperature Sensor located in MediaTIC roof.	FLOAT	15
<b>Solar Radiation</b>	MediaTIC building	Solar radiation Sensor located in MediaTIC roof	FLOAT	15
<b>District heating and Cooling</b>	MediaTIC Building	No sensor; manual reading.	--	
<b>Fan-Coil Temperature</b>	MediaTIC Building	Temperature of fan-coils placed in BDigital Office	ANA	15
<b>Main Air Valves Temperature</b>	MediaTIC Building	Main ventilation device; Temperature of air impulsion and Temperature of air returned	ANA	15
<b>Device Working hours</b>	MediaTIC	Working hours for pumps of the main systems	ANA	

MediaTIC building BMS system provides a graphical user interface mainly targeted for the facility manager, where monitoring and control capabilities are enabled. In contrast, SmartKYE access to MediaTIC data will be enabled through a BMS client with “read-only” credentials, which will enable data retrieval and storage in a local data base. Although a simple user interface is provided for the BDigital BMS client, access to data will be performed directly to the database.

Further sections of this document will focus on the analysis of those systems installed after construction date by any particular company (within its facilities), as is the case of BDigital’s energy management platform, which is outside the control of this MediaTIC’s BMS.

### 3.1.1.2 BDigital Office Energy Management Platform

Besides the system previously described, BDigital has developed and deployed an energy management platform within its office facilities. The platform allows monitoring the energy consumption of the entire facilities as well as some environmental parameters (temperature, humidity and brightness) in specific areas of BDigital’s office.

Following sections of this document provide details regarding functionalities and system architecture of the platform.

#### 3.1.1.2.1 BDigital office energy management platform system description

BDigital’s energy management platform is based on the use of Wireless Sensor Networks (WSN) technologies and off-the-shelf solutions that have been integrated to create a whole energy management platform. As it can be seen, the system is divided into two main branches:

- **BDigital Office energy monitoring:** The overall energy consumption of BDigital’s office is monitored through a set of devices or sensors installed in the mains electric cabinet of



the office. These sensors provide an LED pulse interface which is used by a set of “4Noks Pulse Controllers” to translate these pulses in power consumption data, which is then transmitted through the “4Noks ModBus/TCP Ethernet Gateway” to the energy platform server where data is finally processed and stored.

- Environmental parameters and sub-metering monitoring:** Environmental parameters of the office (such as temperature, humidity and brightness) as well as disaggregated electricity consumption of specific electrical equipment are monitored through several different devices or sensors which create a wireless sensor network. Data gathered is finally transported through the sensor network up to a TCP Ethernet Gateway and finally to the energy platform server where data is processed and stored.

### 3.1.1.2.2 BDigital office energy management platform system architecture

The sensors installed are connected to a server that collects the information. The architecture of the system is shown in Figure 5.

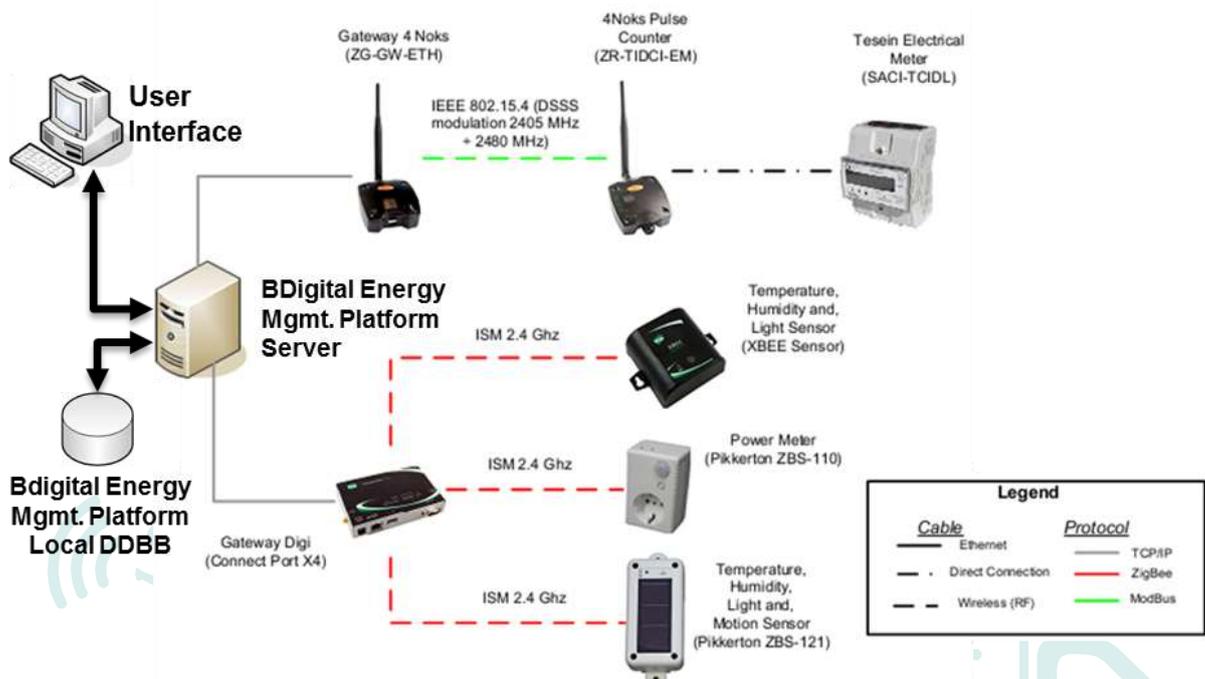


Figure 5 - BDigital energy management platform architecture

A brief description of the main technical specification of the equipment used has been included in the Annex section of this document.



### 3.1.2 Public lighting System

#### 3.1.2.1 Introduction

This section defines the components of the Public lighting control system implemented in Barcelona whose objective is to manage the public lighting in street installations. The following information involves the description of the existing system, with the intention of serve as a basis for the integration within the SmartKYE platform, which will be covered in later sections of this document.

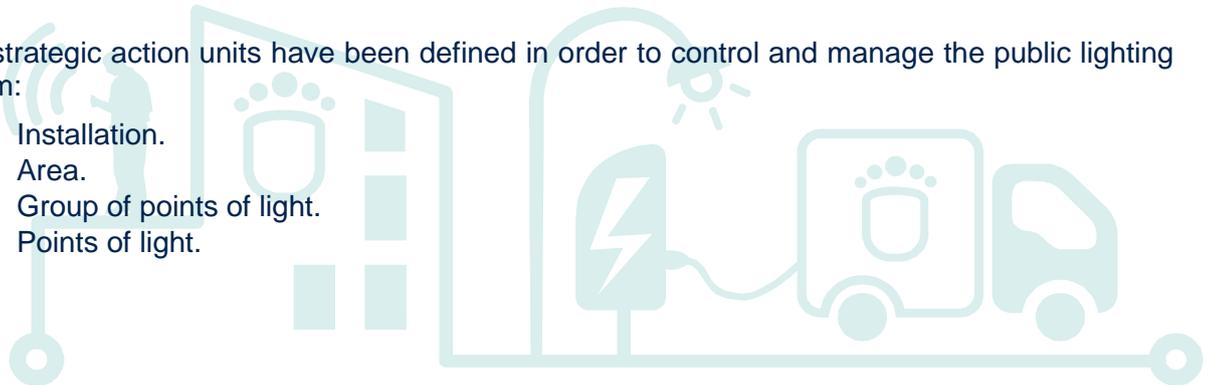
#### 3.1.2.2 System description

The functionalities of the public lighting system implemented in Barcelona are:

- Monitor the actual status of the existing segments and point of light controllers: status of communication, alarms, intensity levels, electrical parameters, consumption and status.
- Define timetables associated with segments and of point of light controllers. These calendars set intervals of time and the associated power or intensity of lighting levels.
- The data collection of the electrical measurements of the segments controllers and points of light and storage in a database with statistical purposes.
- Reporting of consumption by point of light and segment controllers. In the case of segments controllers, the reports are based on aggregated data of each point of light which depends on a segment controller.
- The maintenance of a hierarchical structure of the strategic activation units that allows an optimal and pleasant operation with the user of the lighting control system
- Implementation of strategies for the reduction of consumption in the segments controllers or controllers of point of light in response to a demand by the operator.
- Implementation of strategies to maintain the intensity of the light depending on the weather conditions adverse.

Four strategic action units have been defined in order to control and manage the public lighting system:

- Installation.
- Area.
- Group of points of light.
- Points of light.



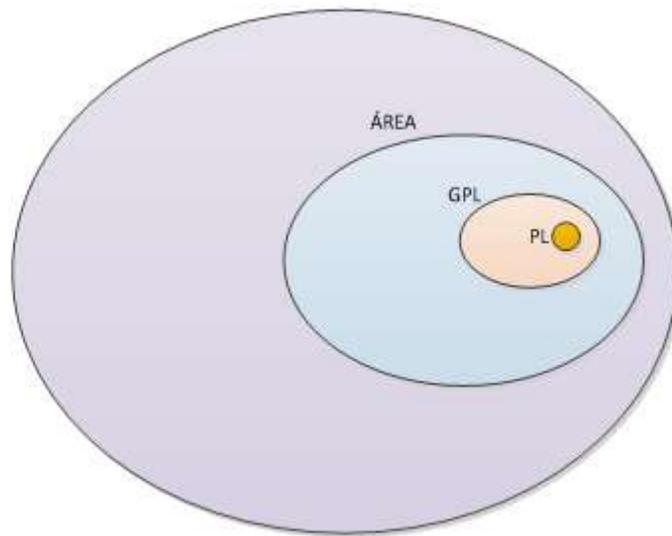


Figure 6 - Strategic action units

These units are hierarchical, so one or more areas will depend on an installation, one or more groups of point of light depend on an area, and each point of light will depend on a group of points of light.

Each strategic unit can be operated locally or remotely.

- In LOCAL mode, the control system does not send any order or message to the segments or points of light. Thus, the equipment acts independently of the control system.
- In REMOTE mode, the control system manages all equipment belonging to that strategic unit. This is the system default control mode.

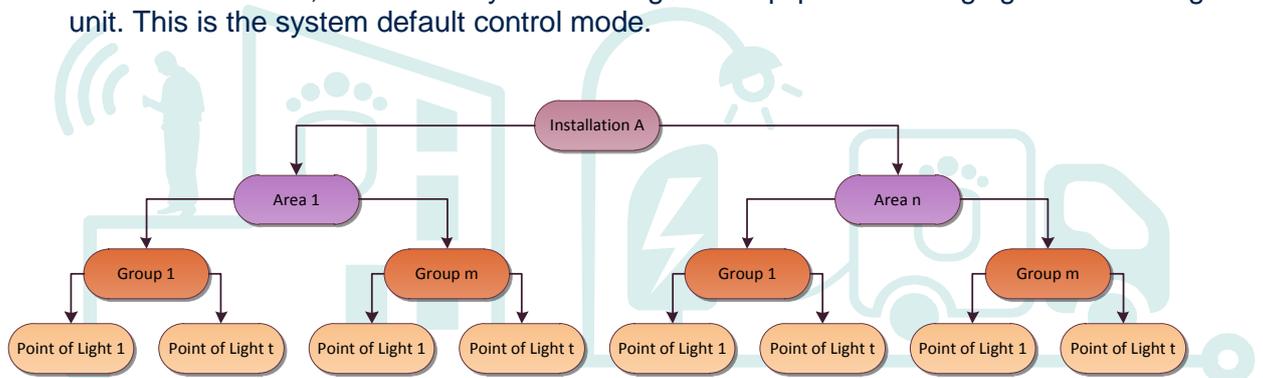


Figure 7 - Hierarchical units

The lighting control system of Barcelona can perform the remote management of a lighting system in the following ways:

- **Control point to point:** Individual control over each point of light is established independently. So, it is necessary to dispose of a point of light controller (PLC) in each point of light and a segment controller (SC).
- **Control groups of points:** Sets a global control over the points of light in the picture, or points of light from each output of the box. So, it is necessary to have box controllers, controllers, flow, etc., depending on each specific configuration.



### 3.1.2.3 System architecture

The following figure shows the architecture of the public lighting system.

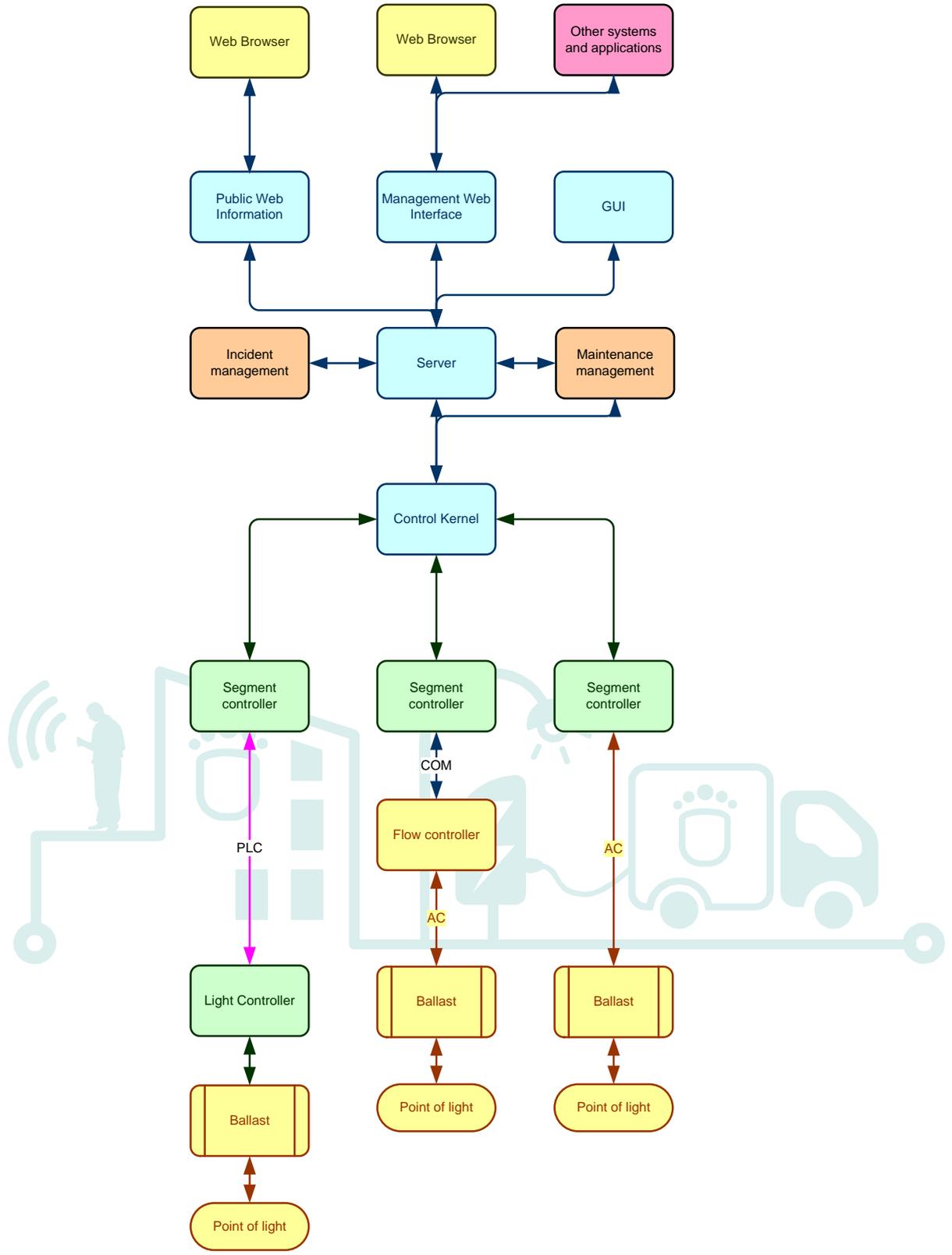


Figure 8- Public lighting product scope



The system is divided into different applications responsible for specific tasks. The **Control kernel** is responsible for handling the communications with the different segment controllers and points of light. It is a generic application that implements a large number of protocols and drivers and allows for communicating with devices from different vendors. The particularities of the different devices brands are hidden and a common interface to PoL and segment controllers are offered to top level application

The **server** is responsible for carrying out the lighting control. It contains the intelligence of the system and includes specific functions for the control of the lighting. Additionally, it enables the integration of the Public Lighting control system with other control systems such as tunnels, facilities, traffic, etc. This approach increases the robustness of the system, separating the control and command activities from the human interaction – or interaction with third modules not critical to the functionality.

The server will be in charge of the publication of the information needed by the enterprise services through the DCP (Data Capturing and Processing).

The server will host the common strategies and the control features to manage the public lighting network (calendars, strategies, events, alarms, etc.). It is the core of the system and makes use of the Control kernel to communicate with the SC. The alarms not addressed by the SC will be treated at this level – and if they cannot be treated they would be forwarded to an Incident Management Module. Moreover, the Public Lighting control centre will be able to react to predefined situations in order to trigger autonomously strategies that could enhance the performance of the network, leading if possible to a save of electricity e.g. adaptation of light intensity depending on traffic conditions.

The actions formulated by the human operator trough the GUI will be translated in concrete commands by The Server module.

The **Graphical User Interface (GUI)** is the graphical interface for managing the whole set of features of the system, it has the form of a Windows application.

The **management web interface** is another GUI that can be used to configure the configuration of the system (elements, hierarchy, groups, etc.)

The **public web information** is a web application that allows for monitoring the system. It is intended to being used by remote users (without the conventional GUI installed) and web mobile clients.

From the deployment point of view, the system has the following architecture:

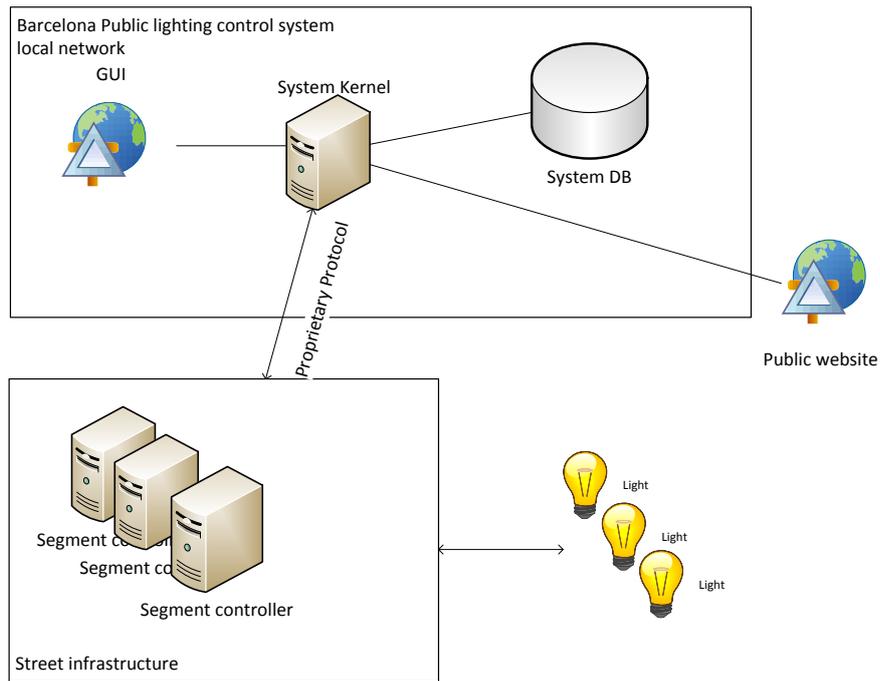


Figure 9 - System deployment architecture

### 3.1.2.4 Graphical User interface

The GUI of the public lighting control system includes the following functions related to the Management Web Interface:

- Representation on the map of the PoL, PoL Controller and SC.
- PoLs and PoL Controllers dialogue
- SCs dialogue
- Installations dialogue.
- Areas dialogue.
- PoL Groups dialogue.

#### 3.1.2.4.1 Web Interface

The Public Lighting control system includes a website for allowing users interact with the system.

As a User Interface (UI), it enables different users of the system accessing public lightning information, in particular to the information of exploitation. The interface will include the areas of the map, menus, buttons, messages and entities.

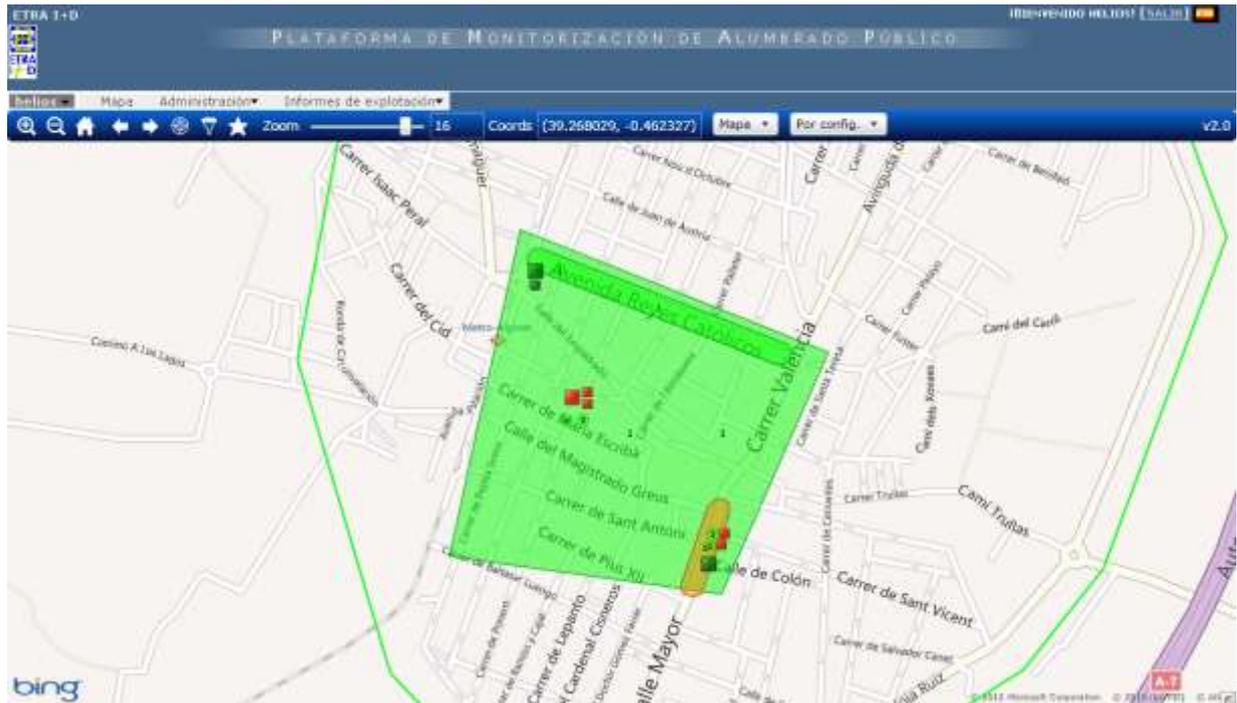


Figure 10 - Public Lighting control system Web Interface

This GUI also includes a dialogue of conflict situations that display information about entities (installation, area, PoL Group, PoL, SC and PoL Controller) about computers that do not communicate and equipment with alarm.

The UI has access to graphs of the temporal evolution of the various parameters from the last periods and also of historical data. Access to recent and historical information is done in a similar way.

### 3.1.2.5 Equipment

The equipment that the public lighting control system can control and manage is:

- **Point of Light controller.** The Point of Light controller (PLC) is the component of the system responsible for monitoring and controlling each point of light (PL). The PLC is able to act on the luminaire to on / off and monitors electrical parameters of operation of the luminaire. It is possible to associate a schedule legal to each point of light controller, managing and operating time and light intensity. In this way, after sending this schedule to the street equipment, this could work in an isolated mode, without the presence of a system of control over him.
- **Segment controller.** The segment controller (SC) is the component of the system responsible for monitoring and controlling that are common to a cabinet.
- **Cabinet controller.** It is the equipment that is capable of monitoring the existing equipment, and acting if necessary.
- **Flow regulators.** The flow regulator (FR) is the component that controls the level of voltage at the outputs of the cabinet controller of lighting and lighting levels.

#### 3.1.2.5.1 Segment controller

The SC is the component responsible for monitoring and controlling the PoL. The SC can make the control of the PoL directly or through a flow regulator.

The SC has been designed to support different communication protocols to interact with the



PoL. The SC has been in charge of the supervision of PoLs. It gathers all the information available from them (such as alarms and consumed electricity) and send the control commands needed to interact with them. Thus, the SC is the mediator with regards to the control and monitoring capabilities.

Furthermore, the SC triggers its own alarms and monitors its own behaviour, adapting the light conditions of each PoL to different local strategies and information – e.g. data coming from a local light meter.

The segments controller software runs on street in embedded PCs that will probably be MOXA IA260 model for the SmartKYE project (to be decided).



Figure 11 - Segments controller

This equipment has the following specifications:

- Processor Cirrus Logic 199 MHz RISC
- 128 MB SDRAM
- ports RS-232/422/485
- 2 port Ethernet
- 8 digital inputs
- 8 digital outputs
- Output VGA
- Socket CF
- Rail DIN

#### 3.1.2.5.1.1 Segment Controller specifications

- **Mechanical design:** The equipment shall have an appropriate mechanical design taking into account the aesthetic aspects.
- **Logical Architecture:** The SC is based on an open architecture operating with Linux.
- **Configuration:** The SC will monitor its configuration data that could be accessed and updated by a parent element.
- **Programming:** The SC will monitor its programming that could be accessed and updated by a parent element.
- **Integrity of information:** The SC will manage the integrity of the information. It will be managed the following groups of information: programme, configuration data, and variable data. For each group of information it will have associated a CRC that enables SC to determine if there has been any change in the information.
- **Parent element communication:** The communication of the SC with the parent control element is based on DCP over IP.

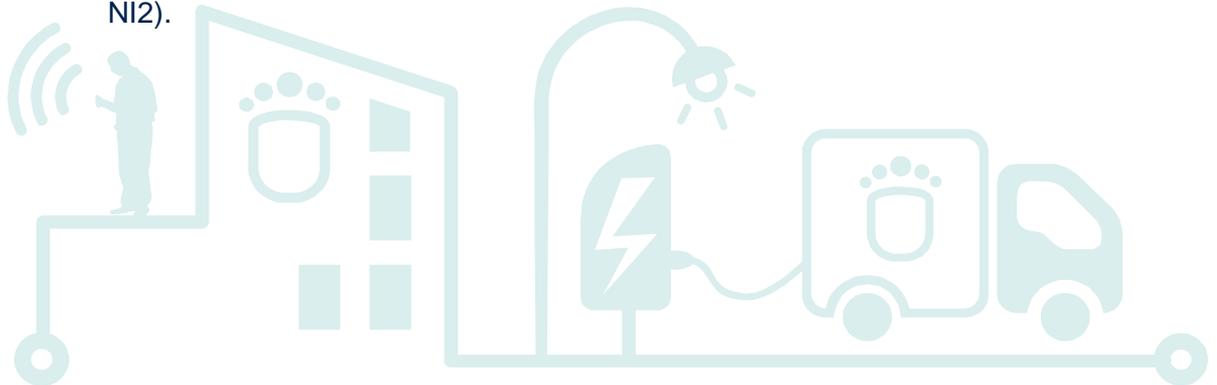


- **Light controller communication:** It must be deployed communications PLC compatible with the PoL Controller.
- **Flow reducer status:** The SC will monitor flow reducer status and their possible alarms.
- **Web page:** It provides an interface software based on a website for direct access
- **Reset:** The SC can be reset by using a command. It will be considered several levels of reset: (reset keeping configuration, reset with deletion of configuration, etc.).
- **Test system:** The system will periodically send an order to indicate to the SC that is functioning properly. If after a configurable period SC does not receive the order, it considers that the system is not active and is in local control. The order of Test of the system allows:
  - To indicate the time out of the system test
  - To indicate that the system is no active.
  - To indicate that the system is active.
- **Event registration:** The SC will register the information of all detected events. The following information will be stored:
  - Own alarm.
  - Alarms of the controlled equipment (FR (Flow Reducer), LPC).
  - State changes.
  - Change of State of the controlled equipment (FR, LPC).
  - Own actions.
  - Performances of the controlled equipment (FR, LPC).
- **Historical registration:** EI SC stores historical and statistical data. The stored information is as follows: registration of own data (electrical parameters, consumption, etc.), registration and collection of data from the points of light and the flow regulator.
- **Performance during alarms:** The SC will have capacity to act before alarms. Alarms will have two possible performance levels. At the first level the SC will inform only about the alarm. At the second level it will act on the elements of the installation. For example, in the case of excess of consumption, it may deactivate a line. Each monitored variable will have a nominal value and lower and higher values for level 1 and level 2 or alarms. Levels can be defined through a percentage of the nominal or absolute value.
- **Alarm information:** The SC will be able to inform about the alarms.
- **Schedule:** The SC includes the management of the following schedules: astronomical schedule (Sun) and legal schedule including the seasonal time change.
- **Electrical measures:** The SC will have the following measures: measurement of electrical parameters (V, I line, I differential,  $\cos \varphi$ ) and measurement of power consumption (Active and reactive energy). The measures may be obtained directly or from the information provided by the PoL Controller. The measures of the SC will be complementary measures of the LPC. Note: The measures of consumption should be considered if it is require managing different electric tariffs.
- **Configuration of the PoL Controller:** The SC will be able to determine if a PoL Controller configuration is correct by using a reference date and a CRC of the data. The SC must be able to dump the configuration of the LPC s.
- **Program of PoL Controllers:** The SC will be able to determine if a PoL Controller program is correct using a reference date and a CRC. The SC must be able to put the program of the PoL Controller.
- **Control mode:** SC has the following modes of Control: Local and remote control. In Local control, the SC is responsible for controlling the level of illumination of the points of light from their LLD. In remote control, SC executes the orders of the lighting Control system based on information of LLDs sent by the control system.
- **Digital inputs and outputs:** SC has digital inputs and outputs. Gateways enable



detection of open door, counting pulses, external alarm, external activation, etc. Departures allow notification of alarms, the act on protection and other performances.

- **Digital outputs actions:** The SC may perform actions through the digital outputs. The actions may correspond to orders based on the schedule and before status variables (Own status, digital inputs, other SC variables, variables of the PoL Controller, etc.).
- **Local control:** The SC will have the opportunity to work in Local Control Status. In this status of the SC for each PoL Group and the LLD is responsible for ensuring that each point of light reach light level required. The SC to determine if the LLD is reached will use the information of the level of external lighting. The SC will compensate the external lighting with lighting of the points of light. If the SC does not have information of external lighting, it will use the theoretical illumination levels associated with the solar schedule. The SC will modify the LLD's unity of action based on the detection of other events such as activation of a digital input.
- **Theoretical levels of lighting:**
  - **Solar light:** It will be available astronomical schedule Sunrise (SR) and sunset (SS) for each day of the year. The lighting level is considered to be constant between by the previous and following moments of the SR, and that is the same for all the days of the year. Note: This management can be improved in facilities that operate at very high latitudes (Northern Hemisphere) or very low (southern hemisphere).
- **Determination of the levels of lighting:** Each logical unit (PoL or PoL Group) must have associated a level of outdoor lighting that is used to adjust the lighting level required. When lighting level used is determined from meters of external lighting (MIE), it can be different options as indicated below.
  - **NI = f (MIE<sub>i</sub>);** Where F can be the middle value, minimum or maximum of all the measures associated with the logical unit. For example for a PoL Group comprising several points of light, two of them with external light meter and the measured own SC can define the level of illumination as: NI = average (NICS, NI1 NI2).





### 3.1.3 Electric vehicle infrastructure

#### 3.1.3.1 Introduction

The Electric vehicle infrastructure implemented in Barcelona consists on a platform that enables the monitoring and management of the electric vehicles charging points located on the public thoroughfare. This platform is designed not only for the management of a small group of charging stations, but for the management of a large system, covering the whole city.

Moreover, in a future, the system can bring added value features such as management of information to the user, multimedia features or means of payment by EMV with RFID cards.

The management of charging system is the core of operation, concentrating all activity and exchange of information.

The system offers a series of reports which provide basic information for the management of the network of charging points. It allows monitoring of the existing subscribers, the charging that have occurred, events related to the equipment, etc.

The access to the information is controlled by users associated to profiles, so that it is possible to control all users access to information through the management of permissions associated with these profiles. For the information provided by the system will have a series of filters to define the search criteria. These parameters can be, for example, charging points, vehicle, Subscribers, registration cards, intervals of time or date, etc.

The system provides web services for management of information coming from other control systems posts of recharging.

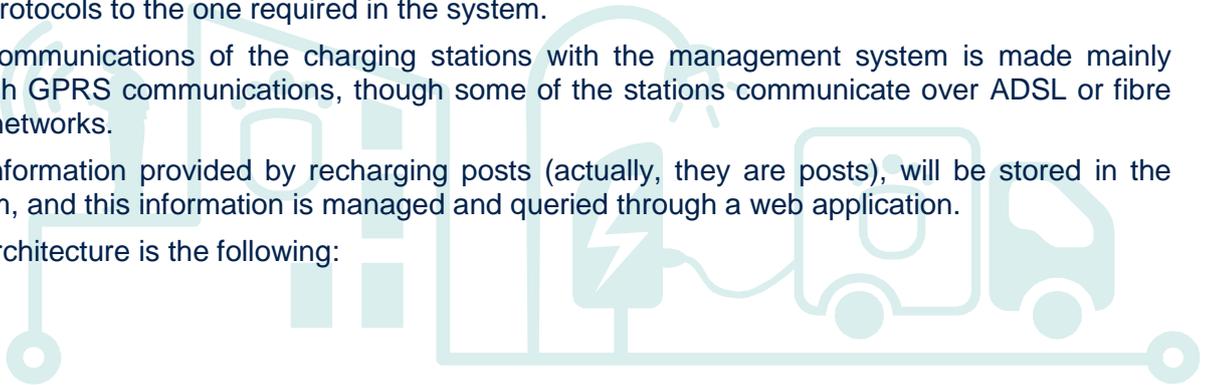
#### 3.1.3.2 System description

The system integrates charging stations for electric vehicles of the Barcelona's municipality and other private charging stations and plugs. The private charging stations and plugs have adapted their protocols to the one required in the system.

The communications of the charging stations with the management system is made mainly through GPRS communications, though some of the stations communicate over ADSL or fibre optic networks.

The information provided by recharging posts (actually, they are posts), will be stored in the system, and this information is managed and queried through a web application.

The architecture is the following:



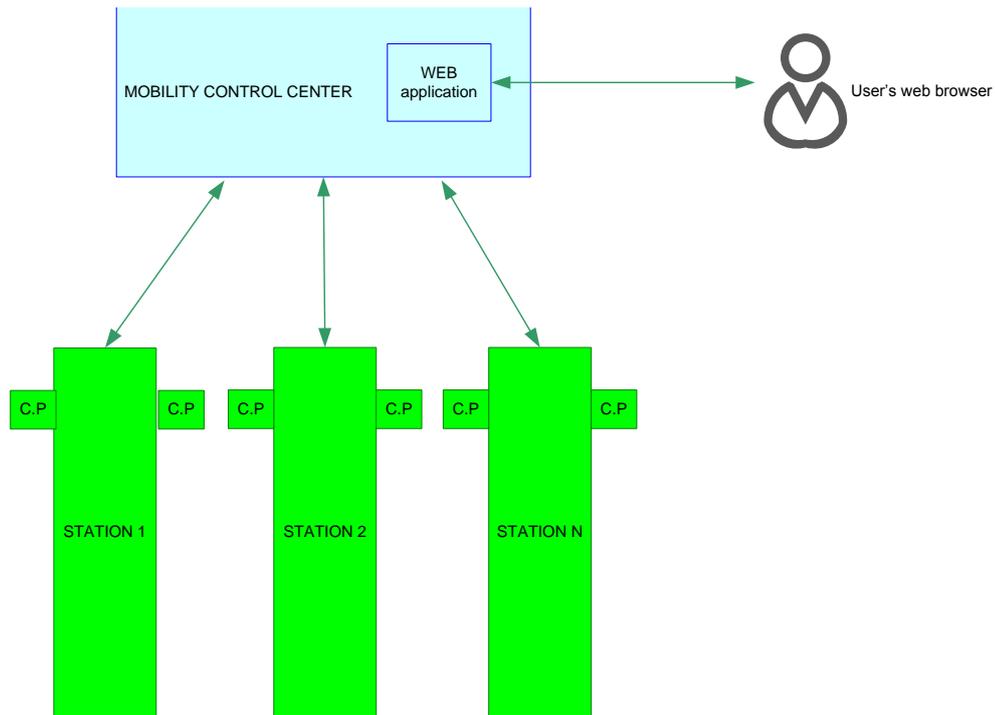


Figure 12 - Solution architecture

Each municipality's charging station is composed of two charging points, allowing independent management of each charging point. The stations deployed covered all needs in electrical vehicles recharge on the street, compliant with all electrical security regulations as well as access security and metering and consumption management.



Figure 13- Two charging stations at @22district

The robustness for its use and against vandalism is one of the aspects taken into account when designing and developing this equipment, as well as fit them with a temperate and smart aesthetic design.

The recharging posts have been equipped with a simple access system and energy payment through contactless cards, as well as a handy and easy opening and closing system. They are remotely managed through some interfaces provided by the public web access.

Users interested in using the system must first open an account and obtain a contactless client card. This card will identify the user and will start the charge of the electric vehicle when plugged. The cards contain the following information:



- The card identifier.
- The ID of the Subscriber to which it belongs.
- The ID of the vehicle associated with the card.
- Type of card (defines the type of user): normal, public service...
- Date of issue of the card.
- Date of subscription to the service.

Each card is associated to a vehicle only and to a single Subscriber. Each charging is also associated with a particular card, hence the importance of identifying the Subscriber card owner. The data associated with the vehicle are:

- Electric vehicle number plate.
- Municipality in which the electric vehicle is registered.
- Type of electric vehicle: motorcycle, quad, private car, van, etc.
- Brand of electric vehicle.
- Electric vehicle model.
- Characteristics of the battery.

The end user can manage their account through a web application (described below).

### 3.1.3.2.1 System actors

The main functionalities available in the web application are these:

- display location map
- access to consumption data
- access to personal data
- access to charging data
- system configuration
- access to operational functionalities system
- permission management
- log in, log out users
- access to system alarms
- access to reports

Each user, depending on their profile will have access to a certain set of functionalities. The existing profiles are the following (from lower to higher permission):

- **User of the system:** They are the people who own electric vehicles and use the system to charge them. Users will be registered by the operators of the system in the center of attention to the user providing the elements necessary for the operation of the charging system. These users will have access to the website from the internet, to view the location of the charging level stations and access their consumption data and their personal information being able to modify their personal data.
- **System administrator:** It is the person responsible for the system, which will have access to all the functions of management and configuration of the management system of charging stations. It will be responsible for the configuration and proper operation of the system. The system administrator is the person responsible for assigning permissions to define which screens can be accessed according to the type of user.
- **System operator:** They are the people responsible for the operation of the system. They can monitor the system and perform actions as register users, access to the system alarms, access to information on the charging, etc.
- **Operating system supervisor:** They are the authorized persons of the Energy Agency, mobility and from the Barcelona City Council, who will have access to monitor the



system and the various reports of the application and that allows them to learn the operation and use of the system by users. In addition, they will have access to general reports of use of the service.

### 3.1.3.3 System Architecture

This is the internal architecture of the Electric Vehicle management system as it is currently deployed.

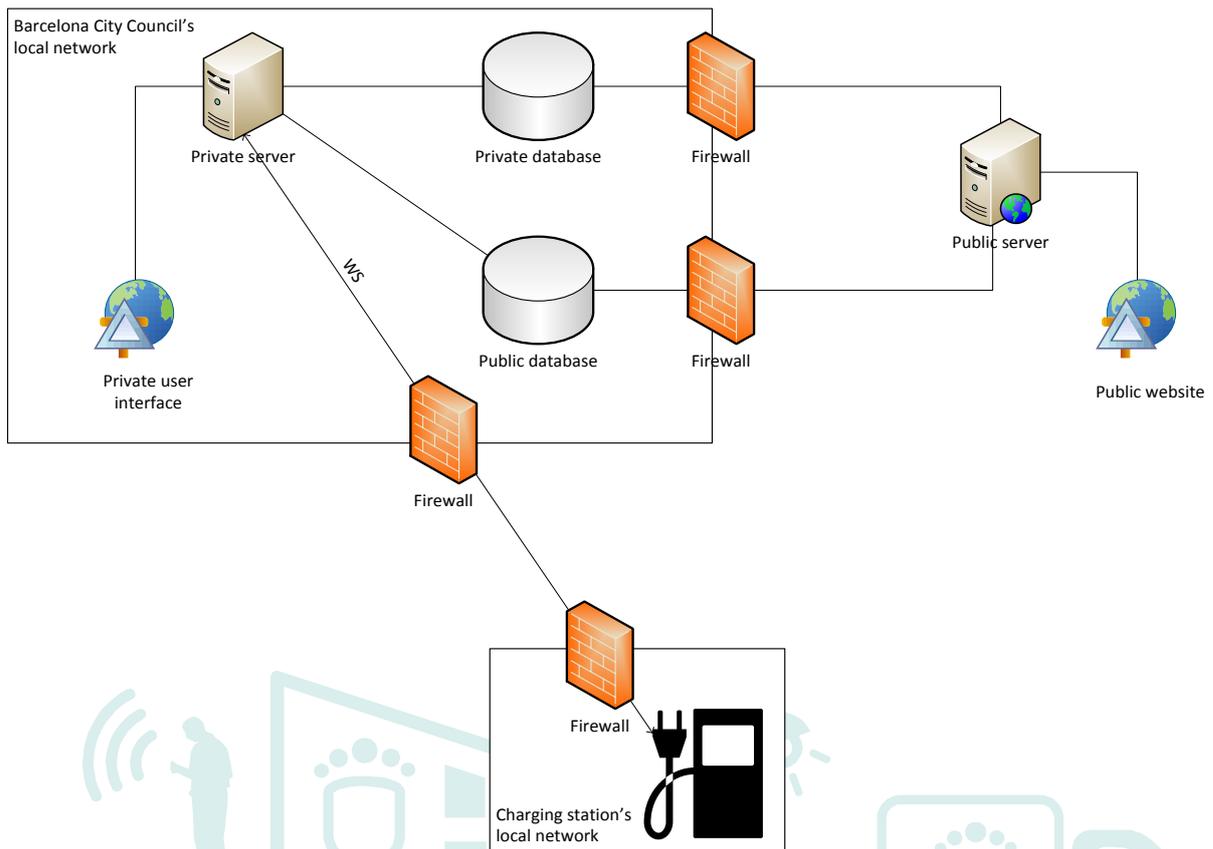


Figure 14 - System architecture

#### 3.1.3.3.1 Data bases

Storage and management of the system data are both performed depending on the nature and use of this information. Two different databases exist for this purpose:

- **Public database:** Stores all the information related to the existing users, the registered vehicles, and the connections between them. System administrators can manage all the information in this database while users are only allowed to read from it, and update their own data when necessary.
- **Private database:** Includes information dealing with charging stations and all the measured data they provide from their everyday functioning. This data is inserted into the database through a set of web services that connect the posts directly to the system. Administrators can access all the information while users can only read theirs through the reports available in the public website.

Both databases are located inside the Barcelona City Council's local network, and thus, every



access performed by an entity outside this network must pass through the appropriate security measures (i.e. firewall).

### **3.1.3.3.2 User interfaces and servers**

As it is depicted, there are two different web interfaces for interacting with the system: a public and a private one. The public one does not have advanced configuration functionalities, and is mainly addressed for end users accessing from their homes. Having two different systems was a requirement of the municipality that do not want to expose in the Internet a web application that allows doing thing potentially dangerous for the system.

As with the separation of databases, the system can be accessed through two different platforms deployed in two separated servers:

- Public server: Contains the public user interface. Every registered user can enter this platform using their credentials and manage their own information. The server is located outside the Council's local network, so a firewall serves as intermediary between it and the two databases.
- Private server: Hosts the interface for administrators of the system to access the databases and their contents. This server is not open to the Internet and can only be reached from within the Council's local network or via VPN connection. Users with granted access can manage part or all data in the system; depending on the type of role they have been assigned. As the server resides in the same network as the databases, communications are allowed at all times and no firewall intervenes between the two parts.

### **3.1.3.3.3 Web services**

Communication between the system and the charging stations (which are provided with some telecommunications hardware, e.g. a GPRS modem) is carried out through a series of established web services. These services allow both the stations to send real-time information to the system and the system to ask the stations about their stored data.

Three web services are currently being used in the platform:

- `srvEstadoEnchufe()`: Used by the charging stations to notify a state change of a charging point (i.e. plug). Information of each charging point is regularly sent to the system, even if no changes have occurred since the last call. If no data of a charging point is received for a certain period of time, the system will assume it is not working properly and will act consequently.
- `srvRecargaTarjeta()`: A charging station makes use of this service each time a vehicle stops using a charging point (i.e. a recharge is completed). The information sent to the system includes identification of the card used, start and end times of the operation, total amount of energy consumed, as well as a charging curve composed by a series of points in time and the energy consumed up to that point.
- `srvTarjetas()`: Through this web service, the system asks a charging station about the user cards that have been registered or unregistered on it, being able to filter the petition by a certain period of time – between two dates or a number of hours from the moment the request is received. The number of values returned depends on the amount of cards that match the parameters of the request.
- All three services are sent or received by a charging station or the private server described in the previous section. As each side of the communications is in a different network, request and responses go through each system's security, and grant their access using credentials.



### 3.1.3.4 Web application user interface

The entrance to the system is controlled by a username and password. When accessing, a user should also indicate his or her user profile (normally each user has only a profile, but some users can have more than one and thus decide which one to use in order to start the session). A user profile indicates which features are available to that user.

The user can select the language of the website at any time using the pull-down menu in the top right of the application.



Figure 15 - User Interface

### 3.1.3.5 Map

In the initial screen, a map is shown of the installation and the current location of the equipment available. Microsoft's Bing maps are used, so the user requires a permanent Internet connection to view the web application.



Figure 16 - Installation map

#### 3.1.3.5.1 Administration menu

From this menu section the user can have access to pages for managing the set of users, the profiles, permissions, etc.

#### 3.1.3.5.2 Equipment menu

From this menu section the user can have access to pages for handling corrective maintenance of the charging stations and the plugs. For each device, its status and alarms are shown.

#### 3.1.3.5.3 Inventory menu

From this menu section the end users (contactless card owners) are created and managed.

#### 3.1.3.5.4 Reports menu

This menu allows charging-related data visualization and printing various reports dealing with charging and other elements of the system.

All reports generated can be displayed on screen and you can save them as files on the client for a consultation or subsequent printing. There are various types of reports:

- Charging reports
- Charging historical report
- Consumption reports
- External reports



### 3.1.4 Energy micro-generators

#### 3.1.4.1 Introduction

The energy micro-generators plant in Sant Guim de Freixenet (Barcelona) is provided and maintained by Ficosa, a multinational corporation which main activity consists in the research, development and production of systems and parts for the automotive industry. The company dedicates an annual percentage of its activity to R&D, in which this project is included.

Only a short number of assets will be monitored by the SmartKYE system, as this installation will be considered as a small sample of the plant's possibilities. The measured data can lately be extrapolated in order to obtain simulated large-scale results.

#### 3.1.4.2 System description

Two types of energy generation devices compose the Sant Guim facilities: wind turbines and photovoltaic (PV) modules.



Figure 17 - Wind turbine at Sant Guim facilities



Figure 18 - Solar panel at Sant Guim facilities

Two Darrierus vertical-axis wind turbines (VAWT) are monitored by the system within the plant, which capacities are 1 KW and 5 KW. Six photovoltaic panels, with a capacity of 240Wp each, are also integrated in the system. Additionally, a weather station provides information about the conditions in the facilities; this station will also be considered by the SmartKYE system.

The energy generated by the turbines and PV panels, the rotation speed of the turbines, and the values measured by the weather station are frequently read and stored in a local database. Periodically, a series of processes are triggered to send the data generated during the last interval and to Ficosa's remote system, where it is stored and combined with previous data. This historical data can eventually be accessed through a GUI.

### 3.1.4.3 System architecture

#### 3.1.4.3.1 General view

The architecture of the energy generation system includes measuring devices, device controllers, an integrated local server, and a remote server. A series of different communications between these components are defined and scheduled in order to measure, store and send the different sorts of data managed by the plant's system.

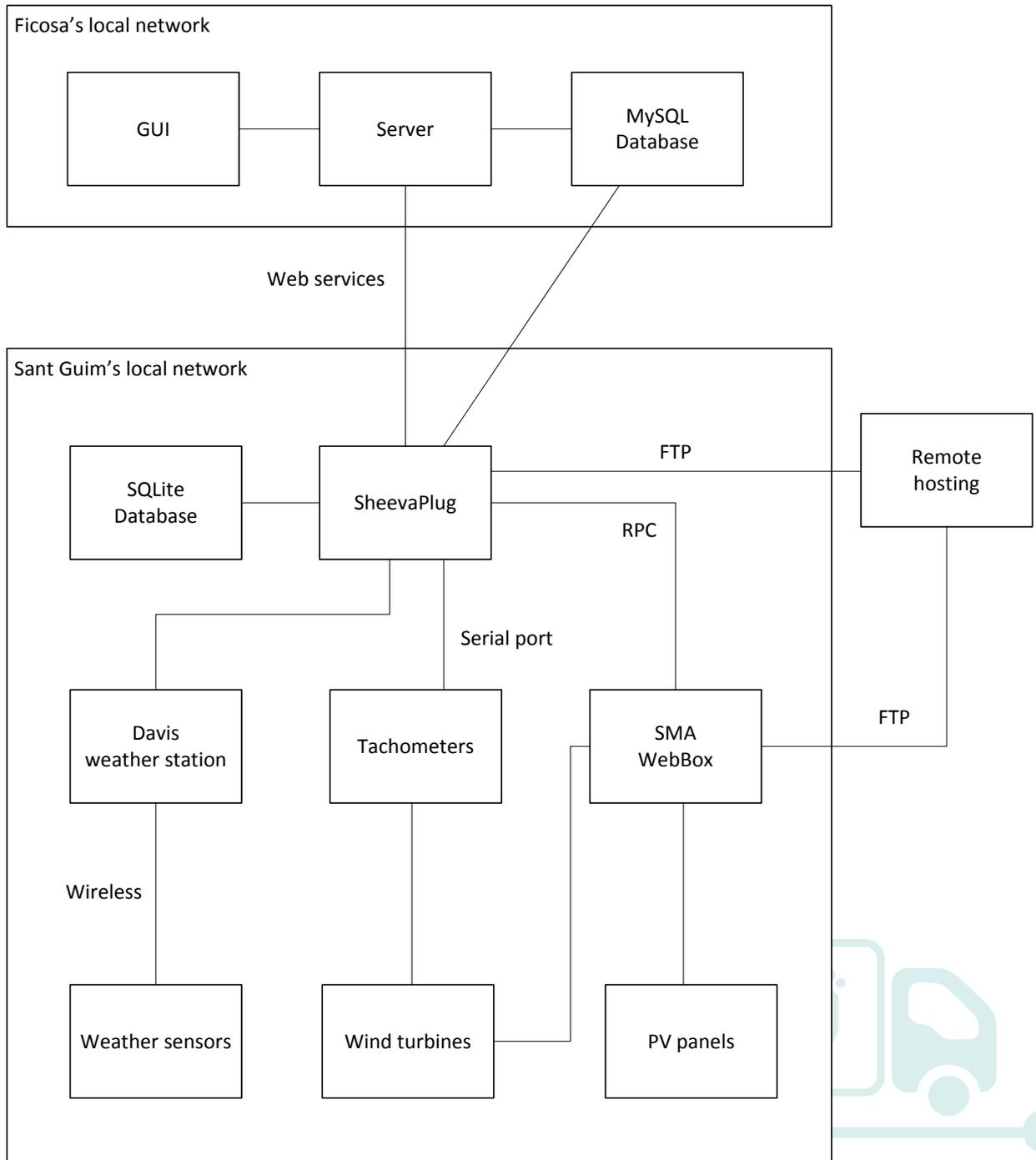


Figure 19 - System architecture

### 3.1.4.3.2 Components

Components in the system are located in two different networks: Ficosa's and Sant Guim's.

Ficosa's local network includes:

- A **web server**, which gets data from the Sant Guim system through web services.
- A **MySQL database**, where remote data is stored when available. This database can be accessed directly by Sant Guim's facilities in order to insert new measured values.
- A **graphical user interface (GUI)**, for users to review the stored data and extract useful information.



Components in Sant Guim facilities, where data is generated, include:

- A **SheevaPlug**, a small plug computer in charge of managing the whole process of data recollection and dispatch. A series of triggers already programmed in the core of this device are periodically launched in order to get the current picture of each asset in the plant.
- A **SQLite database**, used as an intermediate storage device for data to be saved before sending it to the central system.
- 2 vertical-axis **wind turbines**, one with 5 KW of maximum capacity, and 1 KW the other one.
- 2 **tachometers**, each one measuring the rotation speed of one of the wind turbines. SheevaPlug reads directly from each tachometer to know the speed of the turbines.
- 6 **photovoltaic panels** with a maximum capacity of 240 Watt-peak (Wp) each, making a total of 1440 Wp.
- A **SMA WebBox**, which obtains information from the Sunny Boy and Windy Boy modules and makes it available for SheevaPlug to read it.
- A set of wireless **weather sensors**.
- A **Davis weather station**, which reads from the sensors and provides the necessary interface for SheevaPlug to access them.
- Some **remote hosting** also exists, where files are periodically uploaded and downloaded via FTP.

### 3.1.4.3.3 Communications

#### 3.1.4.3.3.1 Dynamic IP and web services

Communications between SheevaPlug and the remote web server take place through web services. The IP of the SheevaPlug device is dynamically assigned, which makes it change periodically and causes some difficulties when accessing from an external source.

To solve this situation, every 5 minutes the SheevaPlug device executes a script that gets its current IP and sends it to the remote web server, which IP remains constant and is always known. This way, the server is able to access SheevaPlug in order to retrieve information that is not stored within the MySQL database.

#### 3.1.4.3.3.2 Weather information

Weather information is constantly observed and processed by the Davis weather station. In order to access this information, SheevaPlug executes two different routines at two different moments:

Every minute, SheevaPlug reads from the weather station a series of variables previously defined on a template, and stores them as current values in the SQLite database. SheevaPlug also offers this data to the external server in JSON format through a public web service, but it is not saved in Ficosa's database. Only the last 100 current values are maintained.

Every 5 minutes, information from the last time interval is read by SheevaPlug and stored in the local database as historical data. With this same frequency, another SheevaPlug process reads this information and saves it in the remote MySQL database.

#### 3.1.4.3.3.3 Solar/wind energy generation

Generation of energy by PV panels and wind turbines is constantly monitored by the SMA WebBox module, which also makes it available for SheevaPlug.



As with weather information, this is accomplished by two different processes: one for obtaining current data, and one for historical information.

For current data, SheevaPlug asks the WebBox for its current status using a remote procedure call (RPC). This returns a list of modules plugged and their current output. This information is temporarily saved in the local SQLite database, and sent to the remote MySQL database when available.

For historical information, a series of XML files with the appropriate information are periodically generated by the WebBox device and uploaded to a remote hosting via FTP. Files are created on the following basis:

- An XML file is created every 5 minutes.
- A ZIP file containing the last three XML files generated is created and uploaded every 15 minutes.

With the same frequency of 15 minutes, SheevaPlug device downloads the ZIP file from the FTP, unzips it, reads the XMLs contained and stores the information in the MySQL remote database. If everything goes as expected, files are deleted from the FTP.

#### 3.1.4.3.3.4 Speed of wind turbines

The rotation speed of the wind turbines at Sant Guim facilities is constantly measured by tachometers (one per turbine). These devices make their measured data available through their serial port, which are periodically accessed by SheevaPlug,

Every minute, the rotation speed of the currently plugged wind turbines is read by SheevaPlug and temporarily stored in the local SQLite database. When available, this information is eventually sent to Ficosa's MySQL database.

#### 3.1.4.4 Web application user interface

To access the web application, the user must enter his credentials, which have previously been provided by Ficosa.



Figure 20 - Web application log-in page

Once the user is logged in, the application allows him to access historical information previously gathered from Sant Guim facilities. Different data from multiple assets (e.g. medium AC power generated, wind turbines rotation speed, wind speed and direction) can be combined and reviewed in a graphical way through an existing web application.

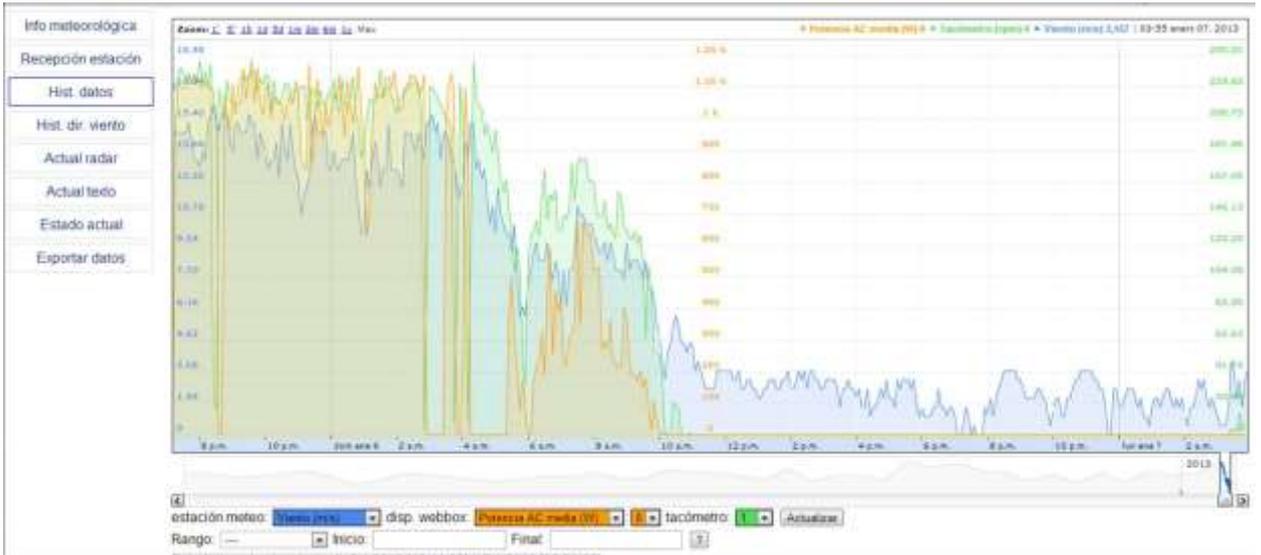
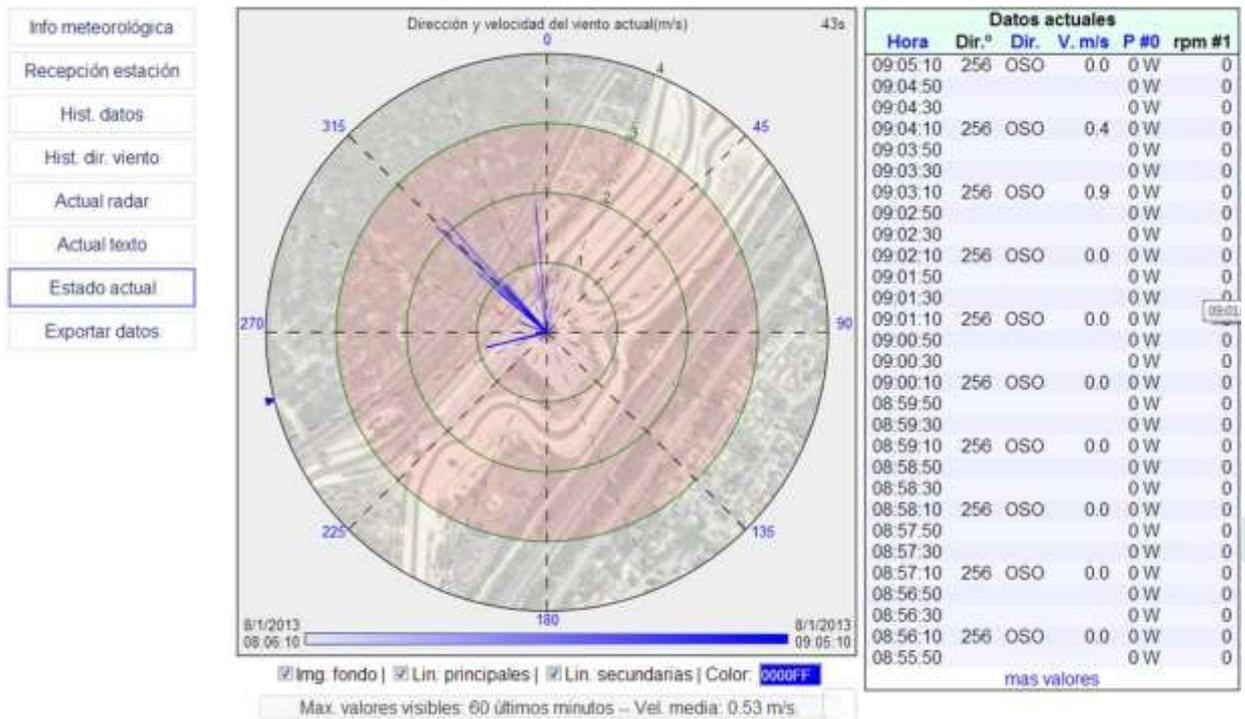


Figure 21 - Sample graph of combined data from the web application

The user is able to select those metrics he wants to combine and the time interval to be taken into consideration. He can also choose whether he wants the information to be shown in graphic or text form.





Uptive St. Guim (mp2) Usuario: uptive (cerrar sesión)

Datos actuales														
Hora	Dir.*	Dir.	V. m/s	P #Palo 1	P #Palo 2	P #Palo 3	P #Palo 4	P #Guinea	P #SOLAR	rpm #1	rpm #2	rpm #3	rpm #4	rpm #5
16:54:10	299	ONO	3.6	NA	NA	NA	NA	NA	NA	0	0	0	23	0
16:53:50				0W	0W	0W	0W	0W	0W	0	0	0	24	0
16:53:30				0W	0W	0W	0W	0W	0W	0	0	0	20	0
16:53:10	299	ONO	3.6	0W	0W	0W	0W	0W	0W	0	0	0	20	0
16:52:50				0W	0W	0W	0W	0W	0W	0	0	0	20	0
16:52:30				0W	0W	0W	0W	0W	0W	0	0	0	16	0
16:52:10	299	ONO	3.6	0W	0W	0W	0W	0W	0W	0	0	0	16	0
16:51:50				0W	0W	0W	0W	0W	0W	0	0	0	16	0
16:51:30				0W	0W	0W	0W	0W	0W	0	0	0	15	0
16:51:10	299	ONO	3.6	0W	0W	0W	0W	0W	0W	0	0	0	12	0
16:50:50				0W	0W	0W	0W	0W	0W	0	0	0	10	0
16:50:30				0W	0W	0W	0W	0W	0W	0	0	0	12	0
16:50:10	299	ONO	3.6	0W	0W	0W	0W	0W	0W	0	0	0	12	0
16:49:50				0W	0W	0W	0W	0W	0W	0	0	0	9	0
16:49:30				0W	0W	0W	0W	0W	0W	0	0	0	9	0
16:49:10	299	ONO	3.6	0W	0W	0W	0W	0W	0W	0	0	0	10	0
16:48:50				0W	0W	0W	0W	0W	0W	0	0	0	11	0
16:48:30				0W	0W	0W	0W	0W	0W	0	0	0	12	0
16:48:10	299	ONO	3.6	0W	0W	0W	0W	0W	0W	0	0	0	13	0
16:47:50				0W	0W	0W	0W	0W	0W	0	0	0	13	0
16:47:30				0W	0W	0W	0W	0W	0W	0	0	0	13	0
16:47:10	299	ONO	3.6	0W	0W	0W	0W	0W	0W	0	0	0	13	0
16:46:50				NA	NA	NA	NA	NA	NA	0	0	0	14	0
16:46:30				0W	0W	0W	0W	0W	0W	0	0	0	17	0
16:46:10	299	ONO	3.6	0W	0W	0W	0W	0W	0W	0	0	0	16	0
16:45:50				0W	0W	0W	0W	0W	0W	0	0	0	17	0
16:45:30				0W	0W	0W	0W	0W	0W	0	0	0	19	0
16:45:10	299	ONO	3.6	0W	0W	0W	0W	0W	0W	0	0	0	21	0
16:44:50				0W	0W	0W	0W	0W	0W	0	0	0	22	0

mas valores

Resumen

Figure 22 - Historical data about wind direction (among others) shown graphic (radar) and text (table) forms

Finally, user is also given the opportunity of exporting the selected data in order to use it outside the application.

### 3.1.4.5 Equipment

#### 3.1.4.5.1 Wind turbines

Ficosa facilities in San Guim de Freixenet include one 1 KW wind turbine and one 5 KW wind turbine.

##### 3.1.4.5.1.1 Mini-aerogenerator of 1kW of power generation.

The Mini-aerogenerator of 1kW of power generation installed in San Guim is a Vertical axis wind turbine of 1000W at 11 m/s.

This micro-aerogenerator includes light aluminum blades, which start in 3.5 m/s arriving to its nominal speed with winds of 11 m/s and a maximum speed of operation of 18 m / s. The system has also magnetic brakes of safety from 18 m/s, decreasing the speed of rotation of the wind turbine to protect the turbine, and steel rotor with a strong, compact and waterproof bearing system. These characteristics make the system an optimal choice of producing renewable energy in urban areas, which can be installed on roofs, decks, gardens, parking, motorways, etc.



Figure 23- Vertical axis wind turbine1 kW

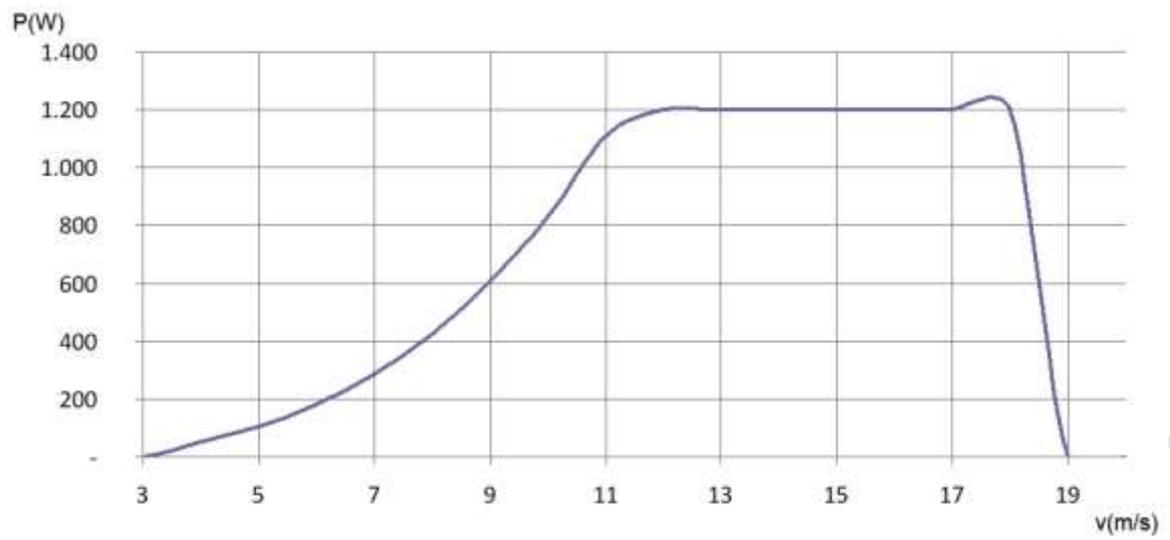


Figure 24 - Yield curve Eolic system 1 kW

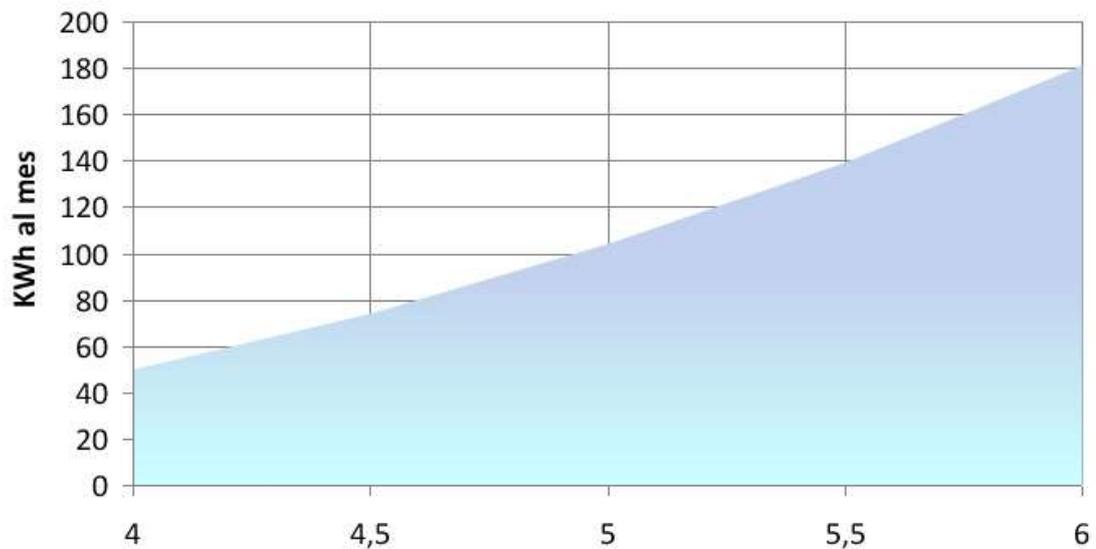
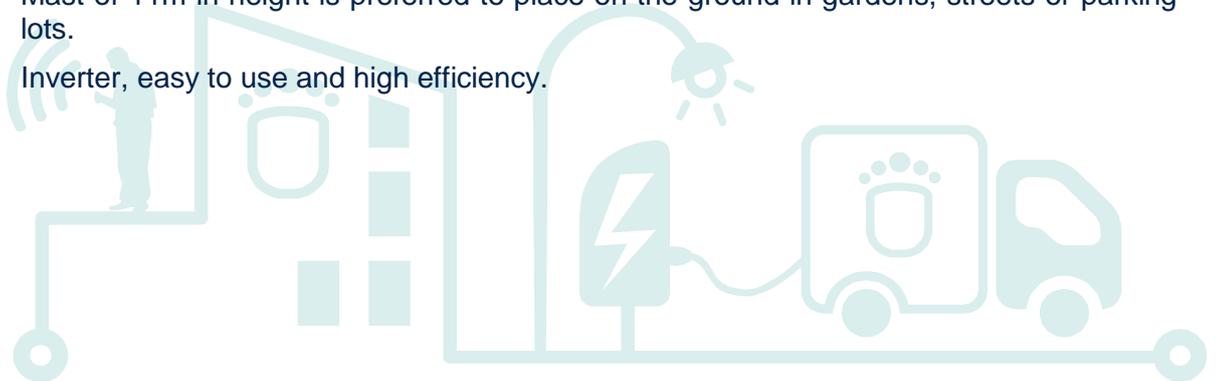


Figure 25 - Average wind Eolic system 1 kW

The system is composed of:

- Blades: Three blades of extruded aluminum protected against corrosion.
- Turbine: Rotor with compact and tight bearing system with dimensions of 2700 mm x 2200 mm.
- Generator electric three-phase synchronous of permanent magnets and high performance, with nominal voltage of 230V converts kinetic energy to electrical energy.
- Mast of 11m in height is preferred to place on the ground in gardens, streets or parking lots.
- Inverter, easy to use and high efficiency.



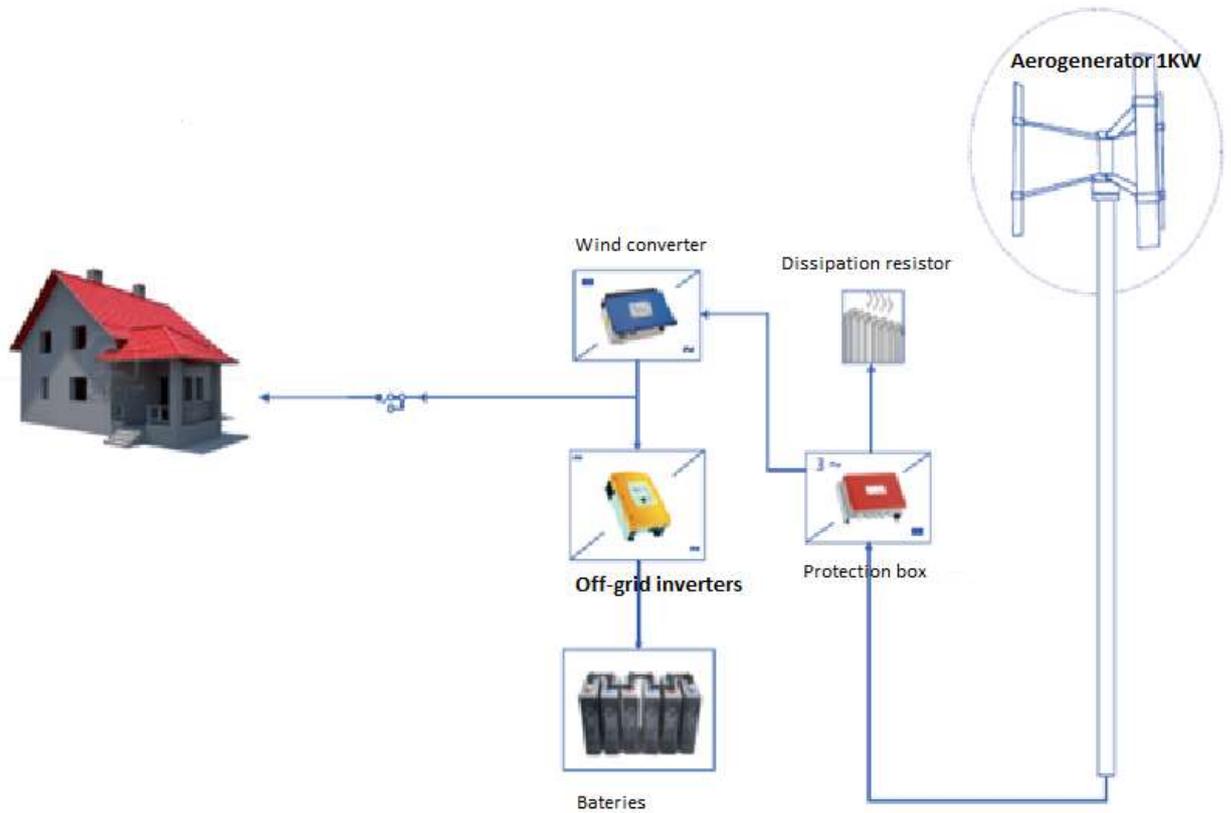


Figure 26 - Installation 1Kw diagram yield curve

### 3.1.4.5.2 PV panels

Ficosa facilities in San Guim, include also 6 photovoltaic solar panels of maximum power of 240 Wp and a maximum power voltage of 30,45V.

The panels are made by 60 cells of 156x156 mm of monocrystalline silicon. Each module is configuring by 6 columns and 10 rows and the dimensions are 1.653 X 990 X 44 mm, as described in the next figure.

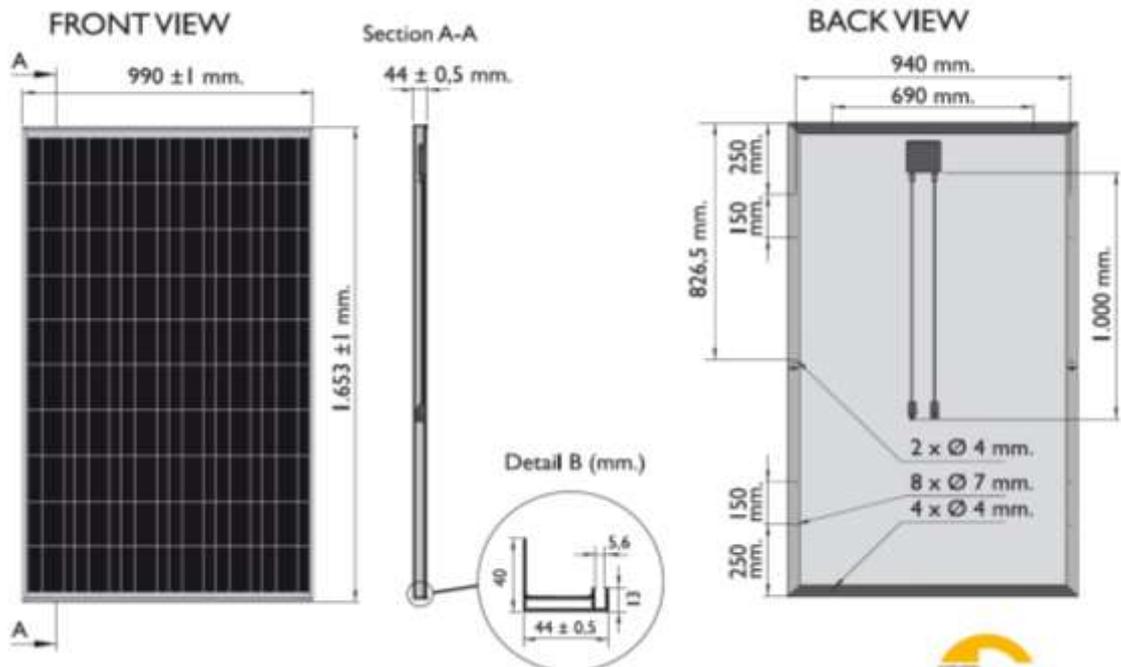


Figure 27 – Sola panel schema

### 3.1.4.5.3 Weather station

The weather station installed together with solar panels and the wind generators in Sant Guim, provides several meteorological parameters. These parameters are:

- Wind speed and direction.
- Temperature and humidity inside and outside.
- Perceived temperature and dew point.
- Current and accumulated daily rain, monthly and yearly.
- Rainfall intensity.
- Current atmospheric pressure and tendency.
- Weather forecast.
- Moon phase and time of sunset and sunrise.

The system includes an interface that shows on a screen graphics with data from the last 24 hours, days or months. In addition, more than 100 different messages show additional details of the forecast and current conditions. In this context, it is possible the configuration of more than 70 simultaneous alarms to warn about dangers such as strong winds, freezing temperatures, rainfall with possibility of flooding, etc.

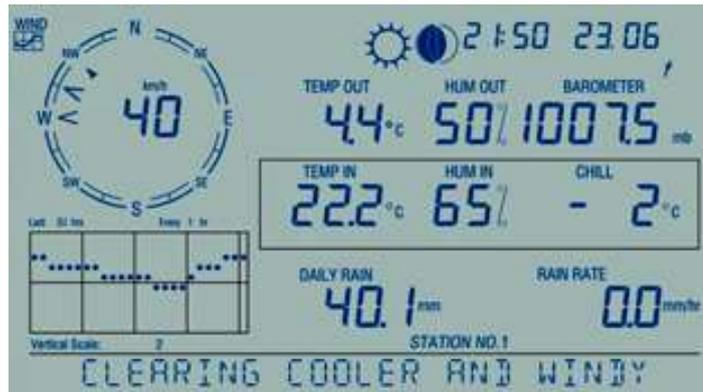


Figure 28 – Weather station interface

The system also provides a Data logger for storage of data in the range of from 1 to 120 minutes. It includes software for analysis and graphing of the records, which are stored in a permanent database. In addition, it allows generate reports, export data to spreadsheets and upload it to the Internet.

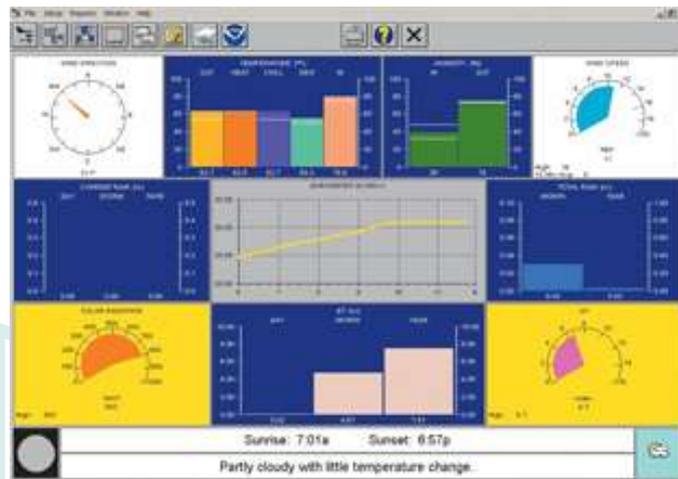


Figure 29 – Weather station software analysis

A solar panel feeds an integrated set of sensors (ISS) during the day, while loading an internal battery that provides power at night. A lithium battery serves as backup in case of need. The console allows viewing all meteorological variables simultaneously and configuring the station without needing a computer. It presents a keyboard and a large screen LCD 15 x 9 cm with backlight, for a perfect reading both day and night. It is possible to add additional consoles to view information in different locations.

The ISS sends data packets to the console wirelessly at a distance of up to 300 meters, with a frequency of update of 2.5 seconds. In addition, spread jump in frequency spectrum radio technology guarantees a reliable and interference-free data transmission. The wireless transmission range can be extended through relays of short and long range.



## 3.2 Lasithi – Crete Pilot site

### 3.2.1 Generator Management System

#### 3.2.1.1 Introduction

The system aims to assist the operators of island systems by proposing optimal operating scenarios for the various power units, as well as the various actions needed to avoid dangerous situations, which might result from a poor prediction of load or weather or preselected disturbances. The insurance of increased security and reliability of the system will allow maximization of renewable penetration.

#### 3.2.1.2 System description

This system includes various modules of forecasting, operational planning and security assessment. Due to the diverse needs of targeted medium and large scale systems, the software is highly modular, allowing integration of the options that are best suited to the particularities of each system. Figure 30 shows the general MORE CARE system architecture.

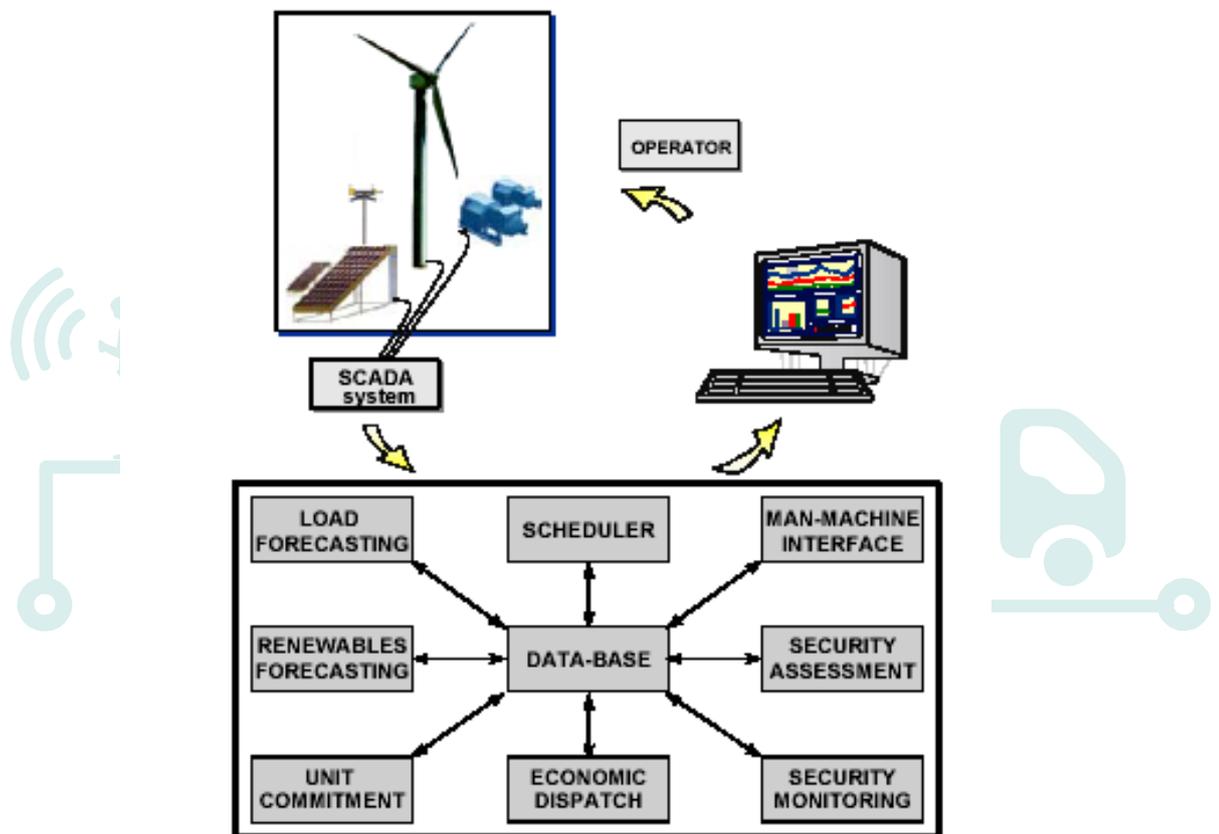


Figure 30 - Overview of MORE CARE functionalities.

In order to perform the Unit commitment and Economic Dispatch functions for the next planning horizon, it is necessary to have a forecast of the profile of the total load of the power system for



this horizon. As “forecasted load profile” is characterized a set of consecutive spot forecast values as well as confidence intervals for these forecasts. Usually in conventional systems forecasts are produced once per day. In autonomous systems with high penetration, it is necessary to update forecasts several times per day.

The purpose of the Wind Power Forecasting (WPF) module is to provide forecasts for the power output of each wind farm connected to the power system, as well as the corresponding confidence intervals. Forecasts are required by the ED and UC functions of MORE CARE software.

The UC module of the MORE CARE software suggests to the operator of the power system a secure operating scenario for the next hours. In an interconnected power system, Unit Commitment is performed usually once a day or more, and is based solely on load forecasts. In isolated systems with high penetration from renewable (i.e. >20%), it is necessary to update regularly the proposed Unit Commitment schedules in order to account for the variability in the production of the renewable. Thus, the UC models developed operate in a “sliding window” scheme. The length of the look-ahead time (planning horizon) depends on the type of the installed power units. On operator's request, the operating restrictions will include preventive control measures on the UC module, coming from the security assessment module.

The objective of the Economic Dispatch (ED) function is to distribute the load among the generator units selected in the Unit Commitment so that the total cost of the power system operation is minimized. The ED function is performed only for the basic time-step (e.g. 20 minutes ahead) of the planning horizon in order to provide the generators set-points to the operators.

The ED module is possible to compute the optimal generation production satisfying constraints of circuit loads, bus voltages and reactive generation to satisfy the load demand and losses of the system. It can also consider constraints related to bilateral contracts and independent producers of renewable power sources according to specific terms and conditions. On operator's request the output of the Economic Dispatch module (set-points) can be checked against security constraints with the security monitoring module, but these constraints will not be fed back as input to the ED modules.

In autonomous power systems, dynamic security assessment is a key issue in the operation and management of the networks. Sudden changes of system operating conditions must be quickly and efficiently compensated by generators to avoid frequency excursions or high  $df/dt$  variations, which may trigger the operation of system frequency relays, like under frequency protection relays of generators, provoking system collapse. This means that expected system frequency excursions and  $df/dt$  values, for some disturbances, must be assessed in a fast way to help in defining the more robust operating strategies. In addition, under- or over-voltages might disconnect generation and have to be guarded against.

### 3.2.1.3 System architecture

The MORE CARE system was designed in a modular way in order to facilitate future application and module integration. In order for the Human Machine Interface of MORE CARE to be accessible from remote locations the MORE CARE System was modified to become a service oriented application. As it is depicted in a simplified manner by [Figure 31](#), the system consists of three distinct parts (modules) that can be run on the same or separate machines.

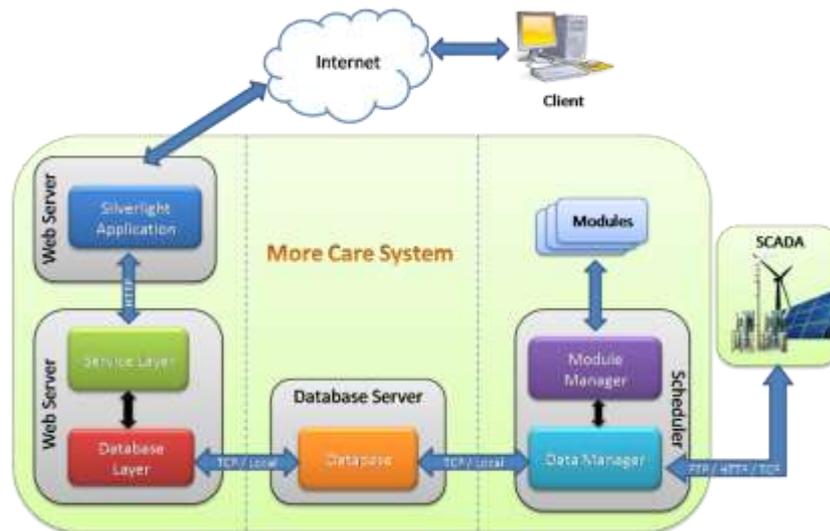


Figure 31- Overview of new MORE CARE architecture

The Scheduler Service Module is responsible for the acquisition and verification of the power systems SCADA data and the external module run schedule based on existing system settings. It can be divided into two parts. A Data Manager which acquires SCADA and forecast data using HTTP (data file download), FTP or connecting directly using TCP/IP, depending on the case and updates the database ensuring historical data are populated for use in the forecast modules. Furthermore it verifies the retrieved data integrity and attempts correction wherever necessary. This module is independent from the rest of the scheduler to ensure that even when the scheduler is not running, the data are always updated. The Module Manager is responsible for the integration and scheduling of the disparate modules (wind and load forecast models etc.) to the system and facilitates the communication between the modules and the database.

The MORE CARE system uses a relational database which serves as the data container holding current and historical data obtained by the SCADA of the power system, the output of the different forecast modules and various system settings.

Furthermore it provides the intermediate between the various disparate modules and unifies the way modules interact with the data. The database can be located either on a separate Database server over the network using TCP/IP for communicating with the other modules or in the same Server as the application.

The Human Machine Interface of the MORE CARE System provides an intuitive visual representation of the data stored in the database by displaying a series of system values and forecast results in a graphical manner enabling the operator to quickly assess the system status. Furthermore it offers the capability of administering system settings, user access restrictions by using user roles and multilingual support.

To enable remote access of the data the MORE CARE system uses a service oriented approach. A Web Server hosts the Windows Communication Foundation (WCF) services, implemented in Microsoft .NET, exposing a service endpoint for use from the Internet. There are two distinct services present in the system, one for data retrieval and one for user identification and authentication. The distinction is made for greater scalability and availability and for using different access policies on the services (e.g., using different communication encryption methods). The Service Layer uses an intermediate Database Layer for retrieving the data necessary to the interface. This layer offers independence from the underlying database changes. The data received by the Database Layer are transformed using an "easy to read" object model and then sent to the client application as a message for interpretation and visualization. This approach offers the capability of implementing different user interfaces using



the existing web services for the data acquisition and user authentication.

The graphical interface and data representation are provided by a Silverlight application hosted on a Web Server. Silverlight is a programming model that is ideal for providing Rich Internet Application user experience by using graphical objects, animations etc. The application uses an ASP.NET Web page as a container that delivers the content to the remote client. To retrieve the data for display the application issues requests to the web service over the Internet using Simple Object Access Protocol (SOAP) as the Remote Procedure Call (RPC) mechanism. The HMI refreshes the data in predefined intervals set by the administration or on demand by user request.

The MORE CARE EMS will have to be adapted and integrated in the SmartKYE vision, in order to interact with the OESP and provide the operator with information coming with other EMS in the Lasithi area. Whenever this additional EMS are not available – for cross-evaluation purposes the same type of EMS integrated in Barcelona will be integrated in Greece too - , this EMS will be emulated or run off-line.

### 3.2.1.3.1 Provided Data – Database Server

There are various sources for the data of the More Care System, as shown in the following figure. These sources can be the SCADA of the electrical system of Crete, meteorological forecasts and independent applications that obtain data from the electrical resources of the system.

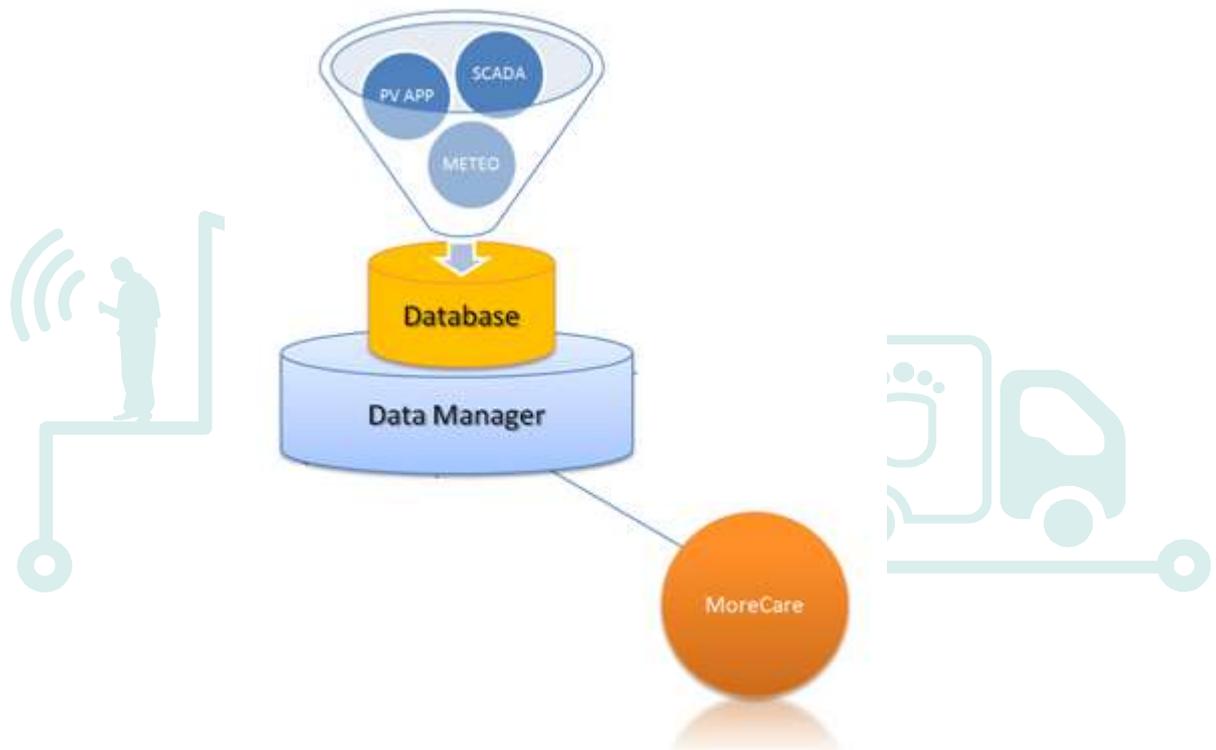


Figure 32 - Architecture of More Care application

All the data are uploaded to a FTP Server. The form of this data consists of a list of tags and the corresponding values. The tags refer to attributes of the resources of the power system (see Table 2 - Some of the SCADA tags) like voltage, current, active and reactive power, etc.



SCADAID	Tag	Description
100	AMENEW	Active Energy Anemoessa
101	AMFCEN	cosf? Anemoessa
102	AMIL2	PhaseCurrent 2 Anemoessa
103	AMIL3	PhaseCurrent 3 Anemoessa
104	AMMAXP	Max Available Active Power Anemoessa
105	AMPHOR	Hour Energy Anemoessa
106	AMRTOT	Reactive Power Anemoessa
107	AMTDEY	Wind Direction Anemoessa
108	AMTEMP	Temperature Anemoessa
109	AMV12	PhaseVoltage 1 2 Anemoessa
110	AMVCEN	Voltage Anemoessa
111	AMWASK	Requested Active Power Anemoessa
112	AMWAVA	Available Wind Turbines Anemoessa
113	AMWSYM	Adjusted Active Power Anemoessa
114	AMWTOT	Active Power Anemoessa
115	ANA215	Current P215 Agios Nikolaos
116	ANA225	Current P225 Agios Nikolaos
117	ANA255	Current P255 Agios Nikolaos
118	ANA305	Current P305 Capacitor Agios Nikolaos
119	ANR1	Reactive Power Trans1 Agios Nikolaos
120	ANR10	Reactive Power P10 Agios Nikolaos
121	ANR2	Reactive Power Trans2 Agios Nikolaos
122	ANR20	Reactive Power P20 Agios Nikolaos
123	ANR215	Reactive Power P215 Agios Nikolaos
124	ANR220	Reactive Power P220 Wind Farm Plastika Agios Nikolaos
125	ANR225	Reactive Power P225 Agios Nikolaos
126	ANR305	Reactive Power P305 Capacitor Agios Nikolaos
127	ANV1	Voltage Trans1 Agios Nikolaos
128	ANV2	Voltage Trans2 Agios Nikolaos
129	ANV215	Voltage P215 Agios Nikolaos
130	ANV225	Voltage P225 Agios Nikolaos
131	ANVZ	Voltage Bus Agios Nikolaos
132	ANW	Active Energy Agios Nikolaos

Table 2 - Some of the SCADA tags

An application called Data Manager is collecting the SCADA Data from the ftp server and data from other sources and informs the corresponding database fields. The database hosting the data of the More Care System is designed based on the CIM standard for electricity. In electric power transmission and distribution, the Common Information Model (CIM) is a standard developed by the electric power industry that has been officially adopted by the International Electrotechnical Commission (IEC). This standard aims to allow application software to exchange information about the configuration and status of an electrical network. Furthermore, the architecture of the developed database of the More Care system allows the integration of any newly introduced electrical resource that does not even exist yet.



### 3.2.1.4 Web application – User interface

The User Interface of the More Care System is a web based application. This allows to the user to access the application from any browser at any place given that he has the required credentials.

In the figures below one can see some snapshots of the user interface.

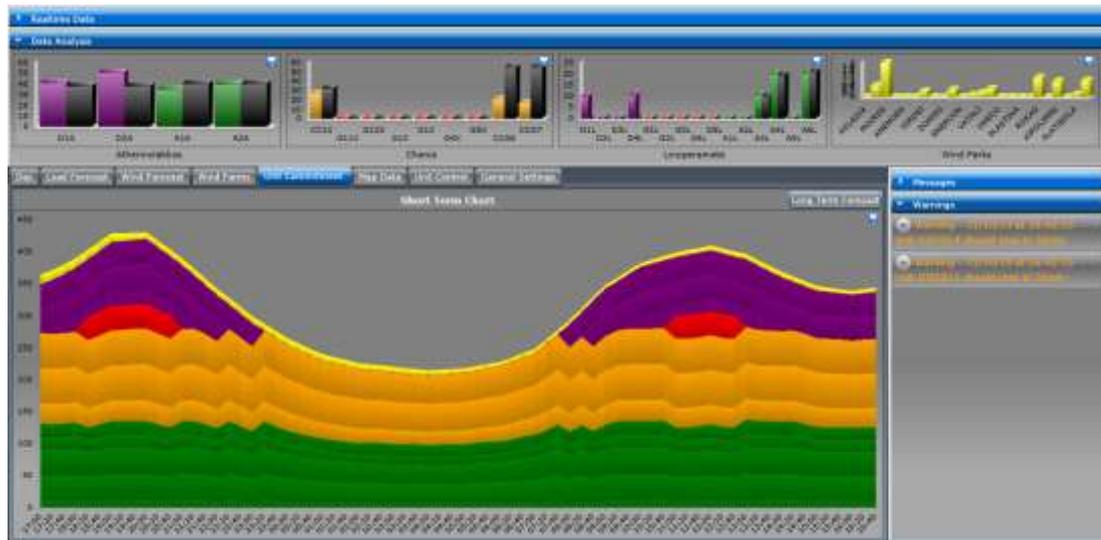


Figure 33 - More Care Main Screen

The main screen of MORE CARE is presented in Figure 33 where the main components exist. The components are:

- **The Main Chart:**

This chart provides information about the current and the past load. More specific the past load is presented by a blue Line the Load Forecast with a Red Line. The horizon for the past load and the load forecast is 12 hours. This is a sliding windows and the current moment is the cross-section of the two lines.

- **The Main Banner**

The banner provides info like total load, production RES penetration etc. Furthermore it includes data about the current and the UC cost. The current cost corresponds to the cost (kgr/MWh) of the current dispatched units and the UC cost corresponds to the average cost of the proposed Unit Commitments (24h). The values are updated every minute upon the refresh of the SCADA data.

- **The Column Charts:**

This chart presents online data from the production units. Furthermore for the dispatchable units (thermal) it provides the Economic Dispatch suggestions (black column). The green lines correspond to Geothermal Units, the Pink lines to Diesel Units, the yellow columns to Renewable (Wind Farm or Hydro). These charts are refreshed every 20 min and the online values correspond to the average value of the last 20min period.



- **Message Box:**

This screen presents messages related to the UC module such as suggestion to start or stop a unit. The user may change the horizon of the messages from the option Menu (please refer to section System Management)

- **Unit Parameter:**

The user may change the power output of a unit or completely disable it. In the drop down list the user may select a unit. Next the user may change the dates of availability. In order to avoid problem with the date format the user should use the +/- buttons. This way the user may increase or decrease the dates and the hours.

- **General Parameters:**

The user may change several parameters in the system such as the penetration level and the reserve dispatch.

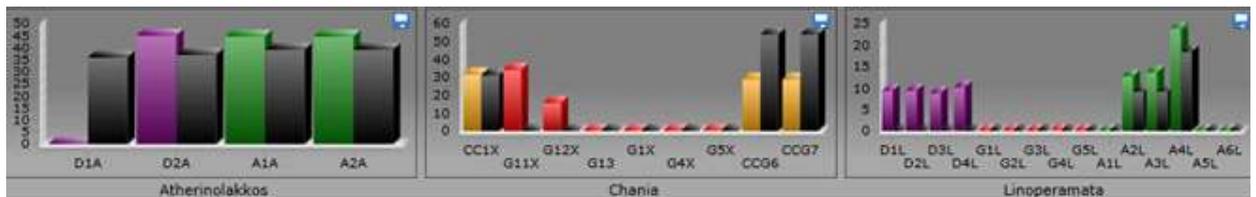


Figure 34 - Thermal Units Current Production

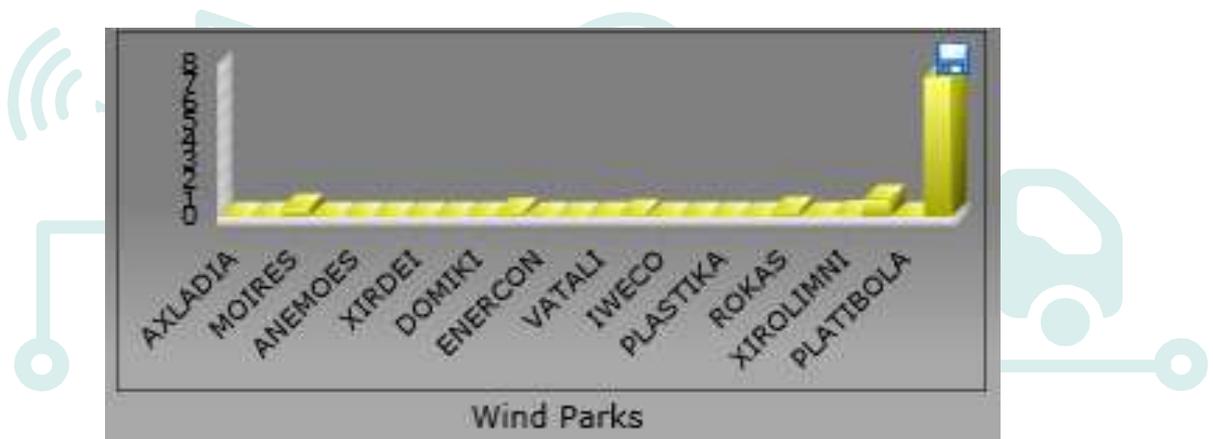


Figure 35 - Wind Farms Current Production

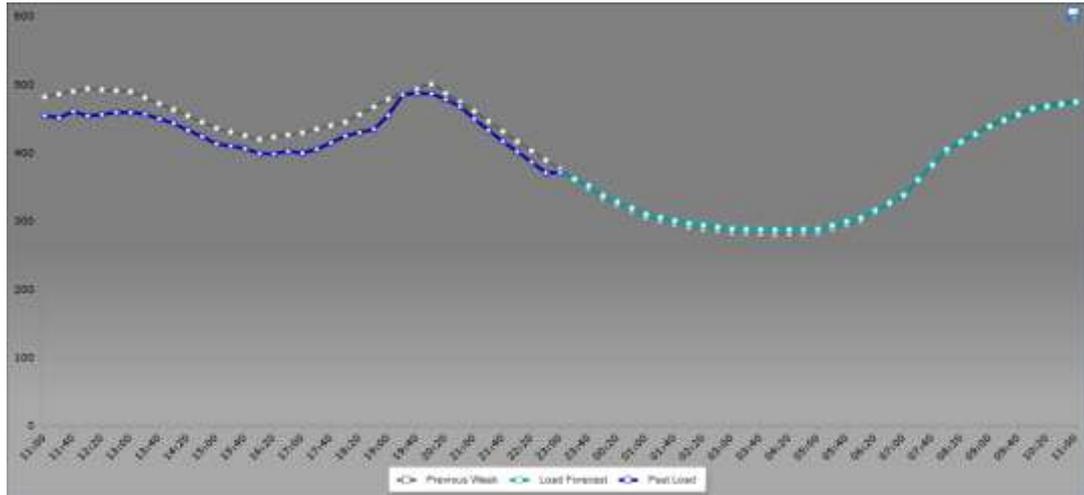


Figure 36 - Island Day Demand Curve and Load Forecasting for the next 12 hours



Figure 37 - Transmission Grid of Crete and optimal power flow visualization



Figure 38 - Technical Characteristics of the Units



Figure 39 - System Parameters

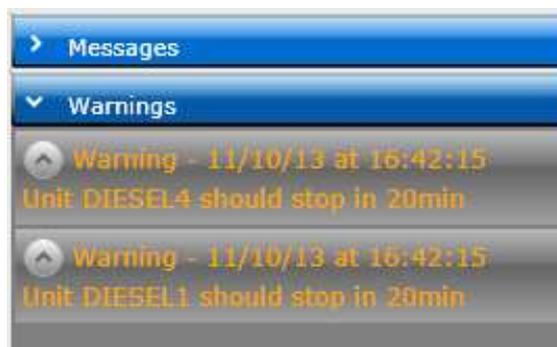


Figure 40 - Messages to the Operator

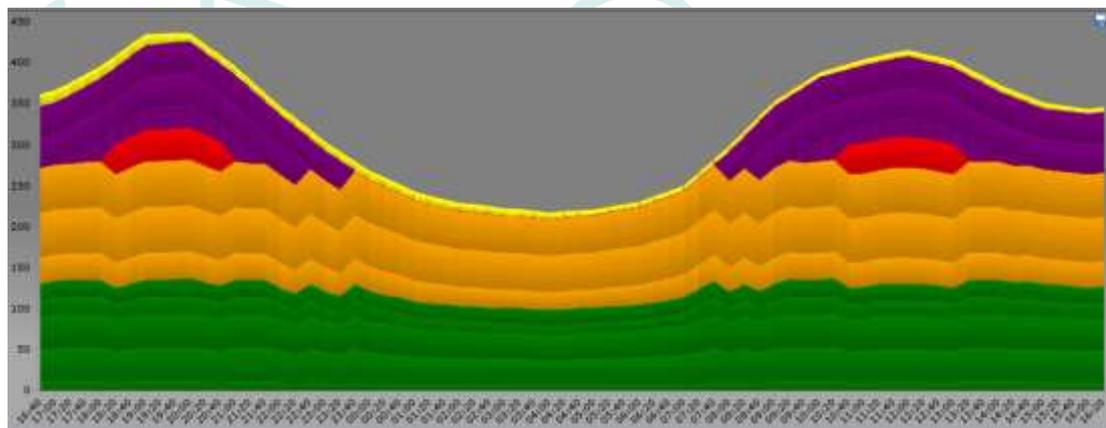


Figure 41 - The Unit Commitment Chart



## 3.2.2 Building Management system

### 3.2.2.1 Introduction

On the scope of the SmartKYE project a set of Smart Controller is installed on a number of public buildings, allowing the monitoring and control of some loads of these buildings.

### 3.2.2.2 System description

The following table shows the building characteristics where the smart controller are installed.

Objective	Building 1	Building 2	Building 3	Building 4	Building 5
<b>Location</b>	Dispatch Center	PPC Agency, Tsalikaki area	Nursing home. Agia Triada Parish Lasithi	Sanatorium for Chronic Diseases , Lasithi	Hotel Havanía , Lasithi
<b>Energy Management System deployed</b>	Controller BK4000TG)	Controller BK3000TG	Controller BK4000TG)	Controller BK4000TG	Controller BK3000TG
<b>Smartmeters Manufacturer</b>	ABB (3 power lines), External Lightning Control	Landis & Gyr (1 power line)	ABB (2 power lines)	ABB (2 Power lines)	Landis & Gyr (1 power line)
<b>Communication technology</b>	GPRS (real time transmission)	GPRS (real time transmission)	GPRS (real time transmission)	GPRS (real time transmission)	GPRS (real time transmission)

Table 3 - Building characteristics

### 3.2.2.3 System architecture

A GPRS communication is established between the controllers and a local database. Through developed stored procedures the database server of the More Care system acquires the data from the local DB server and incorporates them to the total data of the system.

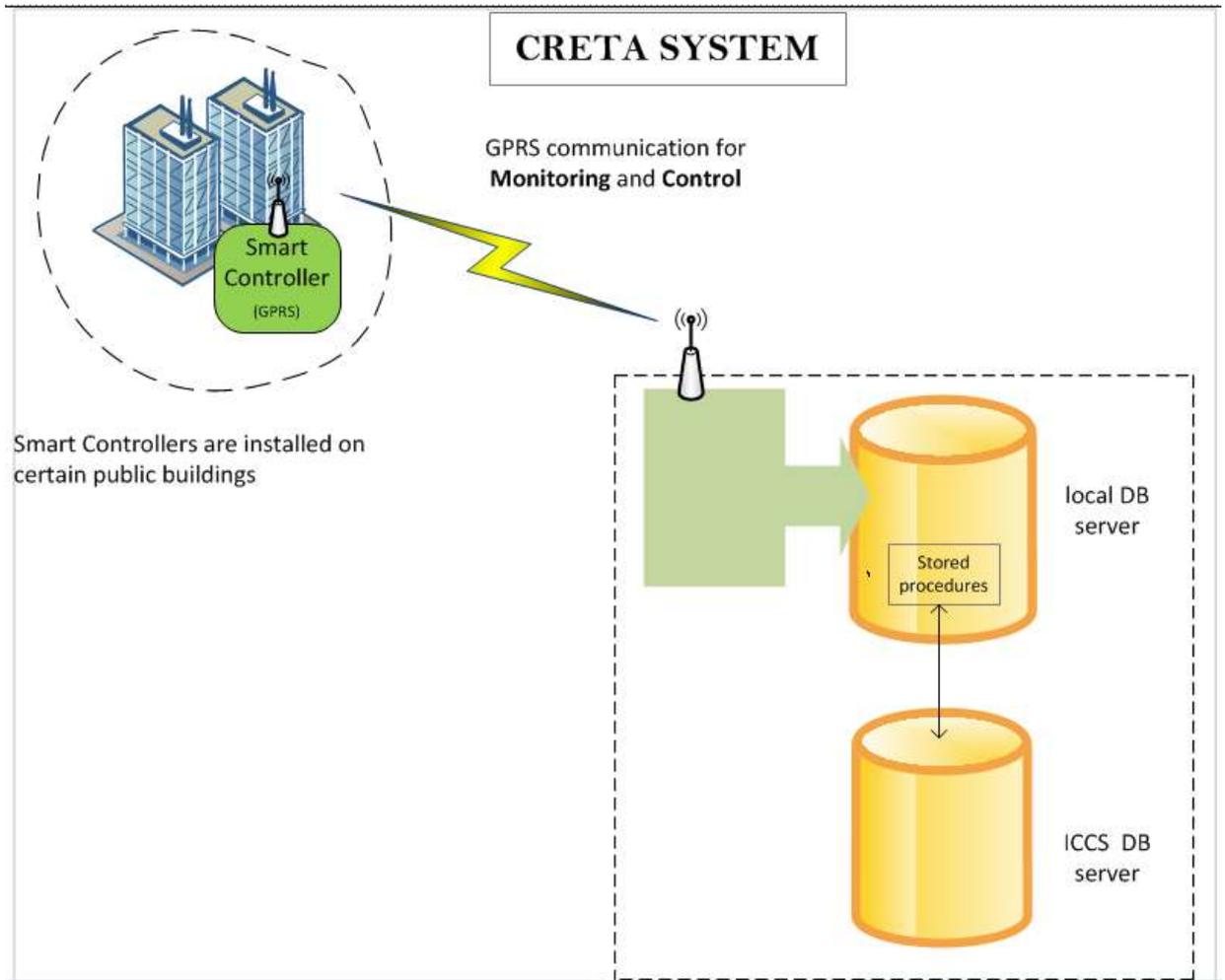


Figure 42 - Architecture of the data acquisition from the public buildings

### 3.2.2.4 Equipment

Next photos of the controllers are presented

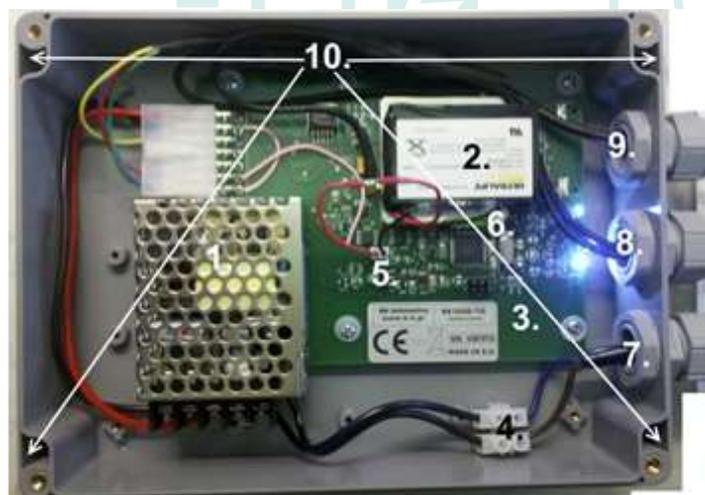


Figure 43 - BK3000TG Controller



Figure 44 - BK4000TG Controller



## 4 Components adaptation definition

Based on the architecture, requirements and use cases defined in previous Work packages, in this section, it will be described the adaptation required by the different EMS and its components, in order to interact with SmartKYE platform.

### 4.1 Barcelona 22@ district – Pilot site

#### 4.1.1 Barcelona Building EMS

Due to the fact that “Barcelona Building EMS” is composed of two sub-systems, namely MediaTIC building BMS and BDigital office energy management platform, both systems will be integrated and adapted to the needs of the SmartKYE platform.

##### 4.1.1.1 Conceptual data model adaptation

The concepts managed by the EMS are not directly equivalent to the concepts managed by the platform. The next table summarizes the EMS conceptual elements and their correspondence in the platform:

**Table 4 - Barcelona Building EMS data model adaptation**

Description (for public Barcelona lightning EMS)	SmartKYE equivalent	Platform (MediaTIC Building BMS)
<b>Building</b>	Device of type “BUILDING”. It will be a child of an entity of type “BUILDING_EMS”	EMS highest level entity. This is the “infrastructure” where all other systems operate. Although several different systems operate within a building, only data from a subset of these systems will be available within SmartKYE, namely some HVAC attributes and metrics and outside environmental sensors
<b>Building HVAC</b>	Device of type “BUILDING_HVAC_CONTR OL”. It will be a child of an entity of type “BUILDING”	Building central heating, refrigeration and ventilation system (connected to a district heating network)
<b>Building Working Hours Schedule</b>	Device of type “BUILDING_TIME_TABLE”. It will be a child of an entity of type “BUILDING”	Building time table operation defined by the building manager. It provides information regarding pre-defined schedules for HVAC system operations and other systems that affect common spaces of the building (i.e., lighting)
<b>Building Weather Station</b>	Device of type “WEATHER_STATION”. It will be a child of an entity of type “BUILDING”	Equipment incorporating several different sensors monitoring building’s outside environmental parameters
<b>Building Outside Temperature Sensor</b>	Device of type “TEMPERATURE_SENSOR”. It will be a child of an	Building outside environmental sensor measuring building’s surroundings temperature



	entity of type "WEATHER_STATION"	
<b>Building Outside Solar Radiation Sensor</b>	Device of type "SOLAR_RADIATION_SENSOR". It will be a child of an entity of type "WEATHER_STATION"	Building outside environmental sensor measuring solar radiation in the building's rooftop
<b>Description (for Barcelona public lightning EMS)</b>	<b>SmartKYE Platform equivalent</b>	<b>Barcelona Building (BDigital Office Energy Management Platform)</b>
<b>Building Office</b>	Device of type "BUILDING_OFFICE". It will be a child of an entity of type "BUILDING"	BDigital Office space within MediaTIC building. All systems within this space are outside MediaTIC building's BMS control
<b>Building Office Inside Ambient Sensor</b>	Device of type "OFFICE_AMBIENT_SENSOR". It will be a child of an entity of type "BUILDING_OFFICE"	BDigital Office sensor unit which incorporate several different environment parameters sensors such as temperature, brightness and humidity.
<b>Building Office Inside Temperature Sensor</b>	Device of type "TEMPERATURE_SENSOR". It will be a child of an entity of type "OFFICE_AMBIENT_SENSOR"	BDigital Office temperature sensors deployed in several different areas of the office.
<b>Building Office Inside Ambient Light (brightness) Sensor</b>	Device of type "BRIGHTNESS_SENSOR". It will be a child of an entity of type "OFFICE_AMBIENT_SENSOR"	BDigital Office ambient light sensors deployed in several different areas of the office.
<b>Building Office Inside Humidity Sensor</b>	Device of type "HUMIDITY_SENSOR". It will be a child of an entity of type "OFFICE_AMBIENT_SENSOR"	BDigital Office humidity sensors deployed in several different areas of the office.
<b>Building Office Sub-Meter Sensor</b>	Device of type "SMART_PLUG_SENSOR". It will be a child of an entity of type "BUILDING_OFFICE"	BDigital Office electronic equipment energy consumption sensors deployed in several different areas of the office.



#### 4.1.1.2 Metrics & attributes provided

Some of the services to be implemented by the EMS involved the transmission of data associated with assets. These are characterised as attributes or metrics, depending on the nature of these data.

The following table shows the metrics and attributes provided by each entity within the Barcelona building EMS.

**Table 5 - Barcelona Building EMS metrics and attributes provided**

	Metrics provided	Attributes provided
<b>Barcelona Building (MediaTIC Building BMS)</b>		
<b>BUILDING_EMS</b>	ENTITY_COUNT ENTITIES_USED POTENTIAL_ENERGY_PRODUCTION TEMPERATURE CO2_EMISSIONS	GEO_LOCATION POSTAL_ADDRESS CONNECTED_ON_GRID BUILDING_PROPERTIES FACILITY_MANAGER
<b>BUILDING_HVAC_CONTROL</b>	TEMPERATURE LOAD	
<b>BUILDING_TIME_TABLE</b>	TIME_TABLE	
<b>WEATHER_STATION</b>	TEMPERATURE SOLAR_RADIATION	GEO_LOCATION
<b>TEMPERATURE_SENSOR</b>	TEMPERATURE	
<b>SOLAR_RADIATION_SENSOR</b>	SOLAR_RADIATION	
<b>BDigital Office Energy Management Platform</b>		
<b>BUILDING_OFFICE</b>	ENTITY_COUNT ENTITIES_USED ENERGY_CONSUMPTION ENERGY_CONSUMPTION_FORECAST MAX_PEAK_POWER_DEMAND ENERGY_PRICE_PER_KWH CO2_EMISSIONS	GEO_LOCATION POSTAL_ADDRESS MEASUREMENT_DEVICE ELECTRICAL_MEASURES FACILITY_MANAGER
<b>TEMPERATURE_SENSOR</b>	TEMPERATURE	
<b>BRIGHTNESS_SENSOR</b>	BRIGHTNESS	
<b>HUMIDITY_SENSOR</b>	HUMIDITY	
<b>SMART_PLUG_SENSOR</b>	ENERGY_CONSUMPTION MAX_PEAK_POWER_DEMAND	MEASUREMENT_DEVICE ELECTRICAL_MEASURES WORKING_MODE SWITCHED

#### 4.1.1.3 Design of the EMS adaption.

This is the overall design of the proposed changes for adapting the EMS to the SmartKYE platform:

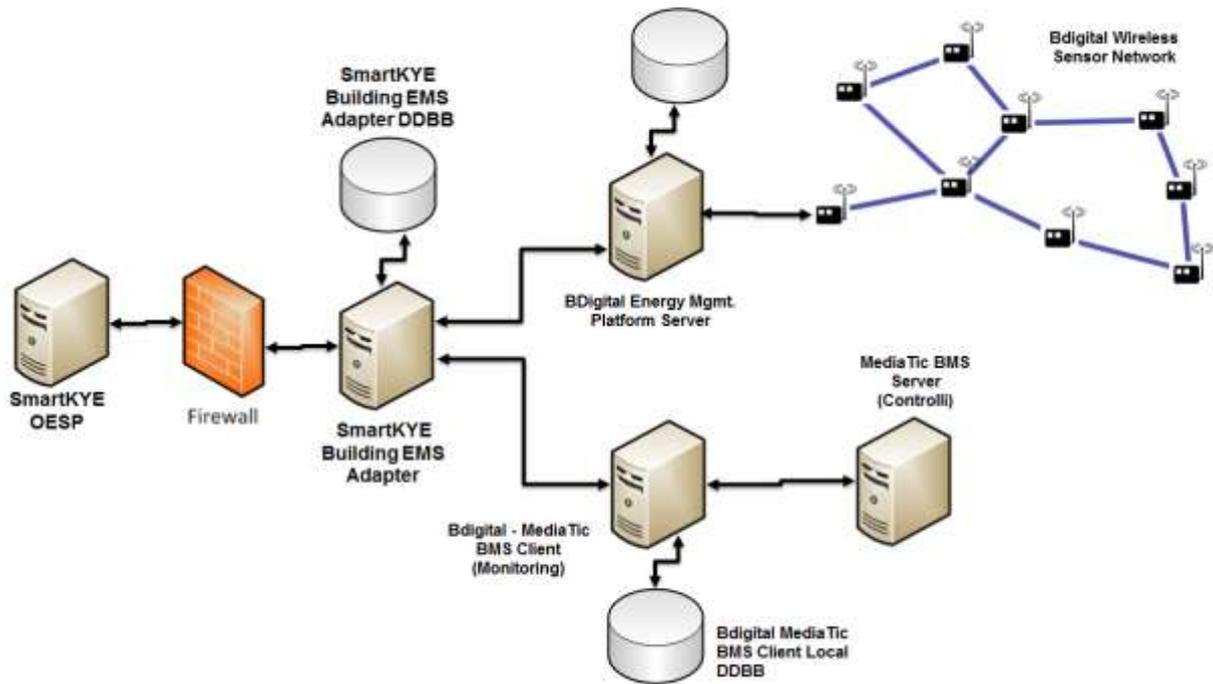


Figure 45 - Architecture – Barcelona Building EMS adaptation

From the previous Figure several important aspects can be highlighted:

- The SmartKYE EMS adapter will be implemented and deployed in a server outside MediaTIC building BMS or BDigital energy platform domains.
- The SmartKYE EMS adapter will basically access MediaTIC building BMS and BDigital energy platform data and publish the data through the SmartKYE web services interface. It is relevant to take into account that due to MediaTIC facility manager requests, data available from this system will be updated on a weekly basis.
- Apart from the existing databases, the EMS adapter will make use of a specific database that will contain all the required information that is not present in the other databases. This information is required for the computation of some of the attributes and metrics handled by the platform, such as the energy price curve or the address of the assets. This database will be completed as one of the tasks to be done during the deployment of the EMS.
- Since the EMS adapter will be deployed within BDigital network, access to or from external systems will have to go through BDigital's network firewall. It is for these reasons that is required that the OESP component or any other system accessing SmartKYE Building EMS have a static IP address.
- The whole system is intended as a demonstration of the SmartKYE platform capabilities. In any case will be a commercial 24x7 service.

The SmartKYE Building EMS adapter will be developed as a background service or application running in the EMS server (deployed in BDigital datacentre). This will allow having the EMS running all the time and not depending on any user or operator interaction. Performance of the application might be monitor for instance through log files or any other similar tool.

Internally, the EMS adapter application will be implemented according to the following structure:

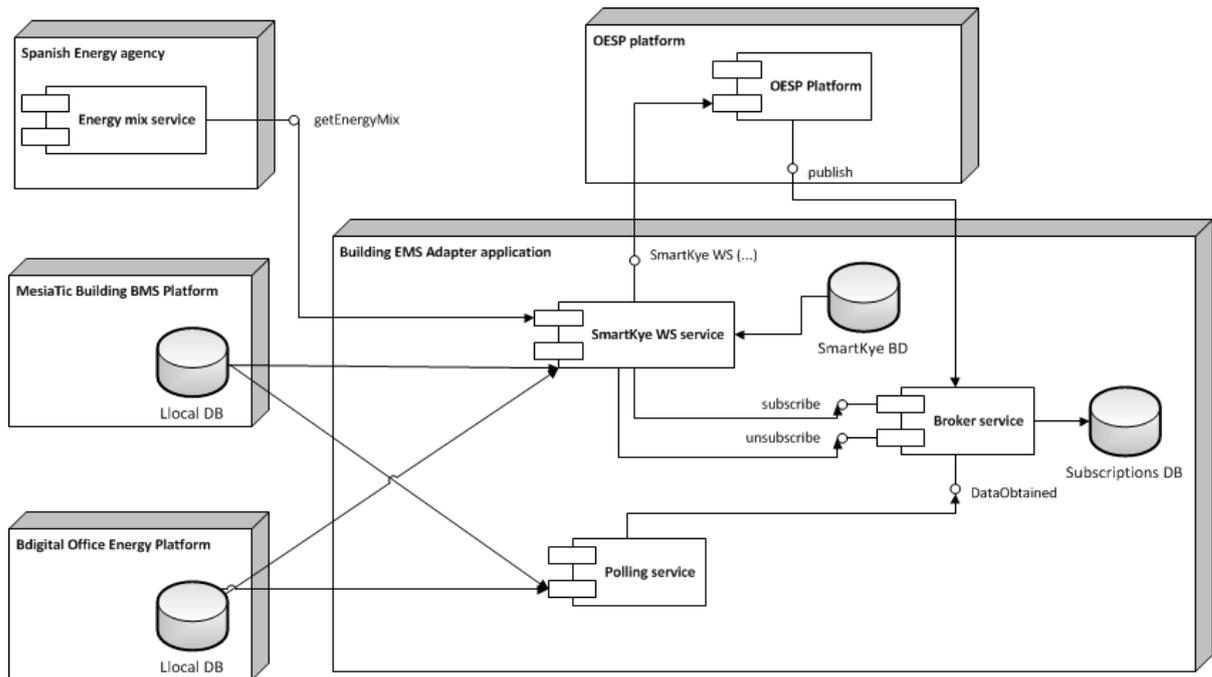


Figure 46 - Barcelona Building EMS adapter structure

Previous Figure illustrates the internal structure envisioned for the Building EMS. This architecture is based on the following components:

### SmartKYE WS Service Component

This will offer interfaces for all the Web Services that are mandatory for the EMS (even though the web service interface is common for both server and client, only a subset of the defined services are mandatory for the EMS to implement).

For the implementation of this component, we will start from the import of the Web Service definition (WSDL) generated by the OESP platform. This can be done with several existing tools, but at the end, most of them produce code that can be used:

- For remotely accessing a service implementing the given WSDL (client code generated)
- For implementing the services described in the WSDL (services stub generated). It is called stub because what is automatically generated in that way creates server methods with a signature that are compatible with those described in the WSDL (name, parameters, outputs, etc.) but do not make anything (empty methods). It is the developer task to give these stubs an appropriate code for returning or performing what is actually expected by the platform.

Besides previous functionalities, this module is also responsible for interfacing third-party systems such as any third-party data provider, for instance, the “Spanish Energy Mix” data providers, as illustrated in Figure 46. In such cases, SmartKYE WS component will handle not only the communications but also the processing and storage of related data in a local database (SmartKYE BD in Figure 46).

Finally, this component will implement functionalities to such as interfacing EMS components such as “BDigital Office Energy Management Platform” and “MediaTIC Building BMS Platform”, obtain specific data and perform advanced calculations with that data, for example, obtaining CO2 impact of a specific entity (by combining energy consumption and local energy mix data). These results could also be stored in the local database.



### Broker Service Component

There are two special methods described in the SmartKYE Web Service Interface that allows subscribing or unsubscribing to specific pieces of data handled by an EMS. When invocations to these services are received by the 'SmartKYE WS service', they are forwarded to the '**Broker service**'. This component handles the registrations of client to specific pair's metric-asset. Potential clients of such interface could be the SmartKYE OESP component, any SmartKYE cockpit such as the Monitoring and Control Cockpit (MCC) or Business Cockpit (BC) and finally any third party system supporting SmartKYE WS interface.

Subscriptions and un-subscriptions to specific data of an EMS will be stored in a local database (which can be physically deployed in the same data base server user for the SmartKYE local data base in Figure 46), and are used when the broker service receives data through the DataObtained interface. The component implements the following algorithm:

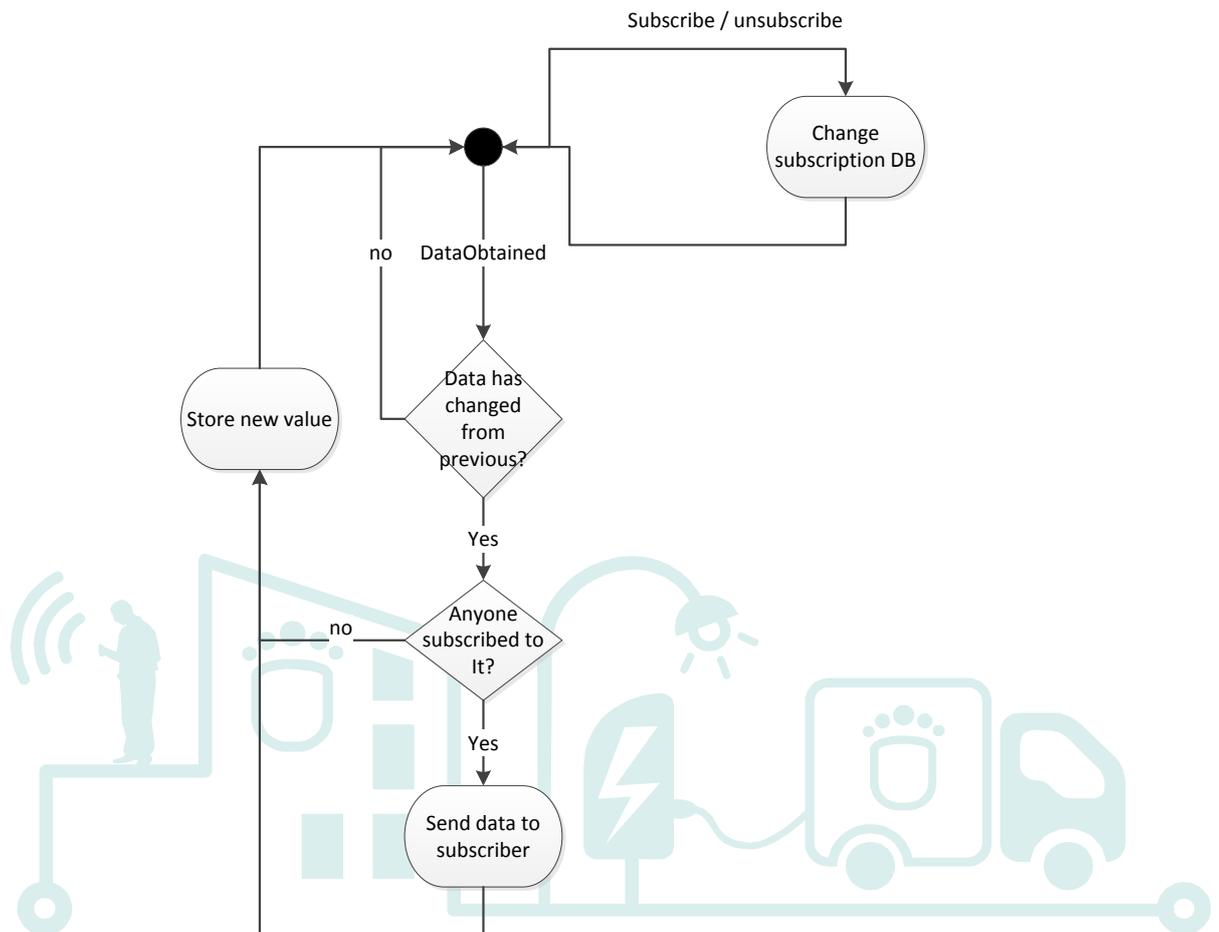


Figure 47 - Barcelona Building EMS adapter – Polling service algorithm

### Polling Service Component

This service will be in charge of periodically querying the appropriate databases of the “BDigital Office Energy Management Platform” and “MediaTIC Building BMS Platform”, obtaining the values and measures of the assets and send them to the broker service so that any client subscribed to a particular data can be notified on time. The polling period will be configurable.

It is important to bear in mind that data will always remain in the databases of those systems where it is originated (MediaTIC and BDigital office platforms), except for any particular data specifically generated by the SmartKYE WS component, as it has been previously detailed.



### 4.1.2 Public lighting System

The information handled by the EMS must be adapted to the needs of the SmartKYE platform.

#### 4.1.2.1 Conceptual data model adaptation

The concepts managed by the EMS are not directly equivalent to the concepts managed by the platform. The next table summarizes the EMS conceptual elements and their correspondence in the platform:

**Table 6 – Public lightning EMS data model adaptation**

	Description (for Barcelona public lightning EMS)	SmartKYE Platform equivalent
<b>EMS system</b>	Barcelona public light management system	Device of type PUBLIC_LIGHTING_CONTROL_ROOM
<b>Segment controller</b>	Device responsible for managing a line of individual lights	Device of type, SEGMENT_CONTROLLER
<b>Point of light</b>	Device representing an individual light in the street	Device of type POINT_OF_LIGHT

#### 4.1.2.2 Metrics & attributes provided

Some of the services to be implemented by the EMS involve the transmission of data associated with assets. These are characterised as attributes or metrics, depending on the nature of these data.

The following table shows the metrics and attributes provided by each element of the EMS

**Table 7 – Public lightning EMS Metrics and attributes provided**

	Metrics provided	Attributes provided
<b>PUBLIC_LIGHTING_CONTROL_ROOM</b>	ENTITY_COUNT ENTITY_USED ENERGY_CONSUMPTION ENERGY_PRICE_PER_KWH MAX_PEAK_POWER_DEMAND CO2_EMISSIONS ENERGY_COST	GEO_LOCATION POSTAL_ADDRESS
<b>SEGMENT_CONTROLLER</b>	ENTITY_COUNT ENTITY_USED ENERGY_CONSUMPTION CO2_EMISSIONS VOLTAGE CURRENT ACTIVE_POWER REACTIVE_POWER	GEO_LOCATION POSTAL_ADDRESS ELECTRICAL_MEASURES SWITCHED DIMMING_VALUE MEASUREMENT_DEVICE
<b>POINT_OF_LIGHT</b>	ENERGY_CONSUMPTION CO2_EMISSIONS VOLTAGE CURRENT ACTIVE_POWER REACTIVE_POWER	GEO_LOCATION POSTAL_ADDRESS ELECTRICAL_MEASURES SWITCHED DIMMING_VALUE MEASUREMENT_DEVICE



For the metric ENERGY\_PRICE\_PER\_KWH, the EMS owner will be queried in order to obtain the price curve of the energy. This will be stored in DB.

For the ENERGY\_CONSUMPTION, if the devices do not produce the instant consumptions directly, the instant KW will be queried and translated to KWh by using the instants of the measures.

For the electrical measures, it is possible that only instant consumption can be obtained, this will be analysed with the EMS owner.

For the MAX\_PEAK\_ENERGY\_DEMAND, the maximum Kw/Hour of the queried interval will be returned.

The CO2\_EMISSIONS will be obtained by using the generation curves obtained from the Spanish energy agency in real time.

### 4.1.2.3 Design of the EMS adaption.

This is the overall design of the proposed changes for adapting the EMS to the SmartKYE platform:

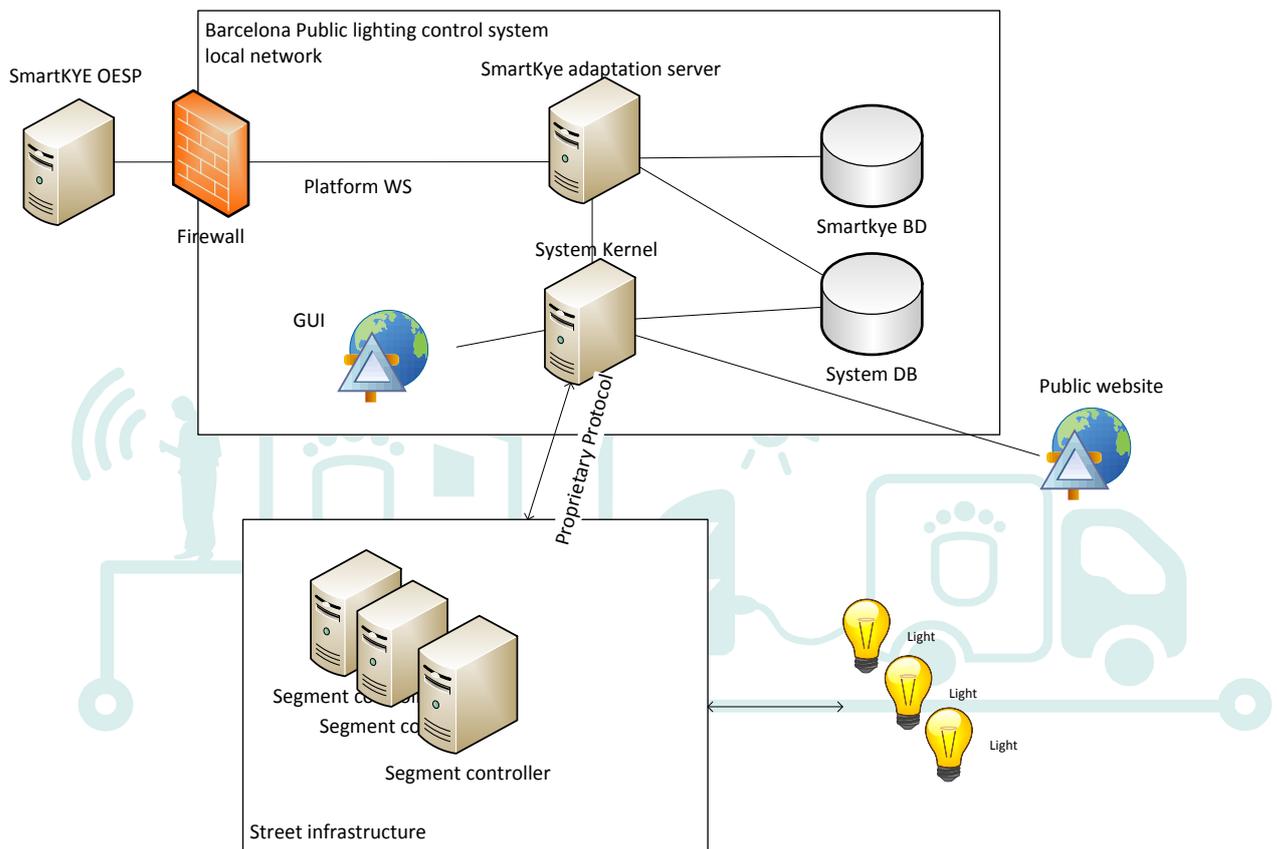


Figure 48 - System deployment architecture

The adaptation to the OESP platform will be carried out by a specific application (that can be hosted in one of the existing servers or in a new one). This EMS adapter application will connect the existing System Kernel applications and modules and will interact with them for obtaining the required information and measures.

Apart from the existing databases, the EMS adapter will make use of a specific database that will contain all the required information that is not present in the other databases. This is



information required for some of the attributes or metrics handled by the platform, such as the energy price curve or the address of the assets. This database will be completed as one of the tasks to be done during the deployment of the EMS.

The different modules of the system kernel should be adapted in order to attend the messages from the adapter application

The EMS adapter application will have the form of a windows service. This will allow having the application running all the time and not depending on a user to start the application on a desktop session. Windows services do not have a graphical interface, so the output and behaviour of the application will be logged to files.

Internally, the EMS adapter application will be implemented according to the following structure:

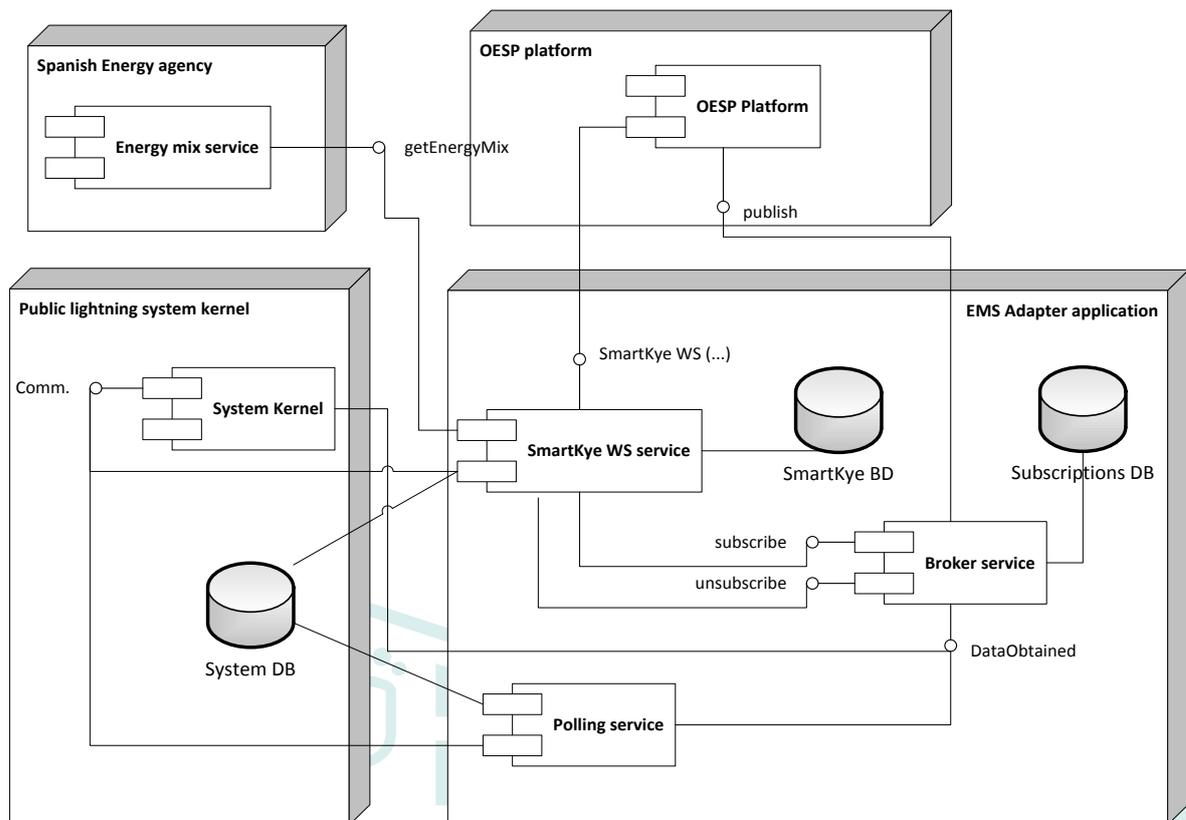


Figure 49 - EMS adapter application implementation structure

The application will implement the SmartKYE Web Services in the ‘**SmartKYE WS service**’ component. This will offer interfaces for all the Web Services that are mandatory for the EMS (even though the web service interface is common for both server and client, only a subset of the defined services are mandatory for the EMS to implement).

For the implementation of this component, we will start from the import of the Web Service definition (WSDL) generated by the OESP platform. This can be done with several existing tools, but at the end, most of them produce code that can be used:

- For remotely accessing a service implementing the given WSDL (client code generated)
- For implementing the services described in the WSDL (services stub generated). It is called stub because what is automatically generated in that way creates server methods with a signature that are compatible with those described in the WSDL (name, parameters, outputs, etc.) but do not make anything (empty methods). It is our task to give these stubs an appropriate code for returning of performing what is actually expected by the platform.



The **'SmartKYE WS service'** will contact the system kernel upon necessary when information is demanded from the platform.

The **'Broker service'** is responsible for handling the subscriptions and publication of data to subscribers upon necessary. The decision of when to send such data is based on the detection of changes in the data monitored by any subscriber. The changes notifications are received through an interface that is used by the polling service and the system kernel to acknowledge the changing of information in real time. The component will implement the following algorithm:

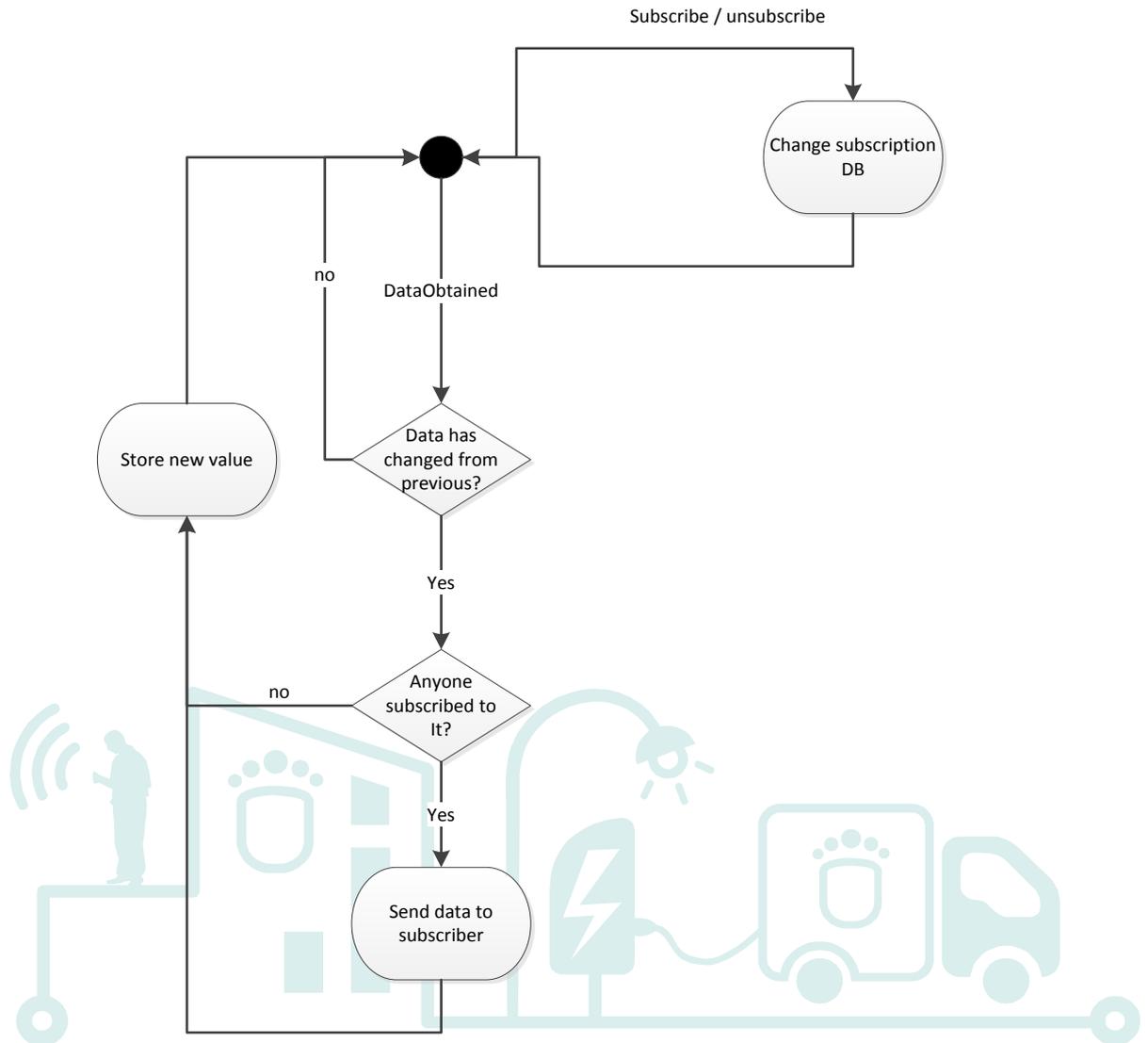


Figure 50 – Algorithm implemented

The **'Polling service'** is responsible for periodically querying the system database and the system kernel modules to detect changes in the measures or parameters. When these changes are detected, it will inform the broker service.

The **'System kernel'** that is currently developed will be changed to accept SmartKYE incoming messages and also a procedure for sending the changes in the measures to the broker service will be developed.

Finally, the energy mix service will be used to obtain the current energy mix, in order to generate the metric involving CO2 footprints.



### 4.1.3 Electric vehicle infrastructure

The information handled by the EMS must be adapted to the needs of the SmartKYE platform.

#### 4.1.3.1 Conceptual data model adaptation

The concepts managed by the EMS are not directly equivalent to the concepts managed by the platform. The next table summarizes the EMS conceptual elements and their correspondence in the platform:

**Table 8 - EV EMS data model adaptation**

	Description (for Barcelona EV EMS)	SmartKYE Platform equivalent
<b>EMS system</b>	Barcelona Live platform for EV management	Device of type EV_EMS
<b>Charging station</b>	Infrastructure containing one or more plugs for charging electric vehicles. It also contains a contactless card reader for identifying the user.	Device of type EV_charging_station. Each one will be a child of a device of type EV_EMS
<b>Plug</b>	Device for connecting and charging an electrical vehicle	Device of type EV_plug. Each one will be a child of a device of type EV_charging_station
<b>User Card</b>	Contactless card owned by the end system user and used to enable the charge of the EV. Contains the details of the vehicle to charge	-
<b>Electric Vehicle</b>	EV	There is no explicit definition of EVs in the platform. Instead of this, in each device of type EV_plug, there will be a set of attributes that will describe the characteristics of the EV connected to the plug: vehicle model, battery characteristics, status, etc. This information will be obtained from the user card used to start the charge

#### 4.1.3.2 Metrics & attributes provided

Some of the services to be implemented by the EMS involve the transmission of data associated with assets. These are characterised as attributes or metrics, depending on the nature of these data.

The following table shows the metrics and attributes provided by each element of the EMS

**Table 9 – EV EMS metrics and attributes provided**

	Description (for Barcelona EV EMS)	SmartKYE Platform equivalent
<b>EV_EMS</b>	ENTITY_COUNT ENTITY_USED ENERGY_CONSUMPTION ENERGY_PRICE_PER_KWH	GEO_LOCATION POSTAL_ADDRESS



	MAX_PEAK_POWER_DEMAND CO2_EMISSIONS ENERGY_COST	
<b>EV_CHARGING_STATION</b>	ENTITY_COUNT ENTITY_USED ENERGY_CONSUMPTION CO2_EMISSIONS ENERGY_COST	GEO_LOCATION POSTAL_ADDRESS
<b>EV_SOCKET</b>	ENERGY_CONSUMPTION STATE_OF_CHARGE CO2_EMISSIONS ENERGY_COST	ELECTRICAL_MEASURES SWITCHED

For the metric ENERGY\_PRICE\_PER\_KWH, the EMS owner will be queried in order to obtain the price curve of the energy. This will be stored in DB.

For the ENERGY\_CONSUMPTION, the instant KWH will be queried and translated to KW by using the instants of the measures.

The ENERGY\_COST will be calculated with the energy consumption and the energy price

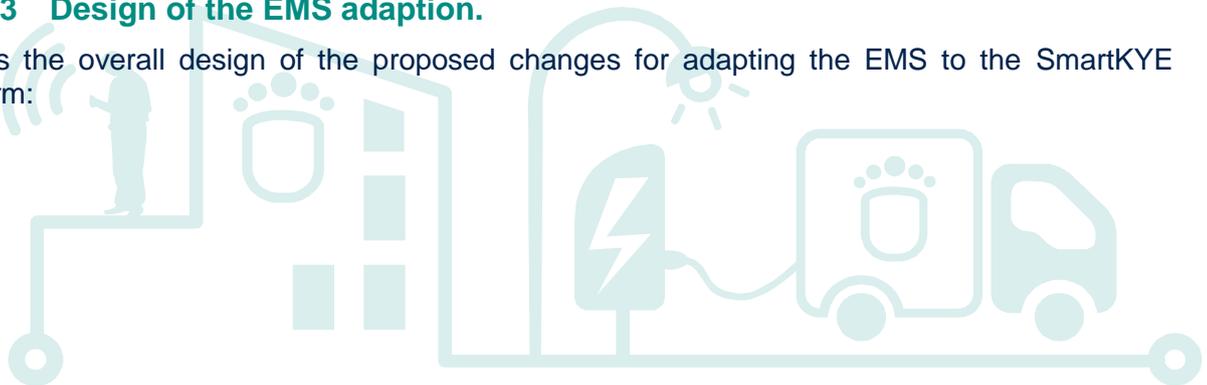
For the electrical measures, it is possible that only instant consumption can be obtained, this will be analysed with the EMS owner.

For the MAX\_PEAK\_ENERGY\_DEMAND, the maximum Kw/Hour of the queried interval will be returned.

The CO2\_EMISSIONS will be obtained by using the generation curves obtained from the Spanish energy agency in real time.

#### 4.1.3.3 Design of the EMS adaption.

This is the overall design of the proposed changes for adapting the EMS to the SmartKYE platform:



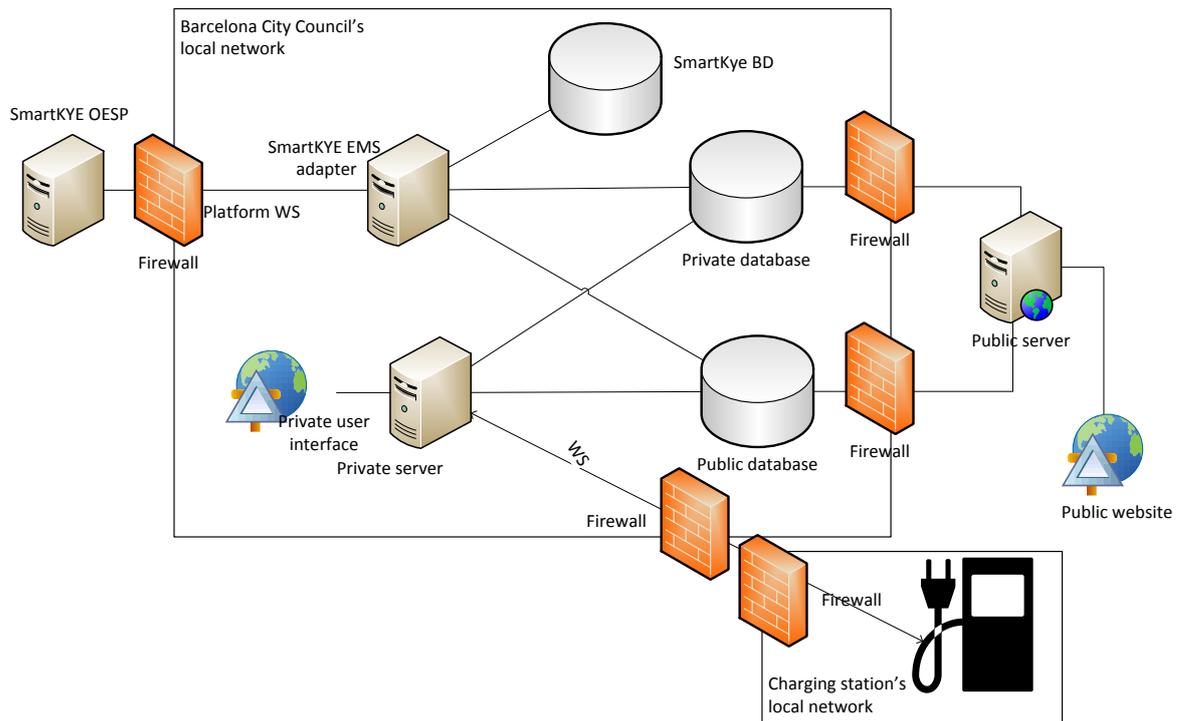


Figure 51 - Architecture EMS adaptation

The adaptation to the OESP platform will be carried out by a specific application (that can be hosted in one of the existing servers or in a new one). This EMS adapter application will access the databases for gathering the required information and will send them to the platform upon necessary.

Apart from the existing databases, the EMS adapter will make use of a specific database that will contain all the required information that is not present in the other databases. This is information required for some of the attributes or metrics handled by the platform, such as the energy price curve or the address of the assets. This database will be completed as one of the tasks to be done during the deployment of the EMS.

Since the EMS adapter will be deployed in the DMZ of the system and will have direct access to the databases, the interface with the existing system will be quite straightforward. Indeed, the point in common between the existing system and the EMS adapter will be the database, so the existing system will not be affected.

The EMS adapter application will have the form of a windows service. This will allow having the application running all the time and not depending on a user to start the application on a desktop session. Windows services do not have a graphical interface, so the output and behaviour of the application will be logged to files.

Internally, the EMS adapter application will be implemented according to the following structure:

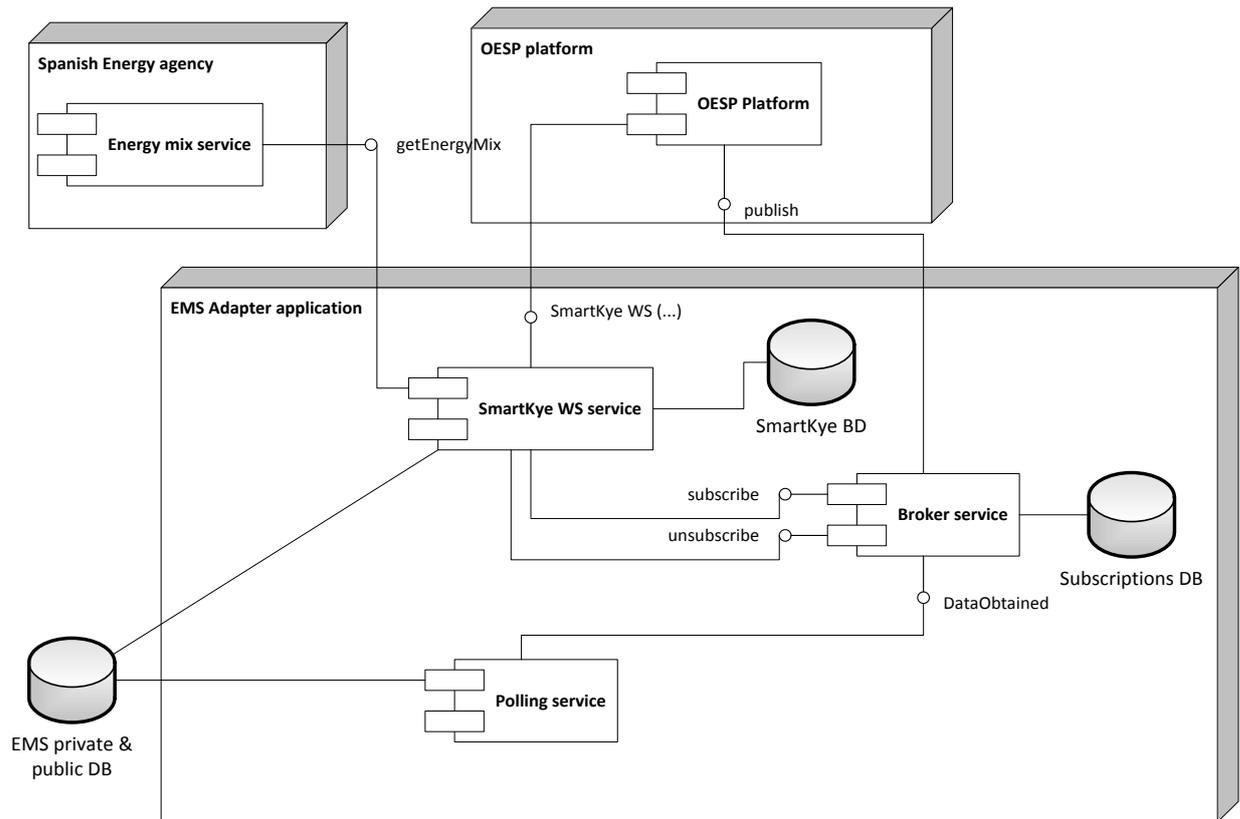


Figure 52 - EMS adapter application implementation structure

The application will implement the SmartKYE Web Services in the ‘**SmartKYE WS service**’ component. This will offer interfaces for all the Web Services that are mandatory for the EMS (even though the web service interface is common for both server and client, only a subset of the defined services are mandatory for the EMS to implement).

For the implementation of this component, we will start from the import of the Web Service definition (WSDL) generated by the OESP platform. This can be done with several existing tools, but at the end, most of them produce code that can be used:

- For remotely accessing a service implementing the given WSDL (client code generated)
- For implementing the services described in the WSDL (services stub generated). It is called stub because what is automatically generated in that way creates server methods with a signature that are compatible with those described in the WSDL (name, parameters, outputs, etc.) but do not make anything (empty methods). It is our task to give these stubs an appropriate code for returning of performing what is actually expected by the platform.

There are two special methods described in the SmartKYE Web Service that allows subscribing or unsubscribing to specific pieces of data handled by the EMS. When invocations to these services are received by the ‘**SmartKYE WS service**’, they are forwarded to the ‘**Broker service**’. This component handles the registrations of client to specific pair metric-asset. At the end that clients will be probably cockpit interested in receiving certain info as soon as it changes. These subscriptions and unsubscriptions are stored in database, and are used when the broker service receives data through the DataObtained interface. The component implements the following algorithm:

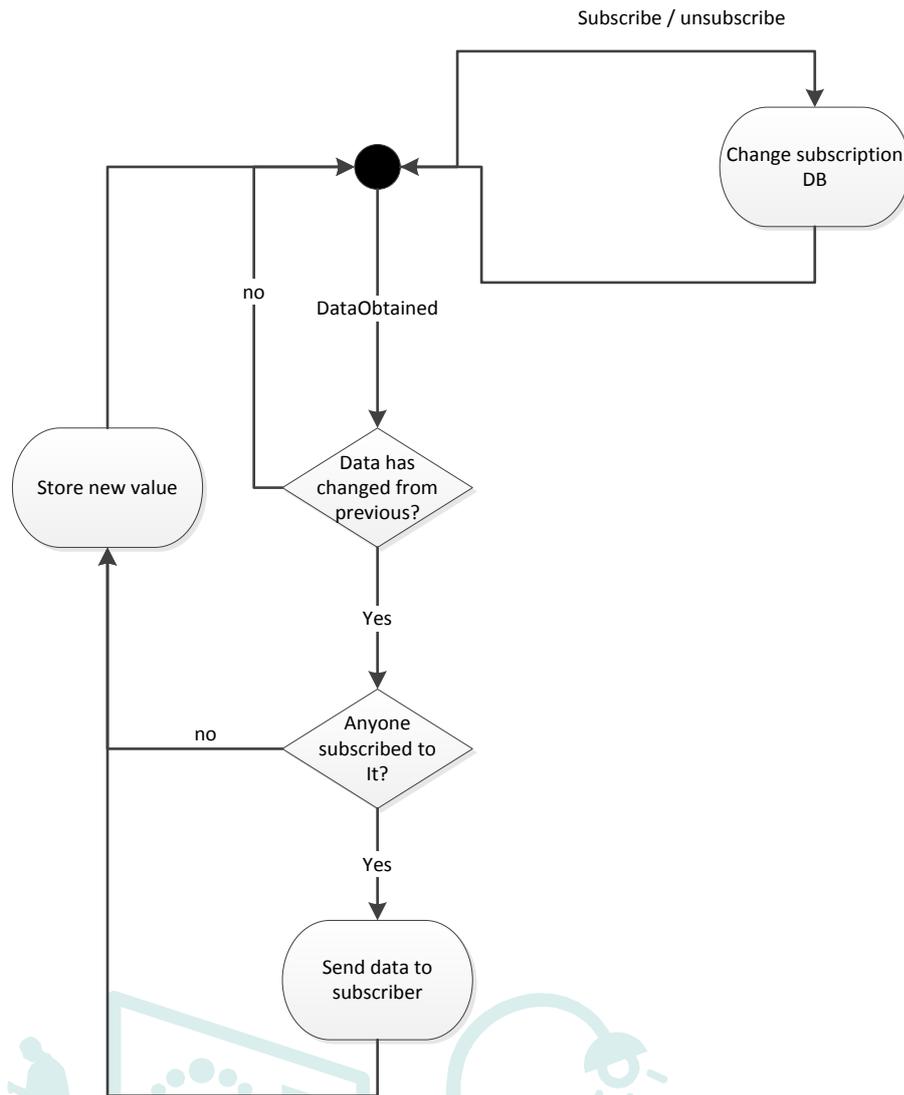


Figure 53 – Algorithm implemented

Finally, the **'polling service'**, will be in charge of periodically querying the appropriate database tables for obtaining the values and measures of the assets and send them to the broker service. The polling period will be configurable



#### 4.1.4 Energy micro-generators

The information handled by the EMS must be adapted to the needs of the SmartKYE platform.

##### 4.1.4.1 Conceptual data model adaptation

The concepts managed by the EMS are not directly equivalent to the concepts managed by the platform. The next table summarizes the EMS conceptual elements and their correspondence in the platform:

**Table 10 – Micro generators EMS data model adaptation**

	<b>Description (for Barcelona energy micro-generators plant EMS)</b>	<b>SmartKYE Platform equivalent</b>
<b>EMS system</b>	Ficosa energy micro-generators plant at Sant Guim de Freixenet (Barcelona)	Device of type ENERGY_PLANT_EMS
<b>Weather station</b>	Device providing weather information by monitoring a set of weather sensors	Device of type ENERGY_PLANT_WEATHER_STATION . Each one will be a child of a device of type ENERGY_PLANT_EMS
<b>Wind turbine</b>	Power generator using wind energy	Device of type ENERGY_PLANT_WINDMILL. Each one will be a child of a device of type ENERGY_PLANT_EMS
<b>PV panel</b>	Power generator using photovoltaic energy	Device of type ENERGY_PLANT_PV_PANEL. Each one will be a child of a device of type ENERGY_PLANT_EMS
<b>SheevaPlug</b>	Plant controller. Gets information from different kinds of devices and sends it to a remote database at Ficosa facilities.	This device does not generate information by itself and thus will not be considered in the platform
<b>Tachometer</b>	Device measuring the rotation speed of an associated wind turbine. It provides information to SheevaPlug.	This device does not generate information by itself and thus will not be considered in the platform
<b>SMA WebBox</b>	Device monitoring wind turbines and PV panels in the plant. It provides information to SheevaPlug.	This device does not generate information by itself and thus will not be considered in the platform
<b>Weather sensor</b>	Device measuring a specific weather property. The weather station read from it.	Information about the actual weather devices in the plant is not available, so they will not be considered in the platform. Instead, it will be assumed that all weather information is being measured by devices of type ENERGY_PLANT_WEATHER_STATION .

##### 4.1.4.2 Metrics & attributes provided

Some of the services to be implemented by the EMS involve the transmission of data associated with assets. These are characterised as attributes or metrics, depending on the nature of these data.



The following table shows the metrics and attributes provided by each element of the EMS:

**Table 11 - Microgenerators EMS metrics and attributes**

	<b>Metrics provided</b>	<b>Attributes provided</b>
<b>ENERGY_PLANT_EMS</b>	ENTITY_COUNT ENTITY_USED ENERGY_CONSUMPTION ENERGY_PRICE_PER_KWH MAX_PEAK_POWER_DEMAND CO2_EMISSIONS ENERGY_COST	GEO_LOCATION POSTAL_ADDRESS
<b>ENERGY_PLANT_WEATHER_STATION</b>	ENERGY_CONSUMPTION WIND_DIRECTION WIND_SPEED INSIDE_TEMPERATURE OUTSIDE_TEMPERATURE ATMOSPHERIC_PRESSURE SENSORS_READING_SUCCESS_PERCENTAGE CO2_EMISSIONS ENERGY_COST	GEO_LOCATION
<b>ENERGY_PLANT_WINDMILL</b>	ENERGY_CONSUMPTION ENERGY_PRODUCTION POTENTIAL_ENERGY_PRODUCTION ROTATION_SPEED CO2_EMISSIONS ENERGY_COST POWER ACTIVE_POWER_MEAN ACTIVE_POWER_MIN ACTIVE_POWER_MAX REACTIVE_POWER_MEAN REACTIVE_POWER_MIN REACTIVE_POWER_MAX CURRENT CURRENT_MEAN CURRENT_MIN CURRENT_MAX VOLTAGE	GEO_LOCATION



	VOLTAGE_MEAN VOLTAGE_MIN VOLTAGE_MAX ENERGY_PRODUCTION_MEAN	
<b>ENERGY_PLANT_PV_PANEL</b>	ENERGY_CONSUMPTION ENERGY_PRODUCTION POTENTIAL_ENERGY_PRODUC TION CO2_EMISSIONS ENERGY_COST POWER ACTIVE_POWER_MEAN ACTIVE_POWER_MIN ACTIVE_POWER_MAX REACTIVE_POWER_MEAN REACTIVE_POWER_MIN REACTIVE_POWER_MAX CURRENT CURRENT_MEAN CURRENT_MIN CURRENT_MAX VOLTAGE VOLTAGE_MEAN VOLTAGE_MIN VOLTAGE_MAX ENERGY_PRODUCTION_MEAN	GEO_LOCATION

For the metric ENERGY\_PRICE\_PER\_KWH, the EMS owner will be queried in order to obtain the price curve of the energy. This will be stored in DB.

For the ENERGY\_CONSUMPTION, the instant KWH will be queried and translated to KW by using the instants of the measures.

The ENERGY\_COST will be calculated with the energy consumption and the energy price

For the electrical measures, it is possible that only instant consumption can be obtained, this will be analysed with the EMS owner.

For the MAX\_PEAK\_ENERGY\_DEMAND, the maximum Kw/Hour of the queried interval will be returned.

The CO2\_EMISSIONS will be obtained by using the generation curves obtained from the Spanish energy agency in real time.



#### 4.1.4.3 Design of the EMS adaption.

This is the overall design of the proposed changes for adapting the EMS to the SmartKYE platform:

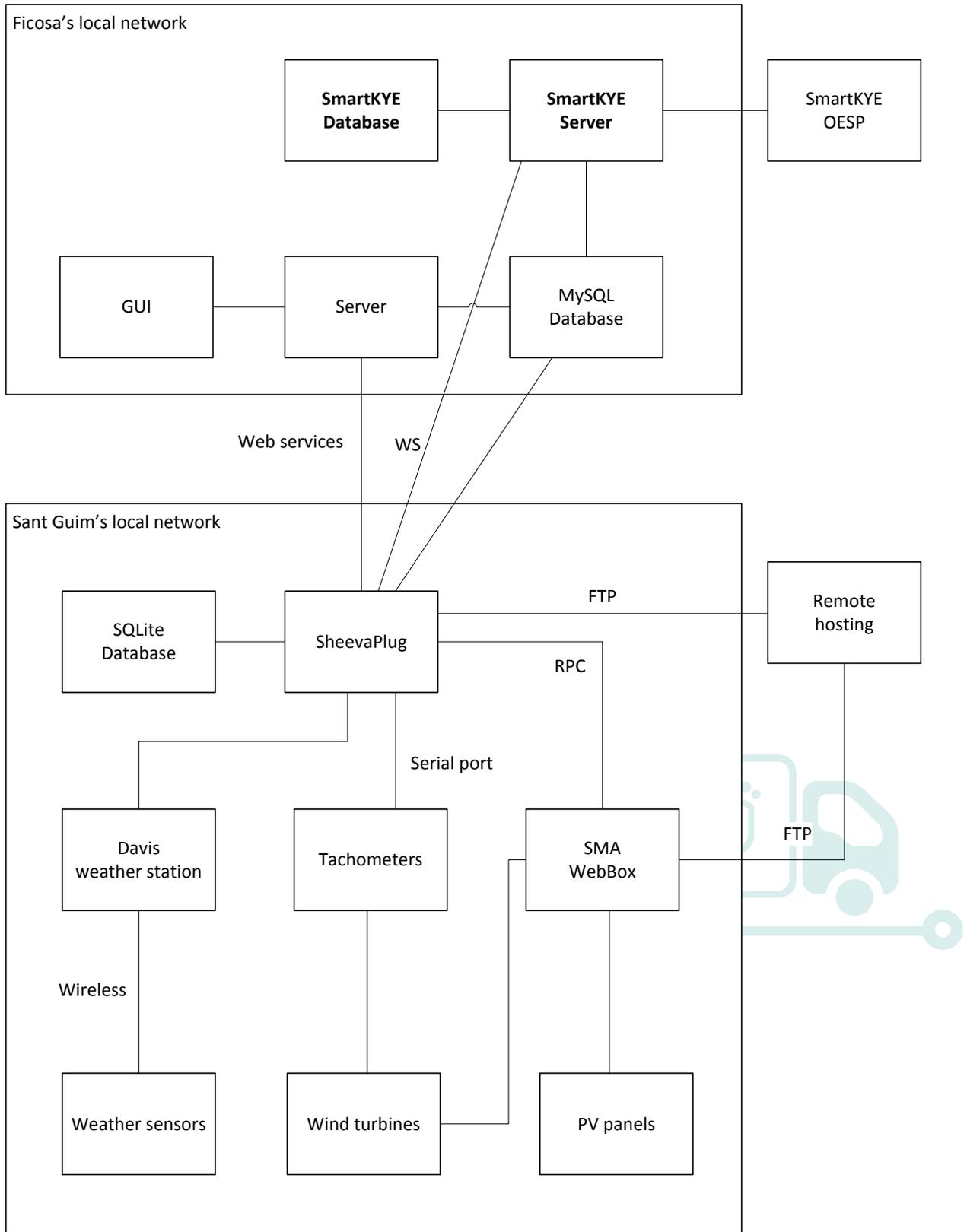


Figure 54 - Architecture EMS adaptation



The adaptation to the OESP platform will be carried out by a specific application (that can be hosted in the existing server or in a new one). This EMS adapter application will access the existing MySQL database for gathering the required information and will send them to the platform upon necessary.

The application will also access the remote SheevaPlug device at Sant Guim facilities to obtain information that is not being stored in the MySQL database. This communication will take place via the same web service currently being used by the server at Ficosa. No problem shall be found when obtaining the current SheevaPlug dynamic IP, as an already existing process stores it in the database and regularly updates it.

Apart from the existing database, the EMS adapter will make use of a specific database that will contain all the required information that is not present in the other databases. This is information required for some of the attributes or metrics handled by the platform, such as the energy price curve or the location of the assets. This database will be completed as one of the tasks to be done during the deployment of the EMS.

Since the EMS adapter will be deployed in the DMZ of the system and will have direct access to the databases, the interface with the existing system will be quite straightforward. Indeed, the point in common between the existing system and the EMS adapter will be the database, so the existing system will not be affected.

The EMS adapter application will have the form of a windows service. This will allow having the application running all the time and not depending on a user to start the application on a desktop session. Windows services do not have a graphical interface, so the output and behaviour of the application will be logged to files.

Internally, the EMS adapter application will be implemented according to the following structure:

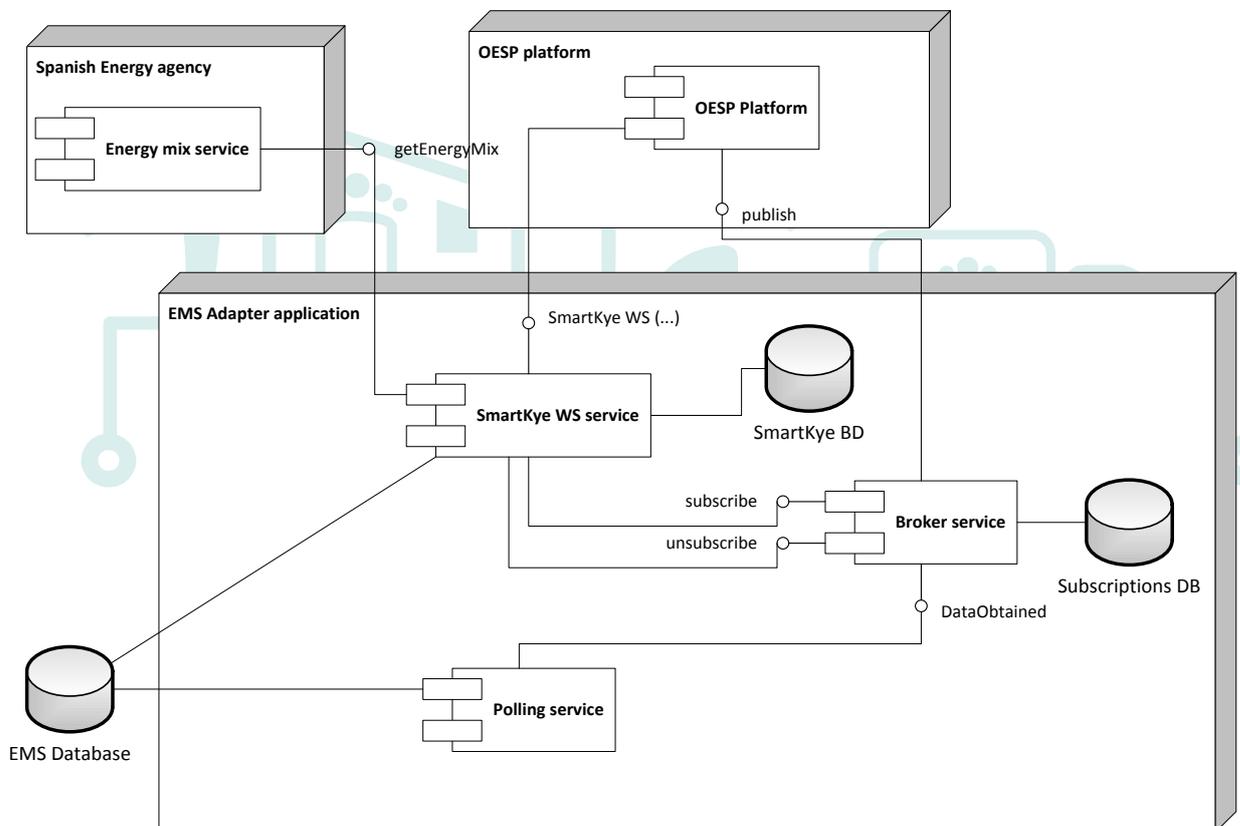


Figure 55 - EMS adapter application implementation structure

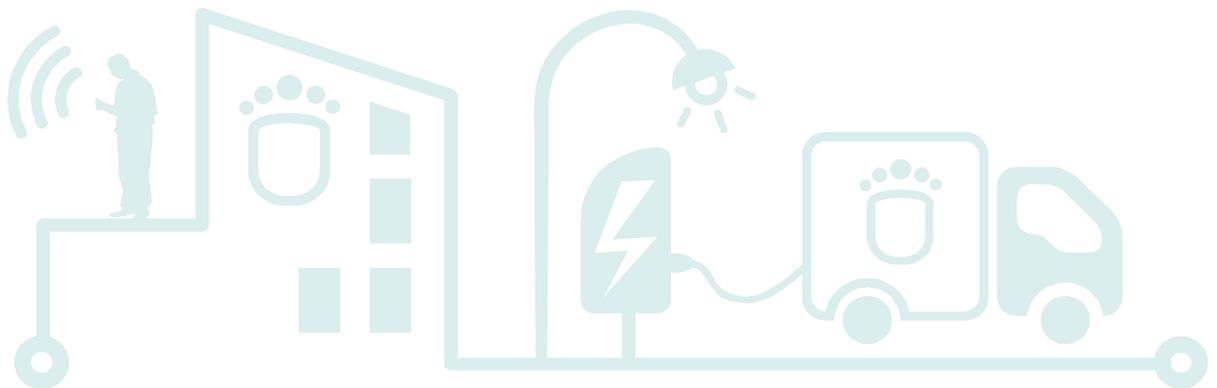


The application will implement the SmartKYE Web Services in the ‘**SmartKYE WS service**’ component. This will offer interfaces for all the Web Services that are mandatory for the EMS (even though the web service interface is common for both server and client, only a subset of the defined services are mandatory for the EMS to implement).

For the implementation of this component, we will start from the import of the Web Service definition (WSDL) generated by the OESP platform. This can be done with several existing tools, but at the end, most of them produce code that can be used:

- For remotely accessing a service implementing the given WSDL (client code generated)
- For implementing the services described in the WSDL (services stub generated). It is called stub because what is automatically generated in that way creates server methods with a signature that are compatible with those described in the WSDL (name, parameters, outputs, etc.) but do not make anything (empty methods). It is our task to give these stubs an appropriate code for returning of performing what is actually expected by the platform.

There are two special methods described in the SmartKYE Web Service that allows subscribing or unsubscribing to specific pieces of data handled by the EMS. When invocations to these services are received by the ‘SmartKYE WS service’, they are forwarded to the ‘**Broker service**’. This component handles the registrations of client to specific pair metric-asset. At the end that clients will be probably cockpit interested in receiving certain info as soon as it changes. These subscriptions and unsubscriptions are stored in database, and are used when the broker service receives data through the DataObtained interface. The component implements the following algorithm:



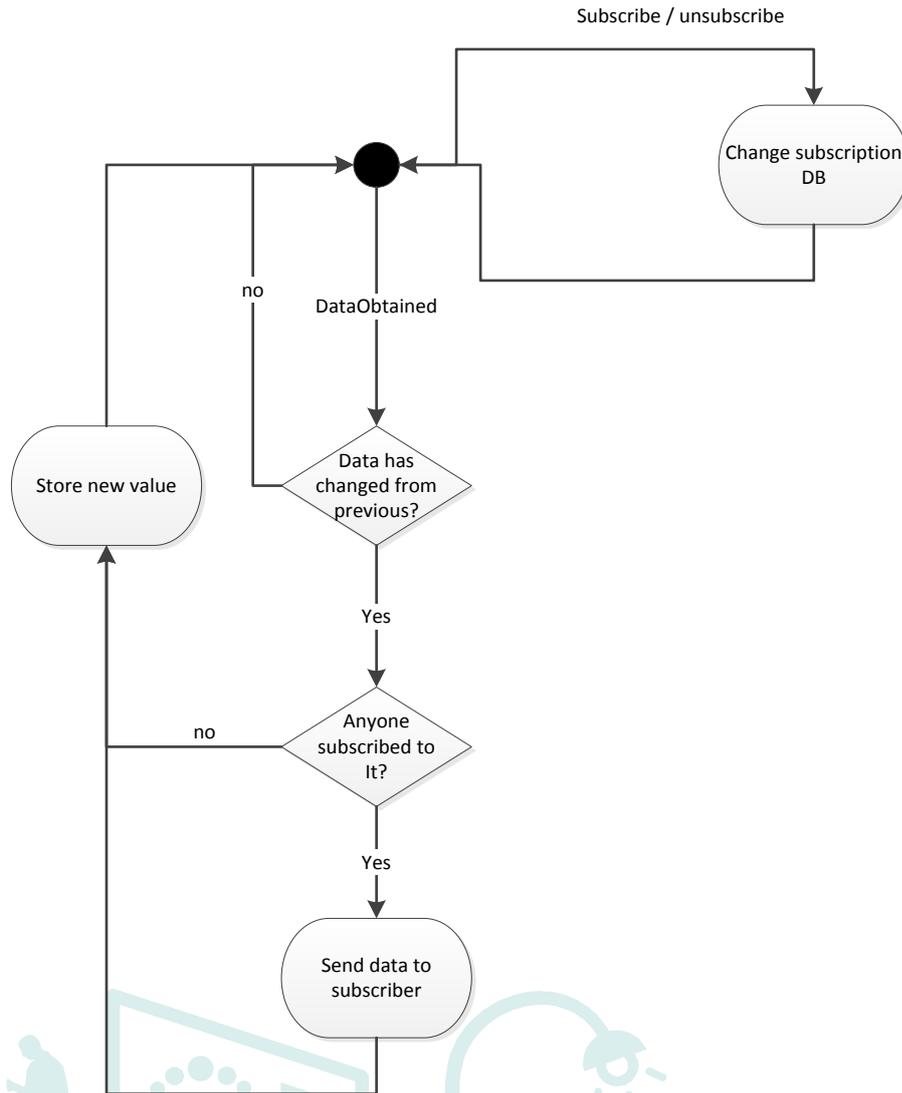


Figure 56 – Algorithm implemented

Finally, the **'polling service'**, will be in charge of periodically querying the appropriate database tables for obtaining the values and measures of the assets and send them to the broker service. The polling period will be configurable.



## 4.2 Lasithi – Crete Pilot site

In the scope of the SmartKYE project the operation of the More Care EMS and the EMS for the buildings must be up rated and adapt to the needs of the OESP platform. The More Care System was designed in such way that any type of data can be stored and expressed through this system. In this context, it was decided that the information acquired from the buildings will be adapted to the More Care EMS. Information will be transferred from the local database communicating with the building controllers to the More Care DB, as information for a new type of power system resource. In such way, the implementation of only one adapter is required for both systems (buildings and generators at Lasithi) hosting all the functionalities that are required, for data as well as control services.

### 4.2.1 Conceptual data model adaptation

Naturally, the concepts and the data managed by the EMS might not be directly equivalent to the concepts managed by the platform. The following table summarizes the correspondence between the More Care System's resources and the data types defined in the data model of the OESP platform.

**Table 12 – More Care data model adaptation**

	Description (for More Care)	SmartKYE Platform equivalent
<b>Power System</b>	An electrical power system is the network of electrical resources used to supply, transmit and use electrical power. In this case the power system of Crete is studied	Device of type POWER_SYSTEM
<b>Power Station</b>	An industrial place for generating electrical power. A power station includes thermal electrical units, transformers and feeders and supplies energy to the distribution network.	Device of type POWER_STATION
<b>Conventional Unit</b>	All the thermal units of the power system, mainly responsible for serving the demand load of a power system, as well as auxiliary services (reserve, frequency and voltage regulation).	Device of type CONVENTIONAL_UNIT
<b>Wind Farm</b>	A group of wind turbines in the same location used to produce energy.	Device of type WINDFARM
<b>Wind Turbine</b>	A device that converts kinetic energy to electrical energy.	Device of type WINDMILL
<b>Capacitor</b>	A passive electrical component used to compensate the reactive energy needs of the electrical network.	Device of type CAPACITOR
<b>Transformer</b>	An electrical device responsible for the elevation or relegation of voltage levels.	Device of type TRANSFORMER
<b>Line</b>	The electrical resource used for transmitting the electrical power.	Device of type LINE
<b>Feeder</b>	The connection point device of lines, transformers, capacitors, conventional units, wind farms, etc.	Device of type FEEDER
<b>Building</b>	Public building with controllers establish giving the capability of taking measurement and controlling loads	Device of type BUILDING



#### 4.2.1.1 Metrics & attributes provided

For the calculation of the desired metrics, KPIs, and System Evaluation Criteria, data must be provided to the OESP thereafter to the cockpits. These data are characterised as attributes or metrics, depending on their nature. If the data are considered static, thus change value rarely, then they are attributed, either way they are metrics.

The following table shows the metrics and attributes provided by each entity type of the EMS More Care.

**Table 13 – Create energy generators metrics and attributes**

	<b>Metrics provided</b>	<b>Attributes provided</b>
<b>Power System</b>	ENERGY_PRODUCTION POTENTIAL_ENERGY PRODUCTION ENERGY_PRODUCTION_FORECAST ENERGY_CONSUMPTION ENERGY_CONSUMPTION_FORECAST CO2_EMISSIONS ENERGY_COST ENERGY_PRICE_PER_KWH MAX_PEAK_POWER_DEMAND	POWER_STATIONS_COUNT CONVENTIONAL_UNITS_COUNT WIND_FARMS_COUNT
<b>Power Station</b>	ENERGY_PRODUCTION CO2_EMISSIONS ENERGY_COST CO2_EMISSIONS ENERGY_PRICE_PER_KWH ENTITIES_USED POTENTIAL_ENERGY PRODUCTION ENTITY_COUNT	GEO_LOCATION POSTAL_ADDRESS
<b>Conventional Unit</b>	ENERGY_PRODUCTION POTENTIAL_ENERGY PRODUCTION STATE_OF_CHARGE CO2_EMISSIONS ENERGY_COST ENERGY_PRICE_PER_KWH ENTITIES_USED ENERGY_CONVERSION_EFFICIENCY ACTIVE_POWER REACTIVE_POWER VOLTAGE CURRENT AC_FREQUENCY	GEO_LOCATION TYPE_OF_UNIT NOMINAL_POWER MIN_ACTIVE_POWER MAX_ACTIVE_POWER MIN_REACTIVE_POWER MAX_REACTIVE_POWER FUEL_TYPE STATUS
<b>Wind Farm</b>	ENTITY_COUNT ENTITIES_USED ENERGY_PRODUCTION POTENTIAL_ENERGY PRODUCTION ENERGY_PRODUCTION_FORECAST ENERGY_PRODUCTION_CURTAILMENT ACTIVE_POWER REACTIVE_POWER VOLTAGE CURRENT	GEO_LOCATION NOMINAL_POWER



	AC_FREQUENCY TEMPERATURE WIND_SPEED WIND_DIRECTION	
<b>Wind Turbine</b>	ENTITY_COUNT ENTITIES_USED ENERGY_PRODUCTION ENERGY_PRODUCTION_FORECAST ENERGY_PRODUCTION_CURTAILMENT_FORECAST ENERGY_PRODUCTION_CURTAILMENT	GEO_LOCATION NOMINAL_POWER WIND_SPEED_CUT_IN WIND_SPEED-RATED WIND_SPEED_CUT_OFF
<b>Capacitor</b>	ENTITY_COUNT REACTIVE_POWER	MAX_REACTIVE_POWER MIN_REACTIVE_POWER
<b>Transformer</b>	ENTITY_COUNT	GEO_LOCATION RESISTANCE REACTANCE NOMINAL_POWER
<b>Line</b>	ENTITY_COUNT	RESISTANCE REACTANCE
<b>Feeder</b>	ENTITY_COUNT ACTIVE_POWER REACTIVE_POWER VOLTAGE CURRENT AC_FREQUENCY	MAX_VOLTAGE MIN_VOLTAGE NOMINAL_LOAD
<b>Building</b>	ENTITY_COUNT ENERGY_CONSUMPTION ENERGY_MANAGED ENERGY_MANAGED_REQUEST MAX_PEAK_POWER_DEMAND ACTIVE_POWER REACTIVE_POWER	GEO_LOCATION POSTAL_ADDRESS

**4.2.1.2 Design of the EMS adaption.**

This is the overall design of the proposed changes for adapting the More Care EMS to the SmartKYE platform:

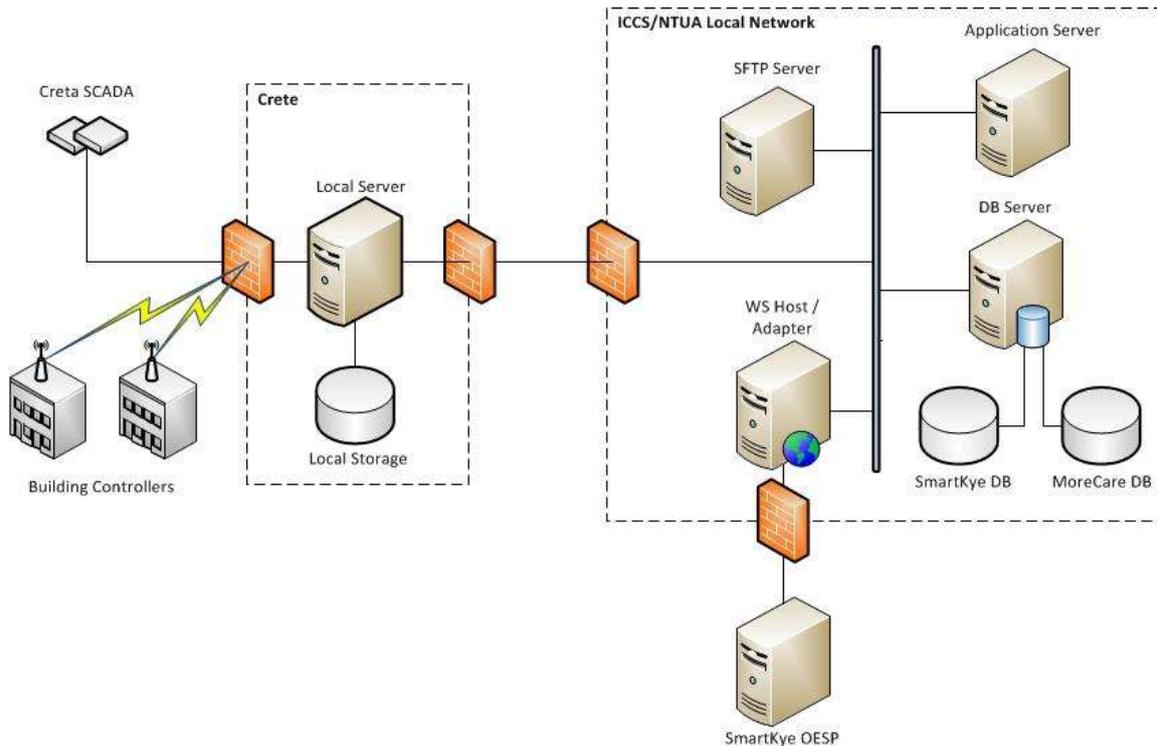


Figure 57 - Architecture EMS adaptation

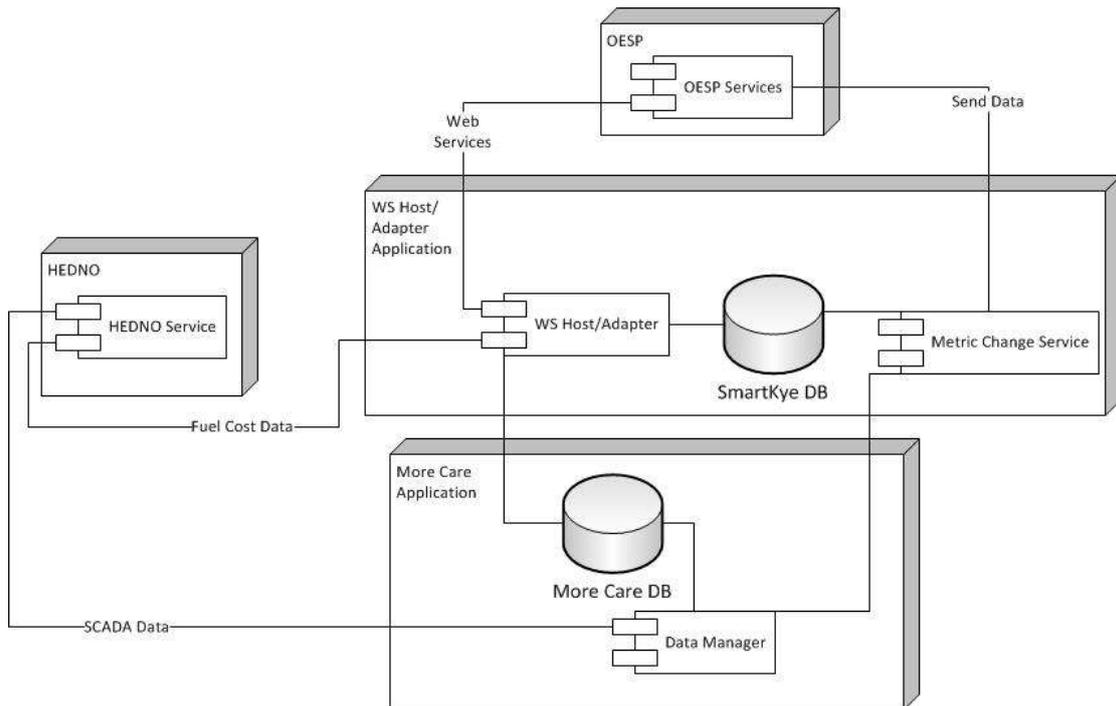
The adaptation process will consist of the following points:

- The development of a new database that will include any necessary supplementary data. An example of these data can whether there is any subscription to the metrics of the EMS or not.
- The implementation of the Web Service Host/Adapter application responsible for the communication with the OESP platform and responsible for hosting all the Web Services.

The new database will be hosted in the existing DB server of the More Care application. The adapter will be hosted in a new server to which OESP platform can have direct access through the internet. The adapter will be in the same subnet with the DB server, thus will have direct access to the database and moreover to the essential data.

The current structure of the architecture will not be significantly influenced since the topology of the system will remain the same. Log data concerning the adapter function (web services request, the data sent, etc.) will be stored in the SmartKYE DB.

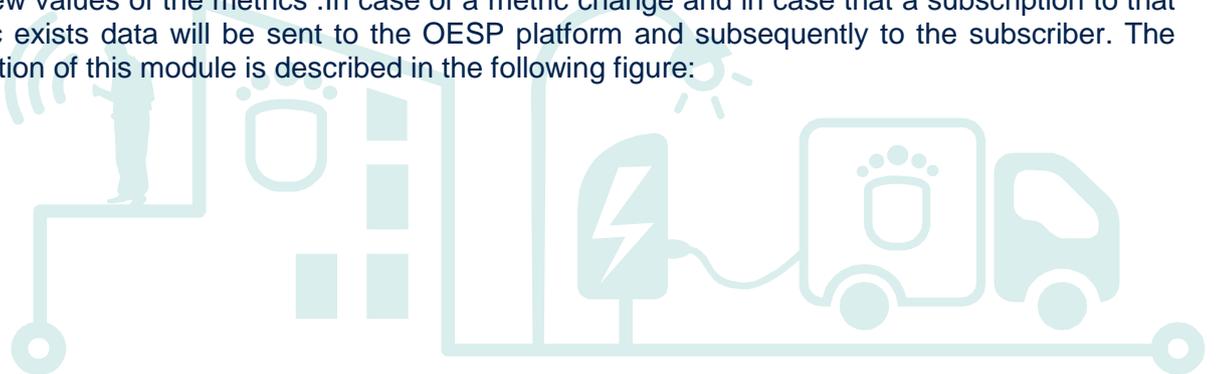
The following picture shows the internal structure of the WS Host/Adapter:



**Figure 58 - EMS adapter application implementation structure**

This application consists of two modules one responsible for the web services invited from the OESP mandatory for the More Care EMS and the Metric Change Service Module.

The Data Manager Module that already exists at the More Care Application gets the SCADA data every 5 minutes and subsequently informs the More Care DB. For the scope of the project Data Manager Module will be extended and inform also the Metric Change Service Module for the new values of the metrics .In case of a metric change and in case that a subscription to that metric exists data will be sent to the OESP platform and subsequently to the subscriber. The operation of this module is described in the following figure:



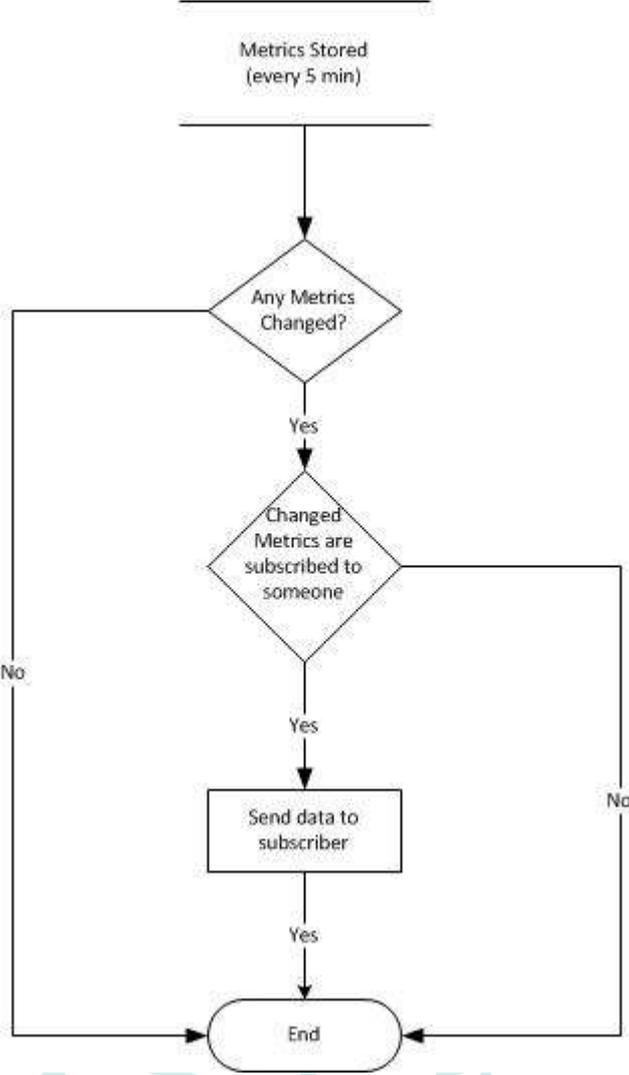


Figure 59 – Algorithm implemented

It is worth noting that data considering the electrical system (conventional units, wind farms, etc.) change almost always, so what is truly queried in our case is whether any metric from the buildings has changed.



## 5 Adaptation process planning

In this section it will be described the planning for the adaption of the different components of the different EMSs. Also in this section it will be detailed which adaptations will take place during the first version (Month 18), and which for the second version (Month 24).

The adaptation will tackle in two phases in order to provide feedback to the OESP developers in WP3. Therefore, all the EMS adaptation will be split in two phases, where basic adaptation and demonstration of functionalities will be performed and delivered for the first iteration; while more advanced functionalities will be left for the second iteration.

### 5.1 22@ district – Barcelona Pilot site

#### 5.1.1 Barcelona Building EMS

Table 14 - Barcelona building EMS adaptation plan - Summary

EMS	Component	Adaptation description	V1	V2
Building Management System - Barcelona	BCN_MediaTIC Building BMS	BCN_Virtual Machine and DDBB setup: Setup of everything required to gather and store MediaTIC data reliably	x	
		BCN_Mediatic Building - <b>SmartKYE-related data</b> setup Configuration of VM, DDBB and Sw required to support entity metrics & attributes (WS implementation will be performed later)	x	
	BCN_SmartKYE adapter	BCN_SmartKYE Virtual Machine and DDBB setup SmartKYE dev and production environment setup (VM, DDBB and everything required)	x	
		BCN_Energy Mix adaptation	x	
		BCN_Building Simple Metrics & Attributes implementation	x	
		BCN_Building Complex Metrics & Attributes implementation		x
		BCN_Office Simple Metrics & Attributes implementation	x	
		BCN_Office Complex Metrics & Attributes implementation		x
		BCN_Building SmartKYE Web Services implementation	x	
		BCN_Building & Office V1 demo testing and validation	x	
		BCN_Building SmartKYE Oauth Client implementation		x
		BCN_Building SmartKYE Web Services update		x
		BCN_Building & Office V2 demo testing and validation		x



### 5.1.2 Barcelona Public Lighting EMS

Table 15 - Barcelona public lighting EMS adaptation plan - Summary

EMS	Component	Adaptation description	V1	V2
Public Lighting Management System - Barcelona	Barcelona Public Lighting Control System	System Kernel - SmartKYE setup: Adaptation of the system to support communications from the SmartKYE adapter	x	
	SmartKYE adapter	SmartKYE Virtual Machine and DDBB setup SmartKYE dev and production environment setup (VM, DDBB and everything required)	x	
		Energy Mix adaptation	x	
		Publish/subscribe adaptation	x	
		PUBLIC_LIGHTING_CONTROL_ROOM Simple Metrics & Attributes implementation	x	
		PUBLIC_LIGHTING_CONTROL_ROOM Complex Metrics & Attributes implementation		x
		PUBLIC_LIGHTING_CONTROL_ROOM SmartKYE Web Services implementation	x	
		PUBLIC_LIGHTING_CONTROL_ROOM V1 demo testing and validation	x	
		PUBLIC_LIGHTING_CONTROL_ROOM SmartKYE Oauth Client implementation		x
		PUBLIC_LIGHTING_CONTROL_ROOM SmartKYE Web Services update		x
		PUBLIC_LIGHTING_CONTROL_ROOM V2 demo testing and validation		x

### 5.1.3 Barcelona Electric Vehicle EMS

Table 16 - Barcelona electric vehicle EMS adaptation plan - Summary

EMS	Component	Adaptation description	V1	V2
Electric Vehicle Management System - Barcelona	SmartKYE adapter	SmartKYE Virtual Machine and DDBB setup. SmartKYE dev and production environment setup (VM, DDBB and everything required)	x	
		Energy Mix adaptation	x	
		Publish/subscribe adaptation	x	
		EV_EMS Simple Metrics & Attributes implementation	x	
		EV_EMS Complex Metrics & Attributes implementation		x
		EV_EMS SmartKYE Web Services implementation	x	



		EV_EMS V1 demo testing and validation	x	
		EV_EMS SmartKYE Oauth Client implementation		x
		EV_EMS SmartKYE Web Services update		x
		EV_EMS V2 demo testing and validation		x

### 5.1.4 Barcelona Energy Micro Generators EMS

Table 17 - Barcelona microgenerators EMS adaptation plan - Summary

EMS	Component	Adaptation description	V1	V2
Energy Micro Generators System - Barcelona	SmartKYE adapter	SmartKYE Virtual Machine and DDBB setup SmartKYE dev and production environment setup (VM, DDBB and everything required)	x	
		Energy Mix adaptation	x	
		Publish/subscribe adaptation	x	
		ENERGY_PLANT_EMS Simple Metrics & Attributes implementation	x	
		ENERGY_PLANT_EMS Complex Metrics & Attributes implementation		x
		SmartKYE Web Services implementation	x	
		ENERGY_PLANT_EMS V1 demo testing and validation	x	
		ENERGY_PLANT_EMS SmartKYE Oauth Client implementation		x
		ENERGY_PLANT_EMS SmartKYE Web Services update		x
		ENERGY_PLANT_EMS V2 demo testing and validation		x

### 5.2 Lasithi – Crete Pilot site

Table 18 – Lasithi EMSs adaptation plan - Summary

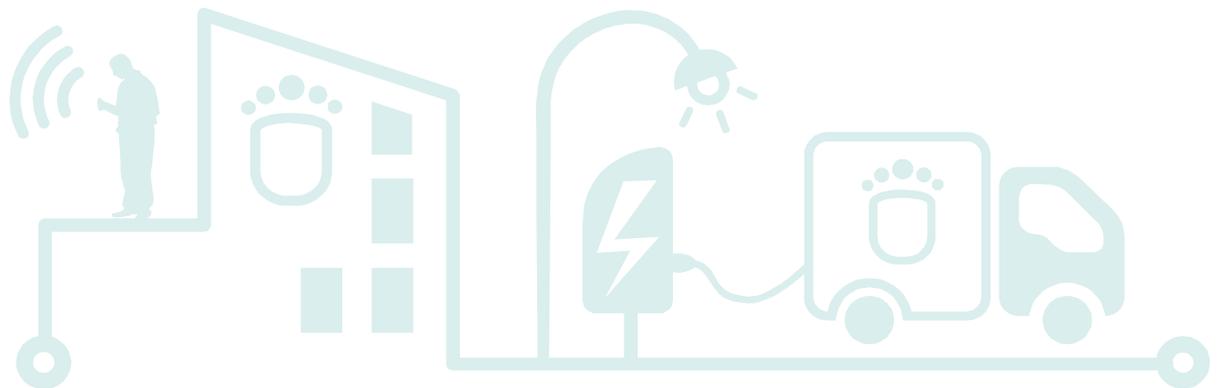
EMS	Component	Adaptation description	V1	V2
Building Management System	Building Controllers	Installation of controllers to buildings and initialization of storing data to More Care DB.	x	
	WS Host/ Adapter	Simple metrics & attributes web services	x	
		Subscribed metrics services	x	
		Complex metrics & attributes web services		x



		Control services	x		
		Oauth Client implementation	x		
		Testing and validation	x		
Energy micro-generators	WS Adapter	Host/	Simple metrics & attributes web services	x	
			Subscribed metrics services	x	
			Complex metrics & attributes web services		x
			Oauth Client implementation	x	
			Testing and validation	x	

### 5.3 Adaptation process Gantt

The following Figure shows a zoom of the SmartKYE project Gantt where all tasks required for the EMS adaptation have been detailed.



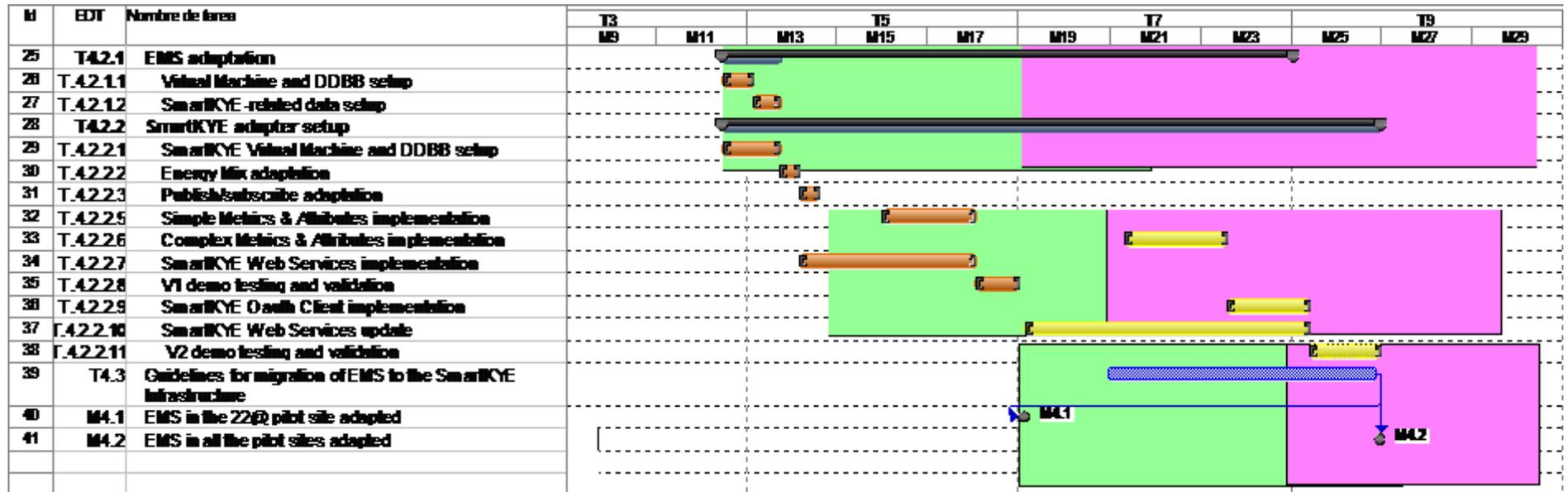


Figure 60 – SmartKYE EMSs adaptation planning

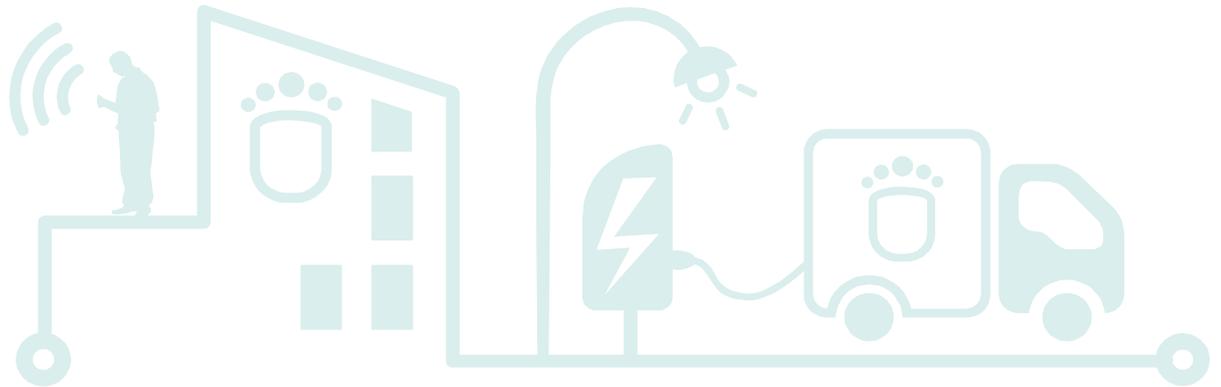
## 6 Conclusions and next steps

Based on the adaptation process specified in this document, during the second task of WP4 T4.2 “EMS adaptation”, the partners involved in this WP4, will tackle with the adaptation of the components of the EMSs already deployed. This adaptation will pave for the installation of the services delivered by the OESP.

As mentioned during the previous sections, the EMSs adaptation defined will be tackled in two stages to provide feedback to the OESP developers in WP3. During the first stage, the basic adaptation and demonstration of functionalities will be performed and delivered; while more advanced functionalities will be left for the second stage. Also during the second stage, it will be covered the potential problems detected during the first stage.

Specifically, the first version of the adapted EMSs will be delivered by the partners in month 18 and the second version adapted EMSs in month 24. In addition to the prototype adaptation, a report explaining the modifications made will be produced at the end of each stage.

During the whole adaptation process, the partners will gather the problems detected and lessons learned in order to provide the guidelines for EMS adaptation in any neighbourhood. This report is the deliverable D4.3 “Guidelines for transferability of EMS adaptation strategies”, to be delivered at the end of month 26.

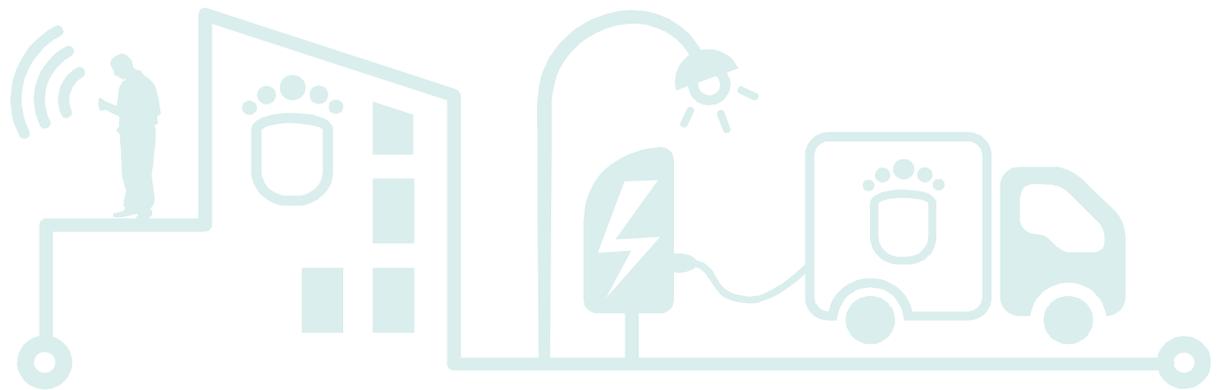


## 7 Acronyms

Acronyms List	
BC	Business Cockpit
BMS	Building Management System
CIM	Common Information Model
CO2	Carbon dioxide
DB	Database
DCP	Data Capturing and Processing
DMZ	Demilitarized Zone
ED	Economic Dispatch
EMS	Energy Management Systems
EV	Electric Vehicle
FR	Flow regulators
FTP	File Transfer Protocol
GUI	Graphical User Interface
HVAC	heating and air condition system
ICT	information and communication technologies
IEC	International Electrotechnical Commission
ISS	integrated set of sensors
KPI	Key Performance Indicator
KW	Kilowatt
KWh	kilowatt hour
MCC	Monitoring and Control Cockpit
NWP	Numerical Weather Predictions
OESP	Open Energy Service Platform
PLC	point of light controller
PoL	Point of Light
RPC	Remote Procedure Call
SC	segment controller
SCADA	Supervisory Control And Data Acquisition
SmartKYE	Smart grid KeY nEighbourhood Indicator cockpit
SOAP	Simple Object Access Protocol
TCP/IP	Internet protocol suite
UC	Unit Commitment
UI	User Interface
UOC	Universitat Oberta de Catalunya
URL	Uniform Resource Locator
WCF	Windows Communication Foundation



WPF	Wind Power Forecasting
WSDL	Web Services Description Language
WSN	Wireless Sensor Networks





## 8 Annex I

### 8.1 MediaTIC building BMS systems

A detailed overview of all systems integrated and monitored within MediaTIC building is provided in the following Figure. The architecture of this system as well as the main components monitored and controlled under this BMS systems are:

- **Rooftop sensors.** In the roof of the building have been installed sensors to measure the temperature (temperature sensors) and solar radiation (solar radiation sensors). The solar radiation sensors are located in the cardinal cross form (east, north, south and west). The objective of this setup is to measure by each facade the solar radiation in a specific time. Some of the building facades are provided by an ETFE system. The ETFE system is installed in the facades with high solar incidence throughout the year (taking also into account the season).
- **In-building environmental sensors.** The sensors installed in each floor of the building are focused on measure:
  - **Temperature** (one temperature sensor by each two fan-coils). Temperature sensor measures the temperature in a specific floor zone. This sensor is connected with the thermostat located in the floor and also is connected with the building management system (temperature can be controlled by this software and displayed in the thermostat also).
  - **Motion Sensors.** The motion sensors measure the movements on the common zones. These sensors are connected with the luminance system and the building management system. The sensors are active when the pre-defined time tables for the luminance are out of schedule. In this period of time, when a movement is detected in the common zones, the light turn on (connect one/two rows of light each movement detected).
  - **Luminance sensors.** The luminance sensor measures the solar luminance close to the exterior walls. This sensors are located near the windows (in the facades where don't have ETFE systems and the solar incidence are plausible). The sensor performance is configured manually and individually by the facility manager (pre-defined thresholds). This kind of hardware is connected with the luminance systems. That means, where the solar incidence near the window is upper of a pre-defined threshold, then the light in this zone is turned-off (the sensor controls lights in a distance less than 3m from the window).
  - **Humidity sensors.** Humidity sensors also are installed in the building floor to measure (in average) the whole building humidity. These sensors are connected with the humidity station located in the facility manager office (ground floor).
  - **Fire sensors.** Also, in the building are installed fire detection sensors (smoke sensors, fire sensors) that measure the possibility of fire in a specific floor or zone.
- **Thermal facility.** The system controls the fan-coils located in all the building floors, the district heating facility and the air renewal machine. It is possible to configure time tables and temperature thresholds. In each floor are installed fan-coils and ventilation elements to maintain an optimal temperature and also keep the ambient air in optimal conditions. The fan-coils are connected with a control unit (PLC-DG7000) (see [Figure 62](#)). This control unit is also connected with the temperature sensor and the thermostat. The control unit is in charge of collect the sensor information, thermostat information and current fan-coil state. Based on this information, this hardware act into the fan-coil (open/close cold/heat valves).

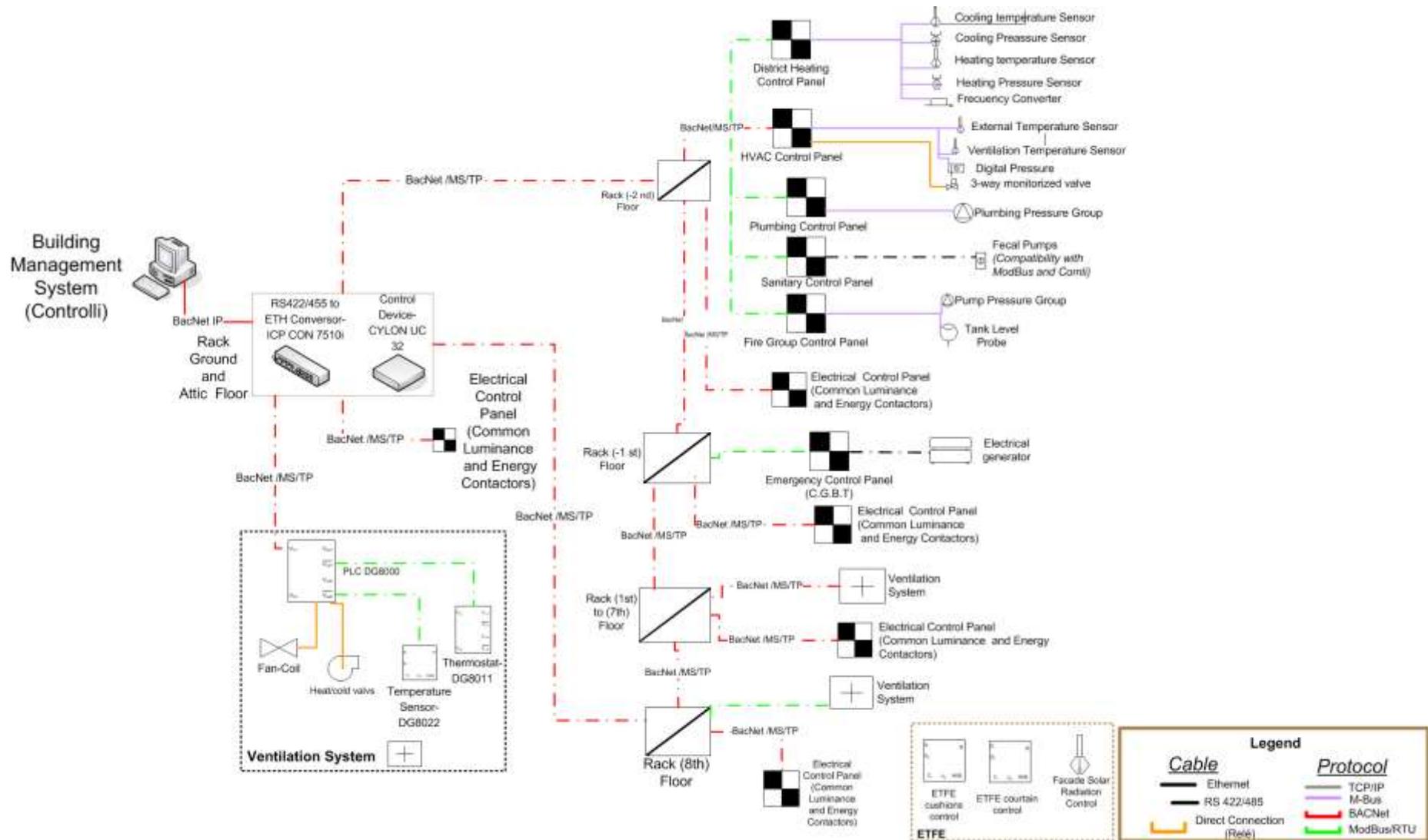


Figure 61 - MediaTIC building BMS architecture





### 8.1.1 BDigital energy management platform – Devices installed

As mentioned in previous sections, BDigital energy management platform is composed of two different subsystems, each one based on a specific set of technologies and off-the-shelf devices. The main technical characteristics of the devices in each of these sub-systems are detailed below:

#### BDigital Office energy monitoring

BDigital's office overall energy consumption is monitored using a set of commercial off-the-shelf devices provided by the manufacturer 4Knoks. The core element in this solution is a “4Noks ModBus/TCP Ethernet Gateway”, which is responsible to translate the data obtained from the sensors (and transmitted wirelessly using ModBus standard over IEEE 802.15.4), and finally send it to the energy platform server where data is finally processed and stored.

The main technical characteristics of the Gw device are detailed below:

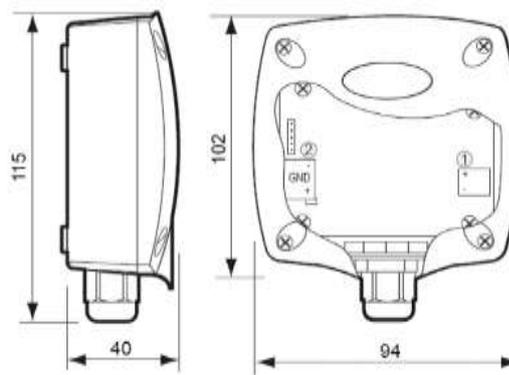


Figure 63 - 4Noks ModBus/TCP Ethernet Gateway

- RF characteristics
  - Frequency: 2405 MHz ÷ 2480 MHz
  - Nominal transmission power: 1mW (0 dBm)
  - Receiver sensitive: -92 dBm
  - External antenna gain: 5,5 dB
  - Outdoor/indoor range: 100m/30m
- Supply
  - ZC-GW-ETH-EM: external +12 Vcc ; 200mA
  - ZC-GW-ETH-EPM: POE – 48Vcc
- LAN Connection
  - Ethernet: RJ45

#### Environmental and sub-metering sensors

Besides electricity consumption, some environmental parameters of the office as well as electricity consumption of specific electrical equipment is monitored. In this case, a platform from the manufacturer DIGI is used, where the main devices (and their technical specifications) are presented below:

- **ConnectPort X gateway:** This device provides IP network connectivity for end point devices in wireless XBee networks. Gateways collect end node data, process it, and send it to a parent application using an Ethernet connection. The main technical specifications of this device are:
  - Wireless XBee to IP gateway supports numerous XBee protocols IPsec and



- SSL VPNs on WAN connections with DES, 3DES or AES encryption
- 128-bit AES encryption on mesh network
- **Temperature/Humidity/Brightness sensor:** This device integrates three different environmental sensors within one single physical device. The main technical specifications of this device as well as the parameters measured are:
  - **Temperature Sensor**
    - Range: -18° C to 55° C (-0.4° F to 131° F)
    - Accuracy: +/- 2° C
  - **Ambient Light Sensor**
    - Range of spectral bandwidth: 360 to 970 nm (similar to human eye)
    - Wavelength of peak sensitivity: 570 nm
  - **Humidity Sensor**
    - Range: 0 to 100% RH
    - Interchangeability:
      - +/- 5 %RH (0% RH to 59%RH)
      - +/- 8 %RH (60% RH to 100%RH)
    - Accuracy: +/- 3.5% RH



Figure 64 - Digi Temperature/Humidity/Brightness sensor

- **Smart plugs (energy consumption sub-metering sensors):** This device (shown in Figure 65) is used to monitor specific electrical equipment energy consumption. Besides energy consumption this sensor is able to monitor other electrical parameters such as voltage, current frequency and power. Specific technical characteristics are listed below:
  - **Nominal load:** 10 A / 250 VAC, 2500 VA
  - **Max. load:** 16 A / 4000 VA
  - **RF:** Protocol IEEE 802.15.4 ZigBee, max. 250 KBit/s, ISM 2.4 GHz
  - **Power consumption:** <0,5 W typ.



Figure 65 - Energy consumption sub-metering sensors

## 8.2 Technoflex energy generators – Equipment information

### 8.2.1 Mini-aerogenerator of 5kW of power generation.

The differences of 1KW and 5KW micro generators are the size of the turbine, where in the micro-generators of 5KW are 5000 mm x 5000 m.



Figure 66 - Eolic system 5 kW

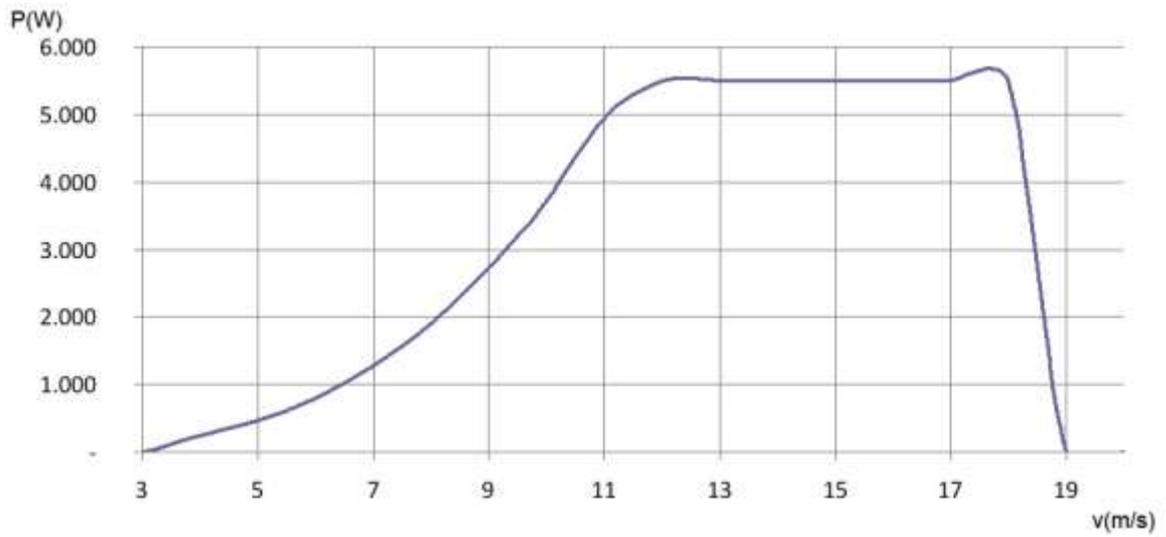


Figure 67 - Yield curve Eolic system 5 kW



Figure 68 - Yield curve Eolic system 5 kW

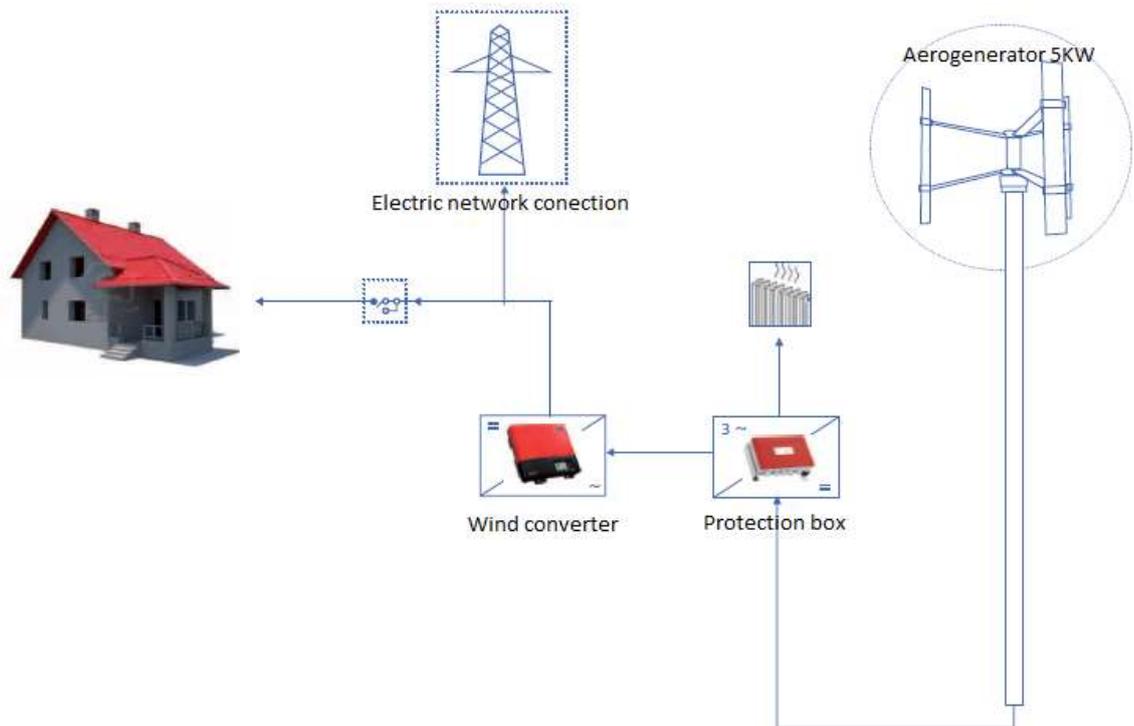


Figure 69 - Installation 5Kw diagram yield curve

### 8.3 Crete pilot site - More Care EMS Algorithms implemented

#### 8.3.1 Load Forecast

In order to perform the Unit commitment and Economic Dispatch functions for the next planning horizon, it is necessary to have a forecast of the profile of the total load of the power system for this horizon. As “forecasted load pro-file” is characterized a set of consecutive spot forecast values as well as confidence intervals for these forecasts.

Usually in conventional systems forecasts are produced once per day. In autonomous systems with high penetration, it is necessary to update forecasts several times per day.

Several methods are being developed for the LF task:

- **Simple forecasting**

A simple algorithm has been implemented using the load value from the same time the previous week, scaled by a factor representing the change in load between the two weeks.

- **Fuzzy neural network model**

This model receives past load values to produce forecasts for the next 48 hours. The model parameters are adapted as new data arrive. Special attention is paid for predicting the load of weekends and special days. Temperature fore-cast is not considered as input to the model since such data is not available. However, the model compensates on this factor through auto-adaptation. The model produces hourly forecasts.

- **ARMA model**

This model is an autoregressive model. All the above methods have been integrated in the LF-module. However, when the software runs on-line only one method will provide forecasts to the rest of the modules (UC, ED) of the MORE-CARE software.



### 8.3.2 Wind Forecast

The purpose of the Wind Power Forecasting (WPF) module is to provide forecasts for the power output of each wind farm connected to the power system, as well as the corresponding confidence intervals. Fore-casts are required by the ED and UC functions of MORE CARE software.

The following methods have been developed:

- **Simple Forecasting**

Persistence consists on using the most recent value of wind speed or power as forecast for the entire planning horizon. Instead of using Persistence, one can use averages of past values as predictors (Naive predictors). Off line analysis permits to define the outperforming simple method for each case study.

- **Fuzzy-neural models**

Fuzzy autoregressive models are applied to predict wind speed or power up to 8-10 hours ahead. The input is past wind speed or power values as well as exogenous input (i.e. wind direction). The model parameters are self-adapted as new data arrive. Several tests using wind speed or power time series have shown that fuzzy logic based models out-perform persistence.

- **Meteorological information based model A**

A long-term (up to 48 hours) wind power forecasting module has also been developed. The module will be as adaptable as possible to varying availability of input data. To achieve the long term forecast, data input from a meteorological forecast model (HIRLAM), is required for one or more wind farms in the system. To make a shorter term, statistical correction, on-line SCADA data is required for one or more wind farms in the system. Where no time series input data is available for a wind farm, multipliers are used to estimate the output from neighbouring locations. This feature is also useful in the event of temporary communications problems.

- **Meteorological information based model B**

This module makes site-specific wind speed forecasts based on the information produced by the SKIRON system of the Atmospheric Modelling & Weather Forecasting Group of the University of Athens. The SKIRON meteorological forecasts cover a grid of 15x15 km of Crete. The operator will have the possibility through the MMI, to choose any of the above methods for on-line use. Special attention is paid to combine the short-term and long-term wind forecasts provided by the statistical and meteorological models, respectively.

### 8.3.3 PV forecasting model

The PV forecasting model that was developed by NTUA, is based on artificial intelligence techniques and is implemented to predict the future solar production of a wide area. This model will be used for the BEAMs project. The proposed model receives as input the Numerical Weather Predictions (NWP) come from the SKIRON model. SKIRON is a high resolution meteorological model and provides NWP once per day with five days ahead forecasting horizon.

The Numerical Weather Predictions (NWP) applied here, are come from the SKIRON model. SKIRON is a high resolution hydrostatic meteorological model that is developed by the University of Athens. The SKIRON model operates with resolution of 5x5 kmxkm, 48 vertical levels and forecasting horizon of five days. It is run one time per day. The SKIRON model will use the GFS global outputs as lateral boundary conditions. The initial conditions will be prepared with the 3-D data assimilation system LAPS. LAPS uses the 0.5x0.5 degree analysis, the surface and upper air data as well as ship and aviation observations available on the GTS



system. Also, SKIRON model can provide forecasts in a lower spatial resolution using the RAMS modelling system. The RAMS modelling system will be utilized in two-way interactive nesting mode with grid resolution 3 km. The initialization will be the same as for SKIRON by using the LAPS assimilation system.

The proposed model was designed adequately for manipulating NWP for multiple points of the SKIRON grid. It is self-constructed and self-adaptive, namely it does not need any historical data or additional time for off-line training. It runs once per day and provides solar power forecasts for the next four days.

### 8.3.3.1 Description of the model

First of all, the PV forecasting model receives the solar parks coordinates of the area of interest in order to estimate the closest points at the NWP grid. In following, it retrieves the predictions of the atmospheric variables, namely the short wave flux, the temperature and the cloudiness coming from the SKIRON model. Then, it produces the four days ahead solar power prediction and updates their parameters with the available solar power measurements.

The proposed model uses a novel neural network for the estimation of the solar power. This neural network is based on the ARTMAP networks and the multi-scale radial basis neural network and will be named here as msRBF-ARTMAP. Since the new msRBF-ARTMAP uses a genetic algorithm to estimate its parameters, it does not need more than ten minutes for one update. This means that the proposed model can be implemented for short-term such as very-short-term forecasting.

### 8.3.3.2 Sort description of the novel msRBF-ARTMAP

The novel msRBF-ARTMAP consists of four layers. At the first layer, at the beginning, the input variables are weighted according to their correlation with the output variable (G. Sideratos, February 2007). Then, the weighted inputs are classified in kernels using the Euclidean distance and a threshold. By this way, the neurons of the second layer are organized in different clusters.

At the second layer, the input is coded to the [0,1] space and its complement is added. So, if the input had M variables, the new input would have 2\*M variables. Where, the first M variables would be the coded and the next M variables would be the complemented. The training procedure of the second layer is similar with the RBF-ARTMAP network that is described in detail at (Sideratos G, 2012). The difference of the proposed network with the RBF-ARTMAP network is that each neuron is weighted with a different parameterization in order to 1) maximize its distance with others neurons, 2) maximize its activation at the cases that point the same target, 3) minimize its vigilance. It should be noted that at this network each neuron has different radius and different vigilance. Also, the second layer of the msRBF-ARTMAP uses as transfer function the following equation.

$$f(j) = \exp\left(-\left\| (c_j^{\hat{w}_j} \wedge inp^{\hat{w}_j}) - inp^{\hat{w}_j} \right\| / b_j^2\right) \quad (1)$$

Furthermore, the msRBF-ARTMAP applies instance counting (G. A. Carpenter, 1998) and reward assignment at each neuron.

Finally, the third layer maps the output variable and the forth layer connects the second layer with the third layer. The following figure shows the training procedure of the proposed neural network.



### 8.3.4 Unit Commitment/Economic Dispatch

The objective of the Unit Commitment (UC) function is to determine the combination of production units that will supply the expected demand of energy over the future period in question. This combination is the result of an optimization procedure that takes into account economic criteria and is subject to different types of economical, technical and security constraints.

The UC module of the MORE CARE software suggests to the operator of the power system a secure operating scenario for the next hours. In an interconnected power system, Unit Commitment is performed usually once a day or more, and is based solely on load forecasts. In isolated systems with high penetration from renewable (i.e. >20%), it is necessary to update regularly the proposed Unit Commitment schedules in order to account for the variability in the production of the renewable. Thus, the UC models developed operate in a “sliding window” scheme. The length of the look-ahead time (planning horizon) depends on the type of the installed power units. On operator's request, the operating restrictions will include preventive control measures on the UC module, coming from the security assessment module.

Two models are developed within the MORE CARE project for the UC task. Both models are based on Genetic Algorithms (GA) and are able to simulate systems with steam units, gas turbines, diesel and combined cycle power units including renewable like wind farms and small hydro stations. The operator will have the possibility to select one of them for on-line use.

### 8.3.5 Economic Dispatch

The objective of the Economic Dispatch (ED) function is to distribute the load among the generator units selected in the Unit Commitment so that the total cost of the power system operation is minimized. The ED function is performed only for the basic time-step (e.g. 20 minutes ahead) of the planning horizon in order to provide the generators set-points to the operators.

The ED module is possible to compute the optimal generation production satisfying constraints of circuit loads, bus voltages and reactive generation to satisfy the load demand and losses of the system. It can also consider constraints related to bilateral contracts and independent producers of renewable power sources according to specific terms and conditions. On operator's request the output of the Economic Dispatch module (set-points) can be checked against security constraints with the security monitoring module, but these constraints will not be fed back as input to the ED modules.

Two different approaches are developed in MORE CARE to perform the economic dispatch function.

1. Optimal Power Flow based on Linear Programming

This module uses a linear model of the power system, which relates the generation production rescheduling and the other control resetting to the operating cost and the transmission network constraints. For the operation of a conventional unit the operating cost is specified by a cost curve expressing either running cost, or bidding price in case of open market operation.

2. Genetic algorithms technique

The Economic Dispatch module based on GA uses a real-coded genetic algorithm to minimize the operating cost while satisfying operating limits (ramp rates included), power balance and network constraints (optional).